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A Loadability Study of 30 kV Misurata Distribution Network

Etohami Elsagahyer
Libyan academy

Jamal Abdulmalek
Libyan academy

Khaled Abojlala
Misurata University

Abstract— **Due to the expansion of power distribution networks, the power delivered to the loads might get through corridors which limits their capability of transmitting the power. This concept is termed as the loadability. An unplanned increase in power consumption in the Libyan network, especially after 2011, led to major problems at different levels of the power network. For instance, these issues are addressed at the generation level as power shortages and load shedding while at the distribution level presented as under voltages and loadability issues. In this paper, a study of the loadability of 30 kV Misurata electrical distribution network (MDN) is carried out using the NEPLAN software. Even though the MDN is considered one of the largest distribution networks in Libya, a lack of data is found which makes an ambiguous vision about this network and the necessary developments required in the future as well as adds some difficulties to making studies. The work presents the steady state operation of MDN under the existence of the current and estimated loads up to the year 2026. The results show significant loading problems in Misurata distribution network which should be considered to avoid the anticipated future power transfer limitations. Some visible solutions are proposed to ensure the optimal operation of the distribution network.**

Index Terms: **loadability, Misurata distribution network (MDN), load growth factor, power transfer capacity.**

I. INTRODUCTION

The expression of distribution network means the networks where voltage levels are reduced to meet customer demands[1]. Even though the reduction of voltage levels can be mitigated by tap changers at the step-down transformers, the loading of power transmission lines and/or the power transformers becomes a crucial factor in this operation[2]–[4]. So, the effectiveness of power distribution networks is measured by their ability to feed the loads without breaching the limits of their components[5].

The electric grid structure is primarily described by the reliability requirements of both the supply and the loads. Each grid structure has defined properties regarding its reliability, power losses, service requirement, operation, and flexibility[6].

The distribution system is considered the most important part of the electrical power systems, as 75% of power losses and more than 90% of faults occur in it. In general, the distribution system is divided into a primary distribution system and a secondary distribution system[1].

The Libyan distribution substations step down the primary distribution voltages level 66/30 kV to the secondary distribution levels at 11 kV, and at each end-user, the distribution transformers step down the voltages to 400/240V.

Due to several factors, more stresses face the operation of the Libyan power network. The core ones are the rapid expansion of the communities associated with a non-planned growth of power consumption areas, the lack of legislation that controls the use of electrical equipment, the old infrastructure of the power grid and the conflicts over the last few years. Such operating conditions make transmitting the power through the grid within the system's limits a challenge to the network operators in both steady and dynamic states.

The objectives of this research are to gather the data of Misurata distribution network, assess the loadability of their components using the well-known software NEPLAN under steady-state operating conditions and propose some solutions to get rid of the existence and forecasted loading issues. The study will cover the operation of Misurata distribution network from 2021 to 2026 with the help of the calculated yearly load growth factor of the national Libyan loads.

This paper is categorized as follows: the first part introduces the 30 kV Misurata distribution network (MDN), while the load growth factor calculation is presented in the second part. The third part presents the results of the simulation of MDN. The solutions to loadability problems are proposed in the fourth part, while the last one contains the conclusions of this paper.

II. MISURATA DISTRIBUTION NETWORK (MDN)

Misurata distribution network (MDN) covers a wide geographical area as Misurata network is counted as one of the largest networks in Libya. The MDN is situated in

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an area that begins from the Al-Karareem area in the east to the Al-Dafnia area in the west, and from the seaside in the north to the Al-Sekt area in the south as shown in figure (1). In the meantime, there are many power plants close to Misurata city which give good support to the MDN, such as the Karzaz power substation in the east, the iron and steel generating plant, and the double cycle generating plant. Generally, the dominant loads are industrial, household, and commercial loads in MDN while the agriculture loads are inefficient.

The data collection of Misurata distribution network was carried out with the help of the documentation and information centres in the general electricity company of Libya (GECOL), while the undocumented data was collected from the field technicians and engineers.

In this research, Misurata distribution network is divided into three regions as follows:

1- City centre region: This part feeds both Al-Jamaa Al-Alaali area and Yedr area.
2- East of Misurata region: This part feeds the Goshe area - Al-Skirat area - Al-Zraug area - the M-port area and Al-Nasem factory.
3- West of Misurata region: This part feeds Zawiyat Al-Mhjob area - Al-Dafnia (1) - Al- Dafnia (2) and Al- Dafnia (3).

Loads of Misurata distribution substations in 2021 are listed in Table (1) which will be used as a base to estimate the s for the following years up to 2026.

III. LOAD GROTH FACTOR OF LIBYAN GRID (LGF)

The planning of the electrical distribution network is of great importance to ensure that the increased power demand can be ideally and economically fed with future additions to the electrical distribution network[2], [7], [8].

Forecasting the expansion of power networks requires a pre-knowledge of some system factors such as the yearly growth of system loads. Many techniques are proposed in the literature to predict the future trend of the loads such as the extrapolation method, correlation method and stochastic models' method [2],[8]. The former method will be utilised in this research to predict the loads of MDN.

Table (2) shows the maximum loads of the Libyan network. It is noted that the power consumption is rocked dramatically each year as presented in figure (2). This referred to the cheap tariffs and the weak system of collecting power usage fees.

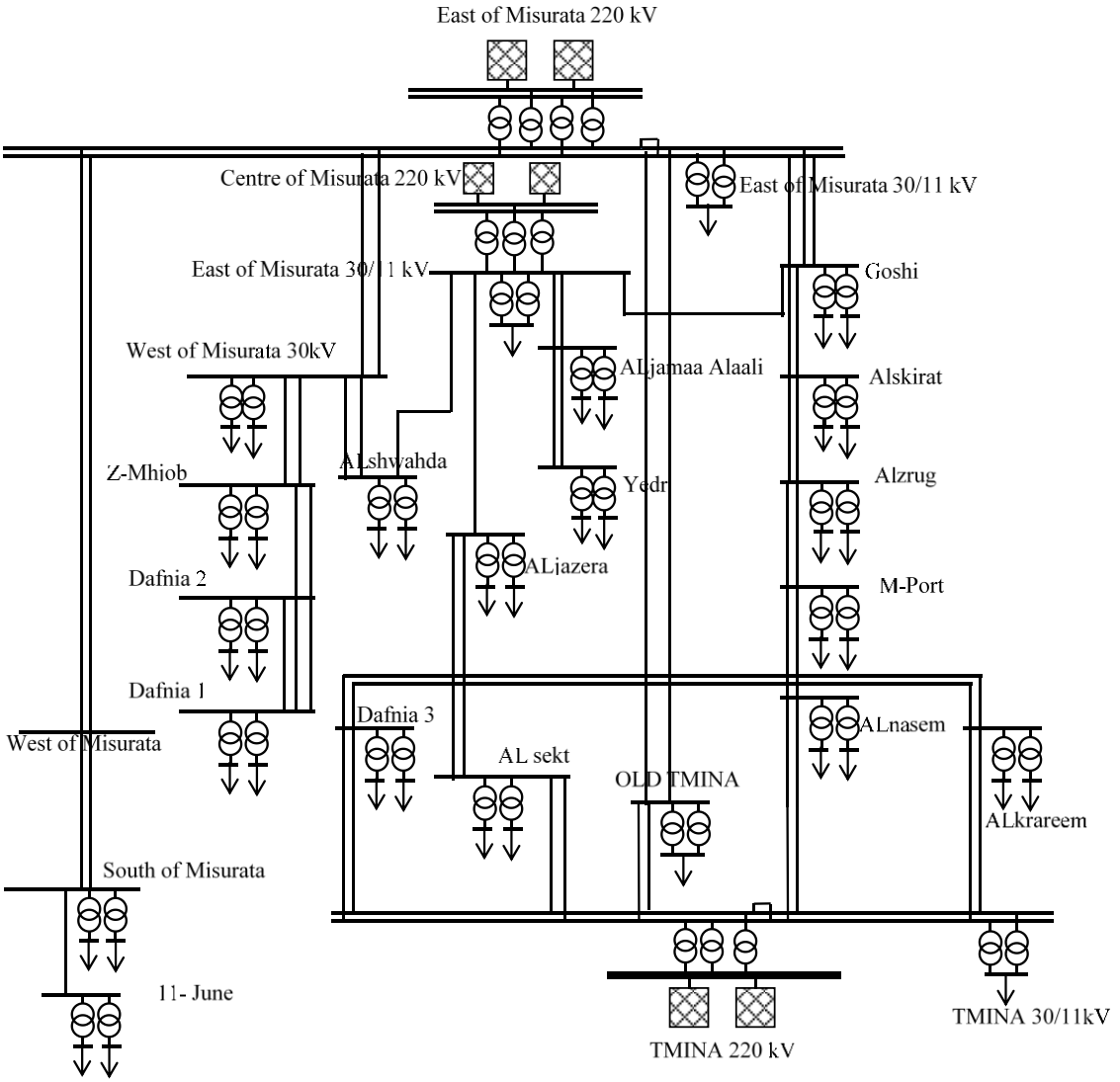

Figure 1. Misurata distribution network

Table 1. Loads of Misurata distribution network substations

Substations	Transform (A) (MW)	Transform (B) (MW)	Total (MW)
Al Nasem	2.70	3.40	6.10
Al Sekt	6.00	5.00	11.00
Al Shwahda	4.50	6.00	10.50
Al Skirat	5.00	5.50	10.50
Alswehle Farm	3.50	3.50	7.00
Alzarug	3.70	2.50	6.20
Goshe	4.70	7.80	12.50
Aljazera	9.20	6.60	15.80
M-Port	8.60	4.00	12.60
Mis-Center	3.00	8.20	11.20
Al-Jamaa Al-Alaali	5.50	5.50	11.00
Yedr	5.70	5.80	11.50
Z-Al Mhjob	8.90	9.10	18.00
Dafnia(1)	-	3.80	3.80
Dafnia(2)	2.00	6.40	8.40
Dafnia(3)	5.50	4.00	9.50
Suk Juma	2.30	4.00	6.30
Old Tmina	4.30	1.40	5.70
West Misurata	8.90	9.10	18.00
Alkarareem	0.00	5.70	5.70
East Misurata	1.00	11.30	12.30
11 June	4.80	2.00	6.80
South of Misurata	5.50	6.00	11.50

In this research, using the extrapolation method, the load growth factor estimation is carried out based on the measurements of the last six years of yearly maximum loading of Libyan loads, where it is calculated using the following form:

$$LGF\ (\%) = \frac{Y_{new} - Y_{old}}{Y_{new}} \times 100 \quad (1)$$

The average load growth factor of the Libyan network is calculated using equation (1) which is about (9.8%) each year. This percentage will be used in this research as the average growth factor of Misurata loads due to the lack of historical data on some power substations in Misurata distribution network as mentioned earlier.

Table 2. Yearly maximum loading of Libyan national Grid

Years	Maximum Loads (MW)
2016	7017
2017	6922
2018	7158
2019	7315
2020	7350
2021	8150

For the years from 2021 to 2026, the loads will be increased by the calculated LGF and the network operation will be assessed. To add, NEPLAN uses the Newton Raphson method to calculate the parameters of the MDN.

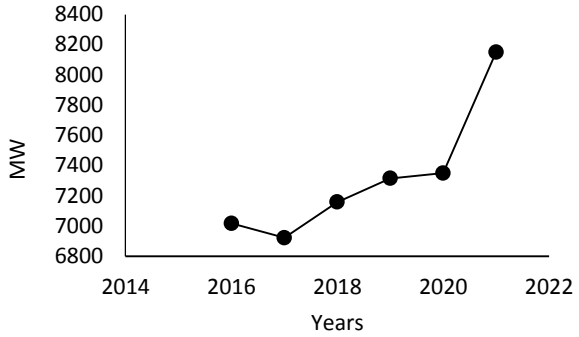

Figure 2. Libya load curve- years (2016-2021)

IV. RESULTS AND DISCUSSION

Table 3. Data of overloaded parts of Misurata distribution network

Node name	Element name	P (MW)	Q (MVAr)	Loading %
Centre of Misurata	Line	45.99	17.485	106.88
TMINA	Line	15.927	14.673	127.84
DAFNIA 3	Transformer	8.983	7.31	115.81
B-2082	Line	-14.606	-12.31	127.97
TMINA	Line	15.929	14.655	127.78
B-2074	Line	-15.159	-13.279	127.86
B-2078	Line	-14.608	-12.294	127.91
B-2074	Line	15.159	13.279	127.86

By considering the estimated loads of Misurata distribution network 30kV for the years from 2021 to 2026, a few remarks presented by executing NEPLAN software:

1. In 2022: It is noted that the loading of the line connects the centre of Misurata and the Aljazera area will be 106%.
2. Generally, for the years from 2023 to 2025, the rest of distribution network will have no big issues, where system's loadability will be less than 105%, which is accepted loading percentage according to power distribution codes.
3. In 2026: some problems are anticipated to appear in Misurata distribution network which are:
   - The loading of the line that connects the centre of Misurata and the Al Shwahda area will be 106.87%.
   - The line connects Al-Karareem and Tmina with a length of 12 km, the loading will be at 127.9%

- The loading of the 10 MVA transformers of the Al-Dafnia substation will be at 115.8%.

The other parameters of these loaded lines/transformers are illustrated in Table (III).

V. THE PROPOSED PLAN TO IMPROVE THE ANTICIPATED LOADABILITY

The enhancement of the loadability of transmission lines and transformers can be done using one of the following methods by[9]–[12]:

a- Adding new components such as adding new lines.
b- Dividing the loading areas to feed from different lines.
c- Improving network power factor whether by installing shunt capacitors or flexible ac transmission systems (FACTS) devices.

The first two methods improve the loadability by providing another path for the power flow in the meantime the third method work to reduce the total amount of transferred reactive power. This technique will be implemented in future research on the MDN.

In this paper, only the former two techniques are implemented here to solve the loadability issues of Misurata distribution network as the following:

1. The line connects Misurata city centre and Al Shwahda and Aljazera: reducing the loading of these lines can be done whether by adding new parallel lines or splitting the feeding of these two areas as shown in figure (2). Such a solution will ensure the loadability of the two lines will be within the limit.

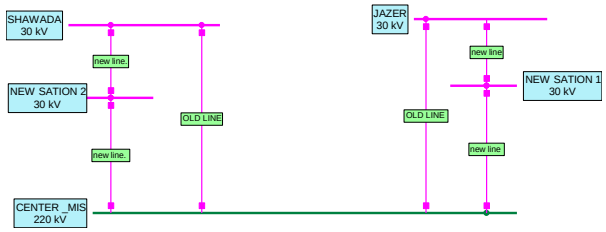

Figure 3. The lines connect the Misurata Centre and Al Shwahda and Aljazera

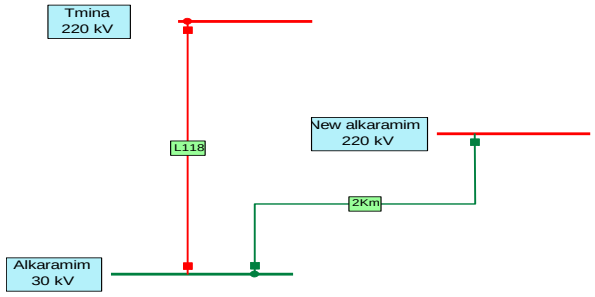

Figure 4. The Al-Karareem and Tomina connection line

2. The line from Al-Karareem to Tmina: a new 30kV substation is under the construction to improve the loadability of this part of the network, the position of this substation is presented in the figure (3). This area should have special care where the area is categorised as an industrial zone where a large demand is anticipated within the next few years. In this regard, a new 220 kV is established as well as replacing the current transformers (3×63) MVA by (3×100) MVA.

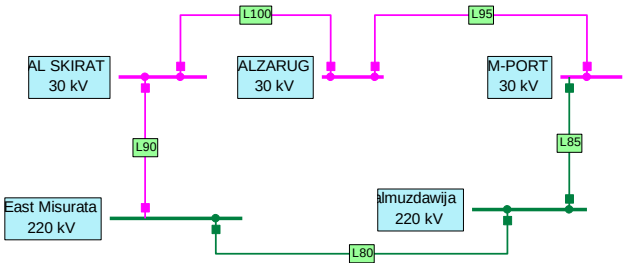

Figure 5. The line connects from Al-Zarrouq area and Al-Sakirat

3. The line connects from Al-Zarouq area and the Al-Sakirat area It is connected with the Misurata seaport substation to decrease the loading on the other substations such as Al- Zarouq as Figure (4).
4. The electrical power transformer located in the Al-Dafnia substation, with a capacity of (10 MVA) changed to (20 MVA).

VI. CONCLUSION

The simulation of 30kV Misurata distribution network presented that some lines and transformers will face critical operating conditions starting from 2025 due to the increase in their loading percentage. The maximum loading ratio was up to 127.9%. Therefore, an upgrading of the current network becomes a necessity to avoid loadability-related problems. As stated in this paper, solving these loading issues can be ensured by the following actions:

- Increase the number of feeding points to the loads. Such a step might require splitting consumers into groups based on their loads, type and feeding priority.
- Accomplish the suspended projects that are supposed to support the current structure of the network.
- Create an updated database for the Libyan power network to assess the current and future operation of the network and present the effect of any future expansions.
- Raise consumer awareness of power consumption to educate consumers about the consumption of electrical energy.
- Manage wisely the currently generated power by prioritising the loads during peak power consumption time.

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