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Optimal Design of Wind Energy System Interconnected with Utility Grid-Case Study of Egypt

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Abstract

This paper presents the optimal design and operation of Wind Energy System (WES) interconnected with Utility Grid (UG). Moreover, the paper introduces a proposed computer program to determine the optimal design of WES to be interconnected with UG. The proposed computer program has been designed to determine the optimum number of Wind Turbine Generators (WTGs) needed to feed a certain load. Many WTG types have been introduced to the computer program to choose the best type of WTG. By using the proposed computer program, the WES components can be completely designed to be interconnected with UG. This program has a subroutine which by using it the optimum operation of WES can be determined hour by hour through the year. Then, the monthly surplus energy, monthly deficit energy and yearly purchase from UG or selling energy to UG can be estimated. The decision from the computer program is based on the minimum price of the generated kWh from the WES. The proposed computer program has been applied on two Egyptian sites. The first sit is Ras- Ghareb which located at the coast of the Red sea and the second site is Ras- EL-Hekma which located at the coast of the Mediterranean Sea.

Keywords: Wind Energy System, Optimal Design, Renewable Energy

I. INTRODUCTION

Energy is the main driving force of modern economic development. With the increase in the world population, more energy is needed to meet the growing human needs for maintaining well-being. Improving the standard of living and prolonging a person's life depends, on average, on energy consumption per person. In Egypt, as throughout the world, energy plays a significant role in economic development. On the other hand, Egypt, as a developing fast-growing country, suffers from rapid annual population growth with a rate of 1.68%. As of October 2017, the population of Egypt was estimated at 96.125 million. According to the Cairo Demographic Center, It is expected that the population of Egypt will reach 110 million by 2031 and 128 million by 2051 [1]. Such rapid population growth along with other environmental problems is overexertion limited energy resources of the country.

The New & Renewable Energy Authority (NREA) plays a strategic role in the government's renewable energy plans. It currently has about 500 MW of wind power plants in operation and 1340 MW under implementation and development and is expected to contribute substantially to the rapid expansion of wind power capacity. There are also three privately owned independent power producers (IPPs) with total generation capacity of about 2.5 GW, which started operations in 2002-2003 under 20-year long power purchase agreements with EEHC. The Egyptian government renewable energy plans for 2015-2023 include 3.2 GW of government projects; 1.25 GW under BOO mechanisms, and 920 MW as IPPs. In January 2017, Egypt selected 67 companies to take part in developing 4.3 GW of renewable energy projects; currently, pre-qualified companies are in the land-allocation process.

These efforts have resulted in Egypt being ranked second among countries making progress throughout the year in the transition to renewable energy in a report by Bloomberg Climatescope. According to the report, Egypt climbed 23 places to rank 19 out of the 71 evaluated countries in emerging clean energy markets. The Egyptian Electricity Transmission Company (EETC) has been inviting tenders for constructing projects with a capacity of 250 MW for wind energy in the BOO (Build-Own-operate) system. Besides, the New and Renewable Energy Authority (NREA) is launching bids to design, supply, and execute projects with a capacity of 750 MW for producing 1980 MW of wind energy. Overall the Ministry of Electricity and Renewable Energy aims to generate 51.3 GW of renewable energy in the next five years. Projects of interest at the moment include a 250 MW wind farm project in the Gulf of Suez, near Ras Ghareb which will increase Egypt's wind energy capacity by 14% once constructed, the Zafarana complex for wind power with a capacity of 545 MW and the Gabal al-Zeit complex for wind power with a capacity of 580 MW.

Recently, fossil fuels comprise the major energy sources in many parts all over the world. These fossil fuels can be exhausted and usually negatively affect the environment while they are being utilized into useful forms of energy [1, 31, 32,33]. Taking into account the drawbacks besides using fossil fuels in energy application, there is an urgent need to find cost-effective, reliable and clean alternative sources of energy. Renewable sources of energy such as photovoltaic (PV), wind turbine and hydropower, are the most attractive candidates for clean energy generation especially in low scale and isolated areas [2]. Each of these renewable energy sources has its unique character and principle of operation, which make it suitable for a certain site and application.

Because of the inherent fluctuations in solar and wind energy resources, the independent use of an individual power source usually results in a very large generation and storage system, which in turn requires a higher operating and life cycle cost [5, 6]. Therefore, the hybrid solar-wind system is usually adopted, which can leverage the strengths of each technology to provide a more reliable and less costly power supply in remote areas [3, 4]. Energy storage systems such as batteries, fuel cells (FC), flywheels, supercapacitors, molten salt, compressed air and hydroelectric pumped storage (HPS) could be a suitable solution to overcome the problems associated with the irregular nature of renewable sources.

Hydrogen tanks as a mean of energy storage in renewable energy systems have been proposed in many research studies [7-9]. Hydrogen storage performs well in both long and short-term purposes and in some cases for enhancement of the dynamic performance of the system, supercapacitors are advisable to be integrated [10]. In comparison with a diesel generator as a method of energy storage, hydrogen-based energy storage systems do not need any external supply of fuel and no greenhouse emissions are exhausted into the atmosphere. Also, due to the continuous increase in the fuel cost and the observable reduction in the cost of FC, it is expected that the hydrogen storage systems will be economically feasible for application as a method of electric energy storage in the form of hydrogen gas [11].

In hybrid renewable energy systems based on hydrogen storage, during the hours of excess energy from the PV and wind systems, electrolyzer coverts the surplus electrical energy into hydrogen stored in the hydrogen tanks. When the peak demand for electricity occurs and the wind speed and solar radiation are not sufficient to satisfy the load demand by converting the stored hydrogen into electricity through the fuel cell [12].

II. RELATED WORK

Since hybrid PV/wind power systems depend mainly on sources having intermittent characteristic (solar radiation and wind speed), it is a great challenge to design such a system with acceptable reliability when considering the investment and operating costs of each component in the system. Therefore, the main goal is the optimal configuration of an economic and reliable power supply. In the literature, there are many research papers, which offer different methods and algorithms of optimal design of hybrid PV/wind power systems [13-30].

In References [13, 14] the optimal sizing of a PV/wind/diesel hybrid system was presented using Strength Pareto evolutionary algorithm by formulating two objective functions, minimization of system cost and greenhouse gases emissions. In [15-17] Genetic algorithm (GA) was used for optimal sizing and configuration of a hybrid PV/wind power system with battery storage under different objective functions; the reliability of the system under weather conditions variations, minimizing the annual cost of the system and to minimize the loss of power supply probability (LPSP). Particle Swarm Optimization (PSO) has been used in many research studies for optimal sizing of hybrid renewable energy systems [18-20]. Simulated Annealing (SA) optimization strategy was used for optimal sizing of hybrid PV/wind energy conversion system, while the objective function was to minimize the total energy cost of the hybrid system [21]. The response surface methodology (RSM) was used for optimizing the size of an autonomous PV/wind system with energy storage in some studies [22]. The results obtained from RSM optimization were confirmed using autonomy analysis and loss of load probability, then the results of this work were used in [21] to be compared with the results obtained from simulated annealing optimization. In [23] Pattern Search (PS) optimizer and sequential Monte Carlo Simulation (SMCS) are combined to obtain the minimum total cost of the system and satisfy the reliability requirements from the consumer side. A comparison with a hybrid GA-SMCS was also performed, from which the PS-SMCS gave a better performance. In [24] cuckoo search optimization algorithm has been used for optimal sizing of an isolated PV/wind/diesel/ battery energy system, while the proposed technique provided high accuracy when compared with GA and PSO. Multi-Objective Self-Adaptive Differential Evolution (MOSaDE) algorithm has been used for optimal sizing and operation of a hybrid PV/wind/diesel microgrid system with battery storage for the city of Yanbu, Saudi Arabia, while, the multi-objective optimization approach is used to reduce the computational time [25]. Optimal sizing and placement of a grid-connected PV-wind-battery storage microgrid using Artificial Bee Colony optimization technique, while the IEEE 30-bus system was used for the application of the optimal operation [26]. In [27, 28] the Hybrid Optimization of Multiple Energy Resources (HOMER) software has been used for optimum sizing of hybrid wind/PV/diesel system in Malaysia in which the weather conditions, maximum availability and minimum cost were considered, respectively. Refs. [29,30], authors present optimal designs of RES in Egypt with pumped storage system and Fuel cell. This motivate us to determine the best design of the WES and also the best location to implement the RES.

This paper introduces a novel design methodology of the integrated wind energy system with the utility grid. The producer and the model have been applied to a practical case of Egypt. This paper aides the researchers and investors for research and technological development to inject capital into various projects happening all over the country.

III. DESIGN METHODOLOGY OF WES AT MAXIMUM POWER POINT

III.I Modification of Average Wind Speed to Hub Height

Usually, weather stations measure wind speed at 10-m or 24-m. If these heights do not match the hub height of a wind turbine it is necessary to extrapolate the wind speeds to the hub height of the turbine [5]. This process can be done by the following equation:

$$u_h = u_{ho}(h / h_O)^{\alpha} \qquad (1)$$

where: u_h is the wind speed at height h-m in m/s, u_{ho} is the wind speed at height $ho - m$ in m/s, (ho is usually 10-m), h is the height from the ground in m. α is the Exponent is usually 1/7 [7].

III.II Calculation of Capacity Factor, CF and ANWTG

The capacity factor, CF, can be calculated by using the following Equation [1, 4]:

$$CF = \frac{Exp\left[-\left(u_c / C\right)^K\right] - Exp\left[-\left(u_r / C\right)^K\right]}{\left(u_r / C\right)^K - \left(u_c / C\right)^K} - Exp\left[-\left(u_F / C\right)^K\right] \quad (2)$$

where; u_c is the cut-in wind speed of the WTG, m/s, u_r is the rated wind speed of the WTG, m/s, u_F is the cut-off wind speed of the WTG, m/s, C and K are the scale and shape Weibull parameters respectively. These parameters can be calculated by using equations in reference [7].

The average electric power output form WTG, $P_{e,ave}$ can be estimated by using the following Equation [1,4]:-

$$P_{e,ave} = \ Prated\ CF \quad (3)$$

where; P_{rated} is the rated electrical power output from the WTG, kW.

The average number of wind turbine generators, ANWTG, can be estimated by using the average load demand, $P_{L,ave}$, from the following Equation:-

$$N_w = \frac{P_{L,ave}}{P_{e,ave}} \quad (4)$$

The energy balance between the load and the output of WES should be carried out to compute the optimum number of WTG's, N_w. The hourly generated power, $P_{WTG,out}(t)$, and hourly load power, $P_{Load}(t)$, are compared with each other. If $P_{WTG,out}(t)$ is larger than the load power demand then there is hourly surplus power, but if $P_{WTG,out}(t)$ is smaller than the load power demand then there is an hourly deficit power. At any value of N_w, if the summation of hourly surplus power approximately equals to the summation of hourly deficit power then this value of N_w represents the optimum number of WTG, ONWTG [8].

III.III Calculation of Energy Cost Figure, ECF, [5, 6, 9, 10]

The ECF of WTG/UG can be estimated as follows:

$The\ total\ cost\ of\ WTG,$

$$TCWTG = TW\ ONWTG * R \quad (5)$$

$Microprocessor,$

$$TCMIC = TP * ONWTG * R \quad (6)$$

$Main\ substation,$

$$TCM = TS * ONWTG\ * R \quad (7)$$

$Remote\ control\ modem\ cost$:

$$TCRC = TM *\ ONWTG\ * R \quad (8)$$

$Central\ station\ control\ cost,$

$$TCCC = TC * ONWTG * R \ (9)$$

$Transmission\ line\ cost,$

$$TLC = TR *\ ONWTG\ * R \quad (10)$$

$$TCC = TCWTG + TCMIC + TCMS + TCRC + TCCC + TLC \quad (11)$$

$$Levelized\ annual\ cost\ of\ WTG, LACw = \ Kw\ *\ TCC \quad (12)$$

where; R is the rating of WTG in kW, TW is the Price of WTG in \$/kW, TP is the price of microprocessor in \$/kW, TS is the price of the main substation in \$/kW, TM is the price of modem for remote control in \$/kW, TC is the price of central station control in \$/kW, TR is the transmission line price in \$/kW, TCC is the total Capital cost.

$$\mathrm{K}_w = \frac{r*(1+r)^{N_w}}{(1+r)^{N_w-1}} \quad (13)$$

Operation and maintenance cost,

$$O\&MC = 0.05 * LACW \quad (14)$$

Total levalized annual cost for WTG,

$$TLACW = \frac{(LACW + O\&MC)}{0.9} \quad (15)$$

Energy cost figure,

$$\mathrm{ECF, \$/kWh} = \frac{\mathrm{TLACW}}{\mathrm{Total\ expected\ yearly\ energy\ generated}} \quad (16)$$

where; N_w is the life period of WTG in years and r is the interest rate of WTG.

IV. SIMULATION RESULTS

A new proposed computer program has been designed depending on the above methodology for calculating the optimum number of WTG. Figure 1 shows the flowchart of the proposed computer program.

The input data of this program are:

IV.I Hourly wind speed, m/s.

The hourly wind speed for the selected sites is the first data required for the design of WES. The data has been obtained from the Egyptian Metrological Authority for Ras- Ghareb and Ras- EL- Hekma sites. Ras Ghareb site is located at Gulf of Suez (Red sea area), Egypt. It has the following data [11]:

Latitude: 28.33° N, Longitude: 33° E and Altitude: 56 m. Height of anemometer: 24.5 m above the ground. The surface consists mostly of sand and gravel with a roughness length of less than 0.01 m.

Ras- EL-Hekma site is located at Northwest Coast of Egypt (Mediterranean Sea area). It has the following data: Latitude: 31.2° N, Longitude: 24.87° E and Altitude: 23 m. Height of anemometer: 24.5 m above the ground.

Figure 2 and Figure 3 show the hourly wind speed over the year seasons as a sample data for months January, April, July and October for Ras- El-Hekma and Ras Ghareb sites respectively.

IV.II Characteristics of each WTG type

In this study, two different selected types of WTG's have been used. The characteristics of these WTG's are revealed in Table 1.

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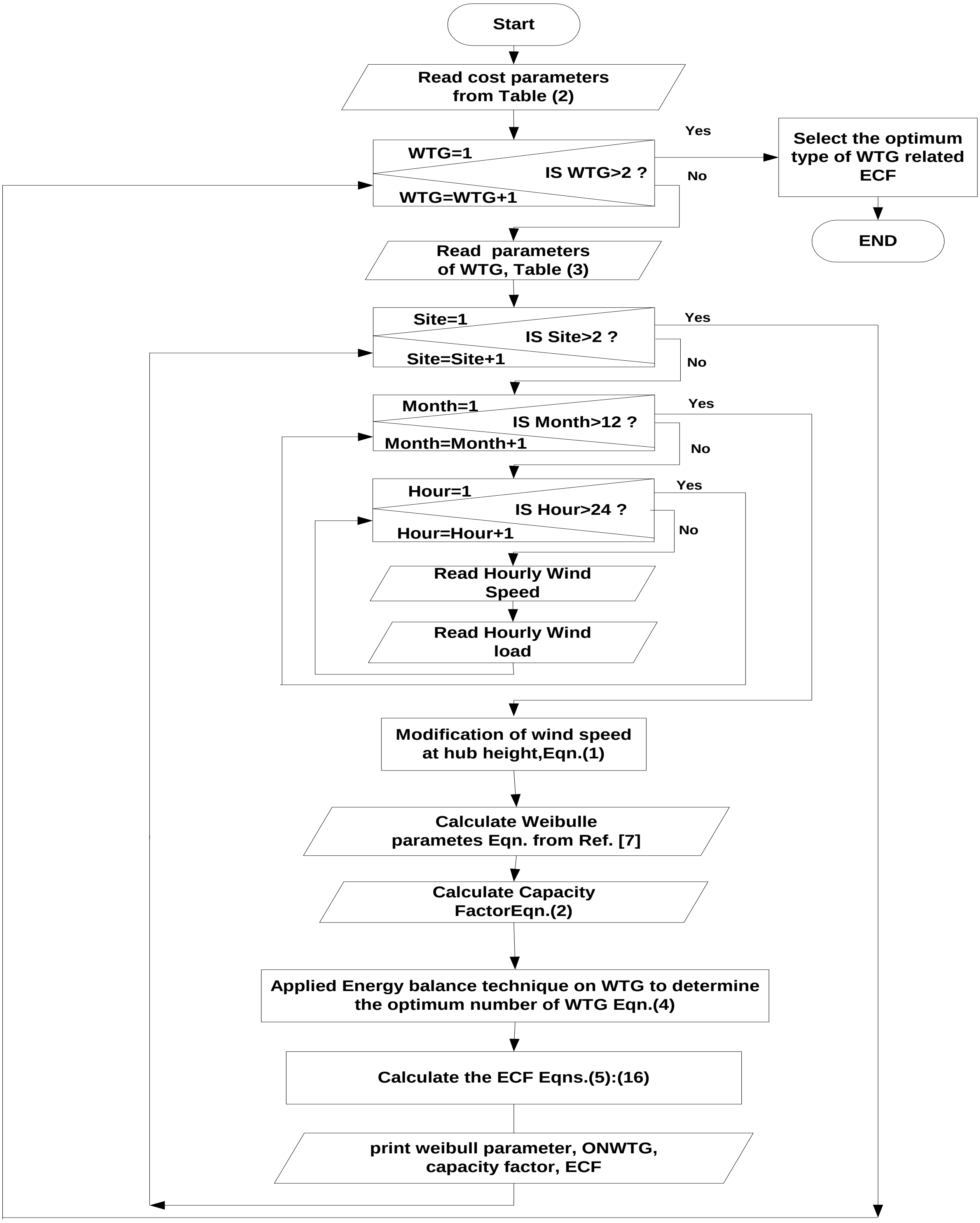

Fig.1 Flowchart of the Proposed Computer Program

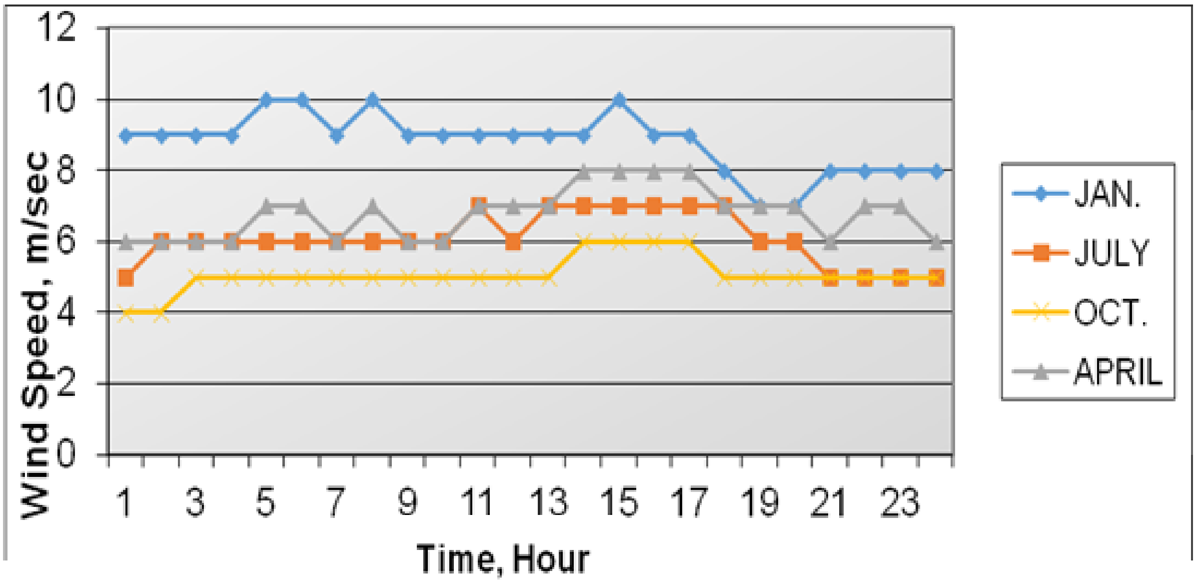

Fig. 2 Hourly Wind speed during January, April, July, and October for Ras-El-Hekma site, Egypt

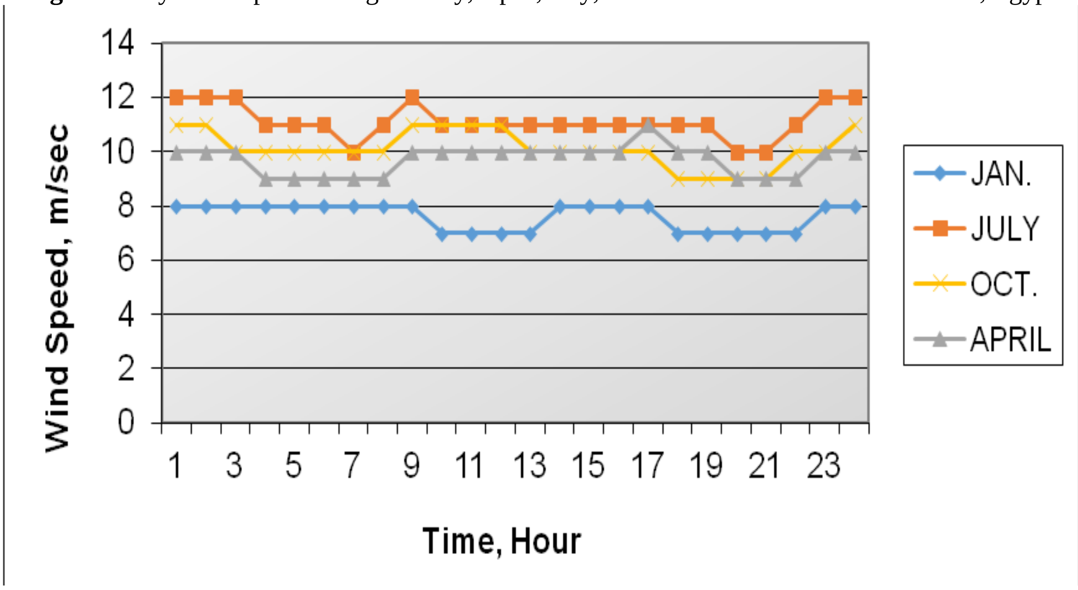

Fig. 3 Hourly Wind speed during January, April, July, and October for Ras Ghareb site, Egypt

Table 1. Characteristics of the selected WTG's

Type of WTG / Characteristics	N90/2500 HS	S52 − 600 kW
Rated Power (kW)	2500	600
H (m)	100	75
D (m)	90	52
Swept Area (m2)	6362	2124
u_c (m/s)	3	4
u_r (m/s)	13	13
u_f (m/s)	25	25
Generator Type	Double − fed asynchronous generator	Single − speed induction generator
Output voltage (V)	660 V	690 V AC (phase to phase)
Frequency (Hz)	50/60	50
No. of Blades	3	3
Power regulation type	Pitch regulation	Pitch regulation

IV.III Hourly load demand, kW

It is assumed here that the load demand varies monthly. This means that each month has a daily load curve different from other months. Therefore, there are twelve daily load curves throughout the year. Hourly load demand is shown in Fig. 4 for months January, April, July, and October.

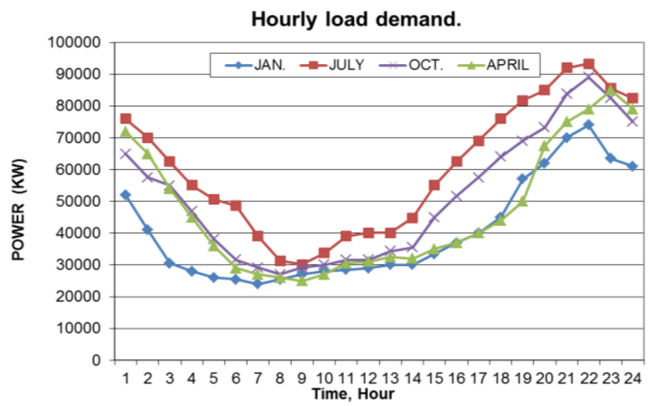

Fig. 4 Hourly load demand

IV.IV The Price of Each Component of WTG's is displayed in Table 2

The outputs of this proposed program are the optimum number for each type of WTG's, Cost of kWh generated for each type of WTG's in $/kWh, Optimum type for each type of WTG's based on its ECF, Monthly surplus energy in kWh, Monthly deficit energy in kWh, Yearly purchase or selling energy to or from UG in kWh.

Table 3 reveals some of the results from a computer program such as Weibull parameters, capacity factor, the optimum total number of WTG's and energy cost figure, ECF, for each type of the selected WTG's and each selected site. From this Table, it can be seen that the N90/2500 HS WTG type has lower ECF than the type of S52-600 kW for the two selected sites. On the other hand, the WTG type of N90/2500 HS has CF value greater than the CF value of S52-600 kW WTG for the two selected sites. This is can be seen in Figs 5 and 6. For these reasons it can be concluded that the N90/2500 HS WTG type is the more suitable WTG type for the two selected sites.

Table 2. Price of Each Component of WTG's [12]

Item	TW	TP	TS	TM	TC	TR
Price, $/kW	600	2.5	11	3	4.2	1.8

Table 4 displays the monthly surplus energy, monthly deficit energy and the difference between them when the WTG 2500 HS type used at Ras- El-Hekma site. Also, Fig. 7 shows the monthly difference between surplus energy and deficit energy (monthly Net energy) for Ras- El-Hekma site when the WTG 2500 HS type used. From Table 4 it can be seen that the yearly surplus energy sent sold to the UG equal to (117097.2374 MWh) and the deficit energy taken purchased from the utility grid.

UG equal to (115746.0825 MWh). From Fig.7 and Table 4 it can be concluded that there is a yearly income fund from the UG to the WES. This income fund represents the price of the net surplus energy which equals to (1351.154889 MWh) yearly.

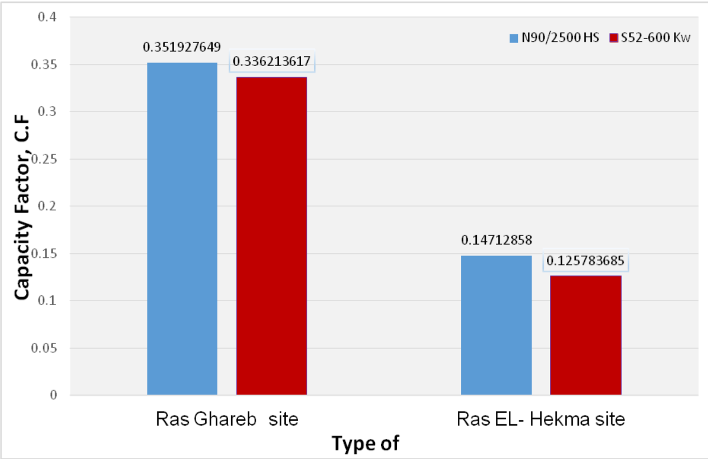

Fig. 5 The Capacity Factor of selected WTG's for Ras Ghareb site and Ras EL- Hekma site, Egypt.

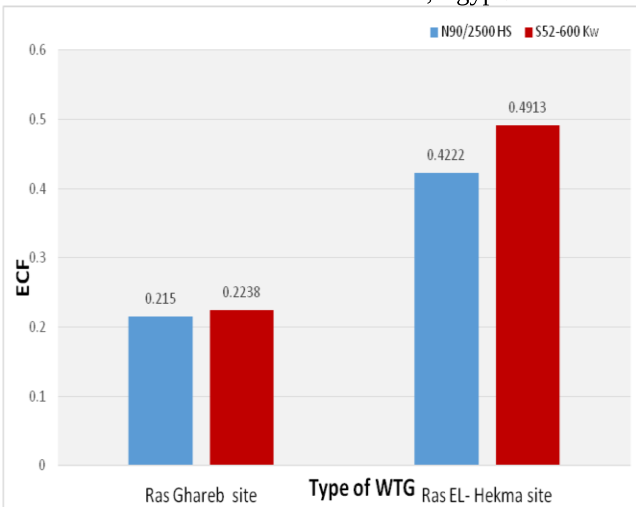

Fig. 6 Energy Cost Figure of selected WTG's for Ras Ghareb site and Ras EL- Hekma site, Egypt.

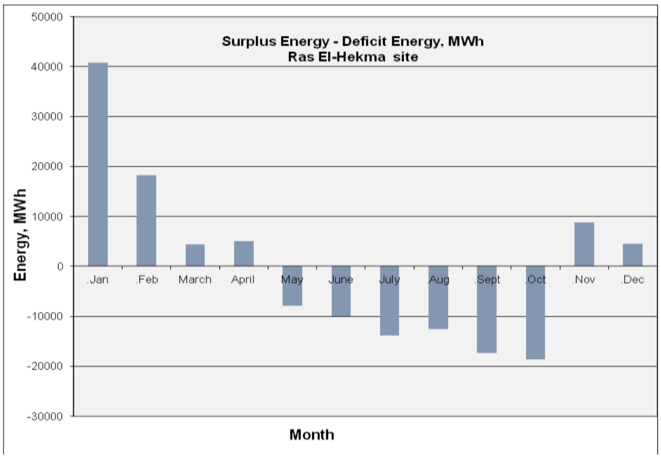

Fig. 7 Monthly Net Energy for WTG 2500 HS for Ras El-Hekma site, Egypt.

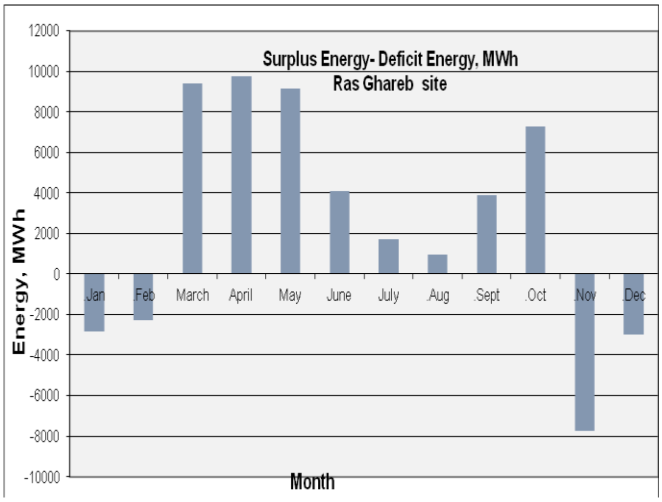

Fig. 8 Monthly Net Energy for WTG 2500 HS for Ras Ghareb site, Egypt

Table (V) reveals the monthly surplus energy, monthly deficit energy and the difference between them when the WTG 2500 HS type used at Ras- Ghareb site. Also, Fig. 8 shows the monthly difference between surplus energy and deficit energy (monthly Net energy) for Ras- Ghareb site when the WTG 2500 HS type used. From Table 5 it can be seen that the yearly surplus energy sent selled to the UG equal to (97223.88453 MWh) and the deficit energy taken purchased from the UG equal to (66891.54714 MWh). From Fig.8 and Table 5 it can be concluded that there is yearly income fund from the UG to the WES. This income fund represents the price of the net surplus energy which equals to (30332.33739 MWh) yearly.

V. CONCLUSION

Considering Ras-EL- Hekma site and the obtained results it can be concluded that there is surplus energy fed to the UG through Jan., Feb., March, April, Nov, and Dec. Also, there is energy taken from the UG to overcome the deficit energy of the load demand during May, June, July, Aug., Sept., and Oct. Considering Ras- Ghareb site and from Table (V) and Fig. 8 it can be concluded that there is surplus energy fed to the UG through March, April, May, June, July, Aug., Sept., and Oct. Also, there is energy taken from the UG to overcome the deficit energy of the load demand during the months of Jan., Feb., Nov. and Dec.

Table 3. Parameters of the Selected WTG's for the two selected sites. [13], [14].

Modes	Ras Ghareb site		Ras EL − Hekma site	
	N90/2500 HS	S52 − 600 kW	N90/2500 HS	S52 − 600 kW
Rated Power kW	2500	600	2500	600
C , m/s	9.024	9.024	6	6
K	2.506	2.506	2.25	2.25
C. F	0.3519276488	0.3362136173	0.1471285796	0.1257836854
ONWTG, No.	25	102	46	223
Total Capital Cost, $	38906249.985	38096999.9	71587499.9	83290199.
Levalized Cost, $	2862789.94	2803243.91	5267533.50	6128660.72
O&MC, $	143139.499	140162.196	263376.679	306433.040
Yearly Energy (kWh), $	15509904	14609050	14556575	14552473
ECF ($/kWh)	0.215	0.2238	0.4222	0.4913
Total Levalized annual cost	3339921.61	3270451.23	6145455.92	7150104.37

Table 4. Monthly Net Energy for WTG 2500 HS for Ras El-Hekma site, Egypt.

Monthly	Surplus Energy, MWh	Deficit Energy, MWh	Surplus − Deficit, MWh
Jan.	41114.29209	328.5703427	40785.72175
Feb.	21952.07376	3697.463169	18254.61059
March	10823.43726	6426.501765	4396.935495
April	11352.861	6333.8475	5019.0135
May	2334.205409	10225.9173	−7891.711891
June	3000.419433	12994.852	−9994.432567
July	1686.12659	15601.401	−13915.27441
Aug.	1660.750936	14229.59418	−12568.84324
Sept.	330.4711999	17672.52945	−17342.05825
Oct.	0	18666.4141	−18666.4141
Nov.	12397.27913	3622.857213	8774.421917
Dec.	10445.32056	5946.134459	4499.186101
Summation	**117097.2374**	**115746.0825**	**1351.154889**

Table 5. Monthly Net Energy for WTG 2500 HS for Ras- Ghareb site, Egypt.

Monthly	**Surplus Energy, MWh**	**Deficit Energy, MWh**	**Surplus − Deficit, MWh**
Jan.	5084.266904	7927.404007	−2843.13710
Feb.	4734.072051	7027.397699	−2293.3256
March	12787.93164	3403.985153	9383.94648
April	13191.68776	3421.91224	9769.77552
May	12236	3082.27806	9153.72194
June	8542.4	4453.6	4088.8
July	7365.920267	5663.520093	1702.40017
Aug.	7363.792102	6399.199768	964.592334
Sept.	8104.336353	4204.928455	3899.40789
Oct.	11201.18391	3933.84836	7267.33555
Nov.	2663.171558	10408.4681	−7745.2965
Dec.	3949.121982	6965.005206	−3015.8832
Summation	**97223.88453**	**66891.54714**	**30332.3373**

REFERENCES

[1] Goedeckeb, M.; Therdthianwong, S.; Gheewala, SH. Life cycle cost analysis of alternative vehicles and fuels in Thailand. Energy Policy 2007, 35(6), 3236–3246.

[2] Kusakana, K.; Vermaak, H.J. Hybrid renewable power systems for mobile telephony base station in developing countries. Elsevier Renewable Energy 2013, 51, 419 – 425.

[3] IEA. Renewable energies for remote areas and islands; April, 2012.

[4] Bernal-Agustín, JL; Dufo-López, R. Simulation and optimization of stand-alone hybrid renewable energy systems. Renew Sustain Energy Rev 2009, 13, 2111-8.

[5] Elhadidy, MA; Shaahid, SM. Parametric study of hybrid (wind + solar + diesel) power generating systems. Renew Energy 2000, 21, 129-139.

[6] Bagul, AD; Salameh, ZM; Borowy, B. Sizing of a stand-alone hybrid wind photovoltaic system using a three-event probability density approximation. Sol Energy 1996, 56, 323-335.

[7] Ghosh, GC; Emonts, B; Stolen, D. Comparison of hydrogen storage with diesel generator system in a PV–WEC hybrid system. Sol Energy 2003, 75, 187–198.

[8] Bak, T.; Nowotny, J.; Rekas, M.; Sorrell, CC. Photo-electrochemical hydrogen generation from water using solar energy: materials-related aspects. Int J Hydrogen Energy 2002, 27, 991–1022.

[9] Kashefi, Kaviani A; Baghaee, HR; Riahy, GH. Design and optimal sizing of a photovoltaic/wind-generator system using particle swarm optimization. In Proceedings of the 22nd power system conference (PSC), Tehran, Iran, December 19–21, 2007.

[10] Khan, MJ; Iqbal, MT. Dynamic modeling and simulation of a small wind-fuel cell hybrid energy system. Renewable Energy 2005, 30, 421–439.

[11] Khan, MJ; Iqbal, MT. Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland. Renewable Energy 2005, 30, 835–854.

[12] Mills, A; Al-Hallaj, S. Simulation of hydrogen-based hybrid systems using hybrid2. Int J Hydrogen Energy 2004, 29, 991–999.

[13] Bernal-Agust´ın, J. L.; Dufo-L´opez, R.; Rivas-Ascaso, D. M. Design of isolated hybrid systems minimizing costs and pollutant emissions. Renewable Energy 2006, 31(14), 2227– 2244.

[14] Dufo-L´opez, R.; Bernal-Agust´ın, J.; Yusta-Loyo J. Multiobjective optimization minimizing cost and life cycle emissions of stand-alone PV-wind-diesel systems with batteries storage. Applied Energy 2011, 88(11), 4033–4041.

[15] Yang, H.; Zhou, W.; Lu, L.; Fang, Z. Optimal sizing method for stand-alone hybrid solar–wind system with LPSP technology by using genetic algorithm. Elsevier Journal of Solar Energy 2008, 82, 354-367.

[16] Bilal, B. O.; Sambou, V.; Ndiaye, P. A.; Kebe, C.; Ndongo, M. M. Optimal design of a hybrid solar–wind-battery system using the minimization of the annualized cost system and the minimization of the loss of power supply probability (LPSP). Elsevier Journal of Renewable Energy 2010, 35, 2388-2390.

[17] Tafreshi, M. S.; Zamani, H. A.; Ezzati, S. M.; Baghdadi, M. Optimal unit sizing of Distributed Energy Resources in Micro Grid using genetic algorithm. In 18th Iranian Conference on Electrical Engineering (ICEE), Isfahan, Iran, 2010.

[18] Pirhaghshenasvali, M.; Asaei, B. Optimal modeling and sizing of a practical hybrid wind/PV/diesel generation system. In 5th Power Electronics, Drive Systems and Technologies Conference (PEDSTC), Tehran, Iran, 2014.

[19] Bashir, M.; Sadeh, J. Optimal sizing of hybrid wind/photovoltaic/battery considering the uncertainty of wind and photovoltaic power using Monte Carlo. In Environment and Electrical Engineering (EEEIC), 11th International Conference on, Venice, 2012.

[20] Navaerfard; Tafreshi, S.; Barzegari, M.; Shahrood, A. Optimal sizing of distributed energy resources in microgrid considering wind energy uncertainty with respect to reliability. In IEEE International Energy Conference and Exhibition (EnergyCon), Manama, 2010.

[21] Ekren, O.; Ekren, B. Y. Size optimization of a PV/wind hybrid energy conversion system with battery storage using simulated annealing. Journal of Applied Energy 2010, 87(2), 592-598.

[22] Ekren, O.; Ekren, B. Y. Size optimization of a PV/wind hybrid energy conversion system with battery storage using response surface methodology. Journal of Applied Energy 2008, 85(11), 1086 - 1101.

[23] A.M. Ghofrani, M. Etezadi-Amoli and M.S. Fadali, "Stochastic Performance Assessment and Sizing for a Hybrid Power System of Solar/Wind/Energy Storage," IEEE Transactions on Sustainable Energy 2014, 5(2), 363-371.

[24] A.M. Eltamaly; & A.A. Hatata, A novel framework-based cuckoo search algorithm for sizing and optimization of grid-independent hybrid renewable energy systems. International Journal of Green Energy 2018, 1-15. 10.1080/15435075.2018.1533837.

[25] Makbul A.M. Ramli, H.R.E.H. Bouchekara, Abdulsalam S. Alghamdi, "Optimal sizing of PV/wind/diesel hybrid microgrid system using multi-objective self-adaptive differential evolution algorithm," Renewable Energy 121 (2018) 400-411.

[26] R. Vijay; R. Sowmya. Optimal Sitting of PV-Wind-Energy Storage System Integrated Micro Grid Using Artificial Bee Colony Optimization Technique. International Journal of Innovative Research in Computer and Communication Engineering 2017, 5, 9640-9652.

[27] Ngan, M.; Tan, C. Assessment of economic viability for PV/wind/diesel hybrid energy system in southern Peninsular Malaysia. Renewable and Sustainable Energy Reviews 2012, 16, 634–647.

[28] Haidar, A.; John, P.; Shawal, M. Optimal configuration assessment of renewable energy in Malaysia. Renewable Energy 2011, 36, 881–888.

[29] Sultan, Hamdy M.; Diab, Ahmed A. Zaki; Kuznetsov, Oleg N.; Zubkova, Irina S. Design and evaluation of PV-wind hybrid system with hydroelectric pumped storage on the National Power System of Egypt. Global Energy Interconnection 2018, 1(3), 301-311.

[30] Ahmed A. Zaki Diab, Sultan I. EL-Ajmi, Hamdy M. Sultan and Yahia B. Hassan, "Modified Farmland Fertility Optimization Algorithm for Optimal Design of a Grid-connected Hybrid Renewable Energy System with Fuel Cell Storage: Case Study of Ataka, Egypt" International Journal of Advanced Computer Science and Applications(IJACSA), 10(8), 2019. http://dx.doi.org/10.14569/IJACSA.2019.0100817

[31] Ayman A. Aly, Mosleh M. Alharthi, B. Saleh, M. M. Bassuoni, Awad M. Aljuaid, Ageel F. Alogla, A. D. Sarhan and Y.S.Hamed, "Energy Saving of Hybrid Desiccant Air Conditioning System Powered by Solar Energy", International Journal of Engineering Research and Technology. ISSN 0974-3154, Volume 12, Number 7(2019), pp. 956-964.

[32] Neel Kamal and Dr. D.K.P. Singh, "Review: Photovoltaic-Thermo Electrical Integrated Power Generation for Desalination Plant", International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 7, Number 3 (2014), pp. 201-205.

[33] Emmanuel Nsengiyumva, Michael. J. Saulo and George. N. Nyakoe, "Adaptive Protection Scheme in Distribution Networks Considering Intermittency of DG Using Fuzzy Logic Controller, International Journal of Engineering Research and Technology. ISSN 0974-3154 Volume 11, Number 7 (2018), pp. 1179-1198.