

# We are IntechOpen, the world's leading publisher of Open Access books Built by scientists, for scientists

6,900

Open access books available

185,000

International authors and editors

200M

Downloads

Our authors are among the

154

Countries delivered to

TOP 1%

most cited scientists

12.2%

Contributors from top 500 universities



WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index  
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?  
Contact [book.department@intechopen.com](mailto:book.department@intechopen.com)

Numbers displayed above are based on latest data collected.  
For more information visit [www.intechopen.com](http://www.intechopen.com)



---

# **Power Quality and System Stability Impact of Large-Scale Distributed Generation on the Distribution Network: Case Study of 60 MW Derna Wind Farm**

---

Saad M. Saad, Naser El Naily, Jamal Wafi,  
Faisal A. Mohamed and Abdelsalam Elhaffar

Additional information is available at the end of the chapter

<http://dx.doi.org/10.5772/intechopen.74796>

---

## **Abstract**

Wind energy (WE) has become one of the most promising and developed forms of renewable energy source due to its efficiency and the availability of different capacities according to the loading requirements. The integration of wind turbines in the Libyan network has become an indispensable choice due to Libya's distinguished location and for the Libyan National Initiative. Despite the numerous benefits of WE, the penetration of WE sources in the distribution network has some negative impacts related to the quality and reliability of the electric power supplied to the network. Owing to, the intermittent nature of these sources and electronic circuits needed to regulate the extracted power to comply with the grid requirements. In this chapter, implementation of the eastern Libyan network in NEPLAN and MATLAB/SIMULINK packages are carried out to investigate and analyze the significance of wind farm penetration in the medium voltage level of Libyan Distribution Network. A 60 MVA wind farm system has been connected to the Libyan distribution network according to the Libyan National Initiative. Different penetration scenarios are simulated to testify the technical aspects of integrating WE on the distribution level.

**Keywords:** renewable energy, wind energy, stability studies, power quality, distribution network, harmonics

---

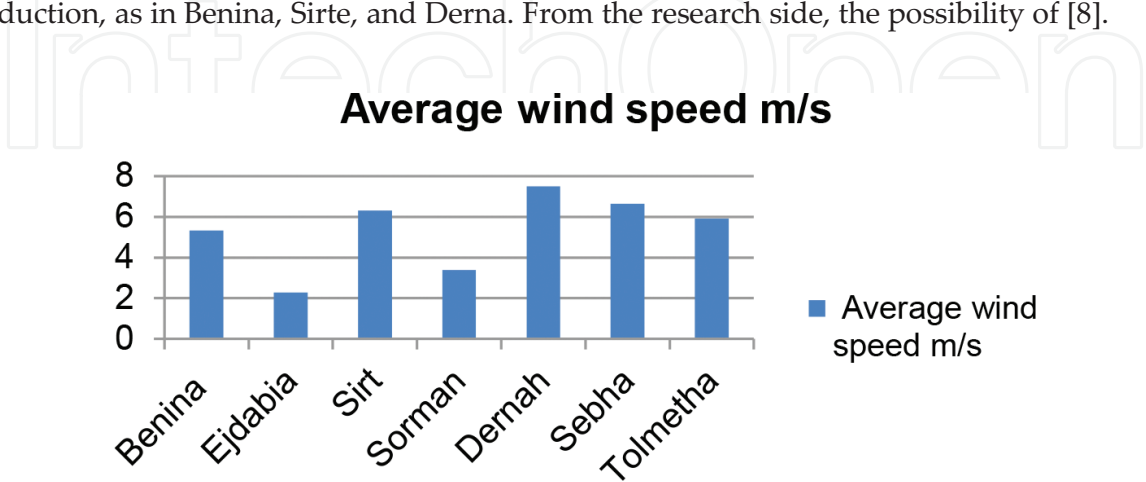
## **1. Introduction**

Libya is one of the leading and largest exporters and producers of oil and gas in North Africa and the world with a total area of 1,750,000 km<sup>2</sup>. It has gifted with a 1900 km Mediterranean

coastline, which has given it enormous potential to generate electricity from wind and solar energies. Most of Libya’s population lives on the coastline. The total population is approximately 6,273,000 [1]. Despite the potential to generate electric energy from wind and solar as a result of the excellent location, Libya’s contribution to alternative energy remains negligible. The production of electricity in Libya depends mainly on fossil fuel sources. After the devastation in Libya since 2011, oil production in Libya has fallen, which has led to a sharp drop in state exports and a frequent shortage of electricity production [2, 3]. As a result of the economic development and reconstruction, the demand for energy will substantially increase in the near future. Therefore, the generation of energy from sustainable energy sources in the country must be taken into account, since it mainly depends on fossil fuels. To avoid the negative results in the near future such as the shortage of oil and gas supplies, and the reduction of emissions from conventional generation sources, the establishment of an urgent plan needs to be considered. However, renewable energy sources have been utilized in Libya since the 1970s, but in small-scale applications. In 1976, solar energy has been applied in the electricity cathodic protection stations for gas pipelines protection. Also, in 1979, four pilot stations in the field of communications were installed. In 1983, the installation of solar energy systems began to pump water for irrigation in El-Agailat city. In 2010, a 60 MW project was launched in Derna due to the high potential for wind power generation with wind speed of between 6 and  $7.5\text{ ms}^{-1}$  at a height of 40 m [1, 4].

According to [5], 10% of the world’s energy will be available through wind power in the next decade. Also, as a result of planning to make electric power from wind energy sources, one of the main sources of electricity in Libya, investigating and verifying the consequence of penetrating wind energy sources on the electrical grid is one of the most critical studies to provide optimum stability when integrating wind farms to the grid. The dynamic response of squirrel cage induction generator (SCIG) with direct grid connection is carried out. In [6, 7], a study proposed a 36 MW fix speed wind farm connected to the grid. It is found that the study was done through calculating its power curve and investigating the effects of wind speed at the beginning.

Libya has enormous potential for solar and wind power generation. **Figure 1** shows wind speed in several cities and regions in Libya. It shows the potential for high wind power production, as in Benina, Sirte, and Derna. From the research side, the possibility of [8].



**Figure 1.** Average wind speed for different cities in Libya.

## **2. Adverse effects of wind energy conversion units on distribution networks**

The electrical power obtained from wind farm system adversely affects the voltage stability in the grid. To improve and maintain the voltage stability, prior understanding of the influences of such sources in terms of power quality and harmonics is significant for better operation and control of the grid.

### **2.1. Protection problems**

The main function of protection system is to ensure the speed of operation and reliability to clear and isolate faulty equipment in case of a fault. The role of protection schemes is to minimize disturbing effects of fault currents and reduce the number of feeder outage. The penetration level of distributed generation (DG) influences the performance of protective relays and deteriorates the distribution network reliability.

The philosophy of protection systems in conventional distribution networks relies on the single direction of power flow from power plants toward the distribution network. The presence of DG turns out the distribution system operation comparable to the transmission system operation [9]. The arrangement of protection schemes becomes more difficult when further DG units connected to the distribution network since DG integration shifts the flow of the power and raises the short-circuit level. Therefore, the protective relays may not carry on its functions accurately, since the operation of the protective relays in the distribution level based upon the short-circuit sensitivity [10]. Introducing DGs to the distribution network associate further protection issues such as blinding of protective devices, false tripping, and reclosure-fuse miscoordination [11, 12]. Moreover, DG units can contribute a large current enough to trip the protective device on the feeder connecting the DG before the protective device on the faulted line, especially in synchronous machines based [13].

### **2.2. Power quality problems**

Voltage regulation may become a challenge in the presence of DGs. Additionally, some DG technologies lack the ability to produce reactive power and compensate for voltage reduction on loaded busbars. The interruption of large DG units in case of faults could influence the reliability of the entire network. The disconnection of synchronous generators with huge capacities and the intermittent nature of DG based on renewable sources may cause voltage fluctuation, especially near these DGs [14, 15]. Some DG technology connected to the grid through power electronic converters such as wind turbine operates with doubly fed induction machine and photovoltaic may become a source of power quality problems too. Capacitors used for induction generators are also a source of harmonics in case of resonances in the network. The growth in integrating single-phase DGs in distribution network could influence the voltage profile and create an eminent unbalancing issue. When wind energy is penetrated into the grid, the power quality of the grid will be affected among other characteristics [16, 17]. The power quality of the grid containing wind systems must comply with the limits and

requirements of the facilities. Therefore, the characteristics of the grid must be evaluated properly after the wind energy systems are connected to the grid. Prior knowledge of wind system characteristics must be adequately defined to avoid the drawbacks of connecting such sources. The electrical characteristics of wind turbines are usually specified by the manufacturer, not by specific site location. For this reason, when the electrical characteristics of a particular wind turbine are known, their impact on the power quality when connected to a particular location in the network can be predicted and calculated as a set of units. The necessity for quality requirements, detailed and applicable documentation on the power quality of wind sources is required. The International Electrotechnical Commission (IEC) started work to facilitate this in 1996. As a result, IEC 61400-21 was developed and, today, most large wind turbine manufacturers provide power quality characteristic data accordingly [18, 19].

### 3. Modeling of Derna wind farm

Darnah wind farm turbines are located in Derna city, which is located on the coastline of Mediterranean around (32° 29' 16.728" N—latitude 200° 49' 54.264" —longitude), in the eastern part of Libya as shown in **Figure 2** with population of 80,000 [1].

#### 3.1. Modeling of wind turbine

The wind energy system transfers the kinetic energy extracted from wind into mechanical energy through rotor blades of the wind turbine, and the permanent magnet synchronous generator (PMSG) transforms the mechanical energy in the rotor blades into electrical energy.



**Figure 2.** The geographic situation of Derna-Libya.

The power extracting from wind depends on the covered area  $A$  of the rotor and the wind velocity  $V_w$  and the air density  $\rho$ . The generated mechanical power  $P_{mech}$  is generally computed from wind energy using the coefficient of power  $C_p$  as follows [4]:

$$P_{mech} = \left(\frac{1}{2}\right) C_p(\lambda, \theta) A \rho V_w^3 \quad (1)$$

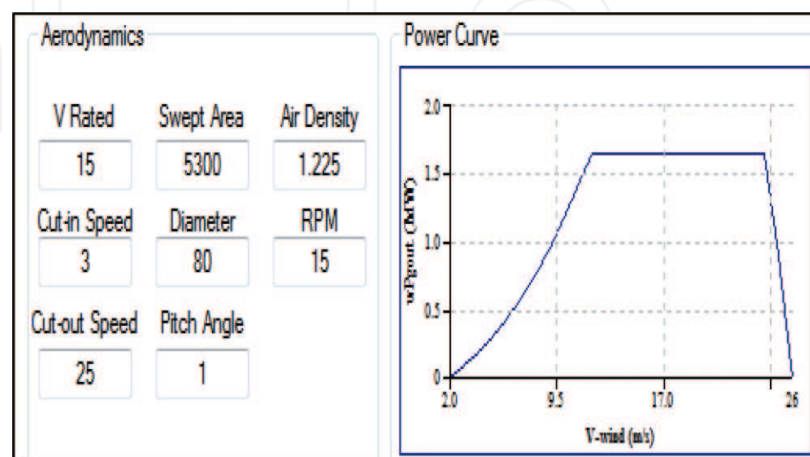
The performance coefficient  $C_p$  is a function of the  $\lambda$  and  $\theta$  that depends on the wind velocity  $V_w$ , the rotational speed of the shaft  $\omega_r$  and the rotor radius  $R_r$ .

$$\lambda = \left[ \frac{\omega_r R_r}{V_w} \right] \quad (2)$$

(r.p.m) tends for speed of the rotor,  $R_r$  stands for e rotor (m) and  $V_w$  stands for velocity of wind (m/s). The power of the wind turbine versus wind speed and aerodynamic coefficients are shown in **Figure 3**.

### 3.2. Modeling of drive train

The behavior of the drive train dynamics is considered by taking three different model approaches such as single mass, double mass, and three mass model design in order to know which of the methods are more noticeable in detaining the performance of the network [17]. The study of drive train models depends upon the complexity of the network. If a study takes interest about the torsion fatigue, it just has to consider the dynamics of all parts of the networks [20, 21]. For these aim, double lumped mass or more accurate models are required. For that, when application targets on the interaction between wind farms and connected loads, the considered drive train model considered being a single mass model for the sake of simplicity. Due to the direct connection of generator shafts of the turbine, the model of drive train can be defined as:



**Figure 3.** Power coefficient  $C_p(\lambda, \theta)$  curves.



$$\frac{d\omega_{mech}}{dt} = \left(\frac{1}{j}\right) (T_{mech} - T_{elec} - f\omega_{mech}) \quad (3)$$

$$\int \omega_{mech} = \theta_{mech} \quad (4)$$

where  $T_{mech}$  stands for the mechanical torque generated by the wind turbine,  $T_{elec}$  stands for the generated electromagnetic torque by the permanent magnet synchronous generator which can also be represented as a  $T_{gen}$ ,  $j$  stands for the inertia moment and  $f$  stands for the viscous friction coefficient that cannot be considered in a medium-scale wind turbine. In order to have the voltage in a-b-c frame from the d-q frame, one can need the angle  $\theta$  that obtained after integrating the mechanical speed of the rotor  $\omega$ .

### 3.3. Modeling of permanent magnet synchronous generator

The model used for modeling the synchronous generator, which is based on permanent magnet (PMSG) is developed on the d-q axes 'park' model as shown in **Figure 4**. The mathematical model of PMSG is implemented using two-phase synchronous rotating reference frame theory in which the q-axis is in 90 degrees with the d-axis with reference to the direction of rotation. All the quantities in the rotor are referred to the stator, and it is given as follows [22, 23]:

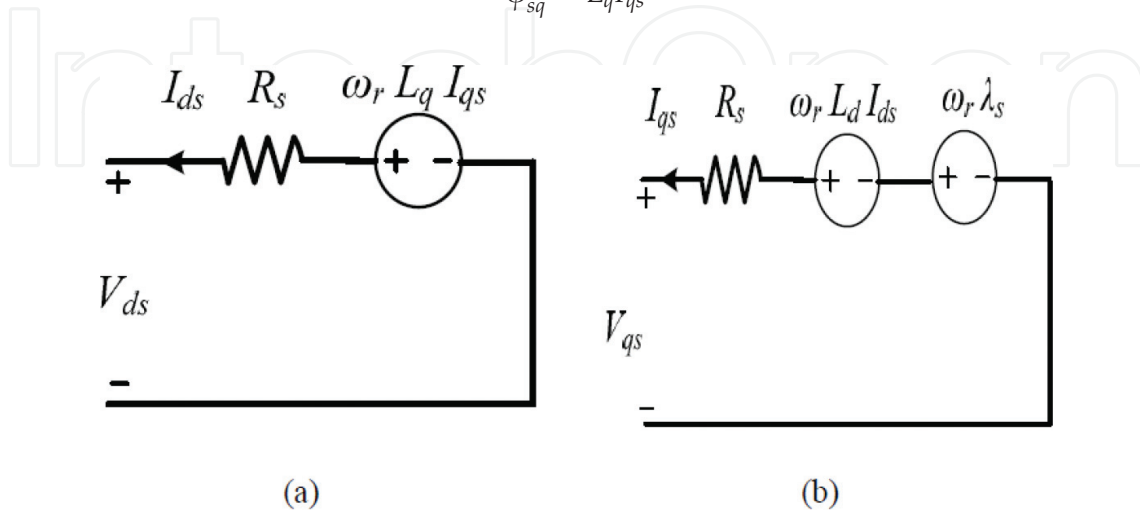
$$V_{ds} = R_s I_{ds} + \frac{d\phi_{sd}}{dt} - \omega_{elec} \phi_{sq} \quad (5)$$

$$V_{qs} = R_s I_{qs} + \frac{d\phi_{sq}}{dt} - \omega_{elec} \phi_{sd} \quad (6)$$

where the stator fluxes are computed by following equation:

$$\phi_{sd} = L_d I_{ds} + \phi_m \quad (7)$$

$$\phi_{sq} = L_q I_{qs} \quad (8)$$



**Figure 4.** PMSG model in steady state condition with respect to the rotor flux reference frame: (a) direct axis and (b) quadrature axis.

Now putting the value of  $\phi_{sd}$  and  $\phi_{sq}$  in Eqs. (5) and (6), so one can land up with the expression as below:

$$V_{ds} = R_s I_{ds} + \frac{d}{dt} (L_d I_{ds} + \phi_m) - \omega_{elec} (L_q I_{qs}) \quad (9)$$

$$V_{qs} = R_s I_{qs} + \frac{d}{dt} (L_q I_{qs}) + \omega_{elec} (L_d I_{ds} + \phi_m) \quad (10)$$

So, again resolving the above mentioned equation we can land up with following equation:

$$V_{ds} = R_s I_{ds} + L_d \frac{d}{dt} I_{ds} - \omega_{elec} (L_q I_{qs}) \quad (11)$$

$$V_{qs} = R_s I_{qs} + L_q \frac{d}{dt} I_{qs} + \omega_{elec} (L_d I_{ds} + \phi_m) \quad (12)$$

Therefore, in order to solve for the d and q axis stator currents, the above mentioned equation can be formed in the following fashions:

$$\frac{d}{dt} I_{ds} = \left( \frac{1}{L_d} \right) [V_{ds} - R_s I_{ds} + \omega_{elec} (L_q I_{qs})] \quad (13)$$

$$\frac{d}{dt} I_{qs} = \left( \frac{1}{L_q} \right) [V_{qs} - R_s I_{qs} - \omega_{elec} (L_d I_{ds}) - \omega_{elec} \phi_m] \quad (14)$$

where  $R_s$  stands for the stator winding resistance,  $L_d$  stands for the stator inductance in direct axis,  $L_q$  stands for the stator inductance in quadrature axis,  $V_{ds}$  stands for the direct axis stator voltage,  $V_{qs}$  stands for the quadrature axis stator voltage,  $I_{ds}$  stands for the direct axis stator current,  $I_{qs}$  stands for the quadrature axis stator current,  $\omega_{elec} = P_{wmech}$  stands for the speed [19, 24].

Since the permanent magnet synchronous generator (PMSG) is a machine similar to wound rotor machine which is better for surface-seated applications, the generated electric torque by the PMSG can be defined as follows:

$$T_{elec} = \left( \frac{3}{2} \right) P (\phi_m I_{qs} + (L_d - L_q) I_{ds} I_{qs}) \quad (15)$$

However, if permanent magnet synchronous generator is surface seated, then it is conceivable to favor the assumption of  $L_d = L_q$ . Then torque can be expressed as follows:

$$T_{elec} = \left( \frac{3}{2} \right) P (\phi_m I_{qs}) \quad (16)$$

So, one can land up with the equation as follows:

$$T_{elec} = \left( \frac{3}{2} \right) P (\phi_m I_{qs}) \quad (17)$$

In steady-state positions, the active power generated e from permanent magnet synchronous generator is given by:



$$P_s = V_{ds}I_{ds} + V_{qs}I_{qs} \tag{18}$$

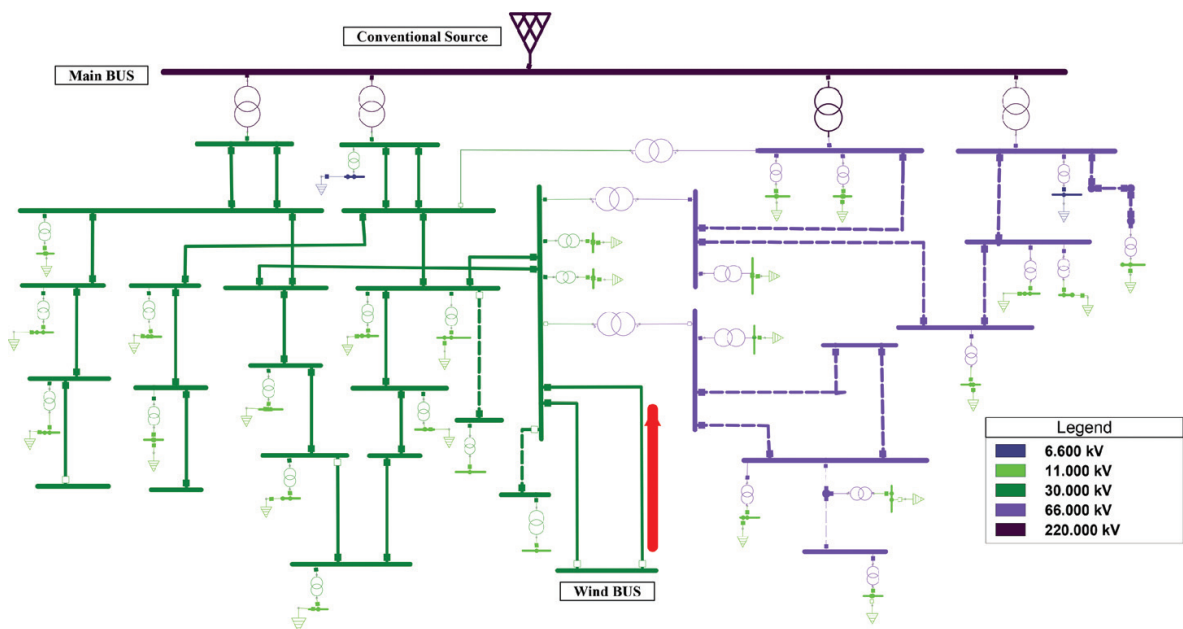
The wind farm is connected to the grid via step-up transformer to the 30 kV busbar [25, 26].

### 4. Simulation results

**Figure 5** shows a single-line diagram of a low-voltage network of Derna City simulated in NEPLAN [27]. The electric grid as shown in **Figure 6** consists of different voltage level busbars. The network feeds from the 220 KV busbar which connects it to the rest of the Libyan network through different capacity power transformers. Also, wind turbines with a total capacity of 60 MW, consisting number of turbines with a rated power of 1.65 MW, is connected to the simplified network in our study. **Table 1** shows data for different components in the network and details of the wind turbines system.

#### 4.1. Load profile

One of the most significant purposes for the integration of renewable energy sources into distribution networks is to reduce the costs of electricity to the consumers derived from charging line losses in this cost. The amount of line losses depends on the distance required to transfer the electric power as well as the value of the drawn current by consumers and thus affect the optimal economic dispatch based on the network configuration. Distribution network operators need to apply simple methods to predict the power flow in the network to ensure the balance of energy demand. Proper integration of the renewable energy sources in the distribution network will reduce the power losses in the transmission lines to a certain



**Figure 5.** Single-line diagram of a low-voltage network of Derna city simulated in NIPLAN.

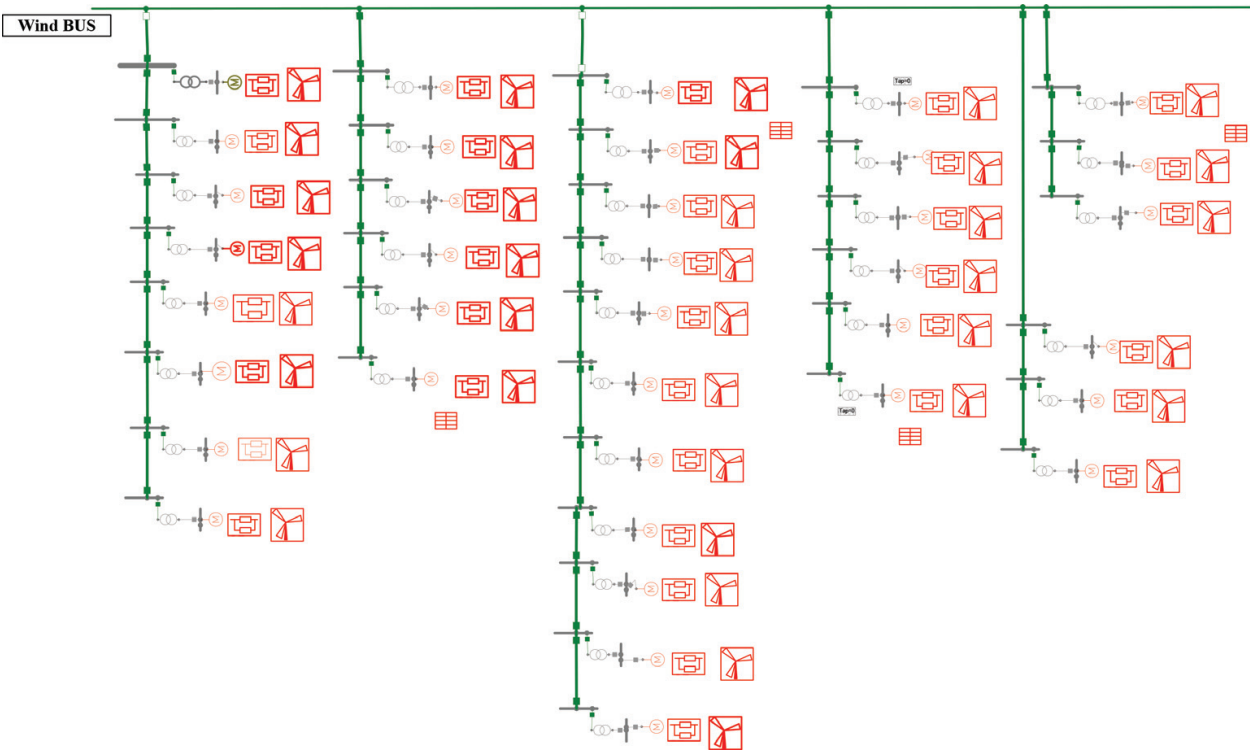


Figure 6. 60 MW wind farm connected to Derna medium voltage network.

Wind bus	Isc-3Ø = 10.02a83.5 Isc-1Ø = 7.99a – 78.9 X0/X1 = 1.73
220/30 KV 63 MVA main transformer	Positive sequence data: impedance voltage = 12.76% X+/R += 34.1 Zero sequence data: impedance voltage = 12% X0/R0 = 34.1
Wind turbine source	Rating: 1.65 MW, 0.69 KV, PF = 0.9 Turbine rated wind speed = 15 m/s Minimum wind speed = 4 m/s Maximum wind speed = 25 m/s Swept area = 2828 Rotor diameter = 80 m Pitch angle = 1 Air density = 1.225 kg/m³ RPM = 15
575/30 KV 2 MVA transformer	Positive sequence data: impedance voltage = 6.25% X+/R += 6 Zero sequence data: impedance voltage = 6.25% X0/R0 = 6
Bear 325 mm² 30 kV transmission line	Z+ = 0.1162 + 0.385 j Ω/km Z0 = 0.3486 + 1.155 j Ω/km

Table 1. Parameters of electric network and wind energy system.

level. This will contribute to the postponement of network infrastructure promotion. Various methods to determine the optimal capacity and location of each renewable DG at the minimum line losses, among which is Branch power loss formula as given in Eq. (19) [28]. **Figure 7** shows the loading profile of distribution transformers with different capacities through the day. **Figure 8** shows the power supplied by the main feeder of the network in different wind farm penetration level.

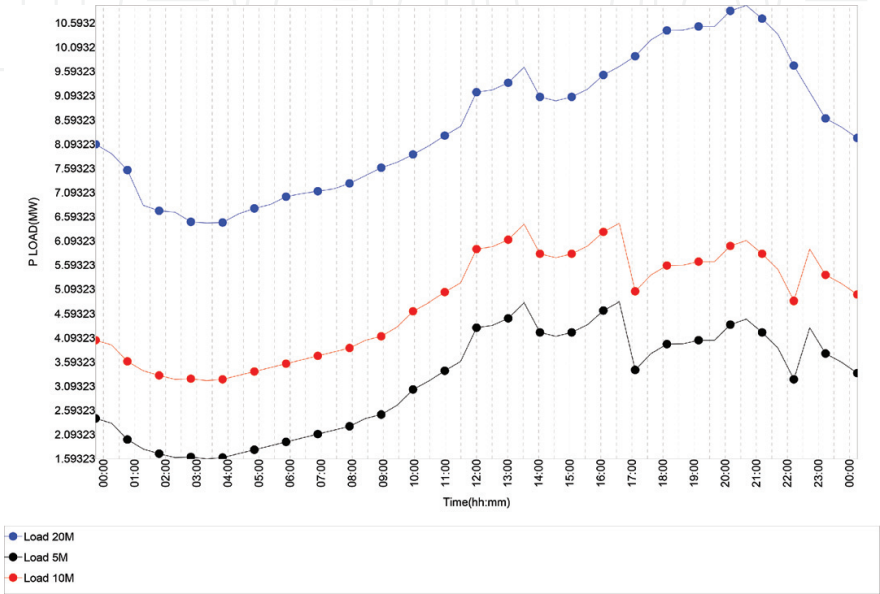


Figure 7. The loading Profile of 20, 10 and 5 MW Distribution Transformers During 24 Hours.

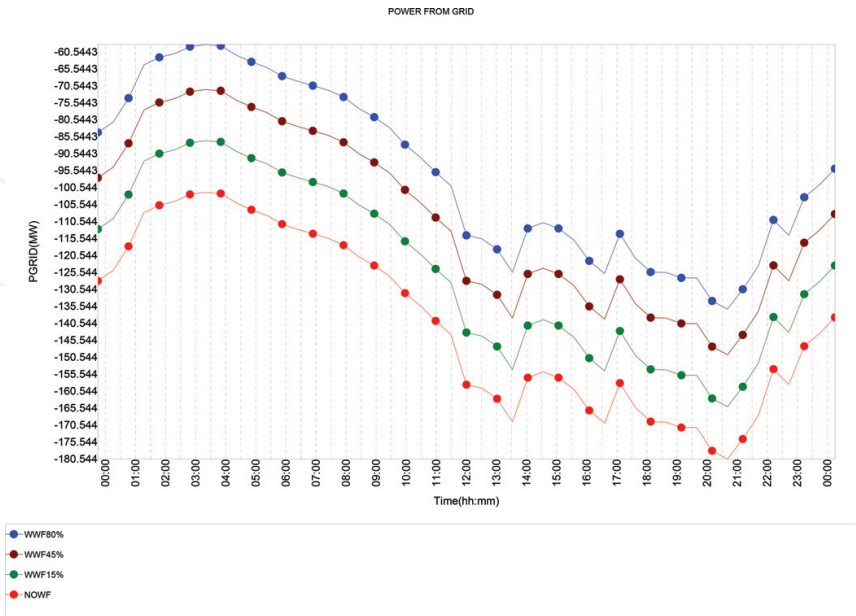


Figure 8. MW power from main feeder with different wind farm penetration.

$$P_{Loss} = \sum_{i=1}^n \frac{P_{bi}^2 + Q_{bi}^2}{|V_i|^2} R_i \quad (19)$$

where  $P_{bi}$  = Active power at branch  $i$ ,  $Q_{bi}$  = Reactive power at branch  $i$ ,  $|V_i|$  = Magnitude of voltage at bus  $i$ .

The investigation of the load curve during the day shows a difference in loading ratios. The maximum rate of loading occurs at 20:30 due to switching lights in most homes. The investigation of energy feeding from the transmission system during the day showed the highest contribution from the grid 180 MW occur during the period of the sunset due to lighting loads, and since most loads in the network is a household loads. The electric supply from the grid decreases at the highest rate of integration of wind farm. This reduces the stress on the cables and improves the voltage profile on all busbars.

## 4.2. Voltage profile

Injection of renewable energy sources into the distribution network alters the direction of power flow in the grid. As a result, it enhances the voltage profile. The integration of such sources thus improves the voltage at feeder endings and thus improves the quality of the power fed to consumers as a whole [28]. The benefits of DG penetration on the voltage profile improvement can be evaluated as follows:

$$V_{11} = \frac{V_{11/wDG}}{V_{11/w0DG}} \quad (20)$$

$$V_{11/wDG} = \sum_{i=1}^n V_i L P_i W_i \quad (21)$$

$$V_{11/w0DG} = \sum_{i=1}^n V_{i0} L P_i W_i \quad (22)$$

$$\sum_{i=1}^n W_i = 1 \quad (23)$$

If all the loads at bus  $i$  are equally weighted,  $W_i$  expressed as

$$W_1 = W_2 = W_3 = W_n = \frac{1}{n} \quad (24)$$

where

$V_{11}$  = Voltage profile improvement benefits.

$V_{11/wDG}$  = General expression for voltage profile at bus  $I$  with the application of renewable DG units.

$V_{11/woDG}$  = General expression for voltage profile at bus I without the application of renewable DG units.

$V_{i0}$  = Voltage at bus I per unit without renewable DG.

$V_i$  = Voltage at bus I per unit with renewable DG.

$LP_i$  = Load at bus I (per unit).

$N$  = Number of busses in the power system.

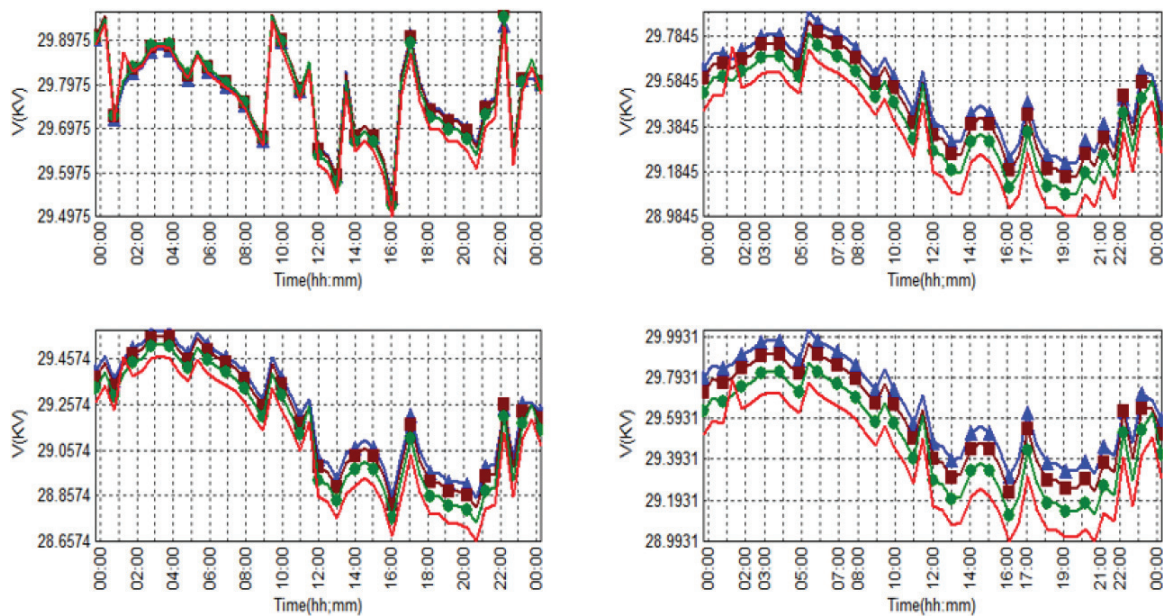
$W_i$  = weighting factor for bus i.

To investigate the fluctuation effects of wind energy source penetration, the voltage profile of different busbars is considered to display and show the excessive loading on the distribution busbars. The voltage profile for different busbars is illustrated in **Figure 9**. The influence of wind energy penetration on the voltage profile is slightly low, and this effect could be increased on radially connected busbars. The impact of wind generation will be noticeable at the busbar of point of common coupling (PCC) connecting the wind turbine to the electric grid. It is shown in **Figure 10**.

It is clear from the figures above, the voltages of all nodes have improved after interconnection of wind farm. The enhancement in voltage for busbars near from busbar of point of common coupling is better than the rest of other busbars in the network.

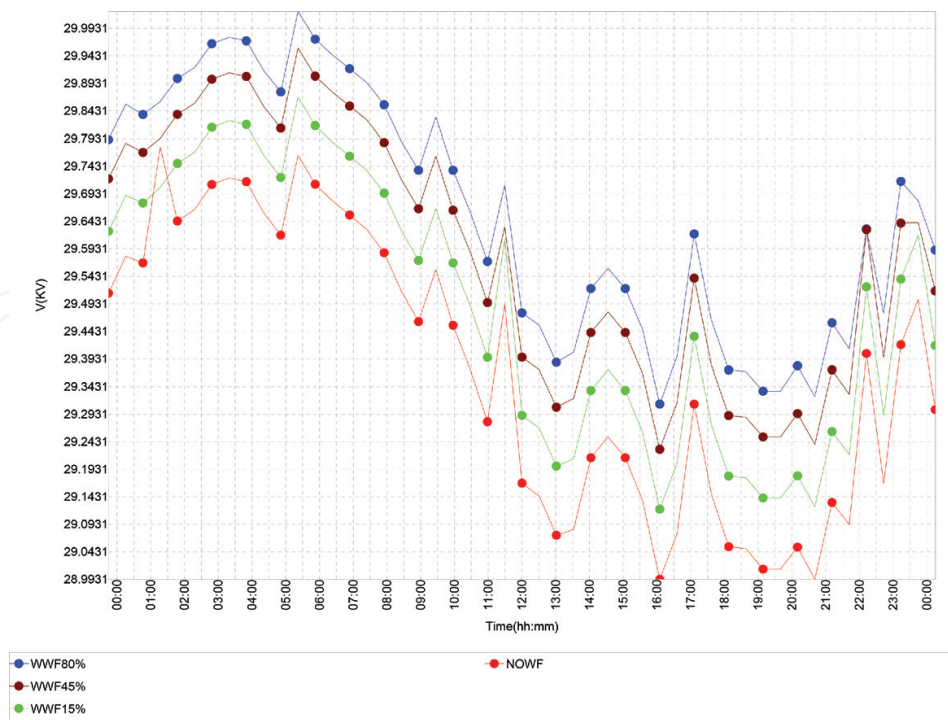
### 4.3. Harmonic distortion

The harmonics are created when non-sinusoidal currents and non-sinusoidal voltages increase in the network, and these distortions are generally called harmonic distortion [29, 30]. The



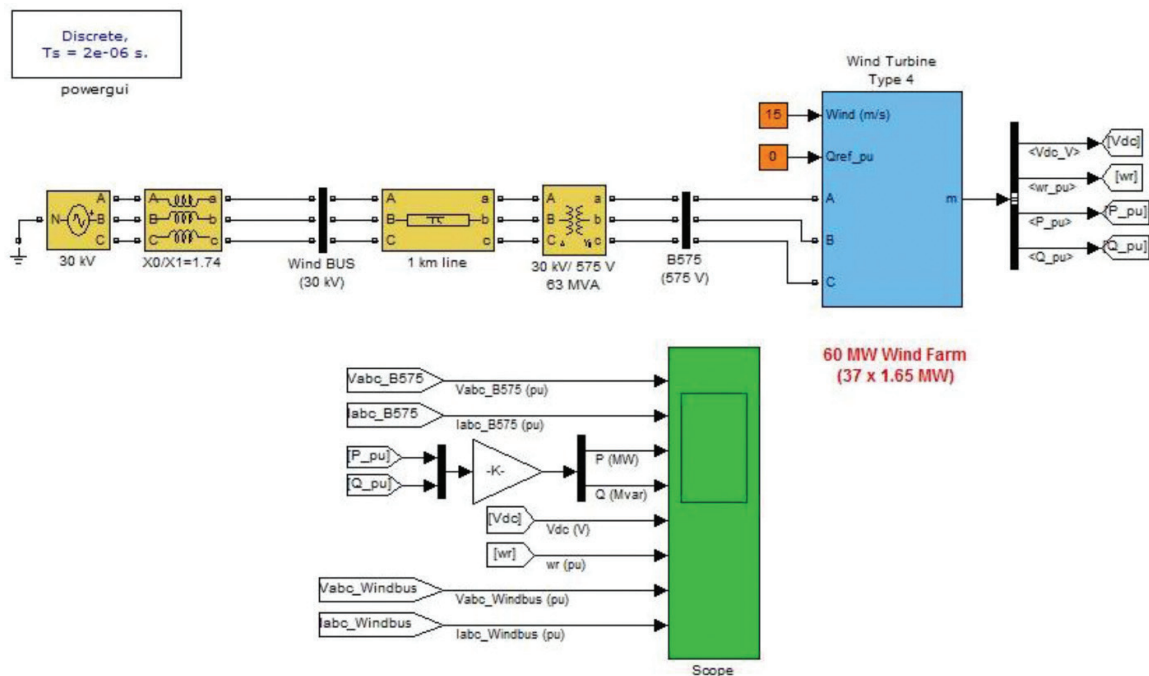
**Figure 9.** Voltage profile for different busbars for 1 day.





**Figure 10.** Voltage profile of point of common coupling (PCC).

basic conditions that lead to network consonances usually result from nonlinear loads, voltage imbalances. Power quality studies are carried out due to summation law [31]. The total harmonic current distortion is given as:



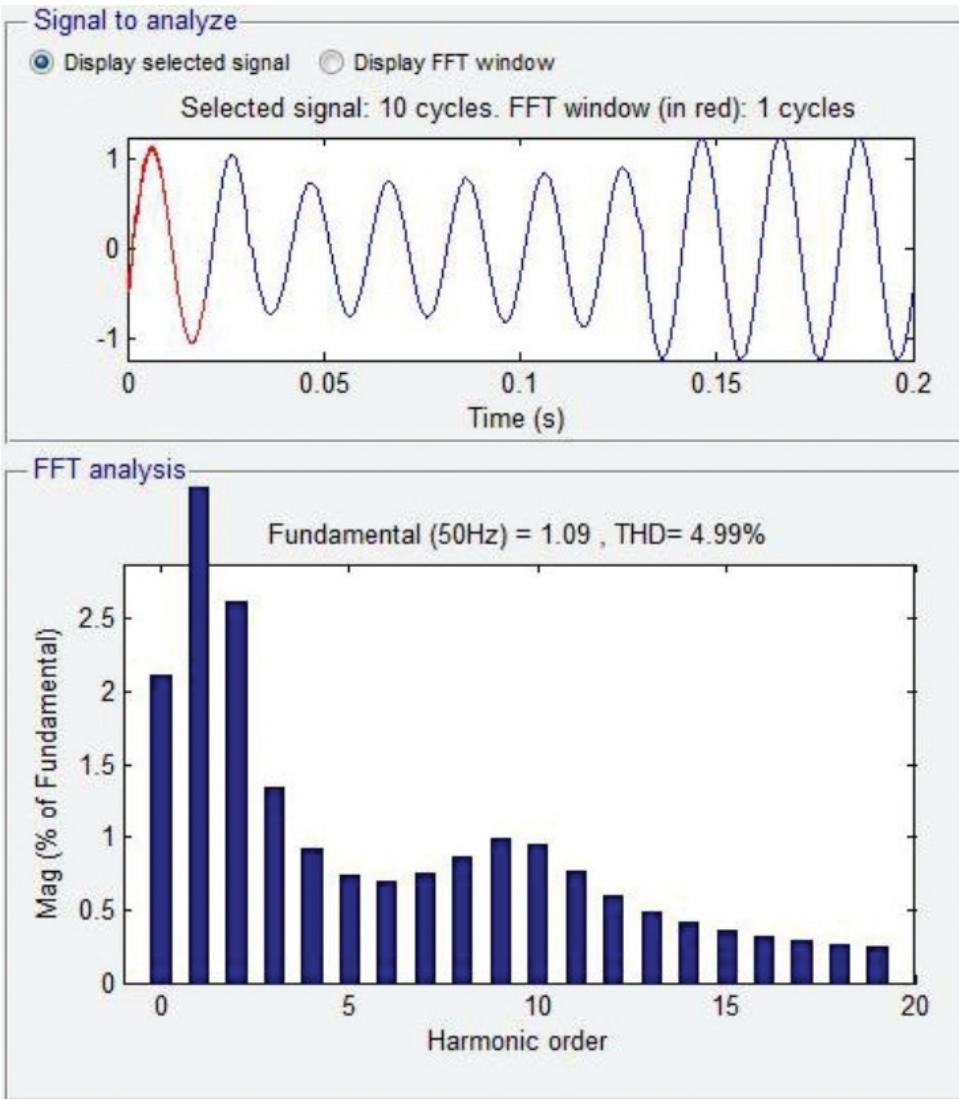
**Figure 11.** Simulated network with wind energy system.



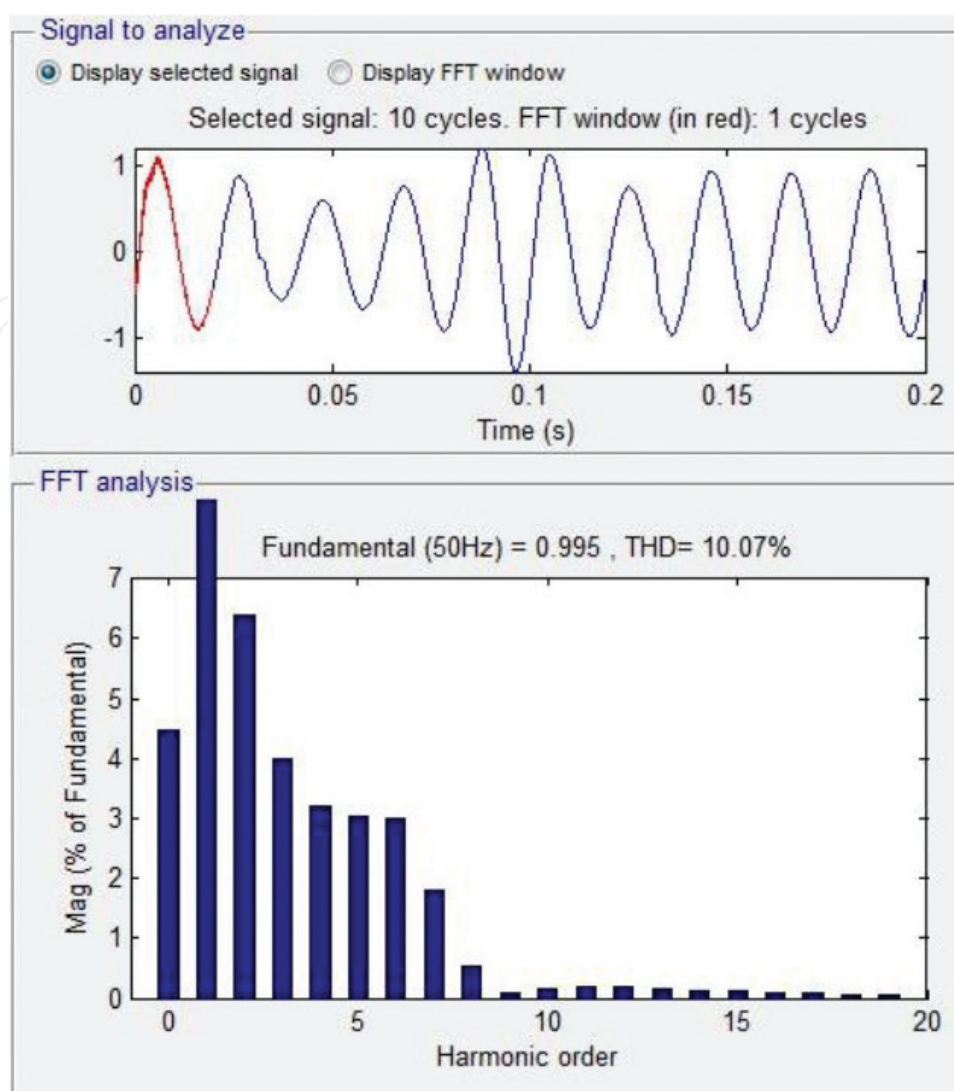
$$I_{THD} = \sqrt{\sum_{h=2}^{40} \frac{I_h^2}{I_1^2}} 100 \tag{25}$$

Harmonics contributed by wind turbines in the network may cause a problem due to the existing harmonics in the network. The current waveform of wind turbines is non-sinusoidal and distorted due to low integer harmonics of second and fifth harmonics. The variable speed of wind turbine equipped with power electronic converters causes an increase in the harmonic distortion at the point of common coupling. **Figure 11** shows the simulated model in MATLAB/SIMULINK.

Measurement of harmonics taken from node 575. Measurement of a number of harmonics in currents has been carried out for different penetration level to study the effect of the penetration on the amount of harmonics in the network. **Figures 12–14** represent the harmonics values



**Figure 12.** FFT output of total harmonic current distortion for 20 MW penetration.



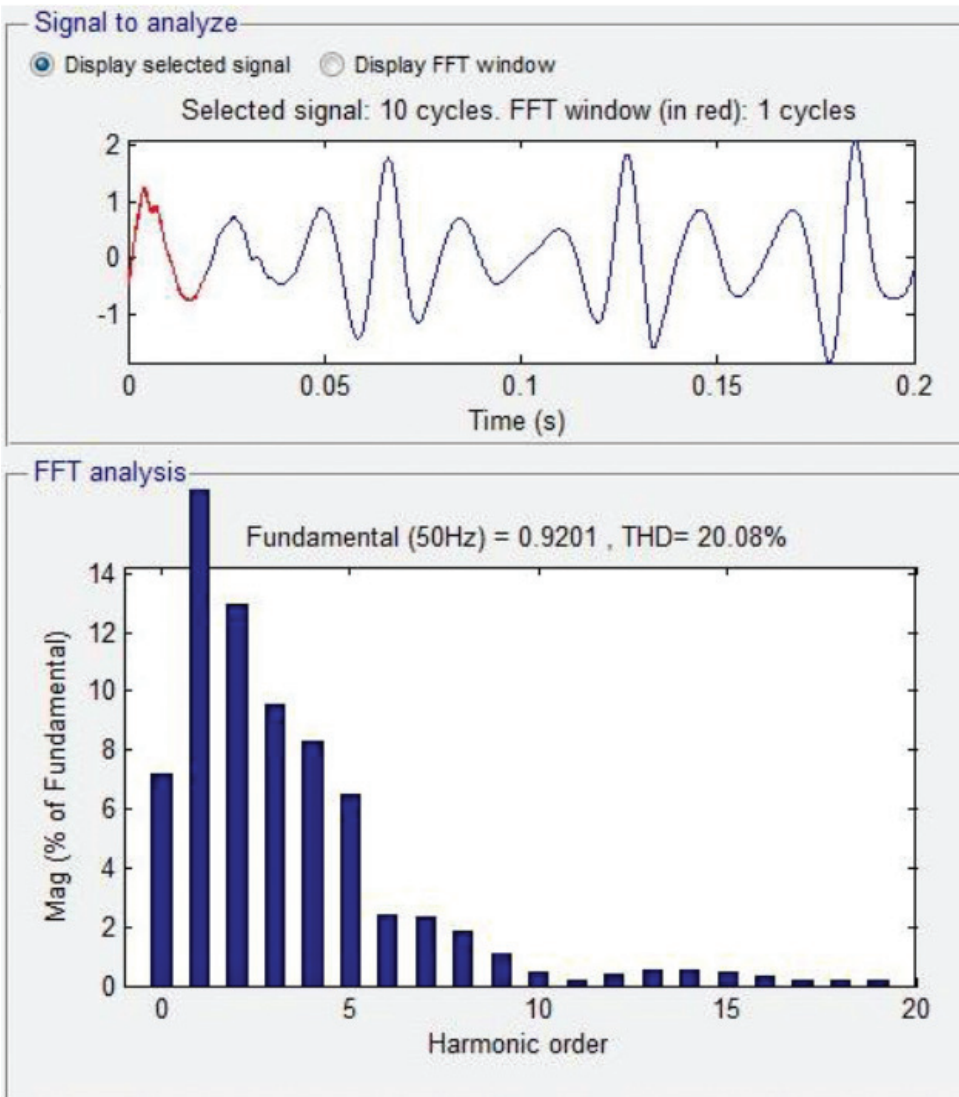
**Figure 13.** FFT output of total harmonic current distortion for 40 MW penetration.

in currents of the main busbar connecting wind farm for 20, 40, and 60 MW of penetration from wind farm. These results were extracted and implemented using MATLAB/SIMULINK after simplifying several wind turbines as one unit.

**Figure 12** represents the harmonic current distortion for 20 MW penetration from wind energy system to the network. However, the total harmonic distortion shows slightly significant increase in the percentage of harmonic currents at PCC specially second and third harmonic currents to reach a value of 4.99% at PCC.

**Figure 13** represents the harmonic current distortion for 20 MW penetration from wind energy system to the network. Moreover, the total harmonic distortion shows further slightly increase in the percentage of harmonic currents at PCC especially second and third harmonic currents to reach a value of 10.07% at PCC.

**Figure 14** represents the harmonic current distortion for 60 MW penetration from wind energy system to the network. Moreover, the total harmonic distortion shows further highly increase



**Figure 14.** FFT output of total harmonic current distortion for 60 MW penetration.

in the percentage of harmonic currents at PCC especially second and third harmonic currents to reach a value of 20.08% at PCC.

The simulation is done at the selected PCC of 33 KV busbar system. The simulation result of current THDs is having low values. Three phases waveform of output currents at 33 KV busbar system is shown. From the three graphs, the result summary of harmonic currents is within permissible limits as compared to IEEE standard values and comply with the grid requirements. Therefore, it can be said that the wind farm power quality is sufficient and did not affect the grid system power quality, except for the case of 60 MW.

## 5. Conclusion

This chapter has interpreted the technical challenges of penetrating wind DG into the distribution system. Renewable DG can perform many significant functions in the economic, technical

and environmental operation of an electric network. A wind energy system interconnected to a real network was investigated. Loads were programmed by NEPLAN. Actual wind measurements were used in this study to measure the extent to which wind power can be provided while ensuring a reasonable power quality and commensurate with international standards. It can be noticed from the results that the influence of the wind energy system can be significant on point of common coupling, which is close to the wind farm. Investigation of the cables connected in a mesh is less affected by the fluctuation more than the cables connected in radial can be further performed. It is also noticeable that energy losses decrease with increased penetration of the wind farm. From the analysis of the harmonic currents in MATLAB/SIMULINK, their impact on the power quality of the energy is insignificant, the effect of the harmonic currents on the grid increase with increasing penetration of wind farm. Finally, it can be said that the performance of the wind farm falls within the limits of international standards but may increase its impact on the voltage profile and energy losses, and power quality with increased penetration of wind energy.

## Author details

Saad M. Saad<sup>1\*</sup>, Naser El Naily<sup>2</sup>, Jamal Wafi<sup>2</sup>, Faisal A. Mohamed<sup>3</sup> and Abdelsalam Elhaffar<sup>4</sup>

\*Address all correspondence to: [smuftahndi@gmail.com](mailto:smuftahndi@gmail.com)

1 College of Electrical and Electronics Technology-Benghazi, Benghazi, Libya

2 Electrical and Electronics Engineering Dept., University of Benghazi, Libya

3 Authority of Natural Science Research and Technology, Tripoli, Libya

4 Electrical and Computer Engineering Dept., Sultan Qaboos University, Muscat, Oman

## References

- [1] Asheibi A, Khalil A, Rajab Z. The economic feasibility of photovoltaic systems for electricity production in Libya. In: The 7th International Renewable Energy Congress (IREC'2016); Hammamet, Tunisia; 2016. pp. 1-6
- [2] Khalil A, Asheibe A. The chances and challenges for renewable energy in Libya. In: The Proceedings of the Renewable Energy Conference; 2015
- [3] Libya Infrastructure Report 2013, Business Monitor International Ltd; 2013
- [4] Khalil A, Rajab Z, Asheib A. Modeling, Simulation, Analysis and Control of Stand-alone PV System at the Seventh International Renewable Energy Congress "IREC 2016"
- [5] Asheibe A, Khalil A. The renewable energy in Libya: Present difficulties and remedies. In: The Proceedings of the World Congress; 2013

- [6] Mehimmedtsi, chenni rachid “dynamic response of SCIG with direct gideconnection” 4th International Conference on Power Engineering, Energy and Electrical Drives Istanbul, Turkey; 13-17 May 2013
- [7] Mohammed MF, Ghosh S. Study of performance and issues of integration of fixed speed scig wind turbines to power system grid. Master of Engineering. In: Power Systems & Electric Drives July 2012
- [8] Rajaba Z, Almaktarb M, Al-Nailyc N, Saad Saadd M, Faisal Mohamede A. Modeling approach to evaluate wind turbine performance: Case study for a single wind turbine of 1.65 MW in Dernah, Libya. In: The 8th International Renewable Energy Congress (IREC'2017); Amman, Jorden; 2017
- [9] Javadian SAM, Massaeli M. Impact of distributed generation on distribution systems reliability considering recloser-fuse miscoordination – A practical case study. Indian Journal of Science and Technology. 2011;4(10):1279-1284
- [10] Elhaffar A, El-Naily N, El-Arroudi K. Management of Distribution System Protection with High Penetration of Distributed Generations, Energy System and Management. Cham: Springer; 2015. pp. 279-291
- [11] Singh M, Vishnuvardhan T, Srivani SG. Adaptive protection coordination scheme for power networks under penetration of distributed energy resources. IET Generation Transmission & Distribution. Nov. 2016;10(16427494):3919-3929
- [12] El Naily N, Saad SM, Hussein T, Mohamed FA. Minimizing the impact of distributed generation of a weak distribution network with an artificial intelligence technique”. Springer. Applied Solar Energy. April 2017;53(2):109-122
- [13] Saad Saad M, Naser El Naily, Abdelsalam Elhaffar, El-Arroudi K, Faisal Mohamed A, Applying adaptive protection scheme to mitigate the impact of distributed generator on existing distribution network. In: The 8th International Renewable Energy Congress (IREC'2017); Amman, Jorden. 2017
- [14] Blaabjerg F, Yang Y, Yang D, Wang X. Distributed power-generation systems and protection. Proceedings of the IEEE. 2017;105:1-21
- [15] Lei Y, Mullane A, Lightbody G, Yacamini R. Modeling of the wind turbine with a doubly fed induction generator for grid integration. IEEE Transactions on Energy Conversion. March 2006;21:257-264
- [16] Dhlamini N, Chowdhury SP. The impact of wind farm aggregation techniques for analyzing power system dynamics. In: 2015 National Universities Power Engineering Conference (UPEC); Sept 2015; pp.1-6
- [17] Geng Z, Conejo AJ, Kang C, Qixin C. Stochastic scheduling ensuring air quality through wind power and storage coordination. IET Generation Transmission & Distribution. June 2017;11(8):2031-2040



- [18] Bubshait AS, Mortezaei A, Simões MG, Busarello TDC. Power quality enhancement for a grid connected wind turbine energy system. *IEEE Transactions on Industry Applications*. 2017;**53**:2495-2505
- [19] Farhoodnea M, Mohamed A, Shareef H. A comparative study on the performance of custom power devices for power quality improvement. In: *Rid Technologies*; 2014; pp. 153-157
- [20] Sultana B, Mustafa MW, Sultana U, Bhatti AR. Review on reliability improvement and power loss reduction in distribution system via network reconfiguration. *Renewable and Energy Reviews*. December 2016;**66**:297-310
- [21] Miller ML. General Concepts Related to Turbine Generator Insulation Materials Used in Rotor Winding Cal Insulation Conference; 2009. pp. 328-332
- [22] Longji L, Geng H, Yang G, Zhang C, Zheng C, Lai C. Comparisons of four rotor speed identification schemes for PMSG based WECS. In: *Proc. of International conference on Electrical Machines and Systems (ICEMS)*; 2011; pp. 1-6
- [23] Pavan Kumar AV, Parimi AM, Rao KU. Investigation of small PMSG based wind turbine for variable wind speed. In: *Proc. International Conference on Recent Developments in Con Automation and Power Engineering (RDCAPE)*; 2015; pp. 107-112
- [24] Barote L, Marinescu C. PMSG wind turbine system for residential applications. In: *Proc. of International Symposium on Power Electronics Electrical Drives Automation and Motion*; 2010; pp.772-777
- [25] Chiradeja P, Ramakumar R. An approach to qualify the technical benefits of distributed generation. *IEEE Transactions on Energy Conversion*. 2004;**19**(4):764-773
- [26] Patel A, Arya SR. Distributed power generation system using PMSG with power quality features. In: *2016 International Conference on Next Generation Intelligent Systems (ICNGIS)*; 1-3 September 2016
- [27] NEPLA Analysis Software. Available online: <http://wloads/2015/01/Electricity.pdf>
- [28] Adefarati T, Bansal RC. Integration of renewable distributed generators into the distribution system: A review. *IET Renewable Power Generation*. 2016;**10**(7):873-884
- [29] Yang K, Bollen MHJ, Amaris H, Alvarez C. Decompositions of harmonic propagation in wind power plant. *Electric Power Systems Research*. 2016;**141**:84-90
- [30] Liu Z, Rong J, Zhao G, Luo Y. Harmonic assessment for wind parks based on sensitivity analysis. *IEEE Transactions on Sustainable Energy*. 2017. DOI: 10.1109/TSTE.2017.2680461 in press
- [31] Mazhari SM, Kouhsari SM, Ramirez A. A novel frequency-domain approach for distributed harmonic analysis of multi-area interconnected power systems. *Electric Power Systems Research*. 2017;**143**:669-681



