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RESEARCH ARTICLE OPEN ACCESS

Extraction of Optimal Solution of Hybrid Energy System Using Graphic User Interface

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Abstract:

This paper proposes an optimum selection for hybrid renewable energy system. A Graphic User Interface (GUI) block is developed and will used in MATLAB software for this purpose. The developed GUI block is available for change any data of the system such as photovoltaic module, wind turbine, cost parameters, weather conditions and load profile. In this work, two methods of optimization are used for sizing the hybrid system; the linear optimization algorithm and an evolutionary optimization algorithm. Linear optimization algorithm is designed to obtain optimum size of a proposed PV-wind- Diesel generator hybrid system with and without battery storage. The objective function always seeks for minimizing the annual cost while the constraints are the Loss of Power Supply Probability (LPSP, Correlation coefficient (CC) and Inequality Coefficient (IC).

Keywords **—**Photovoltaic, wind turbine, genetic algorithm, hybrid system and grapgic user interface.

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I. INTRODUCTION

Renewable energy is a safe and endless energy source that can be utilized for heating, cooling and different purposes. Utilizing this clean energy reduces the utilization of fossil fuels and also reduces the environmental pollutants. Power fluctuation of the photovoltaic array is appeared due to variation of the solar radiation and the temperature during the time. Power fluctuation of the wind turbine is appeared due to variation of the wind velocity during the time. Due to power fluctuation of the photovoltaic module and the wind turbine, hybrid renewable energy system is used to decrease power fluctuation. Hybrid renewable energy systems appear to be viable in locations where electrical grid supply has not yet reached and may be connected to the grid [1-3].

Many researchers have been interested in the optimal design for hybrid renewable energy systems. Diaf *et al.* [4] studied the technical-economic optimization study of the stand-alone hybrid PV/wind system in Corsica Island is presented. Koutroulis *et al.* [5] presented a methodology for optimal sizing of a stand-alone electric system comprised photovoltaic (PV), wind turbine and battery storage.

To design the hybrid photovoltaic- wind system, Yang *et al.* [6] studied the optimal sizing method to calculate the optimum system configuration that can achieve the loss of power supply probability (LPSP) with a minimum annualized cost of system and Yang *et al.* [7] have applied the method to the analysis of a hybrid photovoltaic wind system which supplies power for a telecommunication relay station.

Dufo-López *et al.* [8] presented an optimization method that designs the sizing and operation control of a PV-Battery-Diesel system with the minimum total net present cost by a genetic algorithm. Chen

[9] researched on an optimization methodology for the installation capacity of a stand-alone PV-Wind-Battery-Diesel system, taking into consideration the cost and reliability. Zhao *et al.* [10] studied an optimal unit sizing method for the stand-alone system and applied the method to a real micro-grid system on Dongfushan Island, China. Moreover, the role of the internal combustion generator in a hybrid electric system has been discussed by Perera *et al.* [11–14] by using multi-objective optimization. Furthermore, a number of research works had been done dealing with the optimal design and the sizing of hybrid energy system composed of energy technologies, such as fuel cells and bio-diesel generators [15–17].

Bilal et al. [18] presented the problem of optimal sizing of hybrid solar wind system with battery storage as a multi-objective optimization problem solved using Genetic Algorithms. The system was designed for an isolated site in Senegal's north coast known as Potou and its principal aims were to minimize the annualized cost of the system and to minimize the loss of power supply probability (LPSP). Tafreshi et al. [19] presented a methodology to perform optimal unit sizing for distributed energy resources in a micro grid. They implemented a method based on graphic user interface to calculate the optimal system configuration that could achieve a customer's required loss of power supply probability (LPSP) with a minimum cost of energy.

The organization of this paper is as follow: section 2 discusses modelling of hybrid system. Section 3 explains the objective function. Section 4 the discussion of results and simulation. The conclusion of this paper is in section 5.

II. MODELING OF THE HYBRID SYSTEM

A. Photovoltaic model

The circuit equivalent of single diode photovoltaic model is explaining in figure 1 and the mathematical equation for single diode model is as follow [20-22]:

$$I = I_{ph} - I_{d1} - I_{sh} \quad (1)$$

$$I = I_{ph} - I_{s1}\left[e^{\frac{q(V+IR_S)}{a_1 K N_S T_C}} - 1\right] - \frac{V + IR_s}{R_{sh}} \quad (2)$$

Where I is current output from solar cell, $I_{ph}$is the light generated current, I_{sh} is the leakage current, I_{d1} is the dark saturation current of the first diode, R_{sh} is the shunt resistance, R_{sh} is the series resistance, a_1 is the diode ideality factor, K is Boltzmann's constant, q is the charge of electron, T_c is the cell temperature and N_s is the number of cells in series.

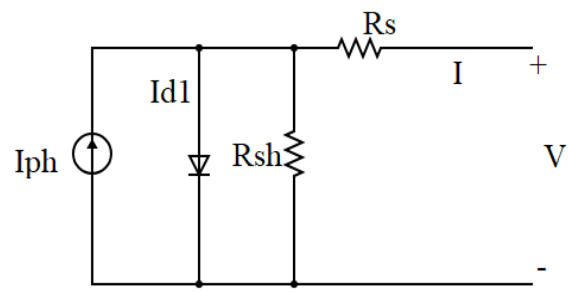

Fig1. Circuit of single diode photovoltaic model

B. Wind Turbine model

The wind turbine generates power P_w when the wind speed V is higher than the cut-in speed V_{ci} and is shut-down when V is higher than the cut-out speed V_{co} [23-24]:

$$P_w = \begin{cases} P_r\left(\frac{V^3 - {V_{ci}}^3}{{V_r}^3 - {V_{ci}}^3}\right) V_{ci} \le V \le V_r \\ P_r V_r \le V \le V_{co} \\ 0 \quad V_{co} \le V \quad or \quad V_r \le V_{ci} \end{cases} \quad (3)$$

III. OBJECTIVE FUNCTION

The correlation coefficient can be expressed as follows [23]:

$$CC = \frac{\sum_{t=0}^{n}(D_t - d).(S_t - s)}{\sqrt{\sum_{t=0}^{n}(D_t - d)^2 . \sum_{t=0}^{n}(S_t - s)^2}} \quad (4)$$

Where D_t is the demand and St is the supply at time t, d and s are demand and supply average over time period n, respectively. S_t is composed of two parts; S1 and S2 are the energy supply sources, PV modules and wind turbines, respectively.

The inequality coefficient can vary in the range of 0–1 and can be given by the following equation [23]:

$$IC = \frac{\sqrt{\frac{1}{n}\sum_{t=0}^{n}(D_t - S_t)^2}}{\sqrt{\frac{1}{n}\sum_{t=0}^{n}(D_t)^2} + \sqrt{\frac{1}{n}\sum_{t=0}^{n}(S_t)^2}} \quad (5)$$

Value of IC between 0 and 0.4 shows good matches and value above 0.5 represents bad match.

The LPSP depends on the deficit in load energy that is produced when the available energy generated and that stored in batteries are insufficient to satisfy the load demand. This constraint can now be written as [25]:

$$LPSP = \frac{\sum_{t=1}^{T} LPS(t)}{\sum_{t=1}^{T} E_L(t)} \quad (6)$$

Where LPS(t) is the loss of power supply for hour t or the deficit in load energy that is produced when the available energy generated and that stored in batteries are insufficient to satisfy the load demand $E_L(t)$ for hour t.

IV. RESULTS AND SIMULATION

The proposed method is to optimally size a photovoltaic –wind turbine in hybrid energy system to electrify a residential remote area household near Red Sea governorate of Egypt. Figure 2 shows the global solar insolation during a year. Figure 3 shows the wind speed variation over a year. Figure 4 illustrates the considered residential remote area load profile.

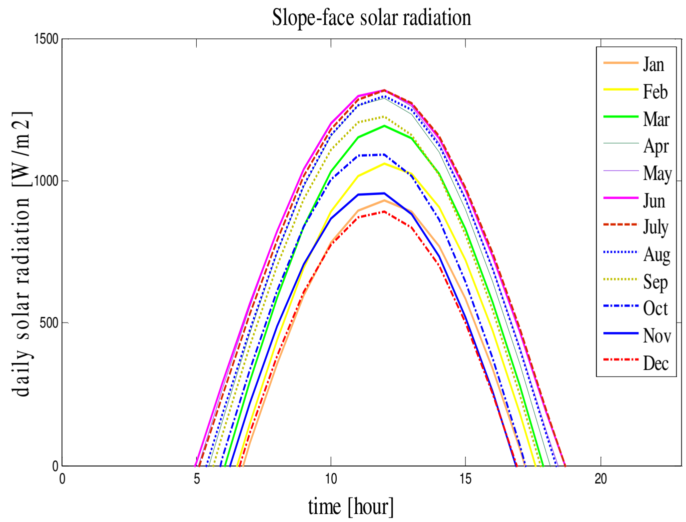

Fig.2 Variety of Solar irradiance over the year

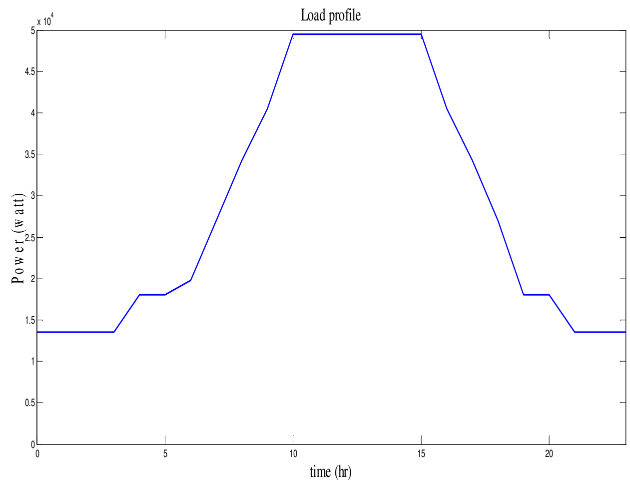

Fig.4 Annual load curve

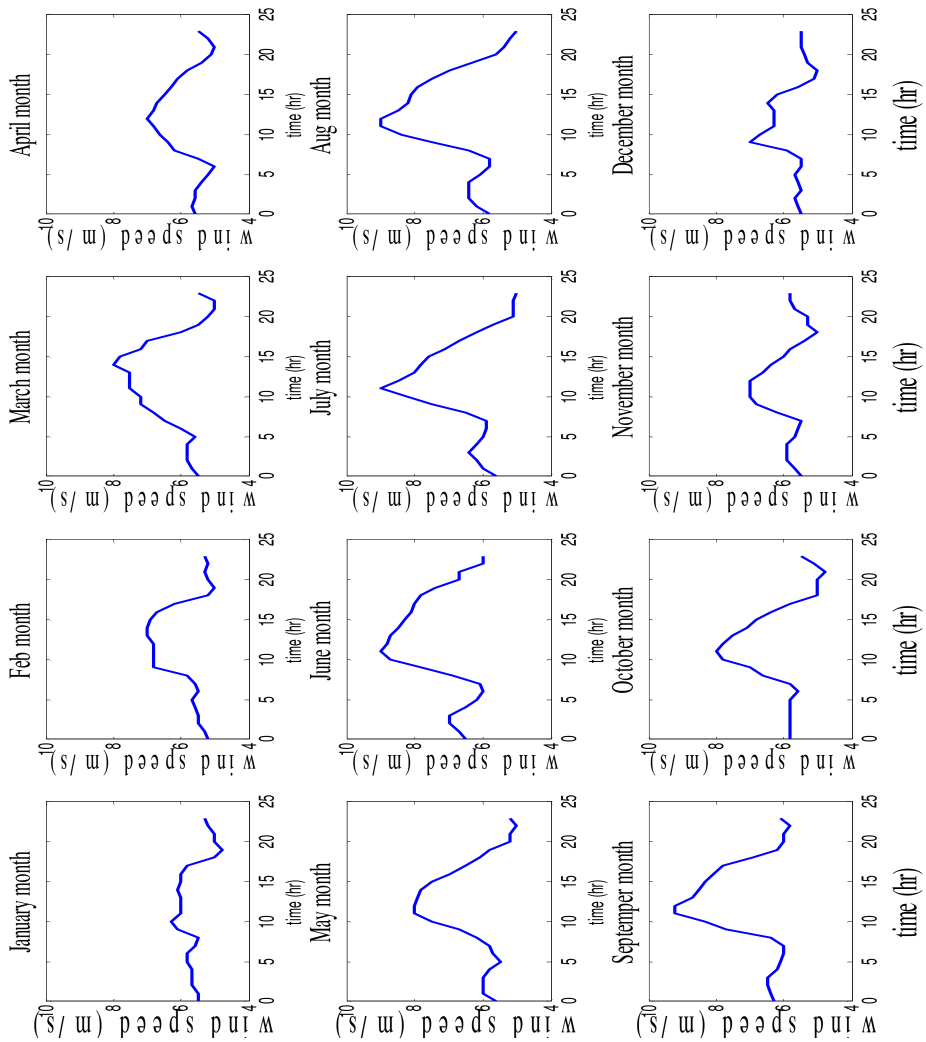

Fig.3 The wind speed variation over the year

Determination of one optimum solution to the load profile is developed according to minimize the objective function is ACS and the constraint is CC, IC and LPSP. The algorithm is developed to minimize the ACS and minimize the IC, maximize the CC of the system and keeping up the LPSP of the system in a certain predetermined value. There are three types of solution such as stand-alone photovoltaic system, stand-alone wind turbine system and photovoltaic-wind turbine hybrid system. The algorithm is operated as the following steps:

Step1: input all data of photovoltaic model and wind turbine model and cost parameters.

Step2: make three for loop of time over the day, variation of N_{pv} from 0 to its length and variation of N_{wind} from 0 to its length; at each point in the tree loop compute the total power generated from the (PV-Wind turbine) sources, compute the energy generated(E_{gen}) and energy of the load(E_{load}, if the E_{gen}>= E_{load} then no diesel used and the capacity of battery is the positive difference between the E_{gen} and E_{load}, Else; compute the difference between the load profile and the total power generated, based on that difference the rated of diesel engine generator is determined as follow," the maximum difference between the load and the total power generated is the rated of diesel engine generator, compute the ACS, compute IC, compute CC, compute LPSP of each point in for loop.

Step3: select the region of solution that satisfied the three condition of CC=0.5:1, IC=0:0.4 and LPSP=$\pm 10\%$.

Step4: make mask for this region of solution and identify the masked region in ACS and rated of diesel engine generator.

Step5: export masked LPSP, CC, IC, battery, Diesel generator, and ACS.

Step6: select type of solution.

Step7: for optimum solution of stand-alone photovoltaic, determine the position of minimum value of ACS in the first column and all rows of the solution, after determine this position the others parameter (LPSP, CC, IC, diesel capacity and battery capacity) can be determined.

Step8: for optimum solution of stand-alone wind turbine, determine the position of minimum value of ACS in the first row and all columns of the solution, after determine this position the others parameter (LPSP, CC, IC, diesel capacity and battery capacity) can be determined.

Step9: for optimum solution of photovoltaic – wind turbine hybrid system, determine the position of minimum value of ACS in matrix except the first row and the first column of the solution, after determine this position the others parameter (LPSP, CC, IC, diesel capacity and battery capacity) can be determined.

Step10: End.

This algorithm is applied to the load described in figure 4; hence the flowing figures explain the optimal solutions. Figure 5 explain the optimal solution of stand-alone photovoltaic system. Figure 6 explain the optimal solution of stand-alone wind turbine system. Figure 7 explain the optimal solution photovoltaic – wind turbine hybrid system.

After applying the procedure using GUI MATLAB package to the load profile, the optimum stand-alone photovoltaic solution is 29 unit of photovoltaic module with maximum power 290 watt, 3 units of 250Ah battery, LPSP=-0.0159, CC=0.9568, IC=0.281 and ACS= 3115.7$/year. The optimum stand-alone wind turbine solution is 76 unit of wind turbine with rated power 400 watt, 1 unit of 250Ah battery, 2unit od 1KW diesel generator, LPSP=0.0993, CC=0.96336, IC=0.086063 and ACS= 12075.7$/year. The optimum photovoltaic – wind turbine solution is 28 unit of photovoltaic module with maximum power 290 watt,2 unit of wind turbine of 400 watt rated power, 3 units of 250Ah battery, LPSP=-0.0046, CC=0.9579, IC=0.27226 and ACS= 3324.7$/year. The cost of wind turbine is very high due to capital cost of blades, generator and tower; so that the cost of standalone wind turbine system is very high compared to the standalone photovoltaic system. The stand-alone photovoltaic system and the photovoltaic – wind turbine hybrid system is lower annualized system cost than stand-alone wind turbine; so that the stand-alone wind turbine solution is inapplicable.

Figure 5 the optimal solution of stand-alone photovoltaic system.

Figure 6 the optimal solution of stand-alone wind turbine system.

Figure 7 the optimal solution photovoltaic – wind turbine hybrid system.

V. CONCLUSIONS

In this paper, a new sizing method has been applied to design the configuration of PV-wind-diesel generator hybrid system with and without battery capacity of electrical energy generation. The outlined technique defines optimum hybridenergy system configuration. The procedure was applied for either the sizing of PV-wind- diesel generator hybrid energy system or the sizing of PV-wind-diesel generator hybrid energy system with battery storage that is considered to a residential building in Red Sea governorate, Egypt. It is worth mentioning that the proposed methodology can be effectively employed for any composition of hybrid energy systems in any locations taking into account the meteorological data and the consumer's demand. The estimation of the size of diesel engine generator is compared with the size of the photovoltaic module and the size of wind turbine to satisfy the supply power to the demand power, and it is also compared with the generated energy is not excessed the demand load energy. The sizing of battery capacity is dependent on the generated power from photovoltaic- wind hybrid system as follow: if the generated energy is excessed the consumed energy by the load, then the capacity of battery is the positive difference area between the generated energy and demand load.

The objective function is ACS and the constraint is CC, IC and LPSP. The algorithm is developed to minimize the ACS and minimize the IC, maximize the CC of the system and keeping up the LPSP of the system in a certain predetermined value. The region of optimum solution of sizing PV-wind turbine- diesel generator hybrid energy system with and without battery storage is developed. There are several modes of solution such as stand-alone photovoltaic system, stand-alone wind turbine system and photovoltaic – wind turbine hybrid system. Determination of one optimum solution to the load profile is developed according to the objective function (minimum annualized system cost) and the constraints (LPSP, CC and IC) using GUI MATLAB package.

The main conclusion of this part is:

- Adding the battery to the photovoltaic – wind turbine - diesel engine generator hybrid system leads to decrease the region of solution that used the diesel engine generator; this leads to decrease emission of gases.
- The region of optimum solution in case3 is satisfied the conditions of LPSP, CC and IC; so that this region is a global solution.
- The GUI MATLAB package is available for change any data of the system such as photovoltaic module, wind turbine, cost parameters, weather conditions and load profile.

REFERENCES

[1] A.Luque and S.Hegedus,"Handbook of Photovoltaic Science and Engineering",Johan Wiley &sons,2003.

[2] S.R.Wenham, M.A.Green, M.E. Watt, and R.Corkish,"Applied photovoltaics", ARC centre for advanced silicon photovoltaics and photonics,2007.

[3] R.A messenger Jerry ventre, " Photovoltaic system engineering", CRC press Bocaraton London NewYork, 2005.

[4] Diaf, S.; Notton, G.; Belhamel, M.; Haddadi, M.; Louche, A. Design and techno-economical optimization for hybrid PV/wind system under various meteorological conditions. *Appl. Energy***2008**, *85*, 968–987.

[5] Koutroulis, E.; Kolokotsa, D.; Potirakis, A.; Kalaitzakis, K. Methodology for optimal sizing of stand-alone photovoltaic/wind generator systems using genetic algorithms. *Sol. Energy* **2006**, *80*, 1072-1088.

[6] 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. *Sol. Energy* **2008**, *82*, 354–367.

[7] Yang, H.; Zhou, W.; Lou, C. Optimal design and techno-economic analysis of a hybrid solar-wind power generation system. *Appl. Energy* **2009**, *86*, 163–169.

[8] Dufo-López, R.; Bernal-Agustín, J.L. Design and control strategies of PV-Diesel systems using genetic algorithms. *Sol. Energy* **2005**, *79*, 33-46.

[9] Chen, H.C. Optimum capagovernorate determination of stand-alone hybrid generation system considering cost and reliability. *Appl. Energy* **2013**, *103*, 155–164.

[10] Zhao, B.; Zhang, X.; Li, P.; Wang, K.; Xue, M.; Wang, C. Optimal sizing, operating strategy and operational experience of a stand-alone microgrid on Dongfushan Island. *Appl. Energy* **2014**, *113*, 1656–1666.

[11] Perera, A.T.D.; Wickremasinghe, D.M.I.J.; Mahindarathna, D.V.S.; Attalage, R.A.; Perera, K.K.C.K.; Bartholameuz, E.M. Sensitivity of internal combustion generator capagovernorate in standalone hybrid energy systems. *Energy* **2012**, *39*, 403–411.

[12] Perera, A.T.D.; Attalage, R.A.; Perera, K.K.C.K.; Dassanayake, V.P.C. Converting existing internal combustion generator (ICG) systems into HESs in standalone applications. *Energy Convers. Manag.***2013**, *74*, 237–248.

[13] Perera, A.T.D.; Attalage, R.A.; Perera, K.K.C.K.; Dassanayake, V.P.C. Designing standalone hybrid energy systems minimizing initial investment, life cycle cost and pollutant emission. *Energy* **2013**, *54*, 220–230.

[14] Perera, A.T.D.; Attalage, R.A.; Perera, K.K.C.K.; Dassanayake, V.P.C. A hybrid tool to combine multi-objective optimization and multi-criterion decision making in designing standalone hybrid energy systems. *Appl. Energy* **2013**, *107*, 412–425.

[15] Morini, M.; Pinelli, M.; Spina, P.R.; Venturini, M. Optimal allocation of thermal, electric and cooling loads among generation technologies in household applications. *Appl. Energy* **2013**, *112*, 205–214.

[16] Barbieri, E.S.; Dai, Y.J.; Pinelli, M.; Spina, P.R.; Sun, P.; Wang, R.Z. Optimal sizing of a multi-source energy plant for power heat and cooling generation. *Appl. Therm. Eng.* **2014**, *71*, 736–750.

[17] Buoro, D.; Pinamonti, P.; Reini, M. Optimization of a Distributed Cogeneration System with solar district heating. *Appl. Energy* **2014**, *124*, 298–308.

[18] M.Said, ammar bakry, Saber.M.Saleh, " Proposed Design of Single Axis Photovoltaic Solar Tracker", MANSOURA ENGINEERING JOURNAL, (MEJ), VOL. 45, ISSUE 3, SEPTEMBER 2020.

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

[20] M.S. El-Negamy, MB Eteiba, GM El-Bayoumi,'Modeling and simulation of Egyptsat-1 satellite system powered by photovoltaic module' , journal of American science 2013; 9(1):110-116.

[21] M.S. El-Negamy, A Galal, GM Ei-Bayoumin, " Extraction of The unknown Parameters of a Photovoltaic Module From Manufacture Data Sheet", International Journal of Innovative Science and Modern Engineering (IJISME) 10 (2015), 6-13.

[22] M.Said and ahmed osama, "Cuckoo Search Algorithm for Extraction Ten Parameters of Photovoltaic Models", MANSOURA ENGINEERING JOURNAL, (MEJ), VOL. 45, ISSUE 3, SEPTEMBER 2020.

[23] Mokhtar Said El-Negamy, Abeer Galal, GM El-Bayoumi, ' controller energy management for hybrid renewable energy system', International Journal of Engineering and Applied Sciences, Vol.3, issue 9, 2019.

[24] M Said, A Yassin, 'Operation Study of a Combined System of Diesel Engine Generators and Wind Turbine with Battery Storage System', 2019 6th International Conference on Advanced Control Circuits and Systems (ACCS) & 2019 5th International Conference on New Paradigms in Electronics & information Technology (PEIT).

