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Techno-Economic Analysis of Hybrid Renewable Energy Power Network for New Community in Egypt, Case Study New El-Farafra Oasis

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ABSTRACT

Renewable energies play an indispensable role in remote areas where the electricity grid is not accessible. Photovoltaic energy (PV), wind energy and biomass energy have been included among the most of renewable energy sources. Hybrid systems are considered the most pragmatic solution for remote areas in off-grid. Combination between these energies to expedient the load requirements with reliable, economical and sustainable energy supply is considered as a critical concern. This paper reflects a techno-economic analysis of hybrid renewable energy power network for new Community in Egypt, EL-Farafra Oasis as a case study. The hybrid system proposed in this paper includes three renewable energy sources, namely, PV systems, wind turbines and biomass generators. The estimated community loads are residential, commercial, small-scale industrial and agricultural. The whole combined system is optimized using the Hybrid Optimization Model for Electric Renewable (HOMER) simulation tools while ranking the system suitability. The results show that the best scenario for the combination is the PV / wind / Biomass / Battery system with the minimum cost of energy (COE) equal 0.293 $ / kW. The optimal hybrid system is 30.687 MW PV-array, 13.5 MW wind turbines, 46 MW biomass generator, generic 1 KW.hr lead-acid battery (117,089 strings) and system converter (32.911 MW) with a dispatch strategy of load following. The optimum design of the proposed system can supply the electric power required for community loads continuously, therefore the combined system proposed is a good Surrogate system that could be implemented in the newly proposed community.

Key Words: *Photovoltaic energy (PV), Hybrid System, Biomass, HOMER, Renewable Energy, Energy Storage.*

1. INTRODUCTION

Renewable energies, exclusively around the globe and particularly in Egypt, could be alternative source for clean and green energy as it becomes the talk of the town. This is due to the depletion of fossil fuels specifically in the coming on the one hand, and the health and environmental hazards are generated on the other hand, The fusion of hybrid system and their advantages in generating energies, particularly in remote areas, are inevitable.. With proper design implementation of the combined system, the problems of oversizing, intermittent of renewable-energy sources and supply reliability can be handled. In recent years, there is an adequate research work on hybrid energy systems. Hybrid renewable-energy systems have become popular to measure up electricity demands [1-2-3]. Control process of these systems is considered as an important issue [4-5]. Egypt is experiencing economic, housing, and energy crises so that the desert must be exploited properly, where the percentage of the desert in Egypt represents a large proportion of the total area (95 %) of Egypt. Egypt's coastal and Nile Delta regions will face many challenges, especially with increasing global warming, that will lead to sea-level rise. These challenges inevitably have a negative impact throughout the economy of Egypt, as well as it will also effect agriculture and industrial output dramatically in near future. One of the most important scenarios that helps Egypt to these challenges is moving people to new residential areas with hybrid systems and renewable energy generation for living [6, 7, 8]. The Egyptian western desert includes some important regions; one of these regions is new Farafra Oasis. There are some challenges in these regions, including water and energy, these challenges can be reduced by using hybrid renewable-energy systems. These sources have become widely used as in Solar, Wind, Biomass, Hydro, Geothermal, fuel cell, etc. These systems are considered the most promising technologies. PV systems are decisive and established energy sources throughout the energy world. On the other hand, Biomass Energy or "Bioenergy" is the energy produced from recently living organisms such as plants (including, crops, trees, and algae), an animal waste, agricultural residues and industrial wastes. Biomass energy accompanied by releasing carbon dioxide in use, so that if this energy is utilized as a sustainable energy, there are no net carbon emissions over the time frame of a cycle for producing biomass [9].

2. LITERATURE REVIEW

H. H. El-Tamaly (2004) [10] presents the studying of the optimal operation of combined PV/battery distributed generation system by using artificial intelligence, especially neural network. Ding (2010) [11] emphasize the modelling and of grid-connected hybrid PV/battery distributed generation system which, is simulated under the environment MATLAB/Simulink. K. Sasidhar (2015) [12] publish [AI] techniques for the desirable sizing of the PV-wind-Hybrid system, these techniques represented in genetic algorithm and particle swarm optimization techniques. The results reflected that the optimal system is PV/Wind/Battery hybrid system with a minimum cost of energy for a remote location. Both Genetic algorithm and particle swarm optimization are used for obtaining the desired system. Dursun (2012) [13] presents optimal size of PV/Fuel cell powers generating system (electrolyzer/hydrogen tank/ fuel cell) in supplying load demand with using simulation tools (HOMER) with taking into account the fact of using of integrated renewable-energy systems in reducing emissions; Jamel et al (2013) [14] bring to light on technical and economic advantages of hybridization of renewable energies such as solar, wind, fuel cell to overcome the problems of conventional power plants, which are represented in provisions and increasing fuel price. Cole (2013) [15] investigators that, in rural and remote areas, the merged system is most useful where the electrical grid is not available, or it is not a cost-effective solution. HOMER software is used for simulation A PV/wind/battery/ generator system to meet the load demand where this combined system selected will help to reduce the greenhouse-gas emissions as well. Rohani and Nour (2014) [16]: expose that, due to the increasing fuel prices over the years, emissions, and pollutions from using conventional energy systems, the hybrid renewable-energy system is more reasonable than the traditional systems taking into account some locations as case studies such as Al Gharbia, Abu Dhabi, United Arab Emirates. Hartner (2017) [17] shows desirable sizing of grid-connected rooftop PV systems from a household's perspective taking into account the economic issue and the investment costs of photovoltaic systems. Fahd Diab (2016) [18] highlight on a case study through using combined renewable-energy systems for supplying the load demand of a factory in New Borg El Arab city - Egypt. The optimum size was PV (60kW) /Wind (100 kW) / diesel (40 kW) / converter (50 kW) and 600 battery. The cost of electricity was $0.19/kWh and shows that the pollution is reduced by using this renewable combined system. El-Raouf (2015) [19] presents an integrated system consists of PV/Wind/ battery storage systems connected to the grid with MPPT for PV systems and wind turbines. The system is succeeded in supplying the load demand using renewable-energy. Dawoud et al (2015) [20] investigate the possibility of using mongrel systems with obtaining the most suited configuration hybrid systems; diesel is compared with renewable combined system and cost of electricity is obtained when the diesel is used alone and when the diesel generators with hybrid systems. Simulation tools were used during the optimization process. The simulation results showed that the optimized crossbred system is very economical and environmentally friendly. Shahid, S. M. (2017) [21] presents the technology of using a

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PV /diesel/battery system to meet the load of the typical residential system in Saudi Arabia region, HOMER software is used for simulation, results from shoes that the hybrid system of 4kW PV /10kW diesel and battery storage of three hours of autonomy (average load), with the same locations and load conditions, the system PV/diesel /battery can be used as a frame of reference in designing process. Abdullah Al-Sharafi (2017) [22] investigate the combined system which consists of two kW PV array, three kW wind turbines, two kW converter and seven batteries storage bank is the best configuration combined the system with the cost of electricity (COE) equal 0.609 $/kWh at Yanbu area- Saudi Arabia. The Homer software was used for the optimization process. An electrolyzer, fuel cell, hydrogen tank as a storage system is used instead of the battery bank; the COE will be increased due to the cost of the fuel cell. If the hybrid system of PV/wind/FC in Abha area was simulated, the COE will be 1.208 $/kWh and the cost of hydrogen production (COH) is 43.1 $/kg. Moreover, literature mentioned above discusses the optimal sizing of renewable-energy systems in most locations around the world and how the system can be used to feed the required load. Techno-economic analyses of hybrid systems have been discussed in some literature. In Egypt, the problem is still now not resolved, and a few kinds of literature have been published associated with problems facing Egypt such as the shortage of electrical power. The main objective of this paper is to determine the optimum size of the hybrid renewable-energy system that enables to fulfill the requirements of the community. PV/ wind / Biomass system within a battery storage system was used to feed the off-grid community with electricity in new Farafra oasis, Egypt as a case study. HOMER software was found the most widely used between 19 software used by Sinha and Chandel (2014) [23], due to its advantages, combine most of the renewable-energy sources, fast optimization process, and sensitivity analysis. In this paper, hybrid optimization model for electric renewable (HOMER) software was used to design and simulate the hybrid energy system.

3. SYSTEM DESCRIPTION

The schematic diagram of hybrid PV/Wind/biomass with a storage battery system is shown in Figure 1, it consists of Biomass generator, Wind Turbines, PV generator, battery storage system, Inverter and AC load. This paper illustrates a new community in the desert based on (PV / Wind /biomass) renewable-energy sources.

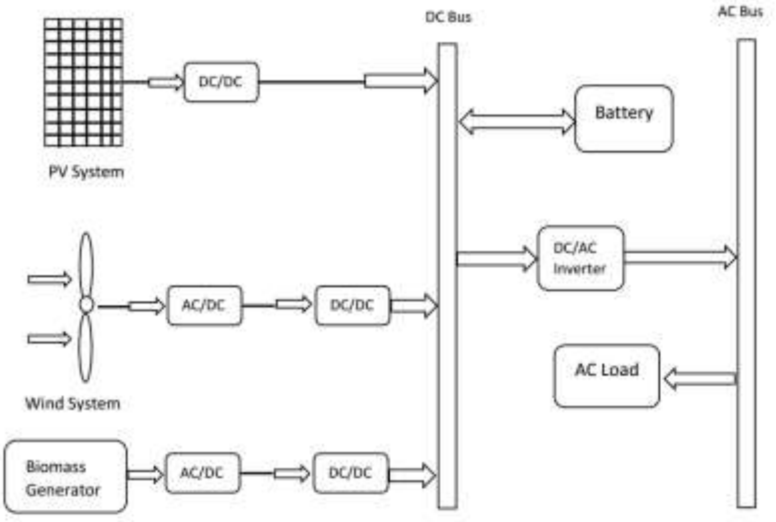

Figure 1: Block diagram of a hybrid energy system

3.1 Site potentials & site selection

There are some far-reaching factors for selecting the new areas in the desert. These factors are

1. Site potential (conditions) that includes
    - Climate, wind speed, irradiation of sun, temperature, water, etc.

- Soil conditions, irrigation are possible or not
- Factors of production: machines, building, agricultural area.

2. The required energy per year for households
3. Number of energy consumers (persons and households)
4. Energy available on site and its potential
5. Energy production and energy management
6. Environmental impact
7. Economic impact

In this paper, the site selected is shown in Figure 2, based on some studies [6, 7, 8]. Water is available on this site, under the Egyptian desert [8]. New Farafra Oasis-extends northeast between latitudes 27° 03' N and 26° 58' E to latitudes 27° 22'30 N and 27° 24' E, with a maximum NE length of 52 km and a maximum width of 20 km, attaining a total area of 932 km2 [24]. Figure 3, shows the solar radiation distribution in Egypt and figure 4, shows wind speed in Egypt.

4. DATA COLLECTION

Solar energy resource, wind energy resource, biomass energy resource, load profile, technical details, and costs are obtained from reliable sources [27,28,29] and calculated carefully according to Egyptian electrical codes and requirements of Egyptian electricity companies because these data are used as inputs for simulation tool. Fig. 5 shows the schematic Homer diagram of hybrid PV / Wind / Biomass energy system. It consists of 30.687 MW PV systems, 13.5 MW, 46 MW biomass generator, generic 1 kWh lead-acid battery (117,089 strings) and system converter (32.911 MW).

4.1 Solar radiation

Solar radiation for a particular location can be given in several ways, including [30]:

Typical mean yearly data for a particular location - Average daily, monthly or yearly solar insulation for a given location- Global isoflux contours either for a full year, a quarter year or particular month- Sunshine hour’s data- Solar insulation based on satellite cloud-cover data - Calculations of solar radiation. The clearness index is a measure of the clearness of the atmosphere. It is the fraction of the solar radiation that is transmitted through the atmosphere to strike the surface of the earth. It is a dimensionless number between 0 and 1, defined as the surface radiation divided by the extra-terrestrial radiation. The solar resource used for the hybrid energy system is located in a new Farafra oasis –Egypt as Figure 3.

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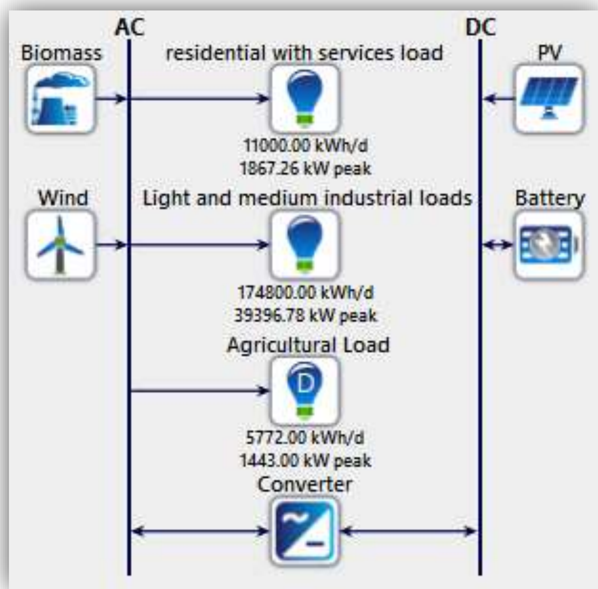

Figure 2: Schematic homer model diagram of hybrid energy system

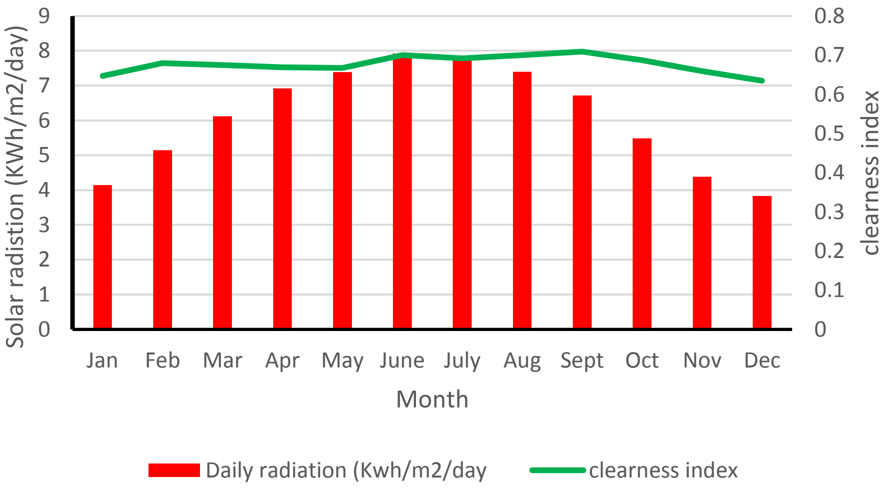

Figure 3: Solar energy profile at the selected location.

4.2 Wind energy resources

The monthly average wind resource data was taken from NASA resource website [27] based on the longitude and latitude of the community location. The annual average wind speed for the location is 5.45 m/s with the anemometer height of 50 m. The average wind speed of new Farafra Oasis in the western desert of Egypt (selected location) is shown in Figure 4.

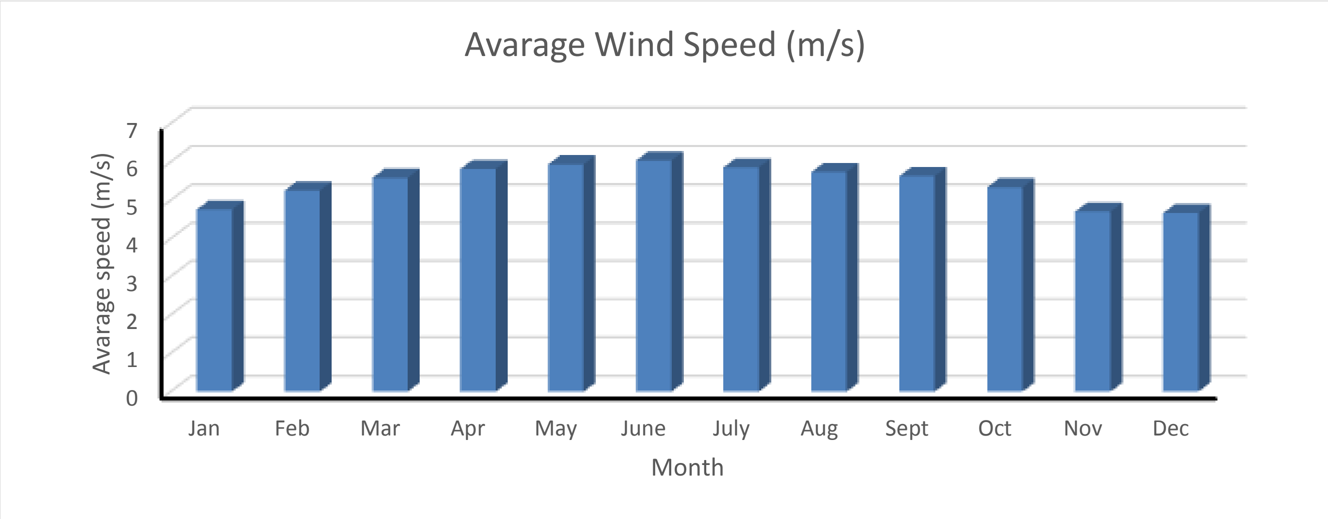

Figure 4: Wind speed profile at the selected location

4.3 Biomass [31, 32]

Bioenergy and Organic matters are used as a fuel by different techniques such as gas collection and gasification (conversion of solids to gas), combustion and digestion (for wet wastes). If biomass is used properly, it can become an alternative valuable source of renewable energy. Some important sources of biomass energy include wet wastes (slaughterhouses, food processing the food) - Mixed solid waste (household waste-Trimming) -Secondary forest products (remnants of wood diffusion and processes Forestry).

4.4 Resources of biomass

Biofuels: Organic materials are used as a source of fuel, by burning them directly to generate heat, or from deriving liquids or gases that can be combustible, four main types are mentioned:

• Solid biofuels

It is a solid renewable energy source produced by living organisms, such as wood, straw, and organic waste after it is directly burned using the resulting heat to generate the water vapour used to propel the generator turbines.

• Liquid biofuels

It is one of the renewable sources of liquid energy produced by living organisms, such as bioethanol, which is the result of fermentation of plants such as sugar cane, and biodiesel produced by the interaction of alcohol with vegetable or animal fats. These fuels are used as fuel for vehicles.

• Biogas

The degradation of solid organic matter, a mixture of methane gas and carbon dioxide, is used as a fuel to generate steam in power plants and cooking.

• Energy crops

Fast-growing plants such as willow trees are grown in large fields to be used as a source of Bioenergy. Organic materials such as wood and solid animal residues are converted into biofuels [32].

5. SYSTEM COMPONENTS

5.1 PV Array

In this case, PV MSX 60 watt [33] is used. The nominal power needed for PV to meet the load demand is 30.687 MW, which is produced from the PV array. The area of each Module is 0.55 m2 (50.2 cm ×110. 5 cm). The panels are modelled as fixed and

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tilted at 27 degrees and mounted such that the module is facing south direction. Table 1, shows all details about PV module which is used in the model [19]. The capital cost and replacement cost for a 1kW PV are taken as $3000 and $3000 respectively [32]. As there is very little maintenance required for PV, only $10/year is taken for O&M costs. The average lifespan for PV is 20 years [32].

Table 1. Specifications of solar MSX60 60 W PV panel

Open circuit voltage	V_{OC}	21.0 V
Short circuit current	I_{sc}	3.74 A
Voltage at max power	V_m	17.1 V
Current at max power	I_m	3.5 A
Maximum power	P_m	59.9 W

5.2 Generator model (biomass)

Conveniences gasses are obtained from solid biomass by using the concept of Biomass Gasification. The reactor is mainly used in this process. Also, the obtained gas is made available for getting and generate the electrical power to supply loads where cleaning and cooling process are required. In this paper, capital costs are evaluated as $ 628 and replacement costs are the same $ 628 while M&O cost is $0.08/h. The lifetime is 20 years. Figure 5, illustrates the distribution of biomass resource in each month [32].

Figure 5: Inputs from biomass (tons/day)

5.3 Wind turbine

The model is based on the steady state power characteristics of the turbine. The output power of the wind turbine is given by equation (1) [19].

$$P_w = \left(\frac{1}{2}\right) C_p\,(\lambda, \beta)\,\rho\,A\,V^3 \qquad (1)$$

Where ρ is the air density (kg/m^3), C_p is the power coefficient, V is the wind speed (m/s) and A is turbine swept area (m^2), λ tip speed ratio of the rotor blade tip speed to wind speed and β blade pitch angle (degree). In this model, the generic type 1.5 MW AC output power is selected. According to Homer program, the output power characteristic of the wind turbine is shown in Figure 6. The capital cost and replacement cost for a 1500kW converter is taken as $3,000,000 and $300,000,000 respectively, O&M cost equal $30,000. Lifetime equals to 20 years.

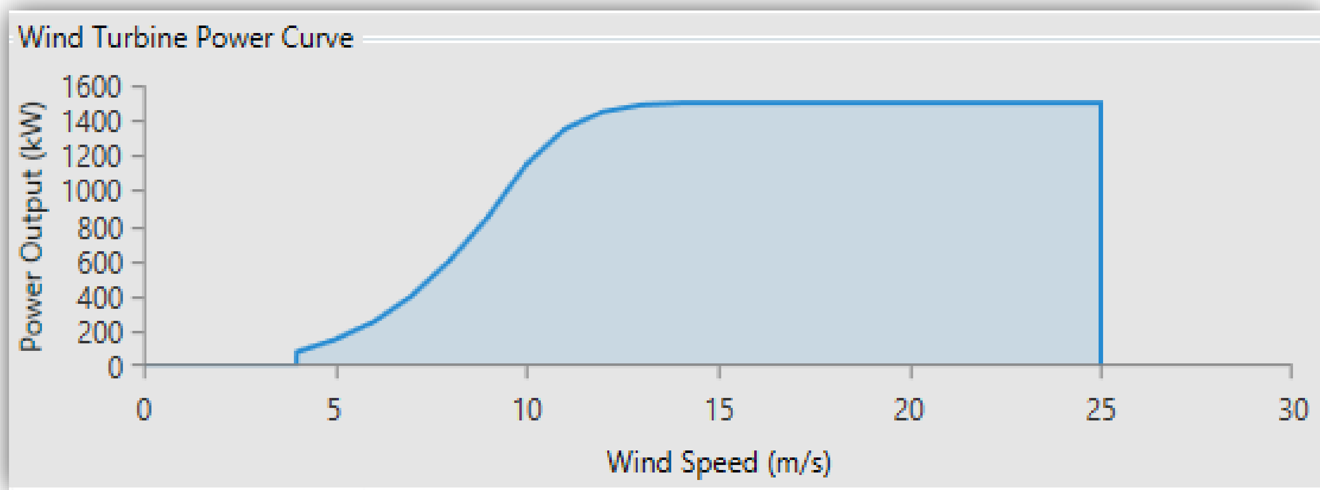

Figure 6: Power curve of wind turbine generated by homer program

5.4 Batteries [19]

The load supplied must be estimated to determine the capacities of the battery required in the hybrid system. To obtain a higher energy capacity, batteries are connected in series. In this study, the lead-acid battery model is selected with the nominal specifications 12 V, 83.4 Ah – 1 kWh. Table. 2 show the details of battery model.

5.5 Inverter

Is used to convert the DC to AC to supply the AC primary load. An inverter is required for a system in which DC components serve as an AC load or vice versa. A lifetime of 20 years is assumed in which both the inverter and rectifier efficiencies are assumed to be 90 %. The capital cost and the replacement cost for a 1kw converter are taken as $300 and $300 respectively [34].

Table 2. Battery specifications.

Description	**Specifications**
Battery model	Lead acid battery model
Maximum capacity	83.4 Ah
Nominal voltage	12 V
Round tip efficiency	80 %
Nominal energy capacity of battery	1 kWh
The capital cost	300 $
Replacement cost	300 $

5.6 Loads profile

Estimating the maximum demand required for community [35]:

The Egyptian Code for electrical connections and installations in buildings states that: Electricity distribution companies in Egypt prepare schedules to estimate the total electrical loads of all types of buildings. These tables are given the minimum total electrical capacity that these companies can contract with the owners of the buildings under which they are fed by electric current. The capacity depends on the total area of all the floors of the building and the nature of the activity in the building (residential, educational, administrative, commercial, etc...) And whether the building is located in an urban or rural area and the classification of its location in those areas, etc... In this work, a new community is proposed in new Farafra oases western desert of Egypt. It

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consists of three loads (residential load with services, light and medium industries loads and agriculture loads) these loads are already existing loads in Egypt and connected to a grid, so these loads are used in a newly discovered area in a desert of Egypt as a case study. The new community is planned for 20,000 inhabitants where,

1. Residential loads with services consumptions represent 11,000 kWh/day as in Figure 7.
2. Light and medium industries loads with services consumptions reflect 174.8 MWh/day as in Figure 8.
3. Deferred Load includes the agricultural load of the community. The scaled annual average deferred load is 5772 kWh/day and has a peak load of 1443 kW. Agriculture loads (irrigation using pumping water systems) represents 5772 kWh/day.

Homer is capable of synthesizing the 8760 hour electrical load values for a whole year, using this hourly load profile and adding random variability factors, known as day-to-day variability and time-step-to-time step variability. In this study, they are taken as 10% and 20% respectively.

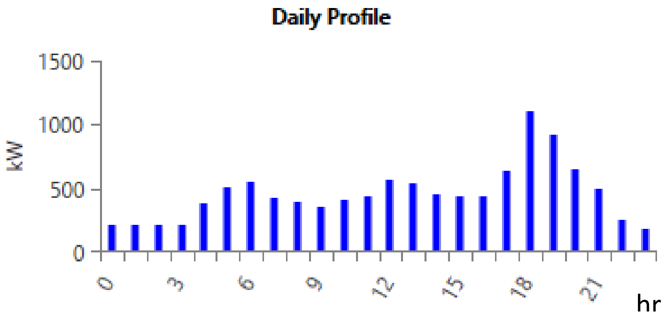

Figure 7: Daily residential load profile

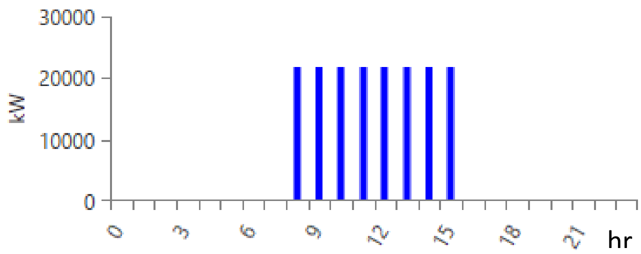

Figure 8: Daily industrial

5.7 Economic Model

From the output of the system configuration by using HOMER the main financial output is obtained. This output has been defined in the concept of the total net present cost (NPC) and cost of energy (COE). (NPC) the analysis is considered as a gauge or scale which is used as a comparator from an economic point of viewpoint for different energy systems, as the NPC balances cost specifications of renewable and non-renewable sources. As well, it explores and summaries all the relevant associated costs that occur within the lifetime of the energy project. The suggested hybrid system PV/Wind/Biomass/Battery parameters are obtained economically through the modelling of this system. For economic aspect, NPC and (COE) of the system is investigated. The NPC is calculated by [36-37].

$$NPC(\$) = \frac{\mathrm{TAC}}{\mathrm{CRF}} \qquad (2)$$

TAC refers to the total annualized cost; CRF refers to the capital recovery factor which can be calculated by Equation (3).

$$CRF(\$) = \frac{\mathrm{i}(1+\mathrm{i})^{\mathrm{N}}}{(1+\mathrm{i})^{\mathrm{N}}-1} \qquad (3)$$

Where N is the number of years and *i* is the annual real interest rate (%). Cost of energy (COE), which is the average cost per kilowatt-hour ($/kWh) of electricity produced by the concerned system is estimated as in Equation (4).

$$COE(\$) = \frac{C_{ann,tot}}{E} \qquad (4)$$

Where, $C_{ann,tot}$ is the annual total cost, $. E is the total electricity consumption, kWh/year.

6. MODELLING OF BIOMASS GENERATOR

The process of gasification can be defined as the process by which the chemical conversion of biomass-based liquid materials or solid materials into combustible gas by partial oxidation of the biomass using a gasification agent. The high temperature of around 800 ºC – 900 ºC is the temperature of the proposed process. When air is used as a gasification agent in the process of gasification of biomass, it will lead to the production of syngas. CO_2, CO, H_2, CH_4, H_2O, trace amounts of n hydrocarbons and inert gases present in the air and biomass are contaminants and gases found in the product gas. Fuel-bound organic nitrogen (FBN) can also be converted into nitrogen oxides (NOx) during gasification [32].

6.1 Gasifier suggested

Different types and sizes of Gasifiers are available for use. One of these gasifiers is the Downdraft gasifiers which are one among the fixed bed gasification systems. Recently, researchers in all worldwide have begun an interest in Downdraft gasification technology as this technology has the possibility to produce the electrical power from biomass with economical and affordable prices. Less tar in the produced gas from downdraft reactor this is because the oxidation zone where this zone is hot and the gases are passed through. Figure 9, shows the system of downdraft gasifier. Co-Current Moving Bed is also the name of this system. From the top, the fuel is fed which is gasifier. From the top or the middle of the reactor, the air, oxygen or a mixture of air and steam is fed where oxidation process is carried out. After the oxidation process, the reduction or extraction of the produced gas process is started. The syngas or producer gas removed from the bottom part of the reactor. In the pyrolysis zone, Devolatilization of the biomass occurs, this zone is reached to its highest temperature by convection and radiation from the lower hearth zone. The hearth zone is embedded on top of the reduction zone, to which char is transferred and gasifier [32].

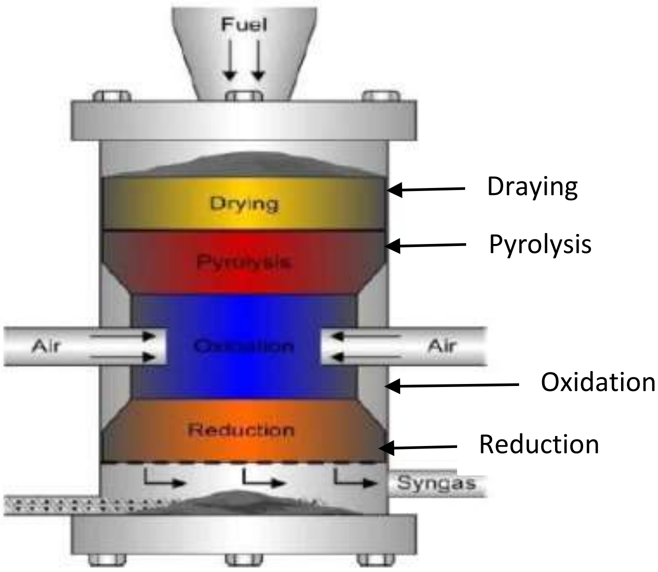

Figure 9: Gasifier from biomass

7. RESULTS AND DISCUSSIONS

This part introduces the results of the analysis also, it presents the optimal results, environmental and economic analysis, sensitivity analysis and all scenarios available.

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7.1 Optimization results

In this case study, the results show that, the optimal combination of integrated renewable energy sources is 30.687 MW PV-array, 13.5 MW wind turbines, 46 MW biomass generator, generic 1 kWh lead-acid battery (117,089 strings) and system converter (32.911 MW) with a dispatch strategy of load following as in table :3. From these results, the total net present cost is $ 265 M, the capital cost is $ 193 M and the cost of electricity (COE) is $ 0.293 /kWh. Fig. 10 shows the monthly average electricity production from the optimum hybrid system in KW from PV array, Wind turbine, and Biomass generator. It is noted that the PV system contributes by a larger percent than wind and biomass. There are six scenarios as follows: PV/Wind/Biomass/battery, PV/Biomass/Battery, PV/Wind/Battery, PV/Battery, Wind/Biomass/Battery and Wind/Battery show the optimal system's configurations, the first scenario is the best optimal hybrid system.

Table 3. Optimal cost and combination hybrid electric system

Cost summary	
Total net present cost	$265 M
Levelized cost of energy	$ 0.293 /kWh
Operating cost	$ 6 M

System architecture	
PV array	30.687 MW
Wind turbines	13.5 MW
Biomass generator	46 MW
Battery	117,089 strings
Converter	32.911 MW
Dispatch strategy	Load following

Electrical		
Component	Production KWh/year	Fraction %
PV array	59,278,095	63.7
Wind turbines	28,040,399	30.1
Biomass generator	5,721,967	6.15
Total	**93,040,461**	**100**

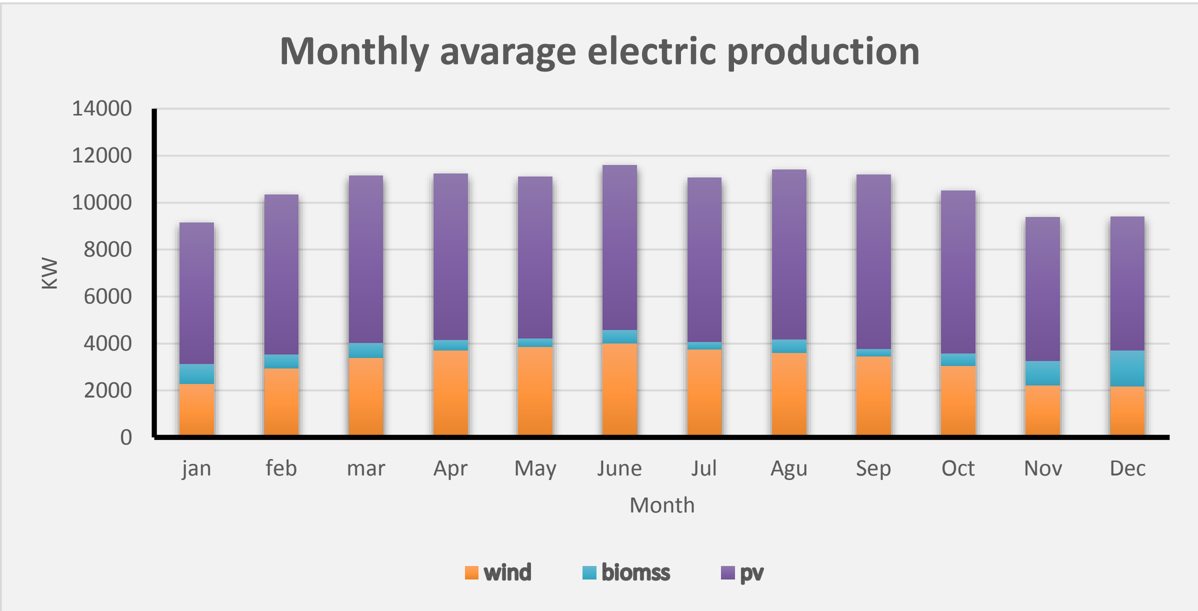

Figure10: Monthly average electricity production

Figure 11, shows the cash flow summary by a component of the optimal hybrid renewable energy system over all the period of the project 25 years. The capital cost of each component emerges at the first beginning time of year equal 0. For a single year, the total inflow or the total outflow is represented in each bar in the graph. The first bar, for year zero, shows the capital cost of the system, which also appears in the Optimization Results. A negative value represents an outflow, or expenditure for fuel, equipment replacements, or operation and maintenance (O&M). A positive value represents an inflow, which may be income from electricity sales or the salvage value of the equipment at the end of the project lifetime.

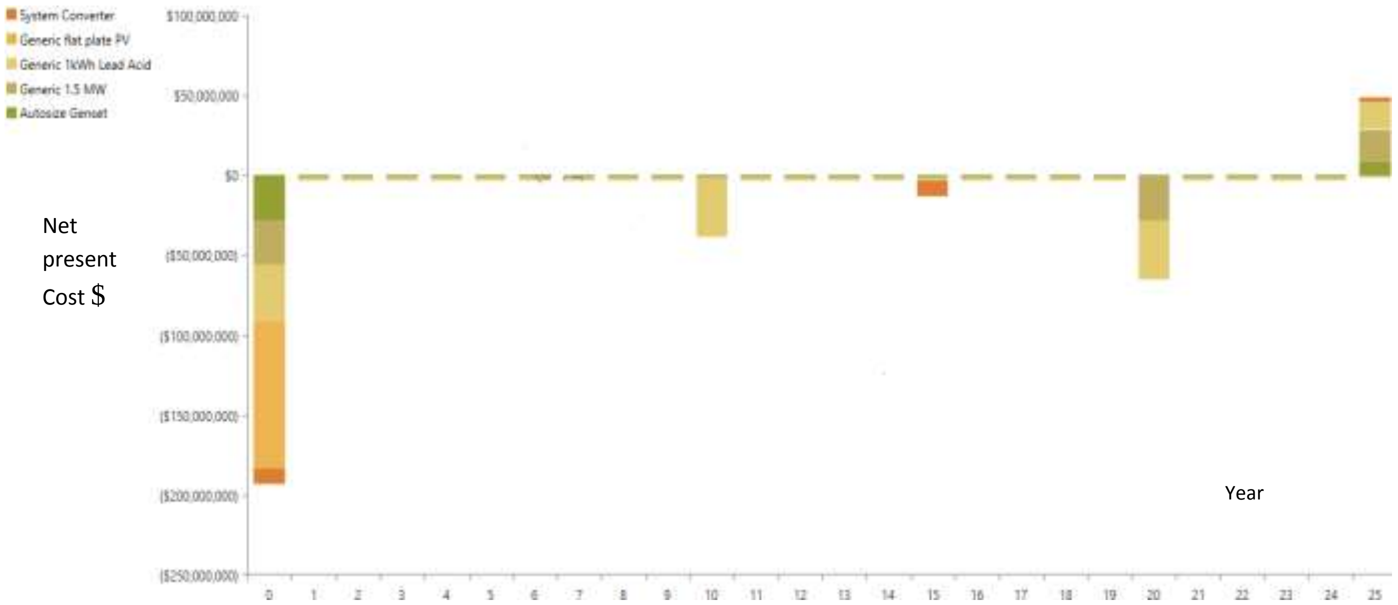

Figure 11: Cash flow summary

7.2 <u>Sensitivity Results</u>

The importance of sensitivity results appears in cancelling all infeasible combinations and arranges or ranks all possible, feasible combinations for taking into account uncertainty parameters. One of the benefits of a HOMER the future developments such as electrical load demand, which may be increase or decrease, the variations or fluctuations of wind speed, variations of biomass prices and other resource's prices. In order to obtain the optimal hybrid system, some important sensitivity variables are taken into consideration. The first hybrid system is the optical system which uses the three resources wind, biomass and PV. If the wind turbine hasn't found the second scenario shows that the system will add several PV arrays to meet the load demand with more net present cost equal $ 379 M. The third scenario shows that the biomass are not used so that the system will add several PV and wind turbines with more net present cost $ 396 M. The fourth scenario shows that if the PV is used only to serve the community loads, the system will add several PV arrays and batteries with a total net present cost equal $ 461 M. The fifth scenario shows that if the PV not used and the systems only utilize wind turbines and biomass generators this scenario has a total net present cost equal $ 846 M. in final scenario, if the wind turbines with battery are used, then this is the most expensive cost with net present cost equal $ 1.068 B. Table 4: depicts the most ranking economic scenarios which are available from the optimization process in this paper, the first scenario is the best optimal system it includes PV, Wind, and Biomass.

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Table 4. Economic scenarios from the optimization process

Configuration	Unit	1st scenario (The best)	2nd Scenario	3rd Scenario	4th Scenario	5th Scenario	6th Scenario
Solar PV	KW	**30,687**	26,626	68,622	77,821	----------	----------
Wind turbine (1.5 MW)	Number	**9**	--------	13	----------	76	57
Bio G	KW	**46,000**	46,000	----------	----------	46,0000	----------
Batteries	Number	**117,089**	238,069	170,845	301,358	745,433	1,224,125
Converter	KW	**32,911**	39,695	47,313	47,624	40,852	91,454
Dispatch strategy	Number	**LF**	LF	CC	CC	LF	CC
Total capital cost	$	**193 M**	282 M	310 M	338 M	493 M	566 M
Total net present cost	$	**265 M**	379 M	396 M	461 M	846 M	1.06 B
Total O&M cost	$	**3.14 M**	3.37 M	2.78 M	3.79 M	11.5 M	14 M
Operating cost	$	**5.56M**	7.47 M	6.61 M	9.51 M	27.3 M	38.2 M
Total fuel cost	$	**0**	0	0	0	0	0
COE	$/kWh	**0.293**	0.419	0.438	0.510	0.937	1.17
PV production	KWh/yr	**59,278,096**	109,383,667	132,555,069	150,326,181	--------	--------
Percentage PV production	%	**63.7**	98.3	76.6	100	---------	----------
Wind production	KWh/yr	**28,040,398**	-------	40,502,798	---------	236,785,589	177,589,191
Percentage wind production	%	**30.1**	-------	23.4	----------	96.2	100
Bio g production	KWh/yr	**5,721,966**	1,902,563	---------------	-----------	9,354,535	-------
Percentage Bio production	%	**6.15**	1.71	---------------	----------	3.08	--------
Total electrical production	KWh/yr	**93,040,464**	111,286,232	173,057,872	150,326,181	246,140,124	177,589,191
AC primary load served	KWh/yr	**69,899,296**	69,899,806	69,905,100	69,923,299	69,877,825	69,877,845
Renewable fraction	%	**100**	100	100	100	100	100
Capacity shortage	KWh/yr	**69,214**	67,833	69,175	64,523	67,666	68,720
Capacity shortage fraction	%	**0.0990**	0.0970	0.0989	0.0923	0.0968	0.0983
Unmet load	KWh/yr	**24,482**	23,493	18,680	0	45,955	35,935
Unmet load fraction	%	**0.0350**	0.0336	0.0267	0	0.0657	0.0514
Excess electricity	KWh/yr	**18,358,694**	26,406,715	99,764,980	75,425,133	170,202,302	95,699,862

7.3 Emissions

It is worthy to be noticed that the optimal proposed system (1st scenario) would reduce CO2 over one year in operation as compare to a central power generation plant or a stand-alone DG system. Due to reliance on renewable energy systems, emission of particulate matters and nitrogen oxides will be reduced as reflected in table 5.

Table 5: Emission reduction.

Quantity	Value	Unit
Carbon dioxide	359	Kg/year
Carbon monoxide	37.7	Kg/year
Unburned hydrocarbons	1.65	Kg/year
Particulate matter	0.229	Kg/year
Sulfur dioxide	0	Kg/year
Nitrogen oxides	35.4	Kg/year

8. CONCLUSION

By highlighting key findings in this paper, the analysis concludes that the hybrid PV/wind/biomass/battery system is a practical and cost-effective solution to satisfy the electrical energy needs for a new proposed community in New Farafra Oasis, Egypt. The optimal hybrid system is 30.687 MW PV-array, 13.5 MW wind turbines, 46 MW biomass generator, generic 1 kWh lead-acid battery (117,089 strings) and system converter (32.911 MW) with a dispatch strategy of load following. Most of the electricity in the optimal solution comes from PV system, where the solar PV, Biomass generator, Wind system contribute 63.7%, 6.15%, 30.1% respectively. The least expensive NPC is the NPC of the optimal system configuration ($265 M) in comparison with the NPC of other system configurations (PV/Biomass $379 M, PV/wind $396 M, PV only $461 M, wind/biomass $846 M and wind only $1.06 B). Additionally, the COE of the optimal system configuration ($0.19/kWh) is the least expensive COE in comparison with the COE of other system configurations (wind/diesel $0.20/kWh, PV/diesel $0.25/kWh and diesel system $0.29/kWh). The cost of energy (COE) of the proposed hybrid system estimated 0.293 $ / kWh, where the initial capital cost evaluated $ 193 M and net present cost (NPC) equal $ 265M. It is shown that the PV/Wind/Biomass/Battery are more and economical than PV/Biomass/Battery, PV/Wind/ Battery, PV/Battery, Wind/Biomass/Battery or Wind/ Battery systems for the community load. The proposed hybrid system could be a good alternative system to be implemented in the proposed residential building where all systems are renewable energy sources 100 % utilization. The obtained results show that PV-Wind-biomass-battery system configuration is the best solution to ensure that the electrical supply is not interrupted to meet the community loads.

REFERENCES

[1] Mohamed I. Mosaad and H.S. Ramadan "Power Quality Enhancement of Grid Connected Fuel Cell Using Evolutionary Computing Techniques: Accepted for publication in International Journal of Hydrogen, 2018.

[2] Mojtaba Qolipour, Ali Mostafaeipour, Omid Mohseni Tousi, "Techno-economic feasibility of a photovoltaic-wind power plant construction for electric and hydrogen production: A case study" Renewable and sustainable energy reviews vol. 78, pp. 113-123, October 2017.K. Elissa, "Title of paper if known," unpublished.

[3] Nandi S. K. And Ghosh, H. R. "Prospect of wind–PV–battery hybrid power system as an alternative to grid extension in Bangladesh" Energy 35, pp. 3040–3047, 2010.

DOI : http://dx.doi.org/10.31695/IJERAT.2018.3268

[4] Mohamed I. Mossad "Model Reference Adaptive Control of STATCOM for Grid-Integration of Wind Energy Systems" Accepted for publication in IET Electric Power Applications Journal, DOI: 10.1049/iet EPA.2017.0662, 2018.

[5] Mohamed I. Mossad, Nagy I. Elkalashy and Mohamed G. Ashmawy, "Integrating Adaptive Control of Renewable Distributed Switched Reluctance Generation and Feeder Protection Coordination" Electric Power System Research journal, Elsevier, Volume 154, Pages 452–462. January 2018.

[6] Abouelfadl S, El-Lithy KH Impact Assessment of Global warming on Egypt. Int J Engg Advtechnol3, pp. 352-360, 2014.

[7] Abouelfadl S, Ouda KH, Atia A, Al-Amir N "The Egyptian Gardens' City- A New City in the Western Desert (EGCWD) -A primary master plan". International Conference on Energy and Sustainability, NED University of Engineering and Technology, Pakistan, 2013.

[8] Abouelfadl S, Ouda K, Atia A, AL-AMIR N, Ali M, et al. "Radical Urban Development in the Egyptian Desert". J Fundam Renewable Energy Appl 5: 158. Do 10.4172/20904541.1000158, 2015.

[9] Robert M. Campbell, Tyron J. Vennc, Nathaniel M. Anderson "Heterogeneity in Preferences for Woody Biomass Energy in the US Mountain West" Ecological Economics, pp. 27-37, 24 August 2017.

[10] H. H. El-Tamaly. F.M and Adel A. ELbaset Mohammed:" Study the optimal operation of electric PV/B/D Generation system By Neural Network" proceeding of International conference Electrical, Electronic and Computer Engineering, ICEEC04, Egypt, 2004.

[11] Fei Ding, Peng Li, Bibin Huang, Fei Gao, Chengdu Ding1, Chengshan Wang1," Modeling and Simulation of Grid-connected Hybrid Photovoltaic/Battery Distributed Generation System", China International Conference on Electricity Distribution, 2010.

[12] K. Sasidhar, B. Jagadish Kumar." Optimal sizing of PV -Wind Hybrid energy system using Genetic Algorithm (GA) and Particle swarm optimization (PSO)" International Journal of Science, Engineering, and Technology Research (IJSETR), Vol. 4, Issue 2, Feb 2015.

[13] Dursun, B. Determination of the optimum hybrid renewable power generating systems for Kavakli campus of Kirklareli University, Turkey. Renew. Sustain. Energy Rev. 16, 6183e6190, 2012.

[14] Jamel, M.S., Rahman, A.A., Shamsuddin, A.H. Advances in the integration of solar thermal energy with conventional and non-conventional power plants. Renew. Sustain. Energy Rev. 20, 71e81, 2013.

[15] Kolhe, M., Ranaweera, K.M.I.U., Gunawardana, A.G.B.S. Techno-economic optimum sizing of the hybrid renewable energy system. In: Industrial Electronics Society, IECON 2013-39th Annual Conference of the IEEE, pp. 1898e1903, 2013.

[16] Rohani, G., Nour, M. Techno-economic analysis of stand-alone hybrid renewable power system for Ras Musherib in the United Arab Emirates. Energy 64, 828e841, 2014.

[17] Hartner, Dieter Mayr, Andrea Kollmann, Reinhard Haas "Optimal sizing of residential PV-systems from a household and social cost perspective A case study in Austria Michael" a solar energy 141, 49-58, 2017.

[18] Fahd Diab, Hai LAN Lijun Zhang, Salwa Ali, "An environmentally friendly factory in Egypt based on hybrid photovoltaic/wind/diesel/battery system" Journal of Cleaner Production, July 2015.

[19] El-Raouf, M.O.A., Mosaad, M.I., Al-Ahmar, M.A. and El Bendary, F.M. "MPPT of hybrid solar-wind-grid power generation system', Int. J. Industrial Electronics and Drives, Vol. 2, No. 4, pp. 234–241, 2015.

[20] Dawoud, S.M., Lin, X.N., Sun, J.W., Okba, M.I., Khalid, M.S., Waqar, A., "Feasibility study of the isolated PV-wind hybrid system in Egypt" sustainable energy and environmental engineering III. Adv. Mater. Res. China 145e151, 2015.

[21] Shahid, S. M., "Economic feasibility of decentralized hybrid photovoltaic – diesel technology in Saudi Arabia" A Way Forward for Sustainable Coastal Development, Vol. 21, No. 1B, pp. 745-756, 2017.

[22] Abdullah-Sharafi, Ahmet Z. Sahin, TahirAyar Bekir S. Yilbas"Techno-economic analysis and optimization of solar and wind energy systems for power generation and hydrogen production in Saudi Arabia" Renewable and Sustainable Energy Reviews, Vol. 69, pp. 33-49, March 2017.

[23] Sinha, S., Chandel, S.S, "Review of software tools for hybrid renewable energy systems". Renew. Sustain. Energy Rev. 32, 192e205, 2014.

[24] Ouda KH, Final report results of new geological and underground water witness at the great sand sea in the western desert–Egypt, a push that leads to agricultural development and architectural societies at the western part of the western desert-Egypt, 2012.

[25] Egyptian Solar Radiation Atlas.

[26] Wind Atlas for Egypt. www.windatlas.dk/egypt/About.html.

[27] NASA Surface Meteorology and Solar Energy. Available from: https://eosweb.larc.nasa.gov/sse/. [Accessed] [Date 20.11.2017].

[28] http://www.eehc.gov.eg/eehcportal/Guidelines/FeedingRules.aspx. [Accessed] [Date 1.11.2017].

[29] http://www.nrea.gov.eg/arabic1.html. [Accessed] [Date 12.11.2017].

[30] http://www.pveducation.org/pvcdrom/properties-of-sunlight/measurement-of-solarradiation. [Accessed] [Date 20.11.2017].

[31] N. Said, S. A. El-Shatoury, L. F. Díaz, M. Zamorano, "Quantitative Appraisal of Biomass Resources and Their Energy Potential in Egypt", Renewable and Sustainable Energy Reviews, Vol. 24, Issue C, pp. 84-91, 2013.

[32] Faten Hosney Fahmy, Hanaa Mohamed Farghally, Ninet Mohamed Ahmed, "Photovoltaic Biomass Gasifier Hybrid Energy System for a Poultry House" International Journal of Modern Engineering Research (IJMER) 2014.

[33] Solarex data sheets, www.solarex.com. [Accessed] [Date 13.10.2017].

[34] O. J. Onojo, G.A. Chukwudebe, E.N.C. Okafor, S.O.E. Ogbogu, "Feasibility Investigation of a

[35] The Egyptian Code for the foundations of design and conditions for the implementation of electrical connections and installations in buildings (Vol. 1, 2, 3) – 1994.

[36] G. Liu, M. G. Rasul, M. T. O. Amanullah, M. M. K. Khan, Economic and Environmental Modeling of a Photovoltaic-Wind-Grid Hybrid Power System in Hot Arid Australia, Int. J. Of Thermal & Environmental Engineering, Vol. 1, No. 1, pp. 15-22, 2010.

[37] Yasser Maklad, "An Introduction and Costing of a Biomass/Wind/Pv Hybrid Energy System for Electricity Micro Generation to Domestic Buildings in Armidale, NSW, Australia", Global Journal of Research Analysis, Vol.3, No.4, pp. 70-74, 2014.

DOI : http://dx.doi.org/10.31695/IJERAT.2018.3268