

Nassar, Ibrahim A.; Hossam, Kholoud; Abdella, Mahmoud Mohamed

Article

Economic and environmental benefits of increasing the renewable energy sources in the power system

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Nassar, Ibrahim A.; Hossam, Kholoud; Abdella, Mahmoud Mohamed (2019) : Economic and environmental benefits of increasing the renewable energy sources in the power system, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 5, pp. 1082-1088,
<https://doi.org/10.1016/j.egy.2019.08.006>

This Version is available at:

<https://hdl.handle.net/10419/243652>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>



Research paper

Economic and environmental benefits of increasing the renewable energy sources in the power system



Ibrahim A. Nassar^{*}, Kholoud Hossam, Mahmoud Mohamed Abdella

Department of Electrical Engineering, Al-Azhar University, Cairo, Egypt

Department of Economic, Al-Azhar University, Assiut, Egypt

Transit Department, Suez Canal Authority, Ismailia, Egypt

ARTICLE INFO

Article history:

Received 1 May 2019

Received in revised form 30 July 2019

Accepted 8 August 2019

Available online xxxx

Keywords:

Wind

Photovoltaic

Economic

Fuel consumption

CO₂ emission

ABSTRACT

Increasing Renewable Energy Sources (RES), impact the power system. Moreover, the system equilibrium and stability are difficult because constant generation cannot be generated from RES concerning conventional energy sources. This paper studies the effect of RES on the power system through the actual application of the Egyptian power system. The strategy of the Egyptian power system aims at increasing the proportion of RES, especially, Wind Power (WP) and photovoltaic (PV). Therefore, Different operation scenarios are presented to illustrate the impact of RES on the Egyptian network. Also, the economic and environmental benefits of increasing the Penetration of Renewable Power Generation are presented by calculating the expected annual reductions of CO₂ emission (ER), certified emission reduction (CER) and the fuel-saving amount. Therefore, how to decrease the cost of electricity (DCOE) model when calculating the cost-benefit analyses from RES. The results show the economic benefits of the point of view of the amount of savings achieved when bringing renewable energy to each scenario. Finally, the economic study shows the benefits renewable energy sources have provided, where the RES by the end of 2022 will reduce the emission of carbon dioxide to 46405×10^3 tCO₂ which yield a return of 433427.6×10^3 \$ according to CER price and the savings of the fuel will reach 19066 ktOE. The model was created using DigSILENT power factory software.

© 2019 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

1. Introduction

The integration of renewable power generation (RPG) poses considerable challenges to power systems because RPGs are located in dispersed areas and are connected to the power system (Herzog et al., 2001; Freris and Infield, 2008). The rapid increase in energy generation that is enlarged by RPG creates a necessity for various studies to investigate the impacts of integration of RPG on the power system (Vilchez and Stenzel, 2013). Nowadays, whereas power systems have evolved through continued integration of the latest units and also the enlarged operation in extremely stressed conditions, totally different types of system instability and security have emerged (Dudiak and Kolcun, 2014; Lira et al., 2013). Thus, the system stability analysis, such as static voltage stability analysis, is incredibly necessary to keep up the equilibrium of the system (Sulaiman and Nor, 2015). Voltage is taken into account a crucial index because of its impact on system security and stability (The stability of voltage is the ability of a

power system to keep the voltage steady at all system buses for a given initial condition and after being exposed to contingencies) (Kundur, 1994; Bhaladhare et al., 2013a). With increasing such amount of RPG in the power system, the inertia of power system will be reduced, and the frequency deviation will be greater, especially after system disturbance and more oscillation will occur (Nassar et al., 2014a; Nassar and Weber, 2013, 2015; Nassar and Abdella, 2018b). In contrast, renewable energy has many advantages, including reducing carbon dioxide emissions, providing clean energy and environment improvement, reducing fuel consumption and low operating costs. The main motivation of this paper is to study the benefits of increasing RPG on the economic and environmental according to Kyoto Protocol greenhouse gas reduction and Decreasing cost of electricity (DCOE) model to calculate the cost:-

- 1- The quantity of RPG that are replacing conventional energy for the three different scenarios (36768 GWh).
- 2- The quantity of fuel oil used is 8869.3 thousand tons of oil equivalent, when bringing renewable energy (PV and wind) Replace petroleum fuels, we find that there are economic and environmental benefits will be clarified later.
- 3- Using renewable energy replace conventional energy for the three different scenarios.

^{*} Corresponding author.

E-mail addresses: ibrahim.nassar@azhar.edu.eg (I.A. Nassar),

Kholoud_hossam@yahoo.com (K. Hossam), Mahd.abdella@suezcanal.gov.eg (M.M. Abdella).

- 4- Dollar savings achieved by the state when reduction use of oil fuel, as a result of bringing renewable energy for the three different scenarios.
- 5- The dollar savings achieved by the state as a result of reduction or capture of carbon dioxide from the atmosphere.

This suggests that the DCOE of grid-connected PV and wind power systems may be less expensive than using medium-speed gas turbines and diesel generators, which represent a significant share of Egypt's current power mix.

The Height of initial construction costs of new and renewable energy systems in general in comparison to the other conventional systems available in the market. Low efficiency of the operation of renewable energy systems after a brief period of work because of the lack of trained technical personnel to operate and maintain these systems. Average per capita use of energy Differs greatly from country to another, where nearly 70% of the world population at a level up to almost a quarter higher than in Europe, and one-sixth that of the United States of America and thus the difference between the different situations obstruct achieving minimum growth of the economy and of course this poses a big problem to make any country pursues Valid a policy, Therefore, these countries must find a real solution. The change in the cost of producing electricity from wind energy affected the capacity of the wind turbine. This led to a reduction in the cost of production of electrical energy (Kholud, 2004; The European Photovoltaic Industry Association, 2014).

2. Statement of the problem

The conventional technologies which are used to generate energy causing the problem of wastage. Poor interconnection is one of the reasons that we cannot transfer excess electricity across the country, as part of the problem of excess power is that electrical grids are not an efficient distributor of power. New and renewable energy includes many problems such as climate, equipment, and cost. There is a problem of Climatic changes such as wind that blows intermittently and solar energy which is not available on cloudy days and as a result, the amount of its utilized energy is reduced. In addition to the enormity and complexity of the equipment used in the exploitation of energies, also the problem of the cost overlaps with all these problems.

3. Egyptian power system overview

Thermal generation is the main power in the Egyptian power system (more than 90%), and the rest are RPG (Hydro, Solar and Wind). The EEHC always does more annual energy projects in production, transmission and distribution, as follow (Arab republic of Egypt, 2016):

- The maximum load has increased to 29 400 MW in 2017.
- Introducing new generating units to total nominal capacity of 35 220 MW.
- Increasing the capacity of transformer stations to reach 171 685 MVA.
- Increasing the lengths of overhead lines and cables up to 488 932 km.
- The fuel average consumption for thermal power stations including is 214.1 g/kWh.
- The availability average of generating units for electricity production following companies is 83.3% compared to 86.8% for the previous year (Arab republic of Egypt, 2016, 2015a).
- The number of customers increased to 31.4 million.

Table 1
Egyptian wind projects.

Project name	Installed capacity (MW)	Project name	Installed capacity (MW)
G-Zeit 1	200	S- Gulf 1	250
G- Zeit 2	220	S-Gulf 2	120
G -Zeit 3	120	S-Gulf 3	200
G-Zeit 4	250	S-Gulf 4	200
G-Zeit 5	250	S-Gulf 5	600
G-Zeit 6	250	S-Gulf 6	250
G -Zeit 7	250	S-Gulf 7	250
Total Capacity at Gabal-Zeit	1540	S-Gulf 8	500
Menia 1	750	S-Gulf 9	500
Mennia 2	250	Zafarana	540
Menia 3	250	Total Capacity at Suez Gulf	3410
B-suief 1	300		
B-suief 2	200		
B-suief 3	250		
B-suief 4	250		
Total capacity at Nile valley	2250		
Total installed capacity		7200 MW	

- Total installed capacitors to improve the power factor and control the inefficient capacity about 10 240 Mvar on the medium and low voltage transmission and distribution networks, in addition to the installation of capacitors of 800 Mvar at (220 kV) (Arab republic of Egypt, 2016).
- The EEHC is divided into several zones as per country geographic location and power is transferred among these zones through three different levels of transmission networks (500, 220 and 132 kV) as given in Fig. 1.
- Wind farm installed capacity increased from 230 MW in 2006 to 750 MW in 2017, for future expansion, the wind farm will reach to (7200 MW) by 2022 as shown in Table 1 and the PV to 3500 GW by 2027 (Arab republic of Egypt, 2015b).

4. Power system model

The electricity network in Egypt has developed into a complex interconnected system serving all major load centers in the country. The model is split into many grids and therefore the association between them has been done to urge the entire Egyptian power grid model. The connection between 500 kV and 220 kV is done by power transformers (500/220 kV). The Egyptian power system includes 60 power stations that incorporate steam, gas, combined, hydraulic, and solar as well as wind farm plants (Omara and Nassar, 2019; Nassar and Abdella, 2017b,a; Nassar et al., 2014b). The signals among components of power plant (generator, turbine, and exciter) must be identified and the composite model frame as shown in Fig. 2 (DigSILENT, 2014a,b).

The deviation of the obtained frequency depends on load damping constant D, power difference and the inertia constant ($T_N = 2 \times H_N$) (Bhaladhare et al., 2013b). Where T_N and H_N are the acceleration time constant in seconds and the inertia constant of the network respectively (Vezmar et al., 2014; Nikolovski et al., 2011). The total system inertia can be calculated as follows;

$$T_N = \frac{\sum_{i=1}^n T_{G_i} \times P_{G_i}}{\sum_{i=1}^n P_{G_i} + P_{RPG}} \quad (1)$$

$$T_{G_i} = \frac{J_i \cdot \Omega_N^2}{P_{G_i}} \quad (2)$$

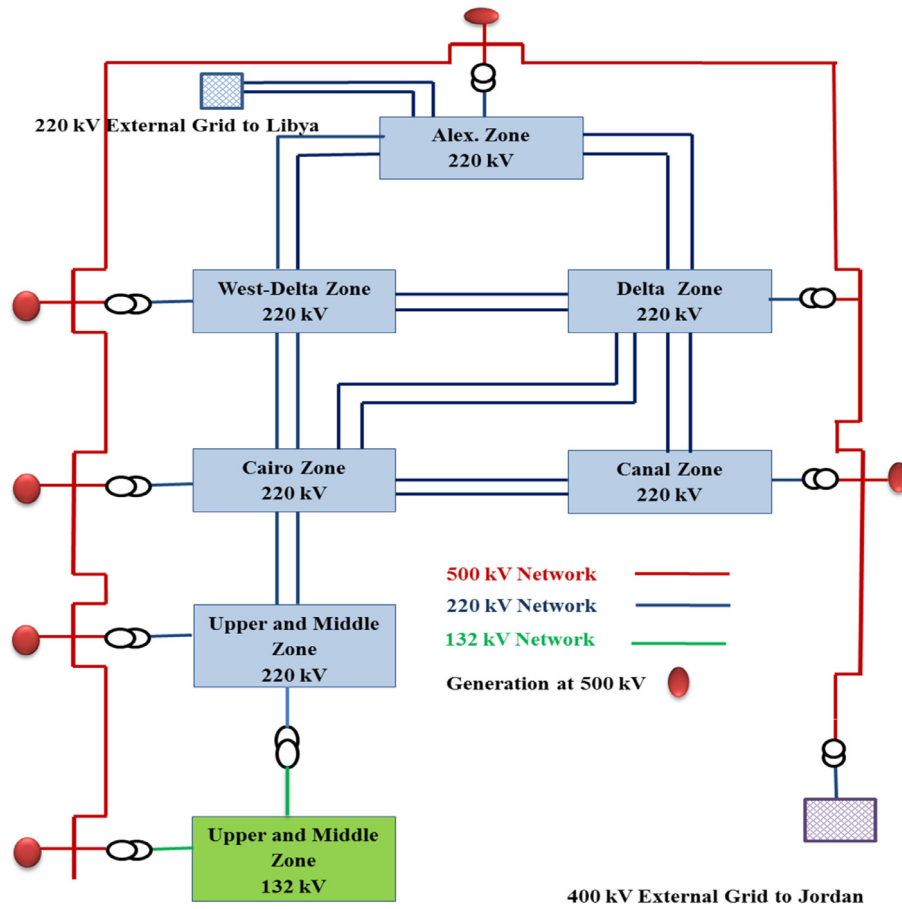


Fig. 1. The three transmission networks interconnections (500-220-132 kV) of the Egyptian power system.

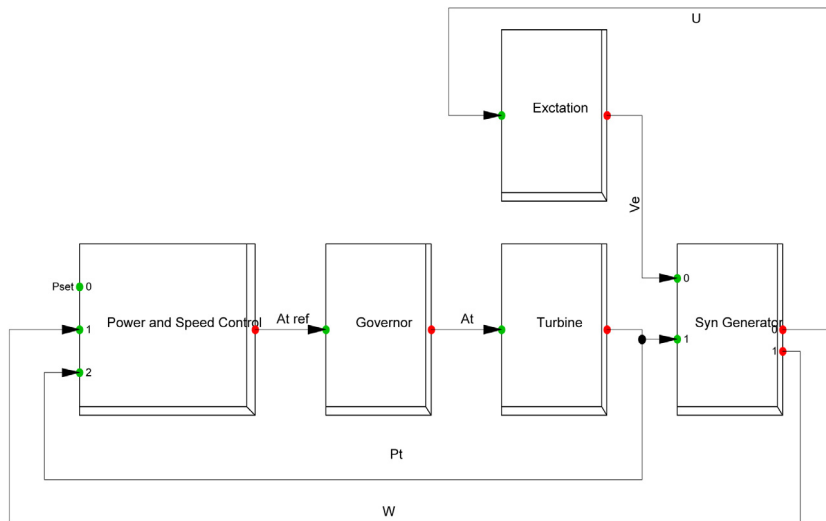


Fig. 2. Composite model frame.

where T_{Gi} represents each single unit acceleration time constant in seconds, P_{RPG} is MW generated from renewable power, P_{Gi} is each single individual generator power in MW, Ω_N is the angular velocity in radians per second and J is the moment of inertia of the rotor mass in the generation and load take place. Thus, it turns out that, the system inertia decreases when the conventional power plants are replaced by RPG as shown in Fig. 3.

5. Wind turbine model

The EEHC has set criteria for selection wind turbine type, each wind turbines presented by the manufacturers should meet the following criteria (Arab Republic of Egypt, 2006):

- At least 2 years of economic operation of the same kind of such turbine.

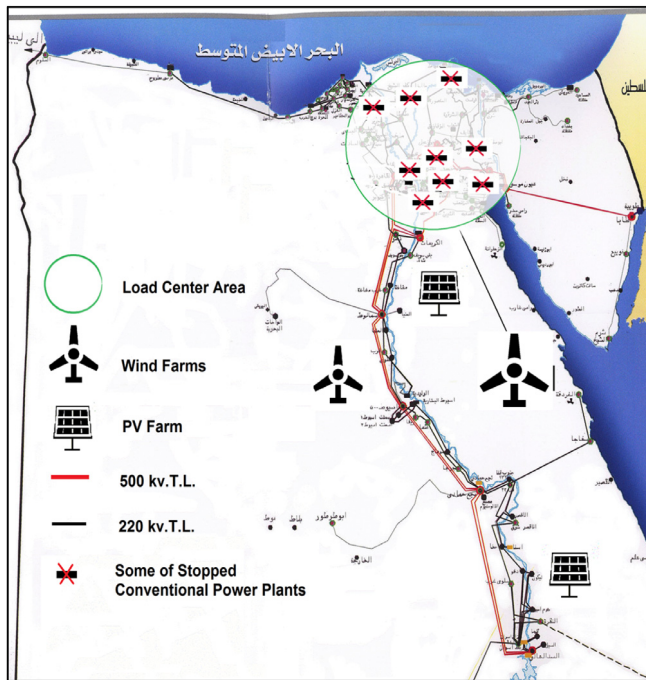


Fig. 3. RPG replaces the traditional power plant.

- At least one hundred commissioned turbines of this kind must be in operation.
- The maximum allowable height is 100 m.
- The operation ambient temperature range of the turbine until 45 °C

These criteria ensure that the selected turbines will have a great contribution to technology transfer into the Zafarana region (Gylling et al., 2006; Tawfic, 2000). As a result, Gamesa G80 wind turbines with 2 MW generating capacity and 60 m hub height were suitable for the project as shown in Fig. 4. The selected wind turbine is considered the highest technological standards. More than 500 of these types have been installed around the world, confirming the capability of this technology and it is with the type of doubly fed induction machine (DFIM) (Ackermann, 2005; Gamesa plat form catalogue, 2016; Clean Development Mechanism, 2015).

6. Scenarios

The future projects expected by the Egyptian network are implemented to reach 22% from wind and photovoltaic through several scenarios. The places specified by the Egyptian network according to Table 1. Each scenario is compared to the base case to determine the impact on the network. In all scenarios, the load power of the Egyptian system is assumed constant and also the power output from wind turbines. The simulation is made in the high load condition of the Egyptian power system (September) where the load was more than 21 GW.

6.1. First scenario (2% RPG)

The first scenario is the current situation of the Egyptian power system where the RPG is only 2% (450 GWh) of the total power generated (Kholud, 2004). Fig. 5(a) shows the energy percentage of the Egyptian power system. With 43% of combined cycle generation, 33% of the steam power plants while the gas power plants represent 14% and the hydro generation are 8%.

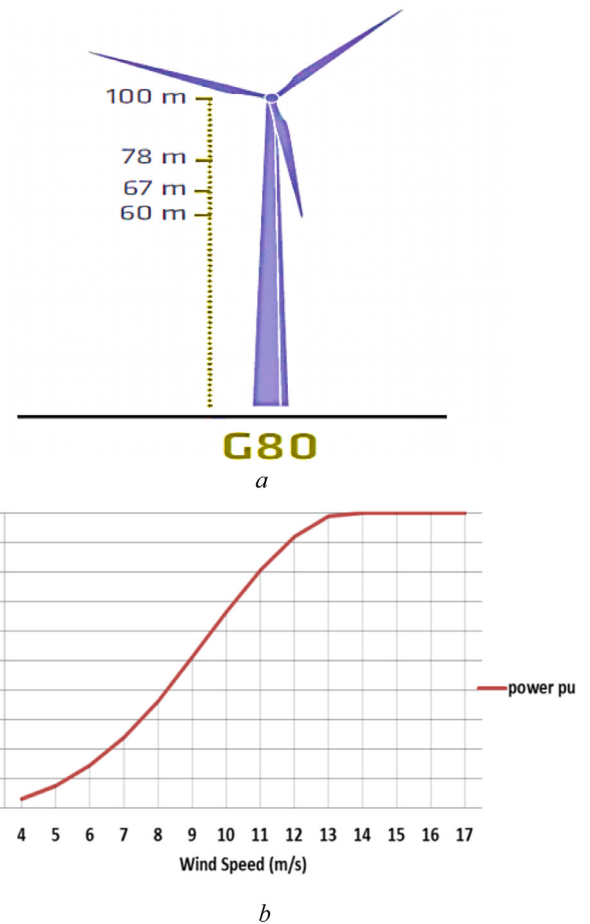


Fig. 4. Wind turbine model, (a) Gamesa (G80-2 MW) turbine frame, (b) Turbine speed/power curve.

6.2. Second scenario (16% RPG)

Fig. 5(b) shows the second scenario with 16% RPG (3559 GWh). In this scenario, some of the steam plants are reduced to 35% of the total generated power. Also, gas and combined power plants are reduced to 13% and 28% respectively. All these conventional power plants are shut down and replaced by RPG (Arab republic of Egypt, 2016).

6.3. Third scenario of summer 2022 (22% RPG)

Fig. 5(c) shows the third scenario of 2022 with 22% RPG (4530 GWh). In this scenario, some of the steam power plants are reduced to 33%. Also more reduction from gas and combined to 12% and 25% respectively. Table 2 shows the details of the expected stopped power plants.

7. Analysis of different scenarios

For the three scenarios, it is clear that the amount of fuel oil used is 8869.3 thousand tons of oil equivalent, with replacing petroleum fuels by bringing renewable energy (PV and wind), we find that there are economic and environmental benefits will clarify the following:-

7.1. Oil savings

By replacing the conventional plants by the renewable energy sources for the first scenario (2% RPG), the second scenario (16%

Table 2
The expected stopped power plants details.

Plant name	No. of units	Total installed capacity (MW)	Total power generated (GWh)	Total fuel consumed (ktoe)
A-KIR	4 × 150	600	2 755	723
TALKHA	8 × 19.5 + 2 × 40	236	1 610	448.8
MAHMODIA	8 × 21 + 2 × 50	268	1 950	468
DAM-GAS	4 × 25 + 1 × 58	158	927	203
DAM-STEAM	3 × 65	195	154	238
WALIDIA	2 × 300	600	4 011	965
CAIRO.S GAS	3 × 110	330	2 140	613
CAIRO.S-COMBINED	1 × 110 + 1 × 55	165	1 086	214
SHOPRA	3 × 315	945	5 480	1321
DOMIAT-COMBINED	6 × 132 + 3 × 136	1200	6 592	1292
S-KRIR	2 × 320	640	3 366	715
MATROUH 02	1 × 30	30	208	57
P-SAED	1 × 340	340	2 145	448
A-SULTAN	4 × 150	600	3 196	832
ATAKA	2 × 150 + 2 × 300	900	1 148	331.5
TOTAL	63 UNIT	7207	36 768	8869.3

RPG) and the third scenario (22% RPG) leads to achieve oil savings 1 770 386 ktoe 241.702 ktoe and 1773.86 ktoe respectively.

7.2. The cost of renewable energy replaces conventional energy for the scenarios

The price of renewable energy is 28 piasters/kilowatt hours and will be converted to \$/kWh. The price of electricity from conventional energy is 98 piasters/kilowatt hours and will be converted to \$/kWh. The petroleum savings were calculated by the total amount of oil used in the model, less the percentage shown in each scenario and replacing them with renewable energy. The savings achieved as a result of the use of new and renewable energy were calculated from the following: Total profits from carbon dioxide capture + money paid to buy oil minus the cost of kilowatt hours of renewable energy. For the first scenario (2%), renewable energy (0.73552 GWh) replace conventional energy becomes the cost of the state (0.22 million\$). The second scenario, with renewable energy (5.148 GWh) replace conventional energy becomes the cost of state (1.5 million\$). The third scenario: with renewable energy (7.3536 GWh) replace conventional energy becomes the cost of State (2.2 million\$). The final result is that the amount of savings achieved when bringing renewable energy for each scenario. The total amount of reduction in environmental cost and reduction of oil for the state as a result of substitution. Subtracting the total cost to bring renewable energy from the total savings of conventional fuel and the ratio of carbon dioxide capture.

7.3. Dollar savings achieved by the state when reduction use of oil fuel

The price of a barrel of oil on 22-2-2019 is 65\$ per barrel, tons of oil = 65\$ × 7 barrel equivalent = 455\$. For the first scenario, the second scenario and the third scenario, the amount of savings is (8.535\$) to provide (177.386 ktoe), (56 474.41\$) to provide (241.702 ktoe) and (807 106.3\$) to provide (1773.86 ktoe) respectively. The dollar savings achieved by the state as a result of the reduction or capture of carbon dioxide from the atmosphere.

The State spend a lot of money to reduce carbon dioxide and capture it, bringing renewable energy replaces conventional fuels have environmental benefits (reduce the cost of capture per tonne of carbon dioxide) and economic benefits (The dollar savings achieved by the state). It should be noted that the RPG does not produce any CO₂ emissions. When bringing renewable energy replaces conventional energy in any percentage will reduce emissions from oil fuels by replacement ratio, for one tonne of oil equivalent will be saved will reduce pollution in the atmosphere

b 3000 tons of carbon dioxide per year. Each one of the tons of oil equivalent is provided will reduce pollution in the atmosphere b 3000 tons of carbon dioxide annually. The processing (capture) of carbon dioxide price is estimated at 270 dollars/tonne when bringing the renewable energies to replace the conventional fuel the amount of processing (capture) 810,000 \$/tonne.

For the first scenario: The reduction of carbon dioxide emissions (5.32158 million tons) and the State financial savings (14.368 million\$). The second scenario: the reduction of carbon dioxide emissions (37.25106 million tons) and the State financial savings (14.368 million\$). The third scenario: The reduction of carbon dioxide emissions (53.21580 million tons) and the State financial savings (1.45 miler\$).

The total amount reduction in environmental cost and reduction of oil for the State as a result of substitution. Subtracting the total cost to bring renewable energy from the total savings of conventional fuel and the ratio of carbon dioxide capture, the following is shown.

For the first, second and third scenarios, the State saving about 5 million dollars, 36 million dollars and 749.2 million dollars respectively. Finally with the conventional fuels replaced by renewable energy sources will lead to cash savings for the state. In addition to low carbon emissions in the atmosphere, reducing the costs of the capture of carbon dioxide or processed, reducing the rate of pollution and the transformation to a clean environment and gradually.

8. Environmental improvement

This section focuses on the study of the economic side resulting from the use of renewable energy by studying the amount of fuel saved Tonne of Oil Equivalent (ktoe) and also calculating the amount of the reduction of the emission of carbon dioxide (tCO₂)

8.1. The emission factor

It is intended to calculate the average emission of carbon dioxide produced by the use of thermal generation in the Egyptian network for each MWh produced by thermal generation in service (tCO₂/MWh) as follows (Clean Development Mechanism, 2015):-

$$EF_K = \frac{\sum_i FC_{i,k} \cdot NCV_{i,k} \cdot EF_{CO_2,i,k}}{EG_{grid,k}} \quad (3)$$

where: $FC_{i,k}$ is that the quantity of fuel consumed per type i used to generate electricity during the year k , $NCV_{i,k}$ is the net calorific value (energy content) for every kind i of fuel in a year (Organization for Energy Planning, 2003). $EF_{CO_2,i,k}$ the emission factor

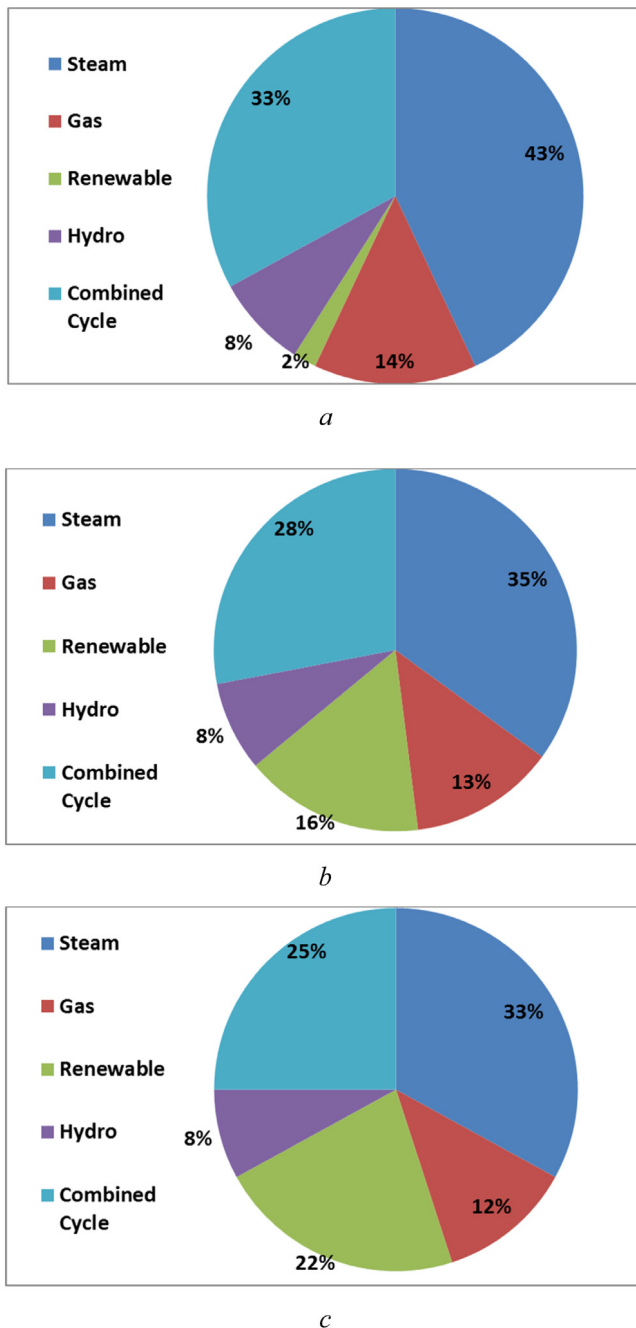


Fig. 5. Different operation scenarios (a) first scenario (2% RPG), (b) second scenario (16% RPG), (c) third scenario (22% RPG).

from CO₂ for each type of fuel during the year in (tCO₂/GJ) (IPCC, 2006). $EG_{grid,k}$ is the amount of grid electricity consumed by the system in year k (in MWh). i is all different fuel types used in power plants in year k and k is the year of the available data.

The steps are taken to calculate the emission factor of the Egyptian network were based mainly on the information provided in the annual report of the EEHC for the year 2017. This report shows the quantities of fuels consumed and their types, as well as the amount of thermal energy produced as shown in Table 3.

The calculations show that the emission factor of the Egyptian network is assumed to be 0.555 tCO₂/MWh, taking into account that the conversion factor from (toe) to GJ is 41.87 GJ/toe (Organization for Energy Planning, 2002; Nassar et al., 2017c; Nassar

Table 3
Egyptian fuel consumption.

Fuel consumption (toe)/2017		EF of CO ₂ (tCO ₂ /TJ)
Heavy fuel oil (toe × 1000)	7 148	75.5
Light fuel oil (toe × 1000)	581	72.6
Natural gas (toe × 1000)	26 249	54.3
Thermal generation (GWh)		161 617
Renewable generation (GWh)		2780

Table 4
Future RPG benefits.

Year	Expected generation (GWh)	ER (tCO ₂ × 10 ³)	CER price (\$ × 1000)	Fuel reduction (ktoe)
2018	8 437	4640.6	43 337.6	1 906
2019	11 812	6496.9	60 681.04	2 669
2020	15 750	8662.5	80 907.75	3 559
2021	21 375	11 756.3	109 803.842	4 830
2022	27 000	14 850.0	138 699	6 102
Total		46 405	433 427.6	19 066

and Abdella, 2019, 2018a). From this point of view, the emission reduction (ER) from CO₂ emissions can be calculated as follows:-

$$ER_{2017} = EG_{2017} \times EF_{2017} \quad (4)$$

$$ER_{2017} = 2780 \times 1000/_{2017} \times 0.555/_{2017} = 1,542,900 \text{ tCO}_2$$

These reductions from CO₂ emissions have an environmental and economic impact, according to Kyoto Protocol, which shows the value of Certified Emission Reduction (CER) is = 9.34 \$/tCO₂ (Reuters, 2018). Thus, the financial return during 2017 is (9.34 × 1 542 900) 14,410,686\$. Beside fuel consumption saving, which represents about 628 (ktoe)

8.2. Expected future-benefits

Based on previous calculations that have demonstrated the environmental and economic benefits of RPG in 2017. The future benefits of renewable energy in economic and environmental terms from 2018 to 2022 are expected to reach 433 427.6 × 10³ \$ as well as the reduction of CO₂ emissions will reach 46 405 × 10³ tCO₂ and the amount of fuel-saving will reach 19 066 ktoe according to Table 4.

9. Conclusion

This paper examined the use of renewable energy as a permanent source of energy. A study was conducted on a real network, the Egyptian Network. The percentage of RPG was increased to 22%. The study showed the economic benefits of the point of view of the amount of savings achieved when bringing renewable energy to each scenario. The total amount of reduction in environmental cost and reduction of oil for the State as a result of substitution. Subtracting the total cost to bring renewable energy from the total savings of conventional fuel and the ratio of carbon dioxide capture. In addition to low carbon emissions in the atmosphere, Reducing the costs of the capture of carbon dioxide or processed, Reducing the rate of pollution and the transformation to a clean environment and gradually. Finally, the economic study showed the benefits renewable energy has provided. Which showed that RPG by the end of 2022 will reduce the emission of carbon dioxide to 46 405 × 10³ tCO₂ which yield a return of 433 427.6 × 10³ \$ according to CER price and the savings of the fuel will reach 19 066 ktoe.

Acknowledgment

The authors are grateful to the Egyptian Electricity Holding Company for their information.

References

- Ackermann, T., 2005. *Wind Power in Power Systems*. Royal Institute of Technology, ohn Wiley & Sons, Ltd, Stockholm, Sweden.
- Arab Republic of Egypt, 2006. Zafarana KFW IV Wind Farm Project, Clean Development Mechanism Project Design Document Form (CDM-PDD) Version 03 - in effect as of: 28 July.
- 2015a. Arab republic of Egypt, Ministry of Electricity and Energy, Egyptian Electricity Holding Company. 'Annual Report 2014-2015', Arabic Version. <http://www.moe.gov.eg> (accessed April 2015).
- 2015b. Arab republic of Egypt, Ministry of Electricity and Energy, New and Renewable Energy Authority (NREA) . 'Annual Report 2014-2015', Arabic Version. <http://www.nrea.gov.eg/arabic1.html> (accessed April 2015).
2016. Arab republic of Egypt, Ministry of Electricity and Energy, Egyptian Electricity Holding Company. 'Annual Report 2015-2016', Arabic Version. <http://www.moe.gov.eg> (accessed April 2016).
- Bhaladhare, S.B., Telang, A.S., Bedekar, P.P., 2013a. P-V, Q-V Curve-A novel approach for voltage stability analysis. In: NCIPET.
- Bhaladhare, S.B., Telang, A.S., P., Bedekar P., 2013b. P-V Q-V Curve-A novel approach for voltage stability analysis. In: NCIPET.
2015. Clean Development Mechanism, Tool to calculate the emission factor for an electricity system, Version 05.0, EB 87, Annex 9 November.
- 2014a. DlgSILENT. DlgSILENT Power factory user manual version', . :<https://www.digsilent.de/en/power-equipment-models.html> (accessed 2014).
- 2014b. DlgSILENT. DlgSILENT power factory software. [Online]. Available: <https://www.digsilent.de/en/powerfactory.html> (accessed 2014).
- Dudiak, J., Kolcun, M., 2014. Integration of renewable energy sources to the power system. In: 14th Environment and Electrical Engineering(EEEIC) International Conference.
- Freris, L., Infield, D., 2008. *Renewable Energy in Power Systems*. John Wiley & Sons, United Kingdom.
2016. Gamesa plat form catalogue, gasema 2.0 MW-G80. <http://www.siemensgamesa.com/en/products-and-services/wind-turbines/catalogue/> (accessed August 2016).
- Gylling, Mortensen N., Usama, Said S., Badger, Jake, 2006. Wind atlas for Egypt. In: Proceedings of the Third Middle East-North Africa Renewable Energy Conference (on CD-ROM).
- Herzog, A.V., Lipman, T.E., Kammen, D.M., 2001. Renewable Energy Sources, Energy and Resources Group, University of California, Berkeley, U.S.A <http://www.eolss.net/Eolss-sampleAllChapter.aspx>.
- IPCC, 2006. Guidelines for national greenhouse gas inventories, Chapter 1 (2) Energy, Table 1.4.
- Kholud, H., 2004. Renewable energy and its potential investment in Egypt. In: MSC. Ain Shams University, Egypt.
- Kundur, P., 1994. *Power System Stability and Control*. McGraw-Hill.
- Lira, R., Wang, D., Wilson, D., Salter, P.J.C., Galzin, C., Stearn, N., 2013. WAMS Application for improving the stability and security of latge interconnected electrical power systems. In: 4th International Exhibition&Conference.
- Nassar, I.A., Abdella, M.M., 2017a. Enhancement of the dynamic model of abusultan steam power plant in the Egyptian power system. In: 19th Middle East Power Systems Conference, MEPCON'2017. Menofia University, Egypt.
- Nassar, I.A., Abdella, M.M., 2017b. New dynamic model for gas power plants for increasing wind and solar energy in the Egyptian power system. Int. J. Innov. Res. Elect. Electron. Instrum. Control Eng. 5 (10), 55–62. <http://dx.doi.org/10.17148/IJIREEICE.2017.51009>.
- Nassar, I.A., Abdella, M.M., 2018a. Effects of Increasing Wind and Solar Power Energy on the Voltage Stability and Losses of the Egyptian Power System", 2018 20th International Middle East Power Systems Conference, MEPCON 2018 – Proceedings.
- Nassar, I., Abdella, M., 2018b. Impact of replacing thermal power plants by renewable energy on the power system. Therm. Sci. Eng. Prog. 5 (1), 506–515. <http://dx.doi.org/10.1016/j.tsep.2018.02.002>, Elsevier.
- Nassar, Ibrahim A., Abdella, Mahmoud., 2019. Parameters calculation of thermal power plant dynamic model using steam cycle data. Therm. Sci. Eng. 9, 259–265, ISSN: 2451-9049/ © 2018 Published by Elsevier Ltd.
- Nassar, I.A., AlAli, S., Weber, H., 2014a. Effects of increasing intermittent generation on the frequency control of the European power system', Preprints of the 19th World Congress, The International Federation of Automatic Control Cape Town, South Africa, 24–29 August, pp. 3134–3139.
- Nassar, Ibrahim A., AlAli, Salaheddin, Weber, Harald, 2014b. Effects of increasing intermittent generation on the frequency control of the european power system. In: 19th IFAC World Congress (IFAC WC 2014). Cape Town, South Africa.
- Nassar, Ibrahim A., Elsayed, Ibrahim, Mostafa, Fatma Alzahraa, 2017c. Optimization and economic evaluation of small scale hybrid solar/wind power for remote areas in Egypt. In: Nineteenth International Middle East Power Systems Conference (MEPCON), Menoufia University, IEEE, Egypt, ISBN 978-1-5386-0990-3/17/\$3100 © 2017.
- Nassar, I.A., Weber, H., 2013. Influence of increasing intermittent renewable energy sources on the power system. In: Nachhaltige Energieversorgung Und Integration Von Speichern Symposium. Hamburg, Germany.
- Nassar, I.A., Weber, H., 2015. Impact of renewable energy sources on the German power system. Recent Adv. Commun. Netw. Technol. 4 (1), 1–9.
- Nikolovski, S., Topić, D., Fekete, K., Slipac, G., 2011. The influence of wind park Krš-Padene on reliability indices of a 110 kV transmission network. In: Proceedings of the 8th International Conference on the European Energy Market (EEM) Zagreb, Croatia. pp. 870–875.
- Omara, Mohammad A., Nassar, Ibrahim A., 2019. Voltage quality in delta Egypt network and its impact in oil industry. Energy Rep. 5, 29–36, ISSN: 2352-4847.
2002. Organization for Energy Planning, Energy in Egypt, Conversion Units, Standard Conversion Factor.
2003. Organization for Energy Planning, Energy in Egypt, Conversion Units.
- Reuters, Thomson, 2018. Carbon market monitor, Review of global markets in 2017 and outlook for 2016–2018, January.
- Sulaiman, M., Nor, A.F.M., 2015. PV And QV curves approach for voltage instability on mesh-type electrical power networks using digsilent. MGNT Res. Rep. (3), 26–42.
- Tawfic, A.M., 2000. Baseline for Japanese Wind Power Plant in Zafarana Project (Arab Republic of Egypt). National Renewable Energy Agency (NREA), <http://cdm.unfcc.int/methodologies/process>.
2014. The European Photovoltaic Industry Association (EPIA) ', [on line] http://www.epia.org/fileadmin/user_upload/Publications/Connecting_the_Sun_Full_Report_converted.pdf.
- Vezmar, S., Spajić, A., Topić, D., Šljivic, D., Lajos, J., 2014. 'positive and negative impacts of renewable energy sources. Int. J. Electr. Comput. Eng. Syst. 5 (2), 47–55.
- Vilchez, E., Stenzel, J., 2013. Impact of renewable energy generation technologies on the power quality of the electrical power systems. In: 22nd International Conference on Electricity Distribution. pp. 1– 4.