Photovoltaic Distribution Generation Case Study of 30/11kV(Alskarait Substation)

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ABSTRACT

Keywords:
 Alskerat (Misurata substation).
Distribution Generation (DG).
NEPLAN software.
PVsyst software.

The Distribution Generation (DG), which is a new member of distribution systems, enhances system performance. The DG improves voltage profiles, reduces real power loss, increases the system capacity and reliability. It is intended to boost the infrastructure in an environmentally friendly manner in comparison to Conventional power sources. Achieving the aforementioned benefits requires installing DGs of appropriate capacity in appropriate location. The ultimate goal of this work is to meet expected load demands for the next ten years in Alskerat (Misurata substation) by means of a photovoltaic (PV) DG system. While PVsyst software was used to identify the type and number of PV modules and inverters, and NEPLAN software has been used to analyze and simulate the work of the PV system. The current loads in the Alskerat power station are 18 MW and the expected loads for the next ten years will be approximately 38 MW calculated by load growth formula rate. The increasing of generating capacity of 20 MW was done by placing an electric power production station using renewable energies, which are the photovoltaic modules. The results of this attempt show an improved voltage profile of the grid and overcome to voltage drop problem while increasing load. From the results, the voltage drop that was addressed to the value 26.89 kV has been improved to a normal 30 kV after connecting the photovoltaic station. In addition, a cost-effect analysis in this work illustrates an advantage for PV systems over Conventional systems.

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1 INTRODUCTION

Distributed generation is defined as a small source of electric power generation or storage (typically ranging from less than 1 KW to tens of MW) that is not a part of a large central power system and is located close to the loads [1]. It is also defined as relatively small generation units of 30MW or less [2], which are sited at or near customers to meet specific customer needs and/or to support an economic operation of the distribution grid. While a very good overview of the different definitions proposed in the literature is provided in [3], the authors put particular emphasis to the definition proposed by [4] which considers the distributed generation in terms of connection and location rather than generation capacity. It

seems to be consensus among researches on considering the small-scale generation units connected to the distribution grid as a part of a distributed generation. Moreover, generation units installed close to the load or at the customer side of the meter are also commonly identified as distributed generation. The DG is expected to play a key role in the residential, commercial and industrial sectors of the power system. The technologies for DG are based on reciprocating engines, photovoltaic (PV), fuel cells, combustion gas turbines, and wind turbines. The DGs are becoming increasingly popular due to their low emission, low noise, and high efficiency. Some of the main applications of DG are to provide support and reliability to the power system in a grid-connected mode or isolated mode[5]. The more increase in load demand occurs, the more complication and problems occur in the distribution network. Voltage regulation is one of these problems of the distribution system that may especially affect much far-end loads and rural areas [6]. This source of power can prevent tons of pollutants and create new jobs. Due to an abundance of oil and natural gas in Libya, all the energy demand may easily be met. In fact, these resources constitute the major source of income in this country. Although the solar irradiance in Libya is very high, making it one of the best sites in North Africa, this source of power is not well-tapped.

This paper deals with the performance of the main grid-connected photovoltaic system (PV). The installation of a PV system on a distribution system is modeled by using a NEPLAN software. The analysis of the results is carried out using a photovoltaic plant with a capacity of 20MW interfaced with the 30kV. Distribution system at Alskerat Substation. A PVSYST software is used to determine the number and type of PV modules, inverters and the geographical area required to produce 20 MW. Overall, the work involves modeling of a full PV system (including the modeling of the PV panel), and monitoring the PV system efficiency with increased load demand expected in the future.

2   MATERIALS AND METHODS

By the beginning of this century, the use of photovoltaic solar systems has expanded and entered into many applications in various fields of the industry of power generation and distribution. Since photovoltaic solar systems have increasingly become involved in power distribution networks, the current case study attempts to design and configure a photovoltaic solar system in the Libyan city of Misurata as a region with growing demand for power and lots of potential for solar energy investments.

The Libyan 30kV power distribution network has some substations suffered from voltage drop problems as SWAWA substation in Misurata. Generally, the Libyan General Electricity Company (GECOL) uses conventional methods (such as installing 220 kV substations) to solve the problem of voltage drop in the 30 kV network.

With the growing interest in using renewable energy in such a system and since Libya is very rich in solar energy, this work proposes the use of solar cells to compensate the voltage drop in the 30 kV network. Alskerat substation power station, which is connected to the 30 kV network, has been chosen as a case study for the implementation of the proposed system and achieving the targeted objectives. Alskerat has been a voltage drop problem.

In this work, the proposed system begins by measuring the load on the selected station in order to calculate the power and energy consumption. The next step is to plan and determine

the required solar array and inverters, taking into account the solar array area and other economic considerations of the implementation.

This study is divided into two parts; the first part addresses the theoretical considerations of the work while the second explains the computer aided design procedures.

2.1   Theoretical Considerations

The goal of this work is to deal with the problem of expected voltage drop due to the increase in power demand for in the next ten years in Alskerat region of Misurata. The following measurements are taken to determine the scope of the problem.

Determining the current load and record BusBars voltage profiles.

Determining the currently load lines and record percentage loads.

Determining the anticipated load for the next ten years by load growth factors formula [7].

$$P_n = P (1+0.08)^n \qquad\qquad (1)$$

where

n   number of years

p   current power

P_n produced power after years

$P_{10} = 18 (1.08)^{10} = 38$ MW.

The load at Alskerat BusBar-B will be about 40 MW. Then, the solar array and inverters are calculated by PVSYST software and simulated by NEPLAN to account for costs and solar array area.

2.2   Software simulation

Two types of software, PVSYST and NEPLAN, are employed. PVSYST is used by architects, engineers, and researchers to study and plan work according to specific solar energy features. Once it is run, the software produces a complete report including the main parameters, the results of the simulation, monthly normalized values and arrow loss diagram. Given the parameters underlying this simulation (Geographic situation, Meteo data, plane orientation, general information about shadings and array configuration), the software recommends using 71434 modules, 22 connected series modules and 3247 parallel connected modules. The number of required inverters is 8. The area of array modules is determined at 116215 m^2. A full analysis of the report is provided in chapter four. NEPLAN Electricity is a software tool used to analyze, plan, optimize and simulate networks. It's allows the user to perform study cases very efficiently.

As shown in figure 1, a 30kV grid model representing actual Misurata grid as built drawing.

The BusBar voltage profiles and load lines are recorded and another 30 kV grid model accommodating anticipated 10-year development of the grid is built.

The BusBar voltage profiles and load lines are recorded and the results are analyzed and discussed. The results of the PVSYST simulation are used to build a model of the PV DG.

The DG is connected to Alskerat BusBar B, as shown in figure 2, and the voltage profiles and load lines are recorded. The contribution of the connected DG to the overall performance of the grid is measured and the results are analyzed and discussed.
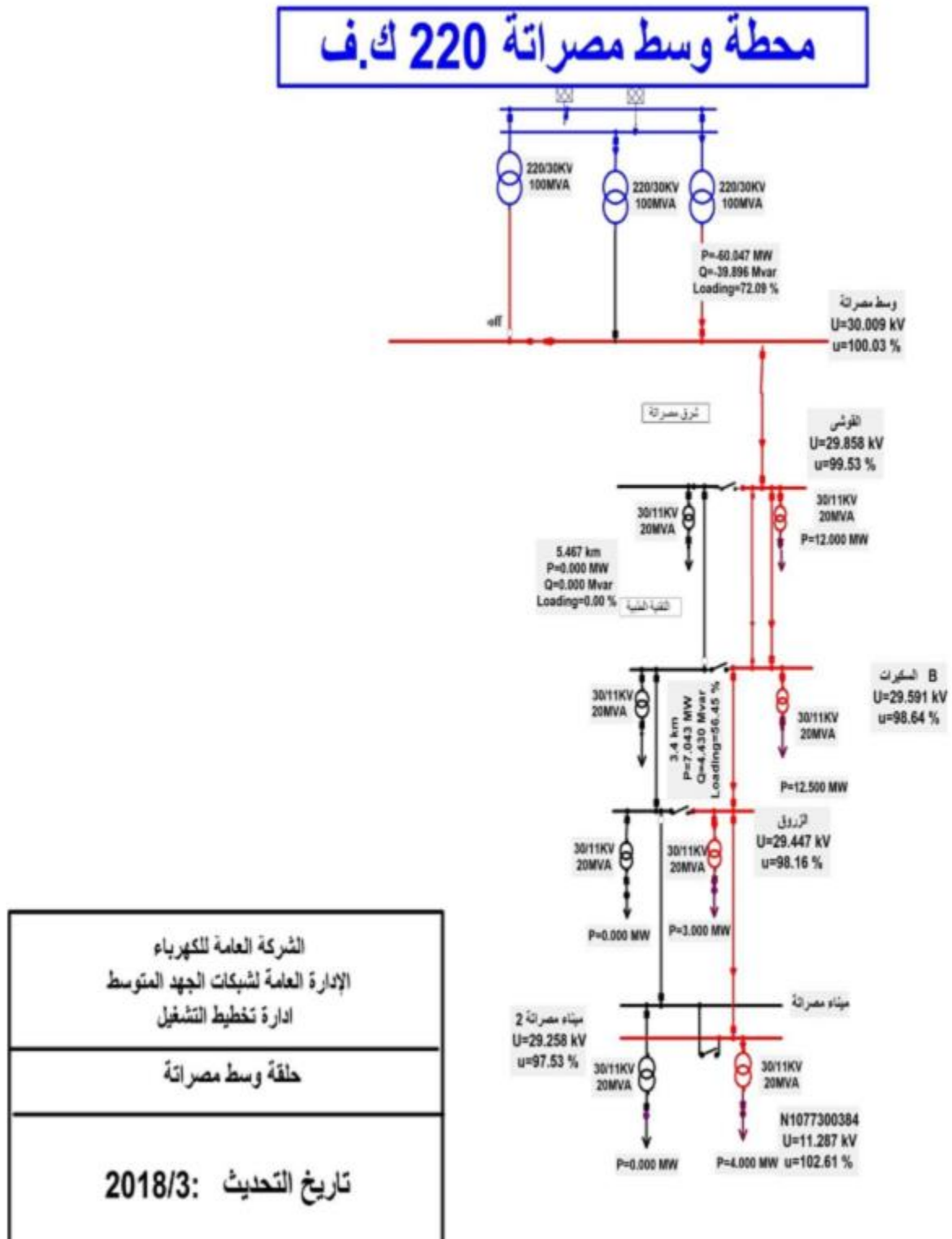
Figure 1.Ssingle line diagram 30kV network in the Misurata city[8].
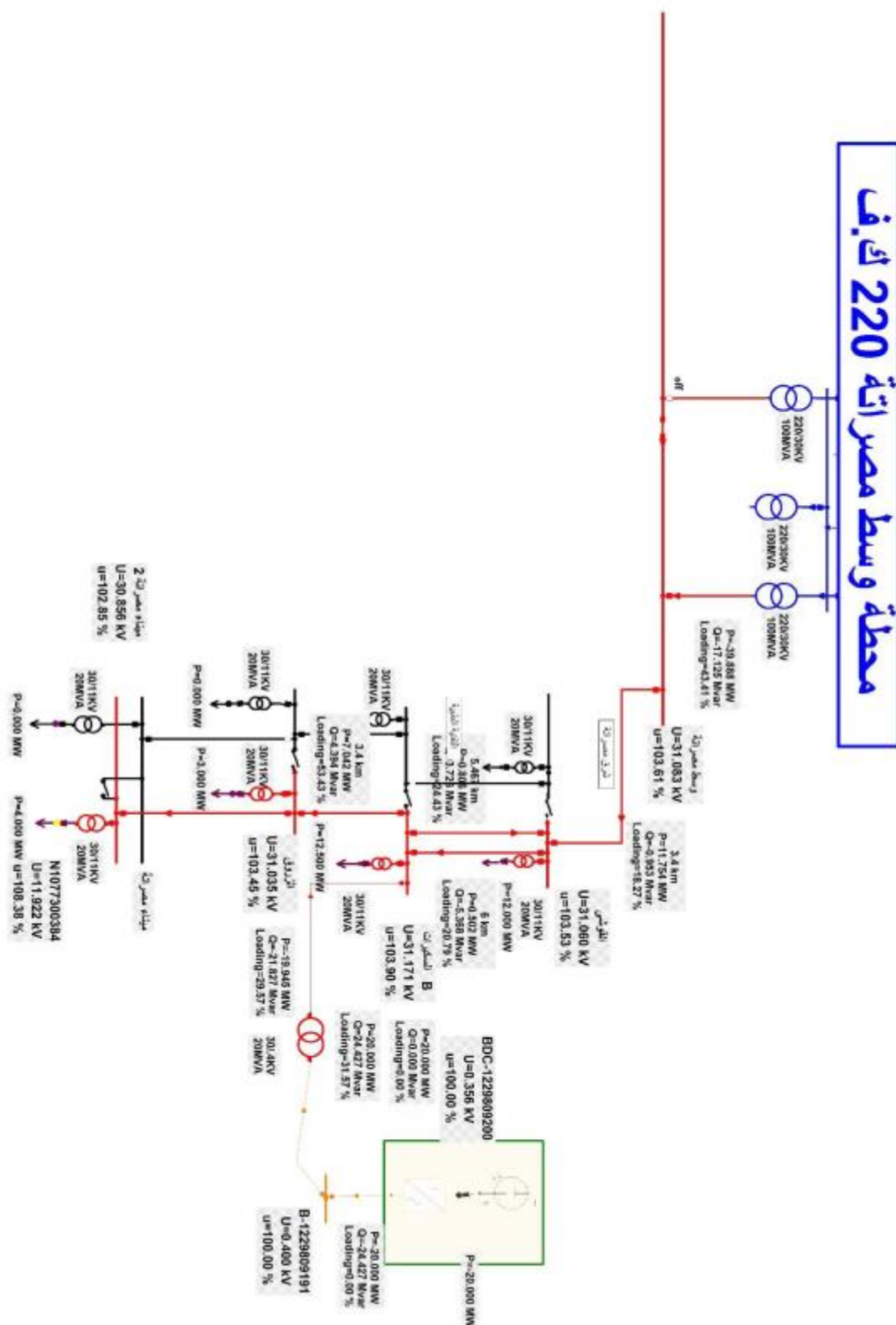
Figure 2. Single line diagram 30kV connected with DG (PV).

3   BUILDING PV-DG MODEL BY NEPLAN

As indicated earlier, the PVSYST software analysis has determined using 22 series-connected PV modules and 3247 parallel-connected PV modules, in addition to specifying other characteristics of the PV module. The results of PVSYST analysis have also recommended employing eight 2.2MW inverters. These specifications have been used as input to build a model PV-DG by NEPLAN.

Figure 3 represents the general outline of the DG unit including the PV module and inverter as proposed by NEPLAN. As can be seen in the figure, a transformer (off load tap changer) model is attached to the outline to allow connecting the DG to the 30kV network. Figure 3 represents three items PV module , Inverter and step-up transformer. The PV and inverter are belted them and simulated in NEPLAN software with all details.
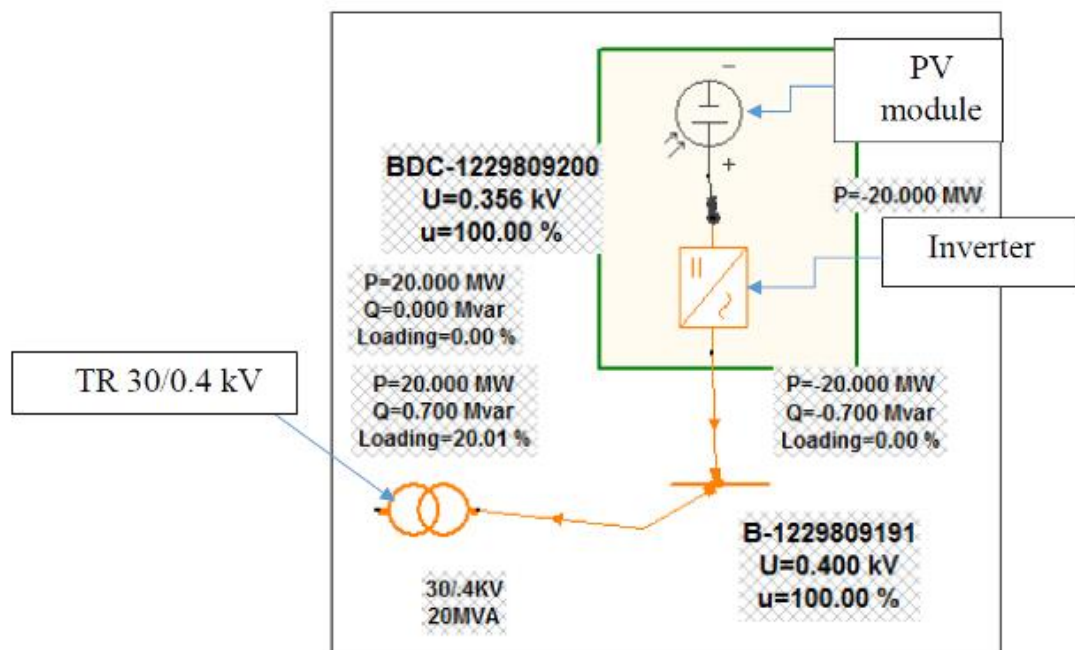

Figure 3. General PV-DG outline generated by NEPLAN.

3.1   Connecting the PV-DG Model to Alskerat BusBar B 30 kV

NEPLAN is used to simulate connecting the proposed PV-DG to Alskerat BusBar B. Figure 4 shows the performance of the simulated network with a load increase expected for the next ten years.
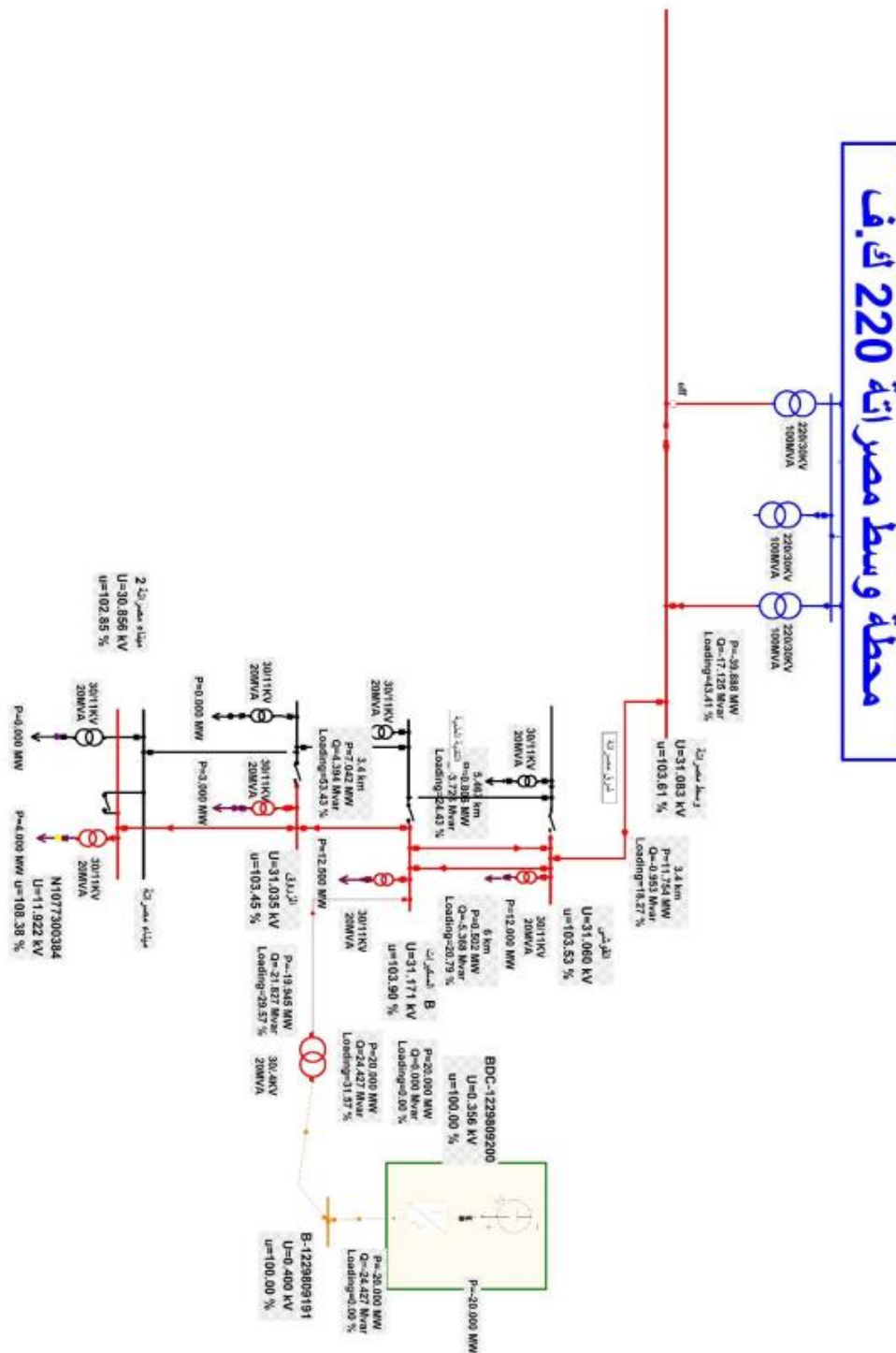
Figure 4. Single line diagram 30kv connected with DG (PV).

4   RESULTS AND DISCUSSION

Based on the data obtained from GECOL, the following system requirements are set:

- The buses voltage limits in normal operating condition range between 95% to 105%.

- The line loading limit is 100% loading according to the line capacity (current carrying capacity).

As shown in figure 1, the target 30 kV line diagram with all system data and loads on 20 March, 2018, also it can be seen in this figure, the substation has two transformers 220/30kV (100MW).

System performance results in terms of voltage and percentage of BusBars are shown in table 1, figure 5 and figure 6. As the data indicates, the voltage values are generally normal at current situation.

Table 1. BusBars names and voltage values feeding on west Misurata substation 220 kV for the Actual situation

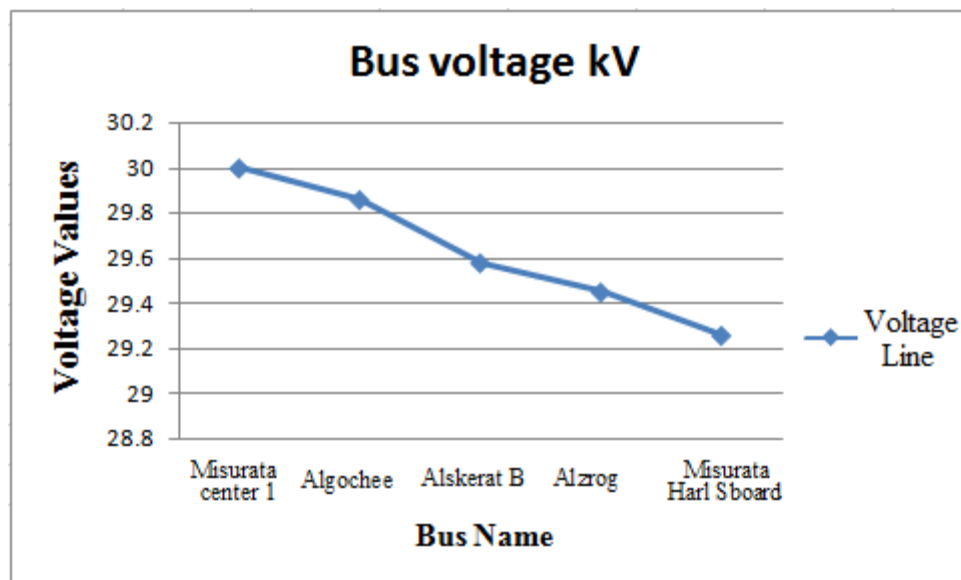| BusBar Number	Bus Name	Bus ID	Voltage kV	Voltage %
1	Misurata center 1	1077452559	30	100
2	Algochee	1077453312	29.86	99.5
3	Alskerat B	1077453298	29.58	98.64
4	Alzrog	1077453493	29.45	98.16
5	Misurata Harl Sboard	1077453517	29.258	97.53

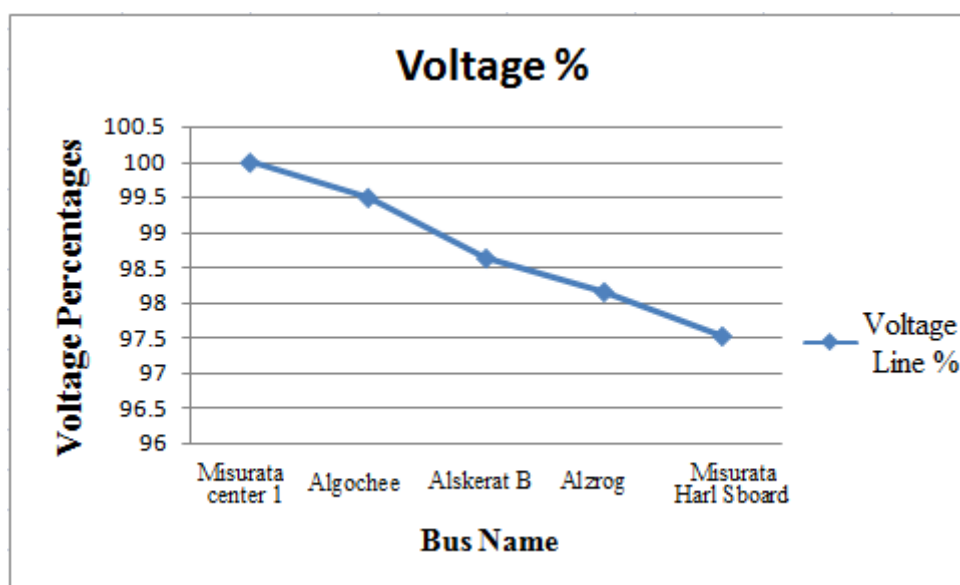*Figure 5. The BusBar voltage values.*

Figure 6. BusBar voltage percentages.

The loads of lines are shown in table 2 and figure 7. The data indicates that the line loads are also normal and within the capacity limits of the system.

Table 2. lines names and voltage value feeding on west misurata substation 220 kv for the current situation.

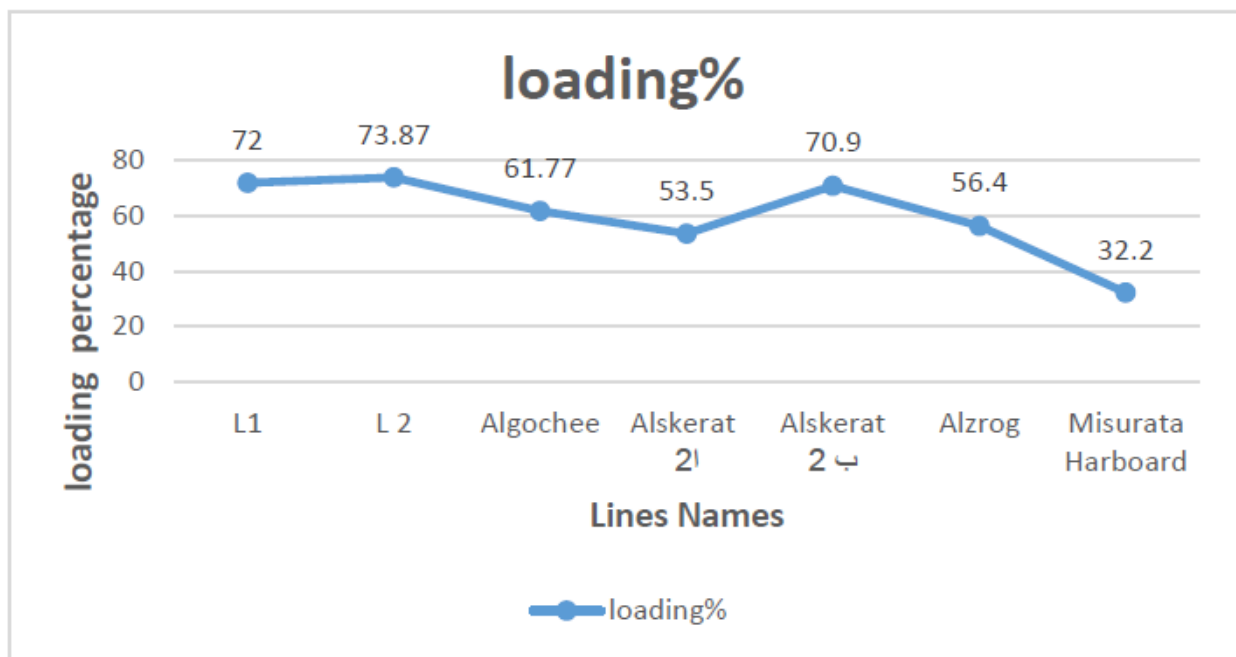| Line Number	Line Name	Line ID	Type	loading%
1	L1	1077453671	over head	72
2	L 2	1077453665	over head	73.87
3	Algochee	1077453313	cable	61.77
4	Alskerat ١ 2	1077233668	cable	53. 5
5	Alskerat ب 2	1077532577	cable	70.9
6	Alzrog	1077453527	cable	56.4
7	Misurata Harboard	1077453581	cable	32.2

Figure 7. Loading lines percentage.

The data presented so far shows that the system is functional data satisfactory level. However, given that some problems may arise due to potential hardware defects or dramatic load increases, cases of system failure seem inevitable in such a network. Dgs can enhance system performance and be a good alternative to conventional methods when dealing with such cases.

5   TEN YEARS GROWTH OF LOADS OF ALSKERAT 30 KV

Figure 8 shows network load increase expected to occur in ten years calculated with 8% as a load growth factor.

As the figure shows, a voltage drop, indicated by yellow colour, in some BusBars is expected to occur in ten years. The alarming values of voltage drop are provided in table 3.
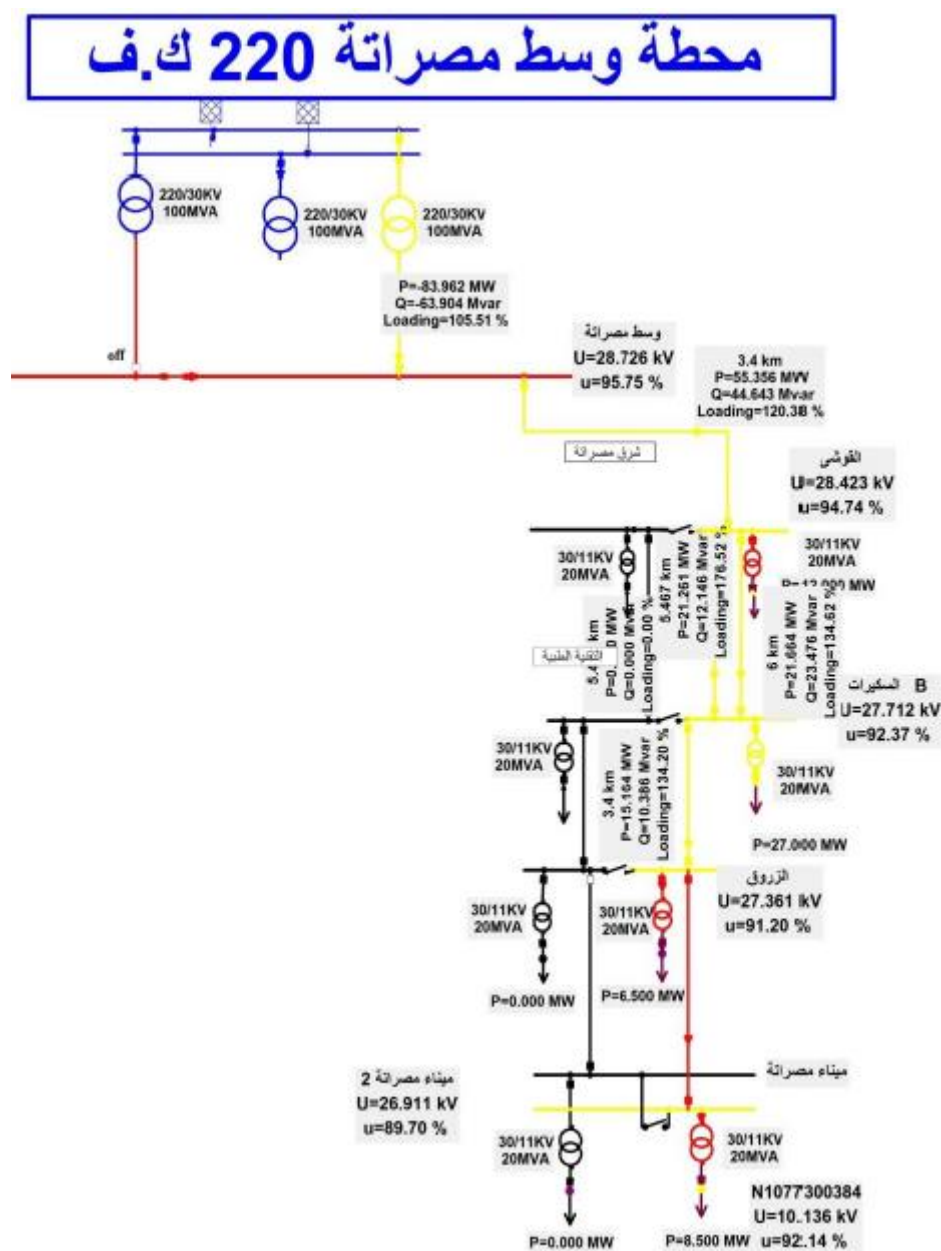
Figure 8. Single line diagram of the 30kV network in 10 years.

Table 3.BusBar names and voltage values

BusBar Number	Bus Name	Bus ID	Voltage kV	Voltage VR %
1	Misurata center 1	1077452559	28.72	4.2
2	Algochee	1077453312	28.41	5.3
3	Alskerat B	1077453298	27.7	7.67

4	Alzrog	1077453493	27.35	8.83
5	Misurata board	1077453517	26.89	10.37

The BusBar number (3-4-5-6) red colour in table 3 for voltage value indicated to under voltage with increase loads, the calculated values and percentages of BusBar voltage profiles are shown in figures 9 and 10 respectively explained the voltage value dropped.
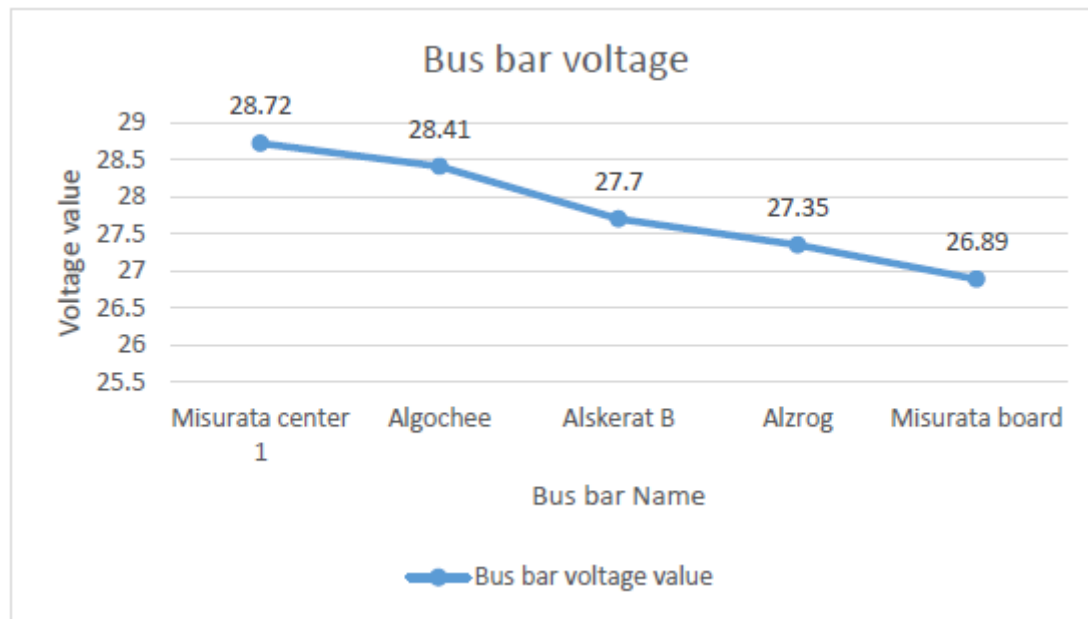

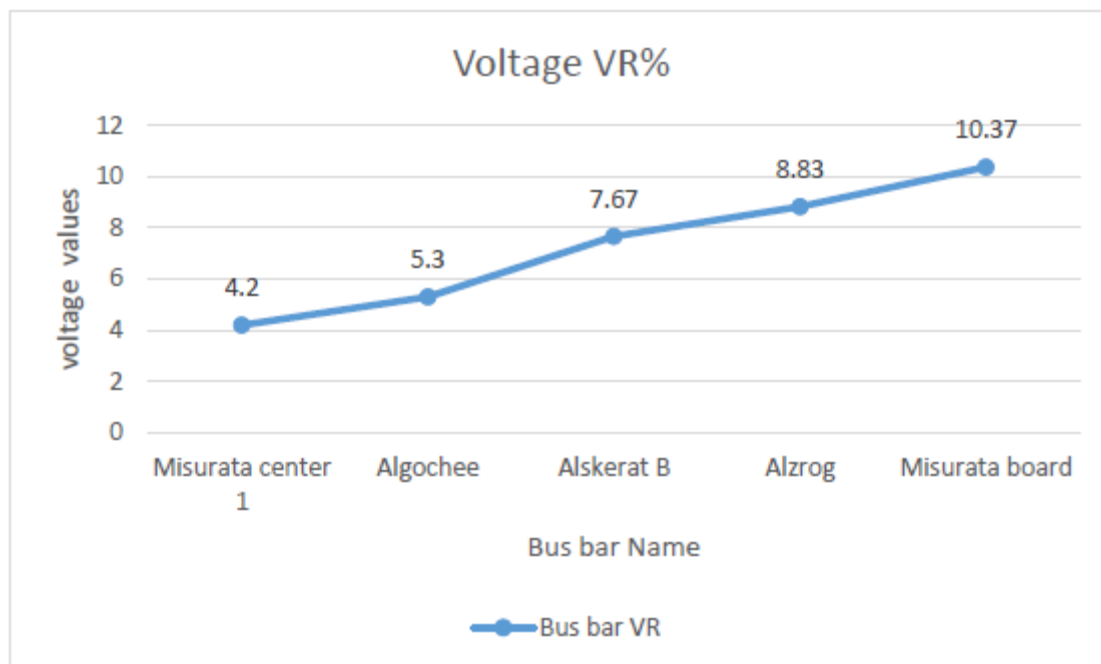*Figure 9. Voltage value.*

Figure 10. Percentage voltage BusBar.

Furthermore, the yellow colour in figure 8, provided earlier, indicates alarming levels of load increase expected to affect some power lines in ten years. The overload levels in red colour (LINE 2, 3,4,5,6) affecting these lines are provided in table 4, and also show in figure 11, these new values after loading and represent over loading for lines.

Table 4. Lines names and voltage values

Line Number	Line Name	Line ID	Type	loading%
1	L1	1077453671	over head	105.52
2	L 2	1077453665	over head	73.87
3	Algochee	1077453313	cable	120.4
4	Alskerat ١ 2	1077233668	cable	176.5
5	Alskerat ب 2	1077532577	cable	134.6
6	Alzrog	1077453527	cable	134
7	Misurata Harboard	1077453581	cable	76.8

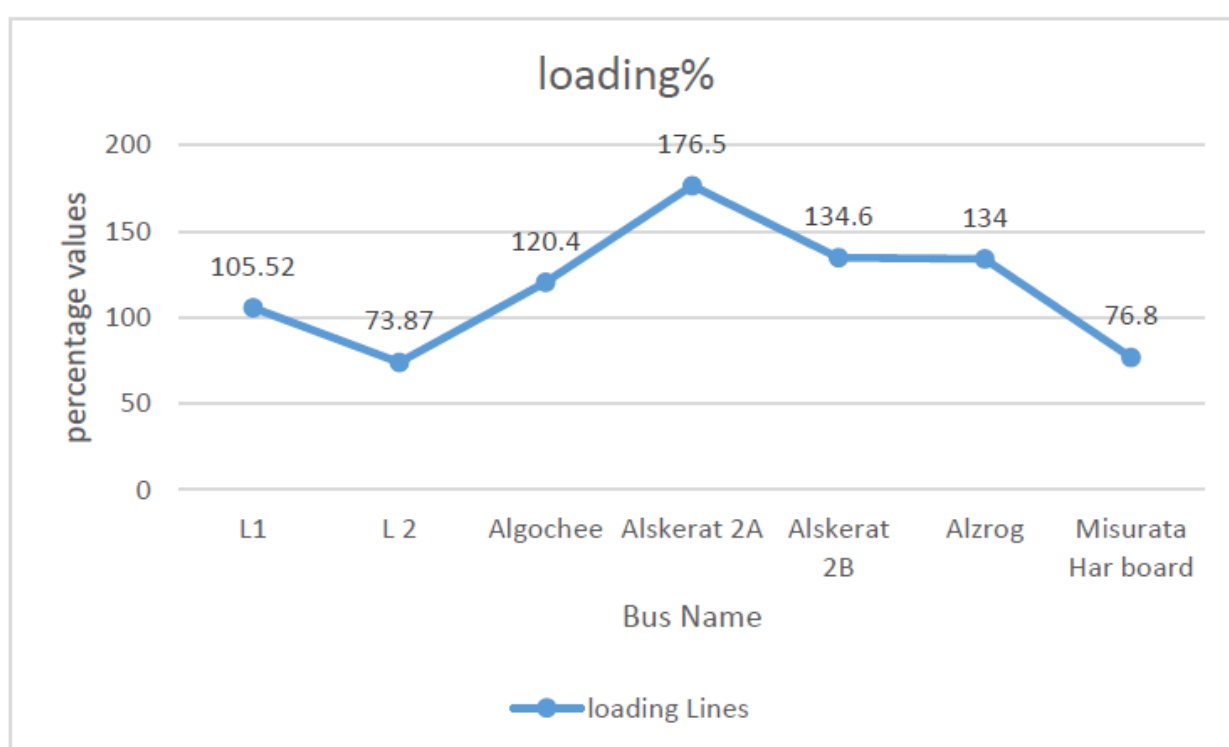Figure 11 Shows the lines with overloads.

Figure 11. Line loads

6   EFFECTS INCREASE LOADS WITHIN TEN YEARS AT (CASE ANALYSIS)

In this case, with increase load, the result shows the system is suffering from the problems of low voltage profile which exceed the limits in some BusBars. The system lines also appear overloaded. To solve this problem, a PV-DG is connected to the network. With noted only concentrated on one line (Alskerat), but actually there is many 30kv substations connected to 220kv Misurata centre substation's loads will increase also.

6.1   The BusBar (Alskerat B) 30kV connected to a PV-DG
Figure 12 shows the planned PV-DG connection intended to deal with the problem of load growth expected in the next 10 years.
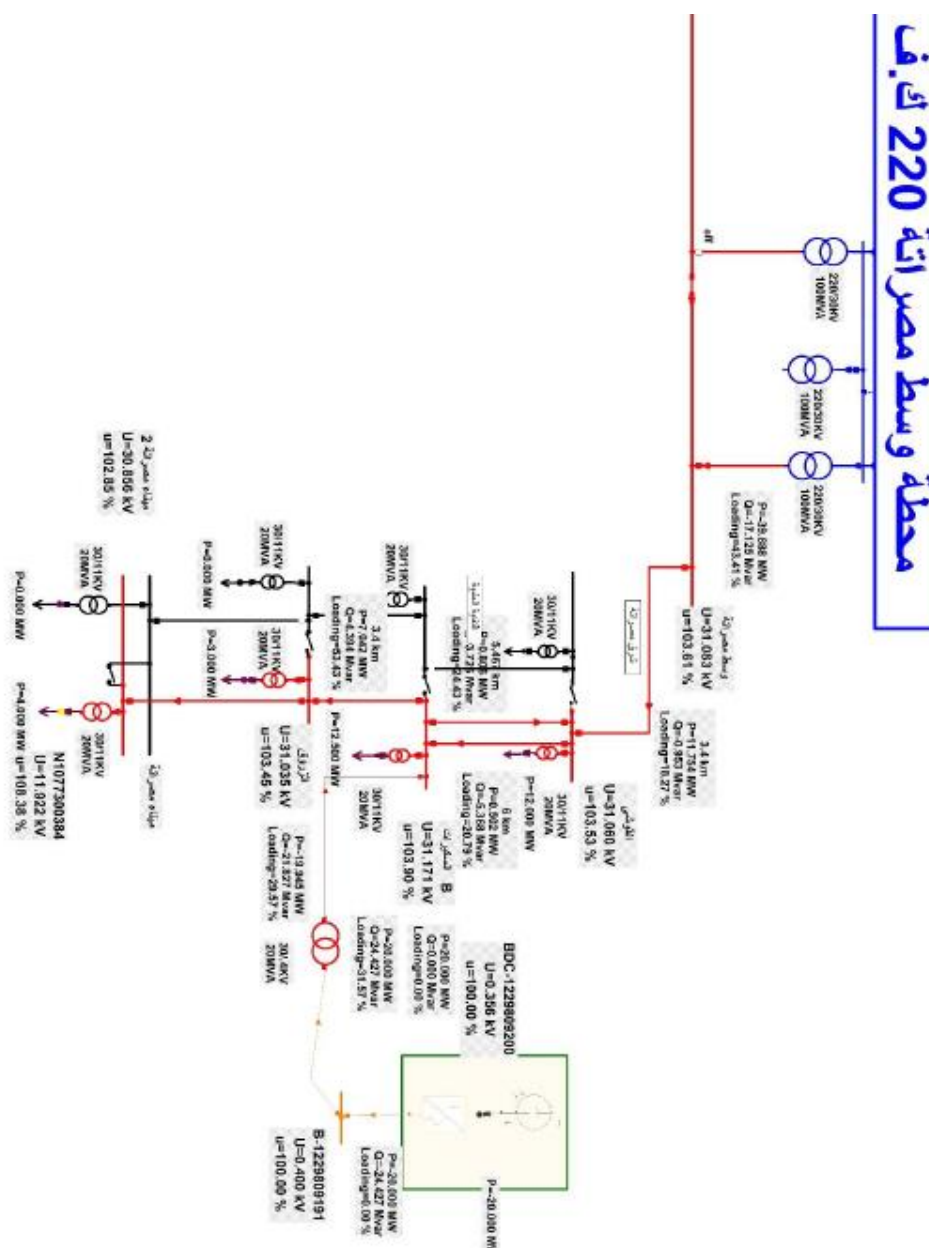

Figure 12. Single line diagram of the PV-DG connected to the 30kV.

As can be seen in the figure, connecting the PV-DG to the network improves the performance of BusBars and leads to overcoming the problem of voltage drop. The BusBar values and percentages are provided in table 5, the voltage value come back to the rated voltage value with new source.

Table 5. BusBbar names and voltage value connected to the PV-DG

BusBar Number	Bus Name	Bus ID	Voltage kV	Voltage VR %
1	Misurata center 1	1077452559	30.59	101.95
2	Algochee	1077453312	30.47	101.5
3	Alskerat B	1077453298	30.36	101.2
4	Alzrog	1077453493	30	100
5	Misurata board	1077453517	29.645	98.82

The calculated values of Busbar voltage profiles are further explained in figure 13 .
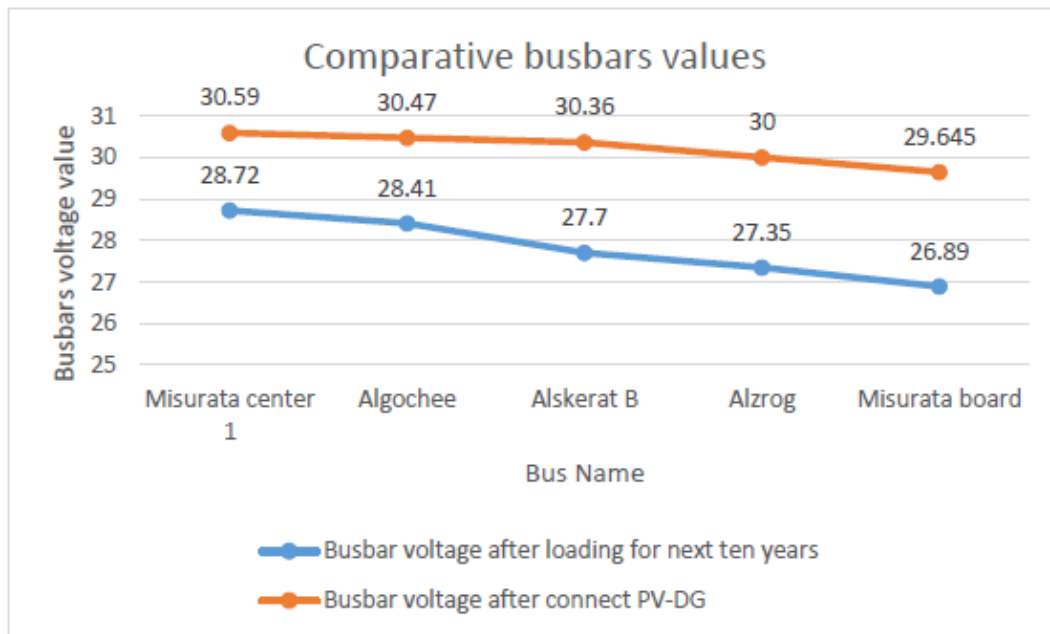

Figure 13. Comparative BusBars values after and before connect PV-DG.

Figure 12 also shows how the PV-DG can solve the problem of line overload by providing a local source of power generation, such as the yellow colour which represents under voltage indictor for BusBars return all to rated colour(red colour) , the values will be about 30kv approximately. The load percentages are provided in table 6.

Table 6. lines names and load percentage connected to the PV- DG

Line Number	Line Name	Line ID	Type	loading%
1	L1	1077453671	over head	68.38
2	L 2	1077453665	over head	73.87
3	Algochee	1077453313	cable	56.44
4	Alskerat ‏ا‎ 2	1077233668	cable	65.88
5	Alskerat ‏ب‎ 2	1077532577	cable	50.65
6	Alzrog	1077453527	cable	121.2
7	Misurata Harboard	1077453581	cable	69.1

Figure 14 provides a visual representation of comparative the line load before and after the PV-DG installation.
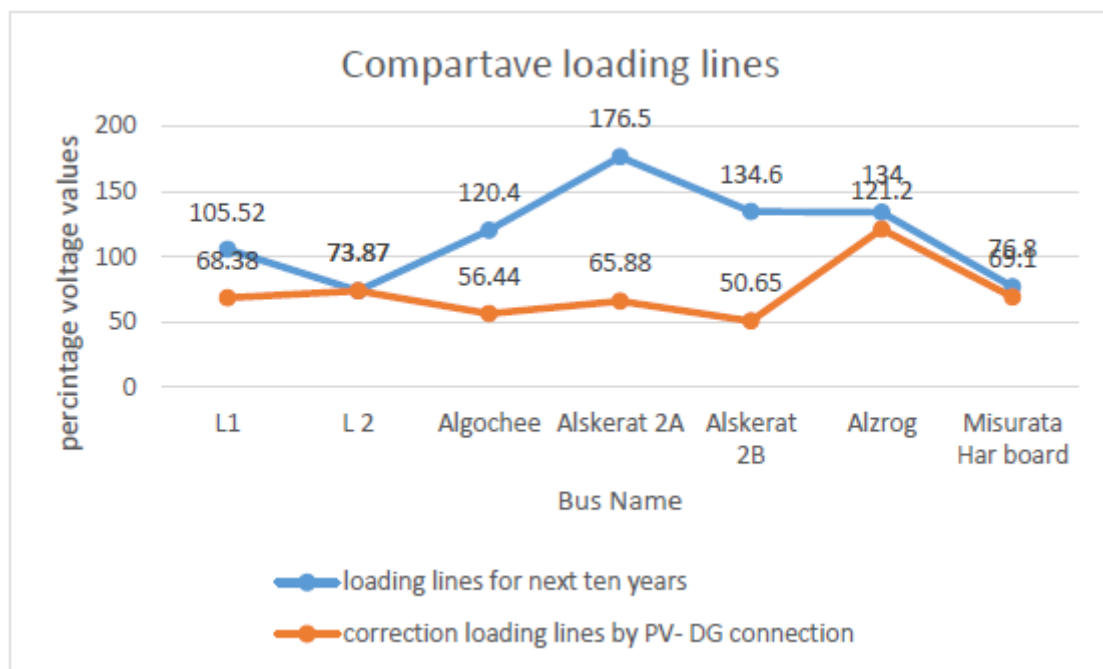

Figure 14. Load lines before and after the PV-DG connection.

6.2   Effects of connecting the PV-DG to the system (case analysis)

The effects of connecting the PV-DG to the system are shown in tables 5 and 6 and in figures 12,13 and 14. The data in these tables and figures show a positive effect of the PV-DG

connection on the system performance in terms of enhancing the BusBar voltage profiles and normalizing the loads of the power lines.

Note: Alskerat B transformer (30/11)20MVA should be upgraded to 50MVA size in order to satisfy the load requirement. Also Azzarook line (1077453527 ID) should be a replaced with two 240 mm^2 cables.

7   CONCLUSION

This paper deals with the performance of the main grid-connected photovoltaic system (PV). The installation of a PV system on a distribution system is modelled by using a NEPLAN software. The results of PVSYST analysis have recommended employing eight 2.2MW inverters. These specifications have been used as input to build a model PV-DG by NEPLAN. Improvement in the performance of the network has been got in this paper as shown the figures 9 and 10.

The effects of connecting the PV-DG to the system were shown in tables 5 and 6 and in figures 12, 13 and 14, which the voltage come back to normal value 30kV. The data in these tables and figures proved a positive effect of the PV-DG connection on the system performance in terms of enhancing the BusBar voltage profiles and normalizing the loads of the power lines.

The results of the paper show that the PV system is a good solution for enhancing voltage profiles and decrease load lines; in the same time Alskerat B transformer (30/11), 20MVA should be upgraded to 50MVA size in order to satisfy the load requirement. Also Azzarook line (1077453527 ID) should be a replaced with two 240 mm^2 cables.

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التوليد الموزع الكهروضوئي دراسة حالة 11/30 كيلو فولت (محطة السكيرات الفرعية)

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الملخص

يعمل التوليد الموزع (DG)، وهو إضافة جديدة في أنظمة التوزيع، على تحسين أداء النظام الكهربي؛ كتحسين الجهد، تقليل من فقدان القدرة الحقيقية، وزيادة قدرة النظام وموثوقيته. باستخدام الطاقات المتجددة كتوليد موزع يؤدي إلى تعزيز البنية التحتية بطريقة صديقة للبيئة مقارنة بمصادر الطاقة التقليدية المعروفة. يتطلب تحقيق الفوائد المذكورة أعلاه تركيب التوليد الموزع ذات سعة مناسبة في الموقع المناسب، ومن هنا واعتمادا على ما سلف كان الهدف الرئيسي من هذا العمل هو استخدام النظام الكهروضوئي (PV) في تلبية متطلبات الحمل المتوقعة لعشر سنوات قادمة في منطقة السكيرات (محطة مصراتة الفرعية). في هذا العمل تم استخدام برنامج PVsyst لتحديد نوع وعدد اللوحات والعواكس للنظام الكهروضوئي، بينما تم استخدام برنامج NEPLAN لتحليل ومحاكاة عمل هذا النظام الكهروضوئي. تبلغ الأحمال الحالية في محطة كهرباء السكيرات 18 ميجاوات، بينما بلغت نتائج الأحمال المتوقعة للسنوات العشر القادمة حوالي 38 ميجاوات اعتمادا على معدل معادلة نمو الحمولة. تمت زيادة قدرة التوليد بمقدار 20 ميجاوات عن طريق وضع محطة إنتاج طاقة كهربائية باستخدام الطاقات المتجددة، وهي اللوحات الكهروضوئية. كانت من نتائج هذه الورقة هو تحسين جهد الشبكة والتغلب على مشكلة انخفاض الجهد مع زيادة الحمل، حيث تم تحسين انخفاض الجهد الذي كانت قيمته 26.89 كيلو فولت إلى 30 كيلو فولت بعد توصيل المحطة الكهروضوئية. بالإضافة إلى ذلك ، يوضح تحليل التكلفة والتأثير في هذا العمل ميزة للأنظمة الكهروضوئية على الأنظمة التقليدية.

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