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The Most Economical Design of Hybrid PV/Wind/Battery/Diesel Generator Energy System Considering Various Number of Design Parameters Based on Genetic Algorithm

By
Eng. Eslam Mohamed Ahmed
Department of Engineering Mathematics and Physics, Faculty of Engineering, Fayoum University.
E-mail: ema09@fayoum.edu.eg
Dr. Mennatullah Mahmoud Albarawy
Department of Engineering Mathematics and Physics, Faculty of Engineering, Fayoum University.
E-mail: mmm08@fayoum.edu.eg
Dr. Khaled Hosny Ibrahim
Department of Electrical Engineering, Faculty of Engineering, Fayoum University
E-mail: khi00@fayoum.edu.eg

Abstract
The optimal sizing of a hybrid energy system may be a difficult undertaking problem, because of the huge number of structure settings and the irregular nature of solar radiation and wind power sources. This issue has a place with the classification of combinatorial enhancement, and its solution dependent on the classical technique may be a waste of time. This paper proposes a Genetic Algorithm (GA) methodology to find the optimal sizing of a hybrid Photovoltaic, Wind Turbine, Battery Storage, and Diesel Generators (PV/WT/BA/DG) energy system based on the number of PV modules, the number of wind turbines, the number of batteries, the number of diesel generators, the slope angle of PV panel and a hub height of wind turbine as the design parameters and study its effect on the Levelized Cost of Energy (LCOE). The proposed method aims to minimize the LCOE with high reliability of load supplying by increasing the design variables gradually. The proposed method will be tested at different sites with various metrological data to ensure its robustness. The results show that the LCOE decreases as the design parameters increase, also that the average wind-speed is inversely proportional to the LCOE of the site under study.
Keywords: Genetic algorithm, hybrid system, Renewable energy, Optimization.

Symbols

	Solar declination angle	h_d	Diesel total operation hours
α	Solar elevation angle	H_{wt}	Wind turbine hub height
θ	Azimuth angle	i	interest rate
$\emptyset$	Location latitude	I_o	Solar insulation at standard conditions
ω	Hour angle	N	project lifetime
β	Panel surface tilt angle	nn	Day Julian number.
ε	Roughness ingredient factor	nb	Battery lifetime
σ	Discharge rate.	N_B	Number of batteries

η_{BC}	Charging efficiency	N_D	Number of diesel
η_{BD}	Discharging efficiency	N_{pv}	Number of PV panels
C_B	Battery cost	N_{wt}	Number of wind turbines
C_{Br}	Battery replacement cost	OMF	Operating and maintenance factor.
C_d	Diesel cost	P_B	Battery power (W)
C_{dc}	Diesel capital cost	P_{dr}	Diesel rated power
C_{fuel}	fuel cost	P_{do}	Diesel average output power
C_{pvc}	Capital cost of PV	p_f	Fuel price per litter.
C_{pvm}	Maintenance cost of PV	p_r	Power rated of wind turbine
C_{wtc}	Capital cost of wind turbine	P_{pv}	PV module output power
C_{wtm}	Maintenance cost of wind turbine	S	Solar insulation
C_{pvw}	Cost of PV/wind system	SFF	Replacement factor
CRF	Capital recovery factor	v	wind speed.
D_f	Hourly fuel consumption	V_c	Cut out speed
$E_B(t)$	The battery capacity kWh at time t	v_H	Wind speed at hub height H
E_B	Battery energy (Wh)	v_{H_r}	Wind speed at reference height H_r
$f1$	Derating factor	v_i	cut in speed
f	Inflation rate	v_r	Rated speed
		y_{pv}	Rated capacity of PV array

1. Introduction

Because of the huge consumption of fossil-fuel resources globally, a critical quest for alternative energy vitality should be presented, so renewable energy resources have become an interesting topic for the past two decades. Renewable energy sources like solar and wind can be defined as "vitality acquired from the continuous or repetitive currents on energy recurring in the natural environment" or as "energy flows which are replenished at the same rate as they are used". Renewable power generating systems are more reliable and environmentally clean. This is the motivation behind why sustainable assets are significant. As the electricity demand is rapidly increasing, but conventional plants cannot supply the electricity requested, hence renewable resources can be utilized to overcome the gap between supply and demand loads or they can be utilized to supply electricity to remote areas where conventional power generation is impractical.

The hybrid power generating systems, which combine two or more sources, are cost- effective compared to standalone systems. They can supply the load with demand energy and also minimize the size of the system components and hence reduce the total capital cost. Attempts have been made to optimize the size of the hybrid PV-wind system. By the aid of Matlab Simulink S. Kumar (2014) [1] presented a design of a hybrid PV -wind generation system considering the change of environmental conditions such as solar irradiation and temperature and tilt angle of the wind turbine, also the maximum power point was tracked using the Perturb and Observe method, but the model had no control method on battery charging. H. Yang, et al. (2008) [2] considered more variable such that (number of PV modules, number of wind turbines, PV modules' slope angle, and wind turbines' installation height) and used a genetic algorithm to find optimal sizing method for a stand-alone hybrid solar-wind system to achieve the customer demand Loss of Power Supply Probability (LPSP)with an optimal annual cost. The proposed model showed good performance and less cost than the one system solution. Since the model depends on statistical parameters, it needs to be redesigned with the variation of those parameters. Koutroulis, et al. (2006) [3] introduced a genetic algorithm methodology as an optimization method for modelling PV -wind systems, such that the system cost was minimal over a 20-year period with supplying a total demand of energy, the proposed method showed that the hybrid system offered a lower cost than using only PV or a wind system. It also allowed selection between various types of devices according to the design parameters such that (number and type of PV modules, number, and type of wind turbines, the PV modules tilt angle, the installation height of the wind turbines). I. Tégani, et al. (2014) [4] applied a genetic algorithm and a differential flatness approach, based on a control strategy to a hybrid PV -wind system for optimizing the proper number of units such that the minimizing the cost over 20 years as well as totally supplying the load demand. The model was also simulated by the Matlab environment. H. Belmili, et al. (2013) [5] presented a computer program based on the LPSP method for sizing an economical model for a hybrid PV-Wind system considering the load profile and the targeted site configuration, the cost optimization was also discussed. Using data collection taken at 10- second data rate, Shadmand and M. Mehran (2017) [6] presented an optimized hybrid PV -wind generation system based on particle swarm optimization (PSO). The proposed method had a good result on the reduction in total system cost. A Matlab modelling for hybrid PV -wind system was introduced by Kasera and Jai Kumar (2012) [7] to provide continuous load supply. In order to electrify the Sudan red sea coast by renewable energy (PV/wind), M.Tasabeeh (2016) [8] used Wasp pc-program for modelling and simulation the system and she concluded that the best solution was to use a wind system at height 80 m with a backup solar energy system. Although the hybrid system provides better performance and cheaper cost compared to a PV or a WT system alone, the combination between PV and WT still has some drawbacks as compared to the conventional system. For instance, the intermittency of wind speed and solar irradiation may cause power fluctuations. However, it can be solved by using a backup storage system such as (batteries or fuel cells) or a backup source like a diesel generator. Atia, Doaa M, et al. (2012) [9] introduced a fuzzy logic controller for modelling and monitoring the performance of the hybrid PV -wind system with battery storage by the aid of Matlab Simulink. The results suggested a high performance for the proposed system with the ability to consider the variation of design parameters. R. N. S. R., Mukhtaruddin, et al (2015) [10] used Iterative-Pareto-Fuzzy (IPF) technique to obtain the best combination of PV-Wind and battery storage system so that the reliability was maximized with optimized energy cost. While Liu, Xin, et al (2017) [11] presented a self-adapted parameters fuzzy controller beside genetic algorithms to optimize the size of hybrid solar/wind power system with battery storage economically to guarantee minimum energy cost and high reliability.A mathematical sizing model for the PV/wind/ battery storage power system was introduced by Mustafa. Engin, (2013) [12] depending on the hourly data -to choose the best sizing units in terms of cost, the results contributed cost-effective hybrid system structure with the lowest Loss of Load Probability(LLP). Considering the hourly solar radiation and hourly wind speed data, Abdullahi. Masud, (2017) [13] applied techno-economic analysis on a hybrid system for supplying maximum power to the targeted site with the minimum operation cost. The probabilistic nature of the battery storage system was also discussed. Ghorbani, Narges, et al (2017) [14] applied Genetic Algorithm with Particle Swarm Optimization(GA-PSO) and Multi-Objective PSO (MOPSO) for The optimization of hybrid PV/wind/battery generation taking into consideration solar irradiance and wind speed as changeable parameters so that the power could be supplied to the load continuously at a minimized energy cost. The Hybrid Optimization of Multiple Electric Renewables (HOMER) software's results were compared with the proposed (GA-PSO) and (MOPSO) model, and the results showed the preference of PV/WT/BAT system in compare to PV/BAT and WT/BAT systems. Akbar. Maleki, (2015) [15] had studied different algorithms such that Particle Swarm Optimization (PSO), Tabu Search (TS), and Simulated Annealing (SA) for sizing a hybrid PV/WT/BAT system. In order to supply the total demand with high reliability and minimum Total Annual Cost (TAC), LPSP technology was also considered for more reliability. Ferrari, Lorenzo, et al (2018) [16] presented a sizing strategy based on the energy cost to design and optimize the best combination of a hybrid PV/WT/ diesel system, the model was applied on an isolated mountain chalet in Italian Alps, and the results suggested that the best configuration for a hybrid system was a mix between the three sources. M. Suresh & R. Meenakumari (2019) [17] introduced an improved genetic algorithm for the optimal design of a hybrid system. To achieve the lowest cost, the renewable energy fraction was increased and the fuel cost was reduced. Therefore the PV/WT/BA system was suggested to supply the load demand.

In this paper, GA is used to find the optimal sizing of a hybrid PV/WT/BA/DG energy system based on increasing the design parameters as the number of PV modules, the number of wind turbines, the number of batteries, the number of diesel generators, the slope angle of PV panels and a hub height of wind turbines. The authors then investigate the effect of these parameters on the Levelized cost of energy. The proposed method aims to minimize the LCOE with high reliability of load supplying. The proposed method has been tested at different sites with various metrological data to ensure its robustness.

2. System Modelling

Over the most recent years, the photovoltaic and wind power generation has been increased significantly. Fig.1 shows the configuration of a hybrid system comprises of wind power source, PV power source, DG, battery bank, charge controller, converter, and actual load. The merit of this configuration is not difficult to be comprehended. The principle load is supplied principally from the WT and PV. The surplus power from the wind vitality framework as well as the PV vitality framework over the load request is stored in the battery bank until the batteries are charged. On the off chance that the battery storing is full, the surplus energy will be utilized to supply certain uncommon burdens (for example, loads for cooling and warming purposes). At the point when the demand power is more prominent than the produced power, the deficit force will be compensated from the batteries. When the battery energy is depleted and the WT/PV system could not satisfy the load need, DG is powered on [18].

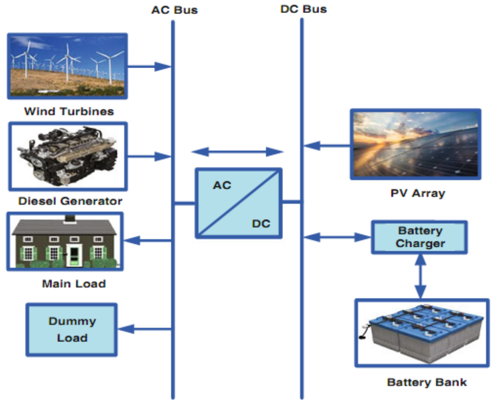

Fig.1 Hybrid PV /Wind/Diesel/Battery system

2.1 Modelling of PV energy system

The total solar radiation on a tilted solar panel consists of the sum of direct, diffused, and reflected components of the radiation hitting the panel surface. Only the direct component will be considered in this study as the other components participate with a very small percentage and could be neglected. It has been taken into account the effect of the panel tilt angle on the pattern of radiation.

The calculation of solar power and solar insulation S can be done using the following equations [19]:

$$\delta = 23.45 \times \sin\left(360 \times \frac{284+nn}{365}\right) \quad (1)$$

$$\alpha = 90° - \emptyset - \delta \quad (2)$$

$$\cos\theta = \sin(\emptyset - \beta)\sin\delta + \cos(\emptyset - \beta)\cos\delta\cos\omega \quad (3)$$

$$S = 1.353 \times (1 + 0.034 \times \cos(360 \times \frac{n}{365})) \times \cos\theta \times \sin(\alpha + \beta) \quad (4)$$

Where: δ is solar declination angle, α is solar elevation angle, θ is azimuth angle, $\emptyset$ is location latitude, ω is hour angle, β is panel surface tilt angle, S (kw/m^2) solar insulation, and nn is day Julian number. The solar power capacity (kw) could be then calculated using the equation [20]:

$$P_{pv} = \frac{S}{I_o} \times y_{pv} \times f1 \quad (5)$$

Where: P_{pv} is solar power capacity (kw), y_{pv} rated capacity of PV array (kw), $f1$ is the derating factor which represents dust, temperature, and other losses, and I_o $(1\ kw/m^2)$ is solar insulation at standard conditions.

2.2 Modelling of wind power

The output wind power depends strictly on the wind speed distribution, and can be calculated using the following formula [15]:

$$P_w = \begin{cases} p_r * \frac{v^3 - v_i{}^3}{v_r{}^3 - v_i{}^3} & if\ v_i \le v \le v_r \\ p_r & v_r \le v \le v_c \\ 0 & otherwise \end{cases} \quad (6)$$

Where: p_r is power rated of the wind turbine, v_i is cut in speed, v_r rated speed, v_c cut out speed, and v is wind speed.

The wind speed profile could be also improved to consider the effect of hub height as follows [13]:

$$\frac{v_H}{v_{H_r}} = (\frac{H}{H_r})^{\varepsilon} \quad (7)$$

Where v_H and v_{H_r} refer to the wind speed at hub height H and reference height H_r, separately, and ε is the roughness ingredient which ranges from 0.14 to 0.25 [19].

2.3 Modelling of the battery storage system

The battery capacity could be calculated based on the surplus power between the energy generated from the PV/wind system and the load demand [18]

$$E_B(t+1) = E_B(t)(1-\sigma) + surpluspower * \eta_{BC} \quad \text{Charging mode} \quad (8)$$

$$E_B(t+1) = E_B(t)(1-\sigma) - deficit\ power/\eta_{BD} \quad \text{Discharging mode} \quad (9)$$

Where: $E_B(t)$ is the battery capacity kWh at time t, η_{BC} and η_{BD} are the charging and discharging efficiency, σ is the discharge rate.

2.4 Modelling of diesel generator

The DG is the power source that supplies the load in case of failure of power generation from the PV/wind system and also the storage system was depleted. The important decision parameter in the design of DG is its fuel consumption, which is assessed by Eq. (10) [21]:

$$D_f = 0.264 \times P_{do} + 0.08145 \times P_{dr} \quad (10)$$

Where: D_f is hourly fuel consumption, P_{do} and P_{dr} are diesel average output power and rated power respectively.

3. Proposed Genetic Algorithm for hybrid system sizing

In 1975, Holland built up his ideas and thoughts in his book "Adaptation in natural and artificial systems ". He portrayed how to apply the standards of natural selection to optimization cases and fabricated the first Genetic Algorithms [22]. GA is an adaptive tool to find the best solution for an optimization problem. GA consists of several procedures which will be discussed briefly in the next subsections.

Initialization: each individual of the population is called a “chromosome” and the gene consists of “genes “, the first step is to encode the individuals of the population.

Selection: it is the phase where two parents are selected from the population for crossing over and produce the next generation.

Crossover: in this process, the chosen parents combine to produce a child chromosome hoping that it has better features.

Mutation: it is a background operator that works on every single individual to prevent the loss of the native genetic materials, also to ensure that a poor solution would not be trapped as a better one.

Replacement: when two parents combine, two children are produced, but only two members can be returned to the population, so two must be replaced [22]. The flowchart in fig.2 shows the structure of the GA optimization procedure [23].

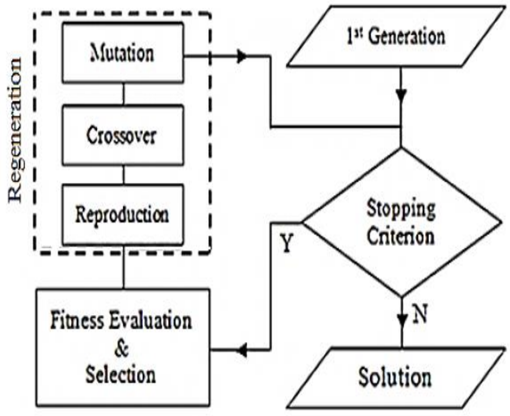

Fig.2 Structure of GA

3.1 Encoding of the proposed GA

The flowchart of the proposed method is presented in Fig.3. The decision parameters considered in the optimization process are $N_{pv}, N_{wt}, N_B, N_D, H_{wt}, \beta$ referring to the number of PV panels, the number of wind turbines, the number of batteries, the number of diesel generators, wind turbine's hub height, and PV surface tilt angle respectively. An hourly data of a typical day including solar radiation, wind speed, and load demand power at four different sites is used in the model. The proposed method firstly will consider four decision parameters then the decision variables will be increased to five and six variables at last.

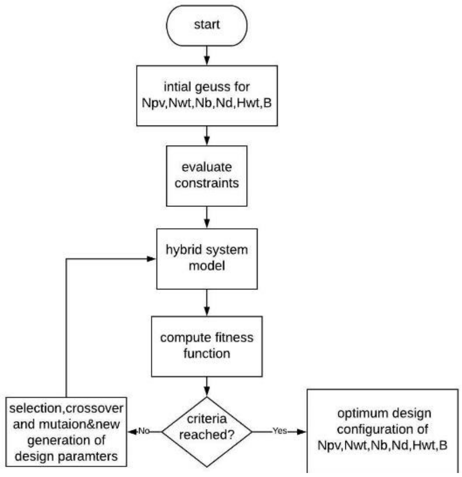

Fig.3 Proposed GA

3.2 Design constraints

The proposed method considered the power reliability i.e. (total power generated is equal or greater than the demand power), the condition that the energy generated should be able to charge the battery just after the battery discharge process, min $(N_{pv}, N_{wt}, N_{BA}) \geq 0$, min$(N_{DG}) \geq 1$ and $0° \leq \beta \leq 90°$ as the system constraints to which the first guess of system configuration will be subject to.

3.3 Objective function

In the proposed hybrid PV/wind/diesel with battery storage system, the objective function is to minimize the Levelized cost of energy (LCOE) which includes the system capital investment cost, maintenance cost, and fuel consumption cost, by employing GA, which searches for an optimal configuration until the criterion that specifies the desired convergence is reached.

3.3.1 PV and wind cost

$$C_{pvw} = CRF \times (C_{pvc} \times N_{pv} + C_{wtc} \times N_{wt}) + OMF \times (C_{pvm} \times N_{pv} + C_{wtm} \times N_{wt}) \quad (11)$$

Where, C_{pvw} is the cost of PV/wind system , C_{pvc} , C_{wtc} , C_{pvm}, C_{wtm} , CRF , OMF are the capital cost of PV, the capital cost of wind turbine, the maintenance cost of PV, the maintenance cost of wind turbine, capital recovery factor, operating and maintenance factor. CRF, OMF could be calculated by the following equations [24]:

$$CRF = \frac{i(1+i)^n}{i(1+i)^n - 1} \quad (12)$$

$$OMF = (1+f)^n \quad (13)$$

Where: n is project lifetime and i is the interest rate, f is the inflation rate.

3.3.2 Battery cost

$$C_B = 1.03 \times CRF(0.2 \times P_B + 0.415 \times E_B) \times N_B + SFF \times C_{Br} \times N_B \quad (14)$$

$$SFF = \frac{i}{(1+i)^{nb} - 1} \quad (15)$$

Where: P_B,E_B, SFF, nb are battery power(W), energy(Wh), replacement factor, and battery life-time.

3.3.3 Diesel cost

$$C_d = 1.03 \times CRF \times N_d \times C_{dc} + C_{fuel} \quad (16)$$

The fuel cost can be calculated as follows [1]

$$C_{fuel} = D_f \times h_d \times p_f \quad (17)$$

Where: C_{dc}, h_d, p_f are diesel capital cost, diesel total operation hours, fuel price per liter.

3.3.4 Levelized Cost of Energy (LCOE)

A Matlab M-file is written for the objective function and another one is written for the non-linear constraints, the M-files are designed to accept a vector of genes representing the design parameters and return the scalar value of the objective function (i.e. the LCOE) which is given as:

$$\text{LCOE}=C_{pvw}+C_B+C_d \quad (18)$$

4. Simulation and Results.

The proposed method was applied to four cases with considerable variation on wind speed.

-As shown in fig.3 daily wind speed in case 1 is the highest one with a maximum wind speed 11.7 m/s during early afternoon hours which drops to its minimum value 7.1 at midnight, also we can observe that the wind speed profile of case 4 is very stable on the contrary of case 1 and case 3 with higher fluctuations. The specifications of the PV module, wind turbine, battery storage, and diesel generator used in that work and their cost values which have been predicted after a detailed survey of researchers [2, 18, 24, and 25], are listed in table 1.

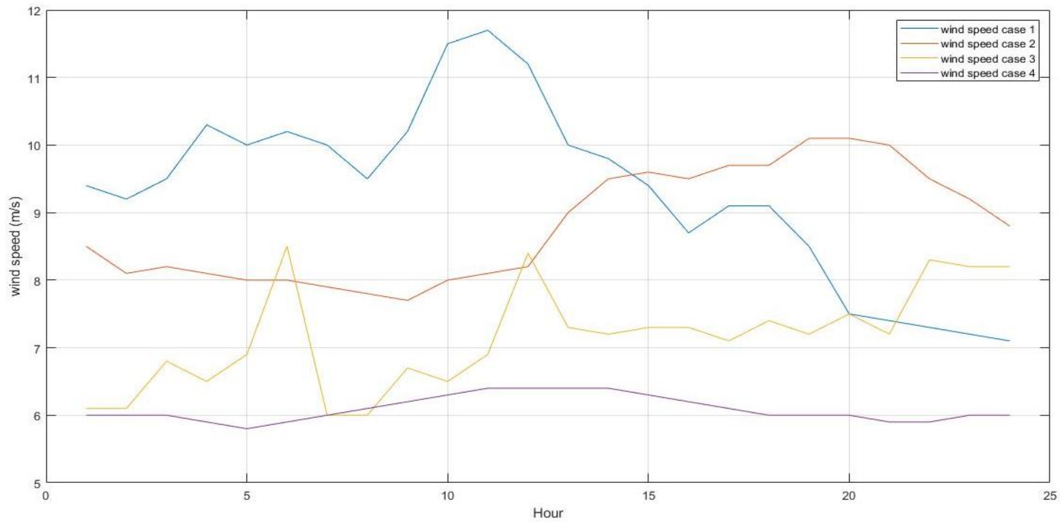

Fig.4 Daily wind speed profiles

Table 1 Cost values and specifications of the proposed hybrid system components

Parameter	Value
Project life-time	25 year
Battery life-time	5 year
Interest rate %	5
Inflation rate %	2
PV rate(w)	120
PV initial cost $/w	5.1
PV maintenance cost $/w	1% of the initial cost
Wind turbine Rated power (watt)	1000
Cut-in wind speed (m/s)	4
rated wind speed (m/s)	10
Cut-off wind speed (m/s)	25
Wind turbine initial cost $/w	3.2
Wind turbine maintenance cost $/w	3% of the initial cost
Diesel rated power(kw)	1.9
Diesel initial cost ($/kw)	850
Diesel maintenance cost ($/kw)	3% of the initial cost
Fuel cost ($/l)	0.5
Battery capacity (Ah)	250, 24v
Battery replacement cost($)	170

4.1 case1

Fig.4 shows the daily radiation, wind speed, and load demand, at a site which has a latitude equal 27.17° and longitude 33.46° normalized to their peak value [26]. The wind speed data was measured at a height equal to 10 meters above its location. Table 2 shows the results and different design combinations for this location and fig.5 shows the resulted power generation of the system.

4.2 Case 2

Fig.6 shows the daily radiation, wind speed, and load demand, at a site located in Pakistan which has a latitude equal 30.3° and longitude 69.34° normalized to their peak value [27]. The wind speed data was measured at a height equal to 10 meters above its location. Table 3 shows the results and different design combinations for this location, and fig.7 shows the resulted power generation of the system.

4.3 Case 3

Fig.8 shows the daily radiation, wind speed, and load demand, at a site located in India which has a latitude equal 10.15° N and longitude 72.12° E normalized to their peak value [28]. The wind speed data was measured at a height equal to 3 meters above its location. Table 4 shows the results and different design combinations for this location, and fig.9 shows the resulted power generation of the system.

4.4 Case 4

Fig. 10 shows the daily radiation, wind speed, and load demand, at a site located in Poland which has a latitude equal 49.74° N and longitude 21.47° E, normalized to their peak value[29]. The wind speed data was measured at a height equal to 10 meters above its location. Table 5 shows the results and different design combinations for this location, and fig.11 shows the resulted power generation of the system.

- It has been noticed that the average wind speed is inversely proportional to the LEC of the site understudy, as shown in table 6.

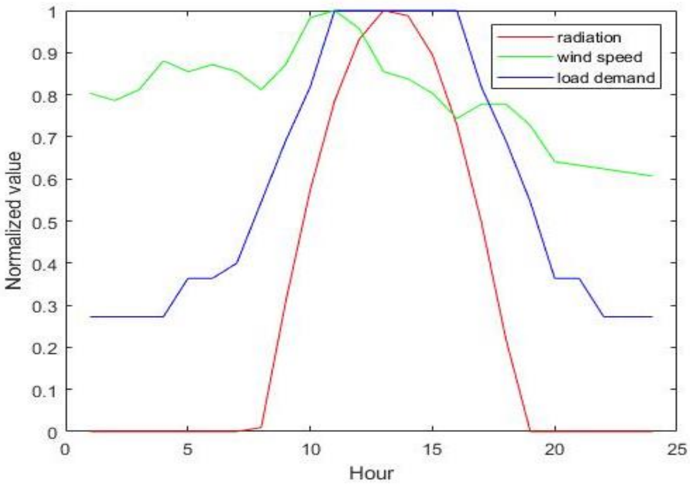

Fig.5 Normalized daily solar radiation, wind speed, and load demand (case 1)

Table 2 Results of the proposed method (case1)

decision variables	N_{pv}	N_{wt}	N_{BA}	BA(kwh)	N_{DG}	DG(kw)	β	H_{wt}	Cost($)
$N_{pv}, N_{wt}, N_{BA}, N_{DG}$	17	2	1	1.8	1	1.1	Null	Null	1580
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta$	17	2	1	1.8	1	1.2	34°	Null	1577
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta, H_{wt}$	17	2	1	1.8	1	1.4	34°	44	1575

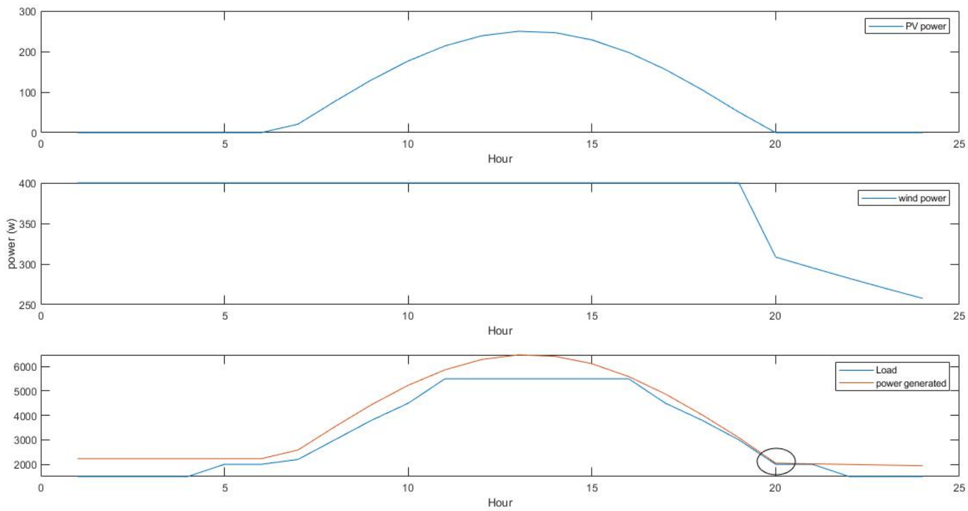

Fig.6 Daily variation of generated power, and load demand (case 1)

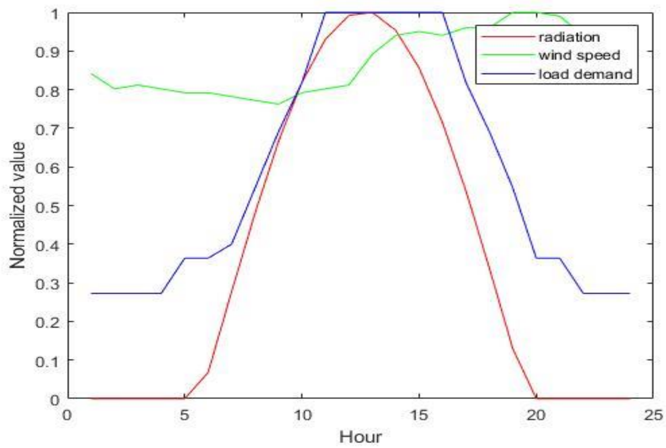

Fig.7 Normalized daily solar radiation, wind speed, and load demand (case 2)

Table 3 Results of the proposed method (case 2)

decision variables	N_{pv}	N_{wt}	N_{BA}	BA(kwh)	N_{DG}	DG(kw)	β	H_{wt}	Cost($)
$N_{pv}, N_{wt}, N_{BA}, N_{DG}$	17	3	1	3.5	1	0.9	Null	Null	1991
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta$	17	3	1	3.5	1	0.77	44°	Null	1974
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta, H_{wt}$	16	3	1	2.7	1	0.5	17°	41	1966

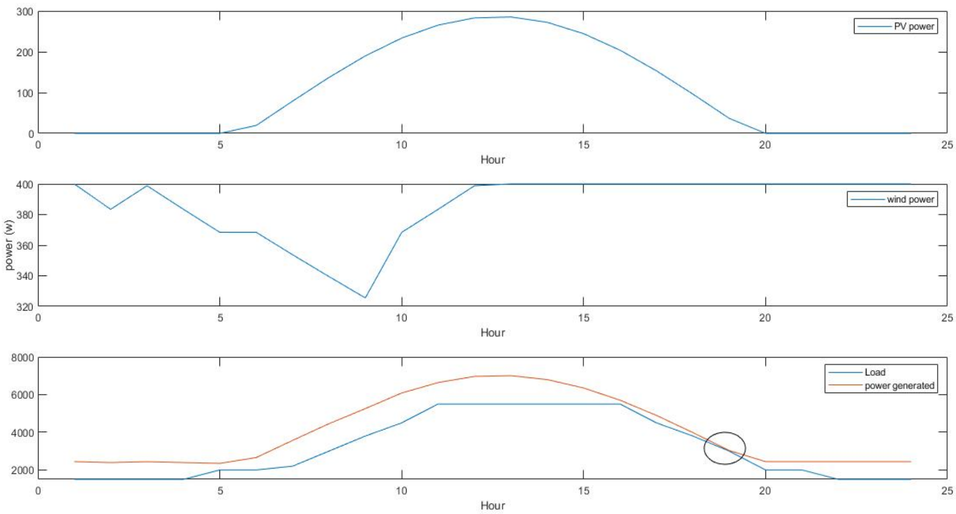

Fig.8 Daily variation of generated power, and load demand (case 2)

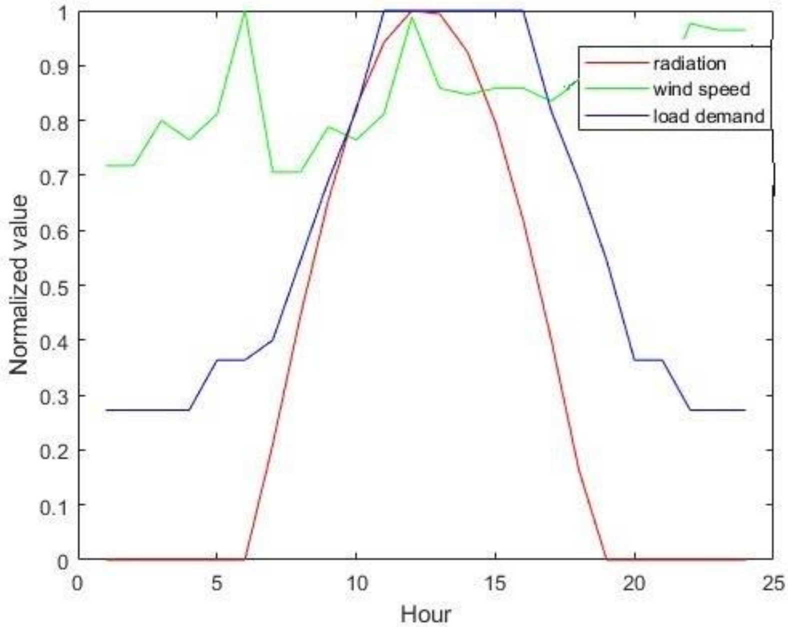

Fig.9 Normalized daily solar radiation, wind speed, and load demand (case 3)

Table 4 Results of the proposed method (case 3)

decision variables	N_{pv}	N_{wt}	N_{BA}	BA(kwh)	N_{DG}	DG(kw)	β	H_{wt}	Cost($)
$N_{pv}, N_{wt}, N_{BA}, N_{DG}$	17	5	1	4.1	1	0.4	Null	Null	2407
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta$	17	4	1	3.9	1	0.66	20°	Null	2369
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta, H_{wt}$	17	4	1	3.7	1	0.66	24°	29	2364

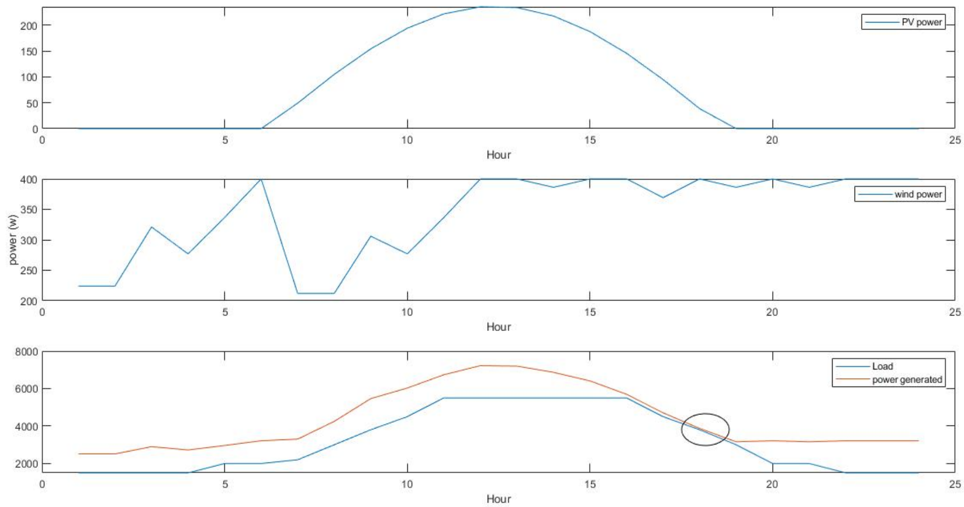

Fig.10 Daily variation of generated power, and load demand (case 3)

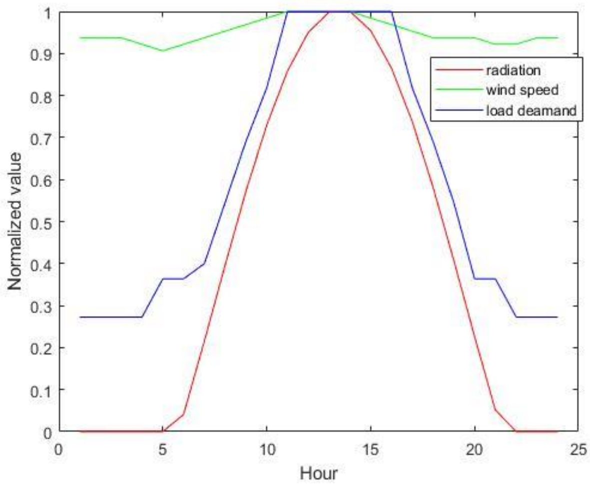

Fig. 11 Normalized daily solar radiation, wind speed, and load demand (case 4)

Table 5 Results of the proposed method (case 4)

Decision variables	N_{pv}	N_{wt}	N_{BA}	BA(kwh)	N_{DG}	DG(kw)	β	H_{wt}	Cost($)
$N_{pv}, N_{wt}, N_{BA}, N_{DG}$	19	4	1	3.8	1	1.4	Null	Null	2440
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta$	19	4	1	2.1	1	1.0	50°	Null	2397
$N_{pv}, N_{wt}, N_{BA}, N_{DG}, \beta, H_{wt}$	18	3	1	1.8	1	1.2	46°	48	2371

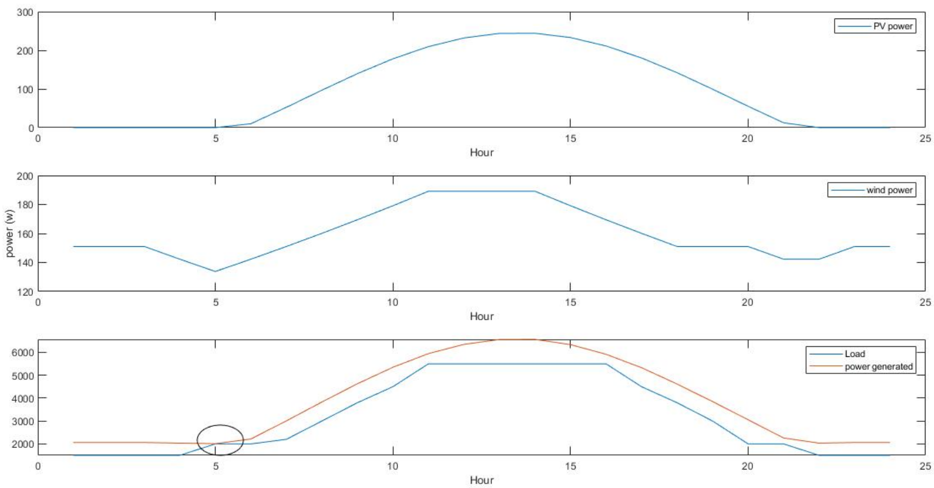

Fig.12 daily variation of generated power, and load demand (case4)

Table 6 Relation between average wind speed and cost for the cases understudy

Cases study	average wind speed(m/s)	Cost($)
Case1	9.3	1577
Case2	8.8	1974
Case3	7.15	2369
Case4	6.09	2397

5. Conclusion

This paper proposes a method for sizing a hybrid system that consists of PV, wind turbine, diesel generator system, and battery storage system taking into account different number of decision parameters by using GA. The proposed approach aimed to reduce the Levelized Cost of Energy (LCOE) with high efficiency to meet the load demand. As the number of decision parameters increases, the results yield that the GA converges and the LCOE minimizes properly, also that the LCOE decreases as the number of decision parameters increases. It has been noticed that the average wind speed is inversely proportional to the LEOC of the site understudy. Besides, it has been shown that the proposed technique can be modified if the location and metrological data are changed or if the variation in wind speed, solar radiation, and load demand has been taken into account and extra work is planned in a future work.

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التصميم الاقتصادى الامثل لنظام الطاقة الهجين (خلايا شمسية–توربينات رياح) باستخدام التقنية الخوارزمية

المستخلص:

يعتبر التصميم الأمثل للنظام الهجين من المشكلات قيد الدراسة, نظرا للطبيعة الاحتمالية للاشعاع الشمسى و سرعة الرياح بالإضافة إلى عوامل التصميم الكثيرة. ويعتبر استخدام الطرق التقليدية لحل هذه المشكلة مضيعة للوقت, لذا نقترح فى هذا البحث استخدام التقنية الخوارزمية الرياضية لإيجاد التصميم الأمثل للنظام الهجين (خلايا شمسية– توربينات رياح–مولد ديزل– بطاريات) من خلال إيجاد أقل تكلفة للنظام مع اعتبار القدرة على تغذية الأحمال الكهربية بشكل متواصل. كما اعتمد البحث على عدد الخلايا, عدد توربينات الرياح , عدد البطاريات, سعة البطاريات, عدد المولدات, سعة المولد, زاوية ميل الخلايا و ارتفاع التوربينة, كعوامل تصميم. و تم تجربة هذه التقنيه على حالات دراسة مختلفة فى العوامل المناخية. و أظهرت النتائج ان التكلفة للنظام تقل كلما زاد عدد عوامل التصميم, كما أوضحت أيضا ان متوسط سرعة الرياح يتناسب عكسيا مع تكلفة النظام فى الموقع قيد الدراسة.