# Impact of Distributed Generation Systems on the Libyan Distribution Network based on (220/30) KV Algaraboly Substation

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## Abstract

The study focuses on distributed generation (DG) systems for renewable energy that can satisfy operational requirements under varied scenarios. Recently, there have been new challenges for networks planning and management due to the rising demand for electric power and greater usage of RES in electrical networks, such as wind and photovoltaic (PV) power. Demand and supply imbalances lead to disturbances in the electric grid, which could affect the operation of the power grid and cause instability. Local electricity users in Libya experience daily load shedding and require electricity to be supplied. Moreover, power system administrators and researchers are looking for a reliable and cost-effective ways to increase the percentage of renewable energy penetration in the grid. Therefore, it is becoming increasingly important to consider sustainable alternatives, such as incorporating green energy sources into current energy infrastructure. This paper explores the impact of renewable energy systems (wind turbine & PV) on the distribution networks and presents various operational scenarios to improve the bus voltage stability in distribution system. The Libyan distribution network's Algaraboly substation (220/30) KV has been selected as a case study. NEPLAN software has been used to simulate and analyse the renewable energy system units. load flow studies were used to examine whether power systems can successfully integrate renewable energy into the grid. It is expected that the findings of this work would support Libya's utility in developing renewable energy power plant integration policies. The results are analyzed and discussed to draw conclusions and suggestions for applying this technology in interconnecting DG systems using sub-transmission networks**.**

Keywords— renewable energy penetration, PV, wind power, voltage stability, NEPLAN software.

## 1. Introduction

Nowadays, there are inescapable changes and difficulties affecting the worldwide growth of the energy industry. Globally, distributed generation (DG) sources like wind and solar power are becoming more prevalent in distribution systems due to environmental factors. With a significant imbalance between demand and output, Libya's power infrastructure is severely short on power. On the contrary hand, there is a method for distributing power (called a load-shedding program) for customers, which makes it challenging to keep providing electricity to homes. Due to Libya's abundance of large-scale solar energy resources, new energy sources are being researched to cater to the country's rising energy needs and make use of other resources that are accessible to produce more power. Investment in alternative and clean energy sources has been increased [1]. The term "distributed generation" (DG) refers to a number of technologies that produce electricity at or close to the distribution system or point of usage (the consumers). Distributed generation, however, is a power generation plant that supplies the electricity grid at the user's facilities or through the network's distribution level, according to the International Energy Agency (IEA) [3]. In [4] the size of DG is defined as it ranging “from a few kilowatts to more than 100 MW”, and according to [5] DG is defined as generating between “500 kW and 1 MW”. Additionally, IEEE [6] describes distributed generation as the production of electrical energy by establishments that are sufficiently decentralized from centralized power plants to permit connectivity at almost each point in the network.

The DG systems can be on-grid or off-grid and can run on renewable or non-renewable energy sources. Distributed generation can be extremely play an essential role when planning energy systems because of its low cost of investment and small scale. DGs in distribution networks could have a significant impact on the current and voltage conditions of consumer and utility equipment. These effects could be negative or positive depending on the distribution system operation and DG characteristics [7-9]. Beneficial impacts are commonly referred to as "system support benefits" and include reduced losses, support for improved voltage and power quality, improved network reliability, delays in modernizing or updating distribution and transmission infrastructure, distribution and transmission. Freeing up capacity and comfort when using renewable energy sources and reducing costs by preventing high voltage transmission over long distances [8, 10].

Libya's power system suffers from a severe shortage of power production, with a large gap between demand and production. On the other hand, a power distribution system for subscribers (load shedding system) has been applied, making it difficult to continue supplying power to households. With the availability of large-scale solar energy sources throughout Libya, alternative energy sources are being developed to meet the growing energy demand and utilize other available resources to supply more energy. Efforts are being made to increase investment in energy sources and renewable energy sources.

Libya has no utility-scale power plants, so solar energy accounts for a small percentage of electricity production. The whole solar energy supply in Libya is derived from modest initiatives like hospital mini-grids and lighting initiatives for public spaces. In order to increase its energy supply, the Libyan government intends to produce 22% of its electrical from renewable sources by 2030 [12]. While the target is ambitious, Libya's huge solar potential is attracting many foreign investors. In addition to recent investments in Libya's oil and gas sector, Total Energies will develop a 500MW solar energy project in the country [13]. Libya has also discussed solar power projects with Shell and ENI. As seen in Figure 1, the residential sector has the highest proportional share of electrical energy demand, representing 36%of total electricity generation, followed by 23% in other sectors, and 14% in the commercial/industrial sector.

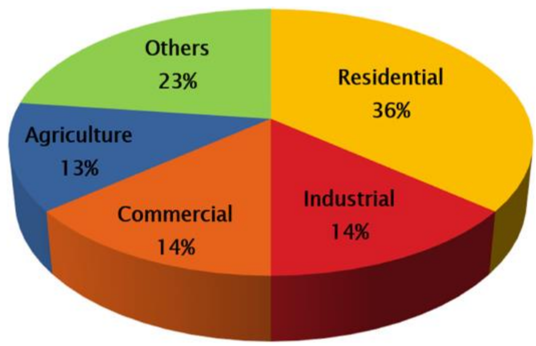


Fig. (1). % of Electricity Consumption by Sector [11]

The electrical system in Libya suffers from a severe shortage in electricity production, where there is a large gap between demand and production. This is addressed through the electricity rationing program for subscribers (load shedding process), making it difficult to maintain continuity of electricity supply for domestic use. Given the availability of vast solar energy sources in all parts of Libya, efforts are being made to increase investment in alternative and renewable energy sources to meet the increasing energy needs and exploit other available resources to provide more energy. Thus, it is crucial for study and research to investigate the possible alternatives for the Libyan energy sector, particularly with regard to its possible use of renewable energy as one of the vital sources in the country. Therefore, it is crucial to analyze and explore the possibilities for Libya's energy sector, especially with regard to the possibility for employing renewable energy as one of the nation's primary energy sources. Furthermore, improvements in solar power energy conversion technologies make its application feasible from an economic and technological standpoint.

In this paper, the main issue that faced in western region of Libyan power system distribution (Algaraboly) due to the actual load demand has been investigated to identify technical solution and suggestions for adding DG so that to meet the load demand.

## 2. Methodology

This study explores the impact of using renewable energy sources, particularly solar and wind power, as distributed generation (DG) in the Libyan electricity grid. The (220/30) KV Algaraboly substation has been selected as a case study to demonstrate the effectiveness of the DG system implementation. NEPLAN software has been used to analyze and simulate the DG units at selected sites, taking into account LF and PV penetration. Load flow study which based on the Newton-Raphson extended approach has been applied to investigate whether the power system is capable of incorporating the proper renewable energy penetration to the electrical grid. The work of this paper considers numerous scenarios to demonstrate the usefulness of RES behavior of voltage profile and system stability under various conditions. The power distribution system is considered to implement the IEC standard. The system modeling was designed with several scenarios which are distribution system model without DG (normal scenario), applying (PV) as (DG) with power system, added wind turbine as (DG) with power system, added wind turbine and PV as (DG) with power system.

## 3. Case Study

The key objective of this study is to utilize renewable energy sources, particularly photovoltaic, and wind power as DGs in the Libyan distribution network.

### *3.1.* Description of the Distribution System

The single line diagram of the power system under study is shown in Figure 2. The electric grid as shown in the Figure consists of different voltage level busbars. Algaraboly substation (220/30) KV is powered from Libya's local grid and experiences low voltage profiles at peak hours and high radiation of reactive power (Q) due to the high reactive load in the region. The network feeds from the 220 KV busbar which connects it to the rest of the Libyan network through different capacity power transformers. Table (1) shows data for different components in the network.

**Table (1). Data for different components in the network**

| | Description | Quantity |
|---|---|---|
| 1 | Voltage source220KV | 1x220KV |
| 2 | PV source. | 5MW |

| | | |
|---|---|---|
| 3 | Wind source3.1KV | 1x3.1KV |
| 4 | Wind source3.7KV | 1x3.7KV |
| 5 | Substation 30/11KV | 13x30/11KV |
| 4 | Transformers220/30 KV | 2x 63MVA |
| 5 | Transformers4.65/30 KV | 1x4.65 |
| 6 | Transformers11/30 KV | 3x20 |
| 7 | Overhead lines & Cables | 1&20 |

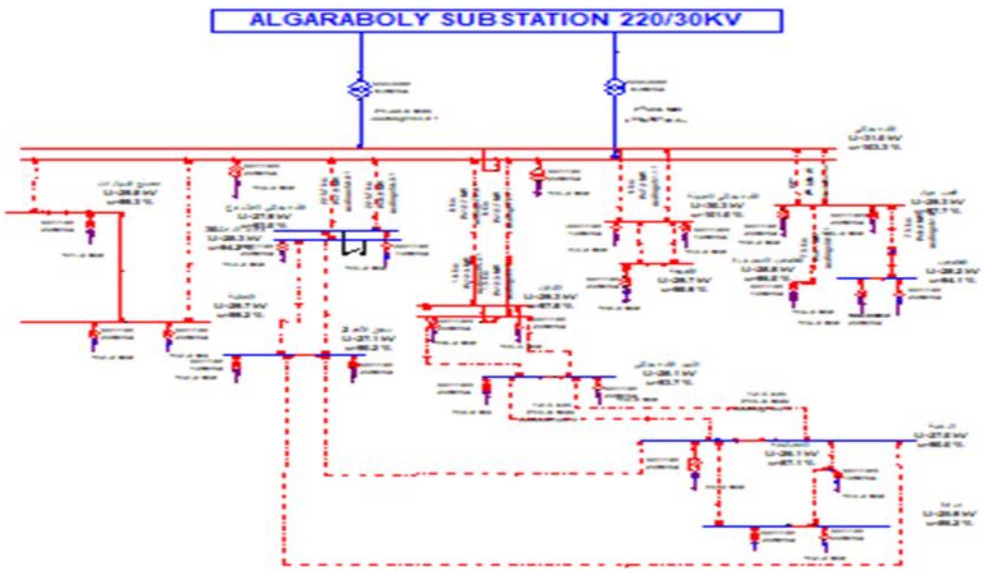


Fig. (2). Single line diagram of the power system under normal operation

### *3.2.* Normal Operation Scenario

The In this case, the network typically operates in steady state (without DG) with 220 kV substations connected to the Algaraboly network. The peak load of the grid is expected to occur in August 2017. The results of load flow analysis are presented in Table 2.

**Table (2). Active and reactive power & power losses**

| Q load (MVar) | P load (MW) | Q Gen (MVar) | P Gen (MW) | Q losses (MVar) | P losses (MW) |
|---|---|---|---|---|---|
| 53.9 | 92 | 83.7 | 97.8 | 29.746 | 5.792 |

The findings clearly show system weakness, voltage violations, high line load capacity, and high losses**.** Figure 3 shows a voltage violation on the system bus outside the voltage profile. Also, the total power consumption is 92 MW and the loss is **5.792** MW, so the system loss is about 6.29% of the load. Resolving such violations with the conventional method of re-planning and re-designing requires a great deal of labor and high construction costs, and the number of years of construction delays the economic growth of society. Figure 3 shows the voltage violation on the busbar as the base case (without RE). It has been found that most buses, especially those in Mrada, Almassabh, Elrrhba and Suk alahad2, have a reduced voltage rating with increasing distance from the distribution transformer and may drop below the minimum voltage allowed by the utility company which can lead to system shutdown. . According to a survey conducted by GECOL, Libya is characterized by semi-permanent sunshine and strong winds in some places. Therefore, the lowest voltage level load buses, Elrrhba bus and Mrada bus, are selected as the main sites for DG installation, Elrrhba for photovoltaics and Mrada for wind turbines). It is also possible to attach the DG to other buses with lower voltage ratings.

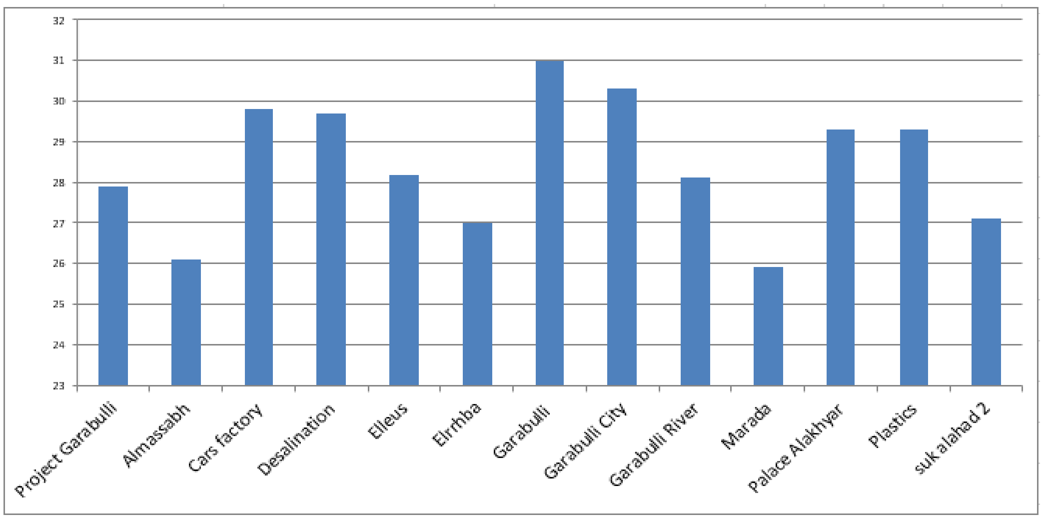


Fig. (3). Single Bus voltages profile (normal case)

### 3.3. Applying (PV) as (DG) with Distribution System

In this scenario, PV generation was connected to Elrrhba bus in order to investigate the impact of PV installations on voltage profiles. The PV unit is assumed to be a PQ bus (load bus) operating at unity power factor at the point of maximum current production. In this scenario, the same peak load is considered and the power loss results are shown in Table 3.

**Table (3). Active and reactive power & power losses**

| Q load (MVar) | P load (MW) | Q Gen (MVar) | P Gen (MW) | Q losses (MVar) | P losses (MW) |
|---|---|---|---|---|---|
| 53.9 | 92 | 54.1 | 91. 2 | 0.095 | 4.2 |

Figure 4 shows Algaraboly grid system configuration under second scenario.. Figure 5 shows the voltage profile of Algaraboly distribution network at the second scenario (applying PV as a DG).

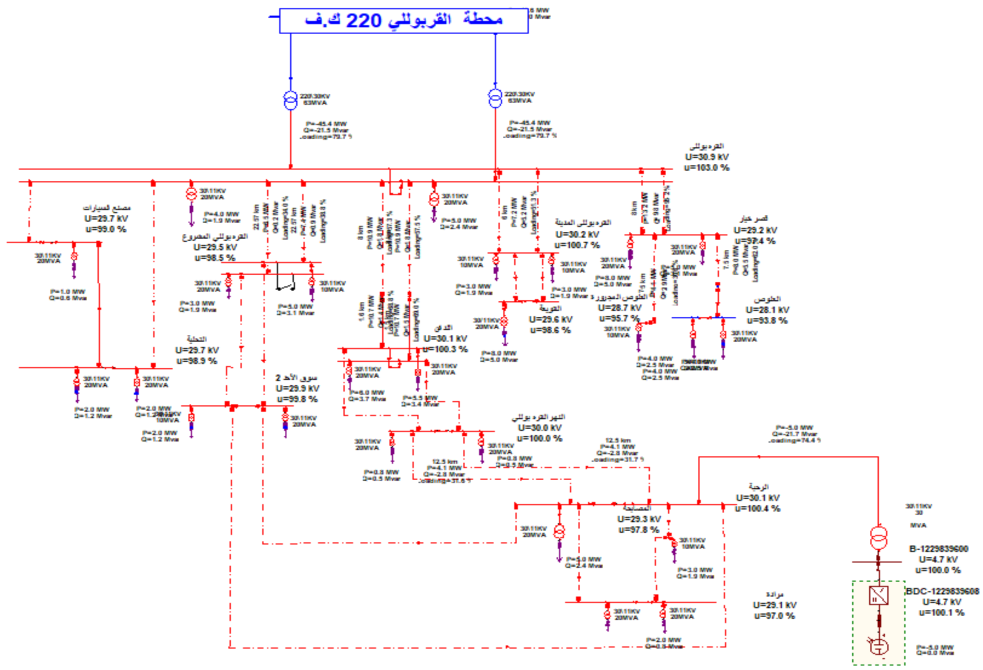


Fig. (4). Single line diagram of the power system under second scenario

To demonstration the influence of PV generation on real power losses, the simulation results have been compared with the base scenario (without RE). As shown in Table 3, the amount of MW loss resulting from the connection of PV generation falls from 5.792 MW in the base scenario (no RE) to 4.2 MW in this scenario (27.5 %). Furthermore, the system voltage levels have been increased and kept within acceptable limits. As a result, the voltage profile is enhanced and MW losses during PV system operation are decreased.

### 3.1. Applying (Wind Power) as (DG) with Distribution System

In this scenario, a wind power generation has been connected to MRADA bus, a load flow (LF) study of the system was initially performed to figure out the system voltage profile and losses,. In this scenario, the same peak load is considered. Algaraboly's grid system is configured in Figure 6 to supply (wind power) as (DG) with Distribution System.

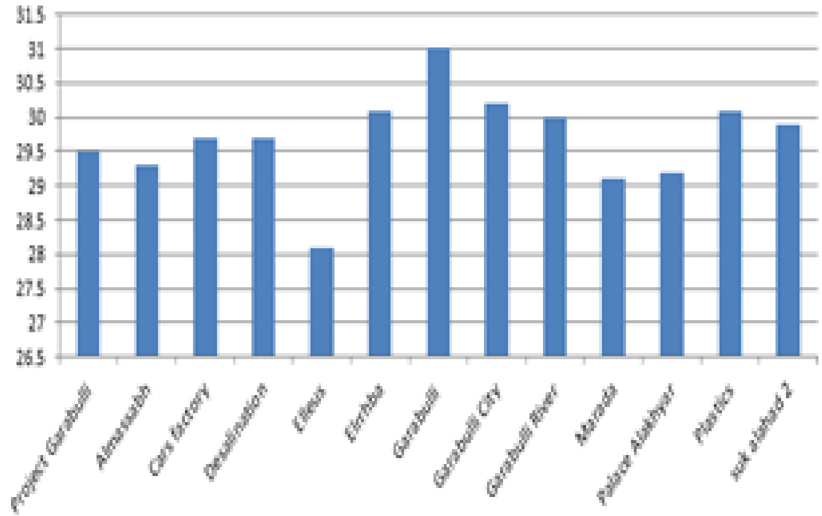


Fig. (5). Single Bus voltages profile (after adding PV)

The values of active power, reactive power and power loss at PV are given in Table IV. Figure 7 shows the voltage profile of Algaraboly distribution network at the second scenario (applying wind power as a DG).

To demonstration the influence of wind power generation on real power losses, the simulation results have been compared with the base scenario (without RE). As shown in Table 4, the amount of MW loss resulting from the connection of wind power generation decreased from **5.792** MW in the base scenario (no RE) to 4.47 MW in this scenario (22.82 %). Furthermore, the voltage level has increased to the accepted limit. As a result, the voltage profile is enhanced and MW losses during wind power system operation are decreased

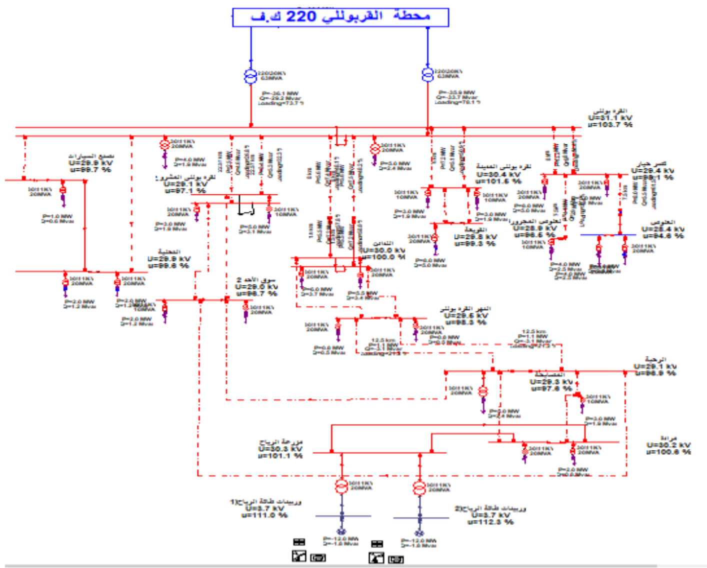

Fig. (6). Single line diagram of the power system under third scenario

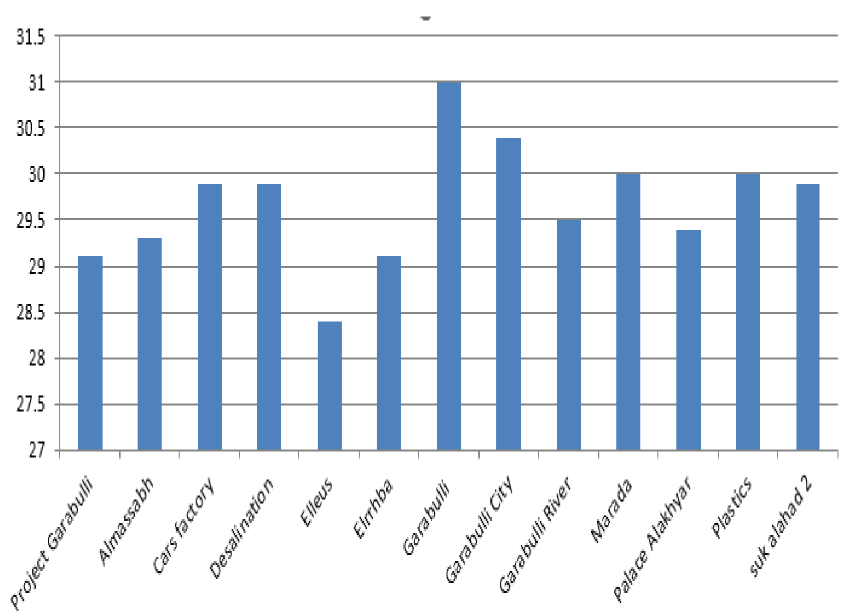


Fig. (7). Single Bus voltages profile (after adding Wind Power)

**Table (4). Active and reactive power & power losses**

| Q load (MVar) | P load (MW) | Q Gen (MVar) | P Gen (MW) | Q losses (MVar) | P losses (MW) |
|---|---|---|---|---|---|
| 53.9 | 92 | 77.12 | 91. 2 | 23.95 | 4.47 |

### 3.2. Applying (PV & Wind Power) as (DG) with Distribution System

In this scenario, a PV and wind power generation has been connected to Elrrhba and MRADA buses respectively, a load flow (LF) study of the system to figure out the system voltage profile and losses. In this scenario, the same peak load is considered. Algaraboly's grid system is configured in Figure 8 to supply (PV & wind power) as (DG) with Distribution System.

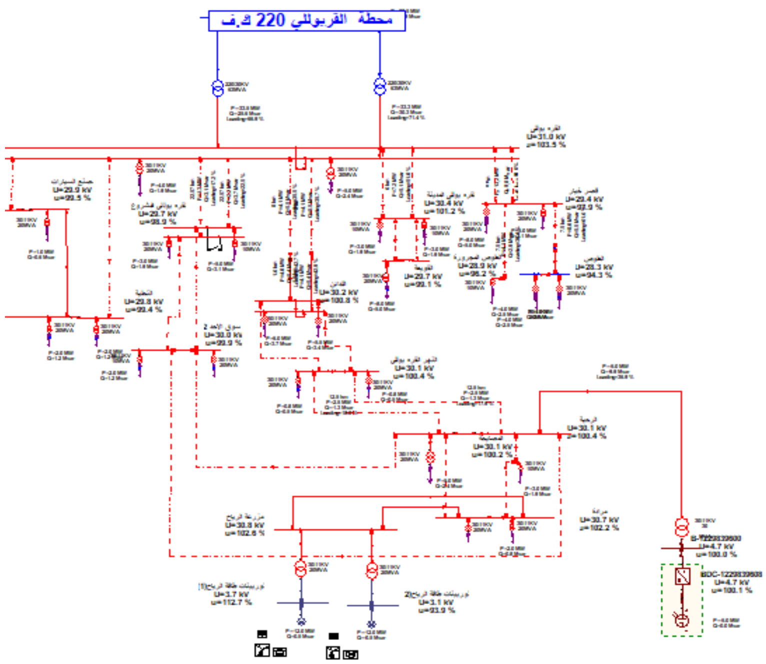


Fig. (8). Single line diagram of the power system under fourth scenario

The values of active power, reactive power and power loss at PV and wind power case are given in Table 5. Figure 9 shows the voltage profile of Algaraboly distribution network at the fourth scenario (applying PV & wind power as a DG).

**Table (5). Active and reactive power & power losses (PV and wind power)**

| Q load (MVar) | P load (MW) | Q Gen (MVar) | P Gen (MW) | Q losses (MVar) | P losses (MW) |
|---|---|---|---|---|---|
| 53.9 | 92 | 64.55 | 91.8 | 10.58 | 4.08 |

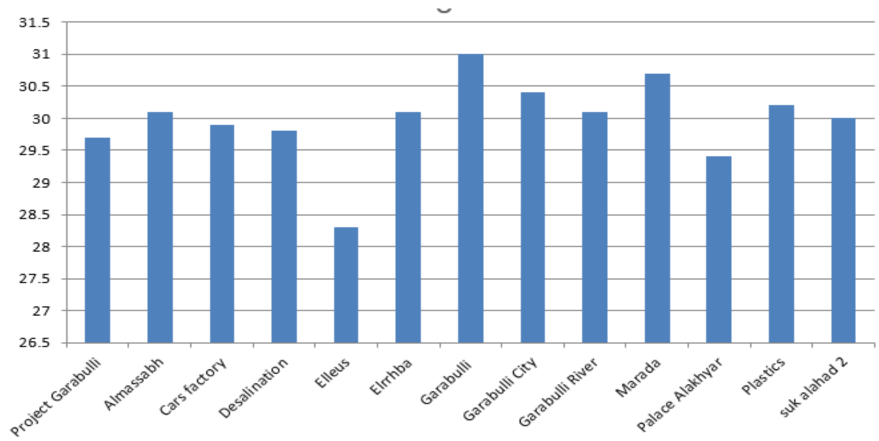

Fig. (9). Single Bus voltages profile (after adding PV and wind power)

To demonstration the influence of PV generation on real power losses, the simulation results have been compared with the base scenario (no RE) and other scenarios. As shown in Table 5, compared to the basic scenario, the amount of MW loss brought on by the connection of both PV and wind power generation dropped from 5.792 MW to 4.08 MW (29.55%). Furthermore, the voltage level has increased to the accepted limit. As a result, the system voltage profile is enhanced and kept within acceptable limits at all time, and the MW losses are decreased.

### 3.3. Applying (PV) and Wind Turbine With Diesel Generator as Stand Alone Grid

In this case, diesel generators were used as slack units for wind turbines and photovoltaic systems to run the grid. Algaraboly's grid system is configured in Figure 10 to supply (PV, wind power and diesel generator as standalone grid) with Distribution System

The Table 6 shows the impact of green energy and the potential to implement green energy alone to meet load demand.

**Table (6). Active and reactive power & power losses (PV and wind power)**

| Q load (MVar) | P load (MW) | Q Gen (MVar) | P Gen (MW) | Q losses (MVar) | P losses (MW) |
|---|---|---|---|---|---|
| 53.9 | 92 | 48.55 | 90.8 | -5.18 | 3.78 |

As shown in Table 6, the amount of MW loss brought on by the connection of both PV and wind power generation dropped to 3.78 MW. Furthermore, the voltage level has increased to the accepted limit (+/-5%) at peak load as shows in Fgure 11.

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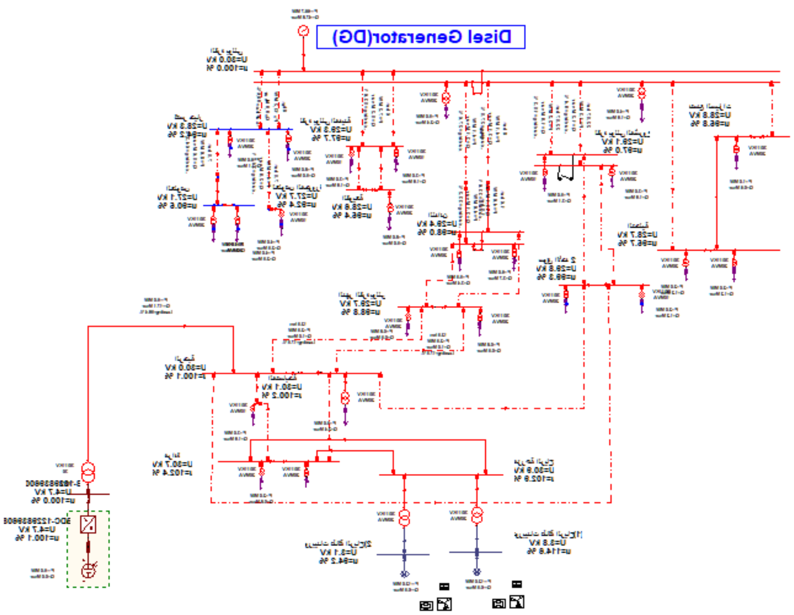

Fig. (10). Single line diagram of the power system under fifth scenario

## 1. . Conclusions

A new In this paper, the impact of renewable energy systems on the Libyan Distribution Network has been investigated, and various operational scenarios to improve the bus voltage stability in distribution system has been presented. Different scenarios of one nonrenewable DG and two types of renewable DG have been studied and their impact on voltage profile and power loss has been. investigated. the NEPLAN software with the help of Newton Raphson have been in the analysis. This paper obviously demonstrated that several tests and simulations were run on the DG renewables network. First, the simulation and its results were tested as a grid in normal operation (no RE). Next, the simulations have been used to analyze the PV diffusion

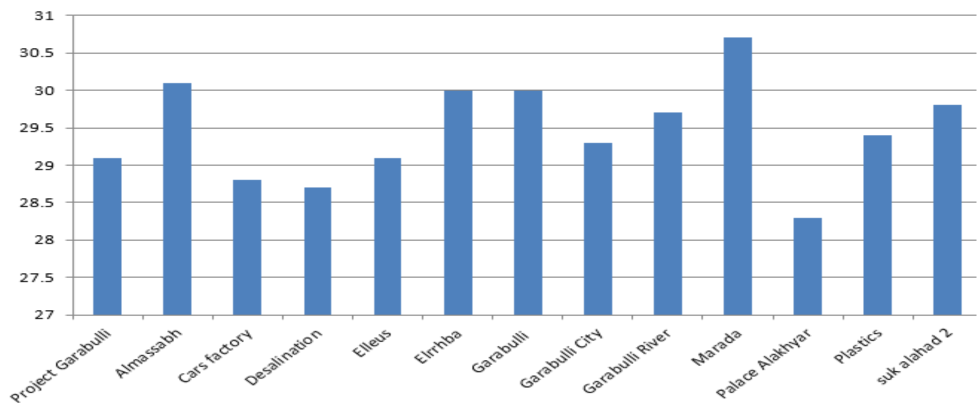


Fig. (11). Voltage profile of standalone grid

process. The outcome demonstrates that PV diffusion is a good solution to improve system performance. Supporting Voltage and Power Quality Improvements Therefore, the planner supports the idea that connecting renewable energy sources as DGs should ensure successful network improvements**.**

In conclusion, as DG penetration increases, renewable energy performance will have a significant impact not only on power quality, but also on voltage profile and power losses. It is also expected that, the outcomes of this study should guide legislation regarding the integration of renewable power plants by Libyan utilities.

Further studies on other renewable energy systems with this existing system such as pumped hydroelectric energy storage (PHES) or fuel cell system can be investigated

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