International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization of IOTPE

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

December 2023 | Issue 57 | Volume 15 | Number 4 | Pages 209-219

OPTIMAL SYNTHESIS OF NEXUS SYSTEMS IN PRESENCE OF LOAD PROFILE AND ENVIRONMENTAL INFORMATION WITHOUT LIMITATIONS IN RESOURCES USING GENETIC ALGORITHM

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Abstract- Due to intermittent nature of single-source renewable energy generators, nexus systems are suitable alternatives for them. For this purpose, there are several objective functions and methods for optimal sizing of nexus systems. One of the most important issues related to nexus systems is to find the optimal size of their components to ensure efficient techno-economic operation. Each of the sizing methodologies has its specific features, but choosing the suitable method depending on the conditions and facilities is very important. In this paper, after mathematical modeling of system components using genetic algorithm, efficient and cost-effective combination of the system is achieved. In the implemented method, there is no limit to the choice of the energy sources' type and it is valid for all situations. Finally, a number of challenges and future research in relation to nexus systems are addressed.

Keywords: Nexus Systems, Renewable Energy, Optimal Synthesis, Load Profile, Genetic Algorithm.

1. INTRODUCTION

Electricity is one of the vital factors in the industrial and economic development of countries. On the other hand, with the increasing population and also the rapid growth of the industrial sector, the electric energy demand is increasing [1-4]. Currently, most of the needed electricity is generated using fossil fuels. These sources are limited and also have unbalanced geographical distribution as well as Greenhouse gas emissions. Increasing demand for electrical energy on the one hand and limited energy production through fossil fuels on the other hand, leads to a gap between energy production and demand [5-9]. The use of renewable energy resources like wind, solar and others can be considered as an appropriate solution to the mentioned issue. However, due to their extreme dependence on environmental and climatic conditions (considering production uncertainties); their independent utilization is associated with many problems. Utilization of hybrid power plants is suggested to solve this problem. These generators consist of two or more renewable and even non-renewable energy sources (mostly as backups) and are used as a complement to each other to supply electricity. Hybrid systems based on renewable energies have many advantages over systems in which there is only one generator; including better efficiency, higher reliability, lower storage costs and higher power quality. These are some of the reasons for rapid grows of hybrid power plants [10-13]. Figure 1 shows the path of progress for electric plants from traditional generators to low pollutants ones and the move towards the use of hybrid plants. In this paper, after mathematical modeling of the plant components using genetic algorithm, the optimal combination of a typical hybrid system is obtained that is capable of supplying load at any moment according to load profile; also, it is economically optimal. There is no limitation for the type of energy sources in the implemented method and it could be applied to all situations. Finally, a number of challenges and future research in relation to hybrid renewable energy systems are addressed.

2. PROBLEM DESCRIPTION AND ITS MODELING

The hybrid power plant considered in this paper, as it can be seen in Figure 2, consists of wind turbines, solar panels, compressed air energy system, water pump system, battery as well as diesel generator. The compressed air and the water pump systems as well as the battery are actually energy storages for the hybrid power plant. These are resources used to compensate unpredictable changes in renewable energies. In other words, the existence of energy storages is essential for achieving sustainable energy supply.

2.1. Input Data

Given the relationships of the wind turbines output power as well as solar cells [14-16], the wind speed and solar radiation information for the area we intend to design the hybrid power plant, is required. So, this information is accessible through the NASA's website by entering latitude and longitude of each location. Table 1 and Figure 3 show the amount of solar radiation as well as Table 2 and Figure 4 show the wind speed in a sample day for Tabriz in every ten-minute interval. It is worth noting, the recorded values for wind speed are calculated at the height of 30 meters. The power demand of a specific day in which its related wind speed as well as radiation in ten-minute intervals have been investigated, is brought in Table 3 and Figure 5 per Watts.

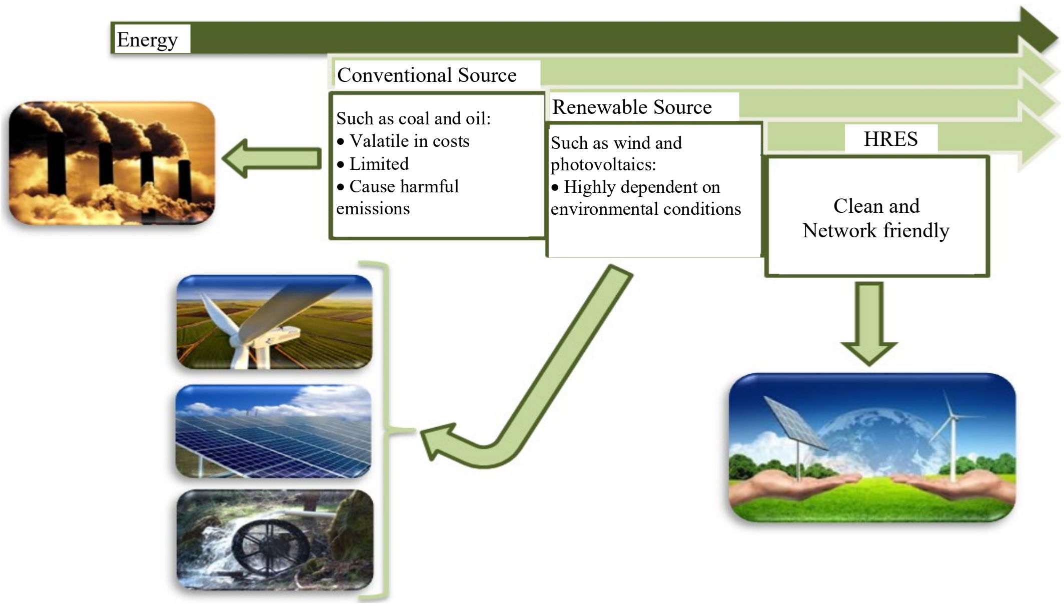

Figure 1. The path of progress for electric plants from traditional generators to low pollutants ones and the move towards the use of hybrid plants

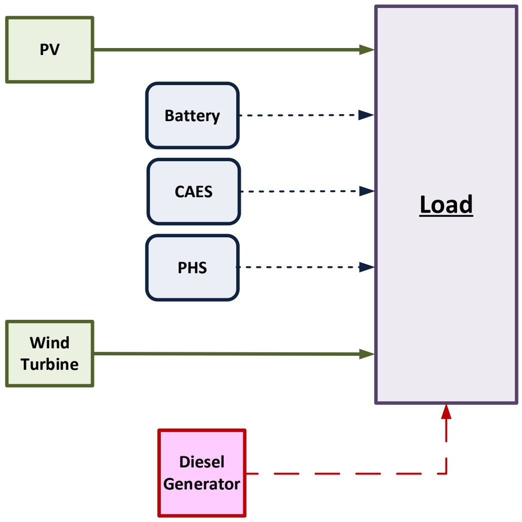

Figure 2. The hybrid power plant

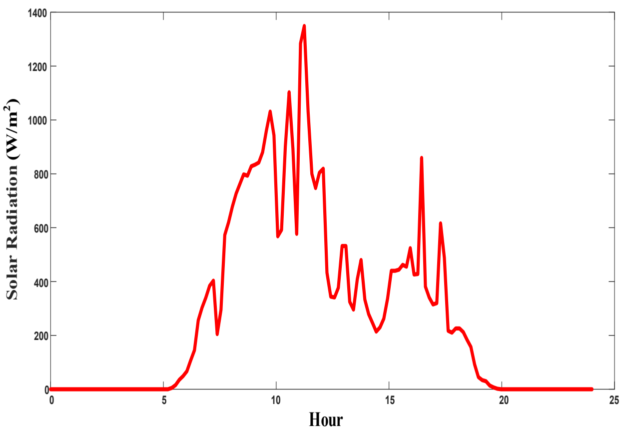

Figure 3. The amount of solar radiation in a sample day

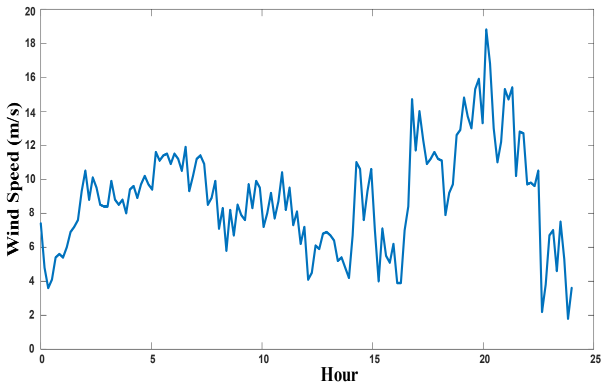

Figure 4. The amount of wind speed in a sample day

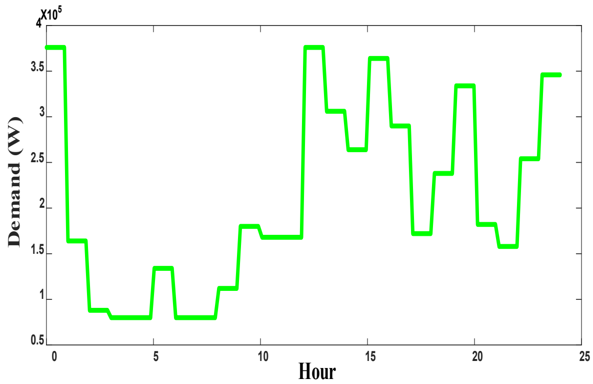

Figure 5. The amount of energy demand in a sample day

2.2. Analysis of the Objective Function as Well as the Assumed Constraints

The cost function of the whole system design is one of the most important functions in the design of hybrid power plants and it is clear that minimizing this function given the constraints and limitations would be desirable.

Table 1. The amount of solar radiation in a sample day

Time [hour]	Solar-Radiation [w/m^2]	Time [hour]	Solar-Radiation [w/m^2]	Time [hour]	Solar-Radiation [w/m^2]	Time [hour]	Solar-Radiation [w/m^2]
00:00	0	06:00	67	12:00	819	18:00	226
00:10	0	06:10	107	12:10	433	18:10	212
00:20	0	06:20	145	12:20	344	18:20	184
00:30	0	06:30	256	12:30	341	18:30	157
00:40	0	06:40	303	12:40	377	18:40	92
00:50	0	06:50	340	12:50	532	18:50	45
01:00	0	07:00	384	13:00	532	19:00	34
01:10	0	07:10	403	13:10	325	19:10	30
01:20	0	07:20	205	13:20	296	19:20	14
01:30	0	07:30	295	13:30	408	19:30	7
01:40	0	07:40	573	13:40	480	19:40	2
01:50	0	07:50	620	13:50	333	19:50	0
02:00	0	08:00	678	14:00	279	20:00	0
02:10	0	08:10	727	14:10	247	20:10	0
02:20	0	08:20	763	14:20	214	20:20	0
02:30	0	08:30	798	14:30	230	20:30	0
02:40	0	08:40	793	14:40	262	20:40	0
02:50	0	08:50	828	14:50	337	20:50	0
03:00	0	09:00	834	15:00	440	21:00	0
03:10	0	09:10	842	15:10	440	21:10	0
03:20	0	09:20	880	15:20	444	21:20	0
03:30	0	09:30	961	15:30	462	21:30	0
03:40	0	09:40	1031	15:40	455	21:40	0
03:50	0	09:50	943	15:50	524	21:50	0
04:00	0	10:00	568	16:00	426	22:00	0
04:10	0	10:10	592	16:10	428	22:10	0
04:20	0	10:20	902	16:20	859	22:20	0
04:30	0	10:30	1103	16:30	381	22:30	0
04:40	0	10:40	893	16:40	341	22:40	0
04:50	0	10:50	577	16:50	315	22:50	0
05:00	0	11:00	1284	17:00	320	23:00	0
05:10	0	11:10	1349	17:10	616	23:10	0
05:20	5	11:20	1032	17:20	488	23:20	0
05:30	16	11:30	800	17:30	217	23:30	0
05:40	35	11:40	747	17:40	210	23:40	0
05:50	49	11:50	804	17:50	226	23:50	0

The total-cost function of nexus design is as follows [17]:

$$\min C_T = C_{cpt} + C_{mtn} \tag{1}$$

In the above formula C_T is total-cost of nexus design, C_{cpt} is the total-cost of nexus investment and C_{mtn} is the total maintenance-cost. As shown in Equation (1), the function related to the total-cost of nexus design consists of the sum of the total-cost of nexus investment and the total-cost related to the maintenance of equipment.

A very important point to consider using Equation (1) is that the cost of investment (C_{cpt}) occurs at the beginning of the project's start-up, while the maintenance-cost (C_{mtn}) happens during the project. As a result, costs cannot be directly compared to each other at different times. To solve this subject, it is essential first to use the attenuation factors to convert a pecuniary value at one time to a tantamount-value at another time. This is done using the capital recovery factor seen in Equation (2) [17].

$$\frac{A}{P} = \frac{i(1+i)^n}{(1+i)^n - 1} \tag{2}$$

In Equation (2), the primary investment-cost (P) is transformed to annual investment-cost (A). Also, i represents the annual interest rate and n represents the lifetime of the nexus. Figure 6 clearly shows this subject.

The design of the hybrid power plant (Figure 2) should be such that the obtained system is economically optimal. In other words, the total cost of system design should be as low as possible. On the other hand, the assumed-constraints must also be taken into account in the design procedure. The most important constraint given in hybrid power plant is brought in Equation (3).

$$E_{pv}(i) + E_{wind}(i) + E_{Batt}(i) + E_{CAES}(i) + \\ + E_{PHS}(i) + E_{Di} - G(i) = E_{Demand}(i) \tag{3}$$

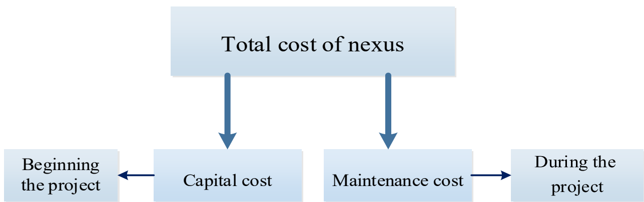

Figure 6. Total cost of system

Table 2. The amount of wind speed in a sample day

Time [hour]	Wind-Speed [m/s]	Time [hour]	Wind-Speed [m/s]	Time [hour]	Wind-Speed [m/s]	Time [hour]	Wind-Speed [m/s]
00:00	7.4	06:00	11.5	12:00	4.1	18:00	11.1
00:10	4.8	06:10	11.2	12:10	4.5	18:10	7.9
00:20	3.6	06:20	10.5	12:20	6.1	18:20	9.2
00:30	4.1	06:30	11.9	12:30	5.9	18:30	9.7
00:40	5.4	06:40	9.3	12:40	6.8	18:40	12.6
00:50	5.6	06:50	10.2	12:50	6.9	18:50	12.9
01:00	5.4	07:00	11.2	13:00	6.7	19:00	14.8
01:10	6	07:10	11.4	13:10	6.4	19:10	13.7
01:20	6.9	07:20	10.9	13:20	5.2	19:20	13
01:30	7.2	07:30	8.5	13:30	5.4	19:30	15.3
01:40	7.6	07:40	8.9	13:40	4.8	19:40	15.9
01:50	9.3	07:50	9.9	13:50	4.2	19:50	13.3
02:00	10.5	08:00	7.1	14:00	6.7	20:00	18.8
02:10	8.8	08:10	8.3	14:10	11	20:10	16.8
02:20	10.1	08:20	5.8	14:20	10.6	20:20	13
02:30	9.5	08:30	8.2	14:30	7.6	20:30	11
02:40	8.5	08:40	6.7	14:40	9.3	20:40	12.2
02:50	8.4	08:50	8.5	14:50	10.6	20:50	15.3
03:00	8.4	09:00	7.9	15:00	7	21:00	14.7
03:10	9.9	09:10	7.6	15:10	4	21:10	15.4
03:20	8.8	09:20	9.7	15:20	7.1	21:20	10.2
03:30	8.5	09:30	8.3	15:30	5.5	21:30	12.8
03:40	8.8	09:40	9.9	15:40	5.1	21:40	12.7
03:50	8	09:50	9.5	15:50	6.2	21:50	9.7
04:00	9.4	10:00	7.2	16:00	3.9	22:00	9.8
04:10	9.6	10:10	8	16:10	3.9	22:10	9.6
04:20	8.9	10:20	9.2	16:20	7	22:20	10.5
04:30	9.7	10:30	7.7	16:30	8.4	22:30	2.2
04:40	10.2	10:40	8.7	16:40	14.7	22:40	3.8
04:50	9.7	10:50	10.4	16:50	11.7	22:50	6.7
05:00	9.4	11:00	8.2	17:00	14	23:00	7
05:10	11.6	11:10	9.5	17:10	12.3	23:10	4.6
05:20	11.1	11:20	7.3	17:20	10.9	23:20	7.5
05:30	11.4	11:30	8.1	17:30	11.2	23:30	5.3
05:40	11.5	11:40	6.2	17:40	11.6	23:40	1.8
05:50	10.9	11:50	7.2	17:50	11.2	23:50	3.6

The terms $E_{pv}(i)$, $E_{wind}(i)$, $E_{Batt}(i)$, $E_{CAES}(i)$, $E_{PHS}(i)$ and $E_{Di\text{-}G}(i)$ in Equation (3) indicate the energy-generated by the photovoltaic-cells, wind, battery, compressed air, water pump and diesel generator at given ith instant, respectively. At specified time i, the sum of energy generated by solar cells, wind turbines, battery system, compressed air system, hydro pump system and diesel generator must be equal to the demand in that moment. In other words, the load must be supplied according to the load profile at all the times. At the hybrid power plant, 200 solar panel is considered which the rated power of each of them is 235 W. Also, there are 20 wind turbines with 30 kW rated power for each one. The wind turbine start, nominal and end speeds are 2.5 m/s, 12 m/s and 24 m/s, respectively. Therefore, the power generated by photovoltaic cells and wind turbines can also be calculated in 10-minute intervals, depending on solar radiation and wind speed [18-22]. Figure 7 and Figure 8 show the power generated by the specified photovoltaic cells and wind turbines, respectively.

In addition to Equation (3), which is mentioned as the main constraint, there are other constraints which we will discuss below.

With respect to the considered systems, the cost of each 1 kW production of solar panels is estimated as 1880 $ and the cost for wind turbines is 2300 $. The battery system is able to produce 50 kW per hour in its full charge state. The cost of battery system production is 250 $ per each kWh. The water pump system has a power range of 100 to 250 kW. 3,000 $ per one kWh is its investment cost and 100 $ per 1 kWh is its operating and maintenance cost. It is also assumed that the compressed air system has a power of 10 to 200 kWh, with an investment cost of 1500 $ per kWh and 50 $ per kWh operating and maintenance costs. The diesel generator also has a rated power of 250 kW. The cost of investment for this system is 400 dollars per kWh as well as the maintenance cost which is 0.05 dollars per kWh. It also costs 1.3 dollars per liter of fuel (diesel) which the amount of fuel consumed is calculated from (4) [23].

$$F = 0.08415 P_{rated} + 0.246 P \tag{4}$$

In this respect, F represents the amount of consumed fuel (liter per kWh), P_{rated} is also the nominal power of the diesel-generator and P is the power produced by the diesel-generator. It should be noted, the penalty for the production of pollutant gases should be taken into account when the diesel-generator is operating. Figure 9 clearly summarizes the intended constraints.

Table 3. The amount of energy demand in a sample day

Time [hour]	Demand [w]	Time [hour]	Demand [w]	Time [hour]	Demand [w]	Time [hour]	Demand [w]
00:00	376000	06:00	80000	12:00	376000	18:00	238000
00:10	376000	06:10	80000	12:10	376000	18:10	238000
00:20	376000	06:20	80000	12:20	376000	18:20	238000
00:30	376000	06:30	80000	12:30	376000	18:30	238000
00:40	376000	06:40	80000	12:40	376000	18:40	238000
00:50	376000	06:50	80000	12:50	376000	18:50	238000
01:00	164000	07:00	80000	13:00	306000	19:00	334000
01:10	164000	07:10	80000	13:10	306000	19:10	334000
01:20	164000	07:20	80000	13:20	306000	19:20	334000
01:30	164000	07:30	80000	13:30	306000	19:30	334000
01:40	164000	07:40	80000	13:40	306000	19:40	334000
01:50	164000	07:50	80000	13:50	306000	19:50	334000
02:00	88000	08:00	112000	14:00	264000	20:00	182000
02:10	88000	08:10	112000	14:10	264000	20:10	182000
02:20	88000	08:20	112000	14:20	264000	20:20	182000
02:30	88000	08:30	112000	14:30	264000	20:30	182000
02:40	88000	08:40	112000	14:40	264000	20:40	182000
02:50	88000	08:50	112000	14:50	264000	20:50	182000
03:00	80000	09:00	180000	15:00	364000	21:00	158000
03:10	80000	09:10	180000	15:10	364000	21:10	158000
03:20	80000	09:20	180000	15:20	364000	21:20	158000
03:30	80000	09:30	180000	15:30	364000	21:30	158000
03:40	80000	09:40	180000	15:40	364000	21:40	158000
03:50	80000	09:50	180000	15:50	364000	21:50	158000
04:00	80000	10:00	168000	16:00	290000	22:00	254000
04:10	80000	10:10	168000	16:10	290000	22:10	254000
04:20	80000	10:20	168000	16:20	290000	22:20	254000
04:30	80000	10:30	168000	16:30	290000	22:30	254000
04:40	80000	10:40	168000	16:40	290000	22:40	254000
04:50	80000	10:50	168000	16:50	290000	22:50	254000
05:00	134000	11:00	168000	17:00	172000	23:00	346000
05:10	134000	11:10	168000	17:10	172000	23:10	346000
05:20	134000	11:20	168000	17:20	172000	23:20	346000
05:30	134000	11:30	168000	17:30	172000	23:30	346000
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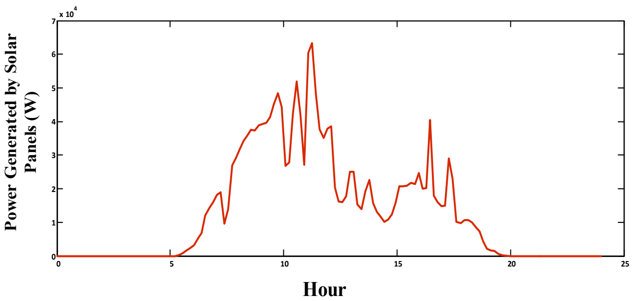

Figure 7. Power generated by solar panels in a sample day

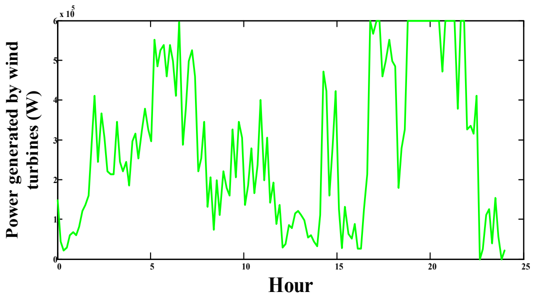

Figure 8. Power generated by wind turbines in a sample day

3. SIMULATION RESULTS

Given that the information about solar radiation and wind speed is given in ten-minute intervals and the power demand is specified in ten-minute intervals, too; the optimal, in other words, the economical combination for every ten-minute interval per day, which is equivalent to 144 scenarios are investigated.

The convergence to the minimum design cost is performed by genetic algorithm in MATLAB software and finally the system cost for each case, the capacity of each resource to have the optimal economic system in each case as well as the level of charge of all storage systems in each case have been determined.

Genetic algorithms are a set of evolutionary algorithms that are designed and developed based on natural patterns. Evolutionary algorithms are also a set of search algorithms that examine and store a population of answers in each iteration. Genetic algorithm, in other words, is a method of optimizing finite and infinite problems based on the philosophy of choice of best in nature. The genetic-algorithm frequently adjusts a population of solutions. At every stage, the genetic-algorithm randomly chooses a number of persons from the current-population to be parents for the next stage children. In successive generations, the population is moving toward the optimal solution [24-27].

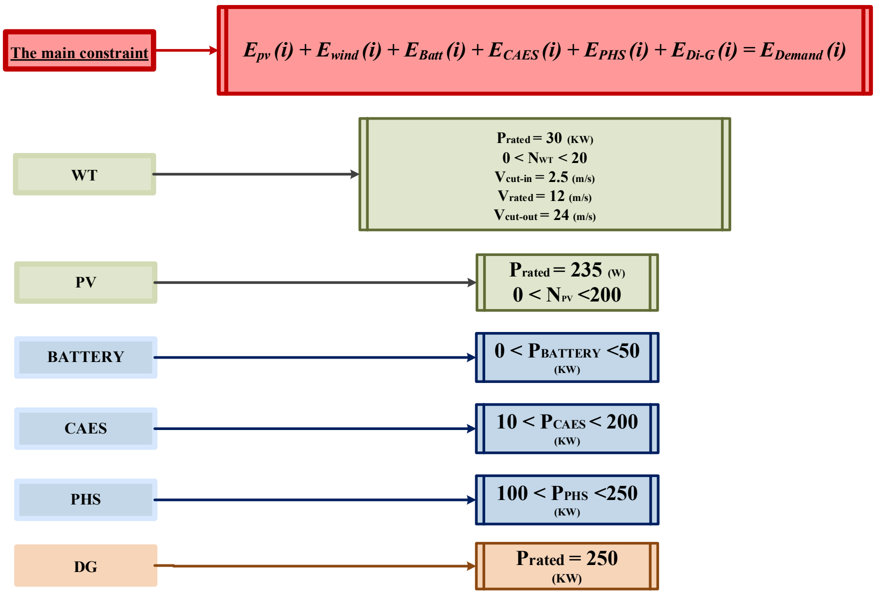

Figure 9. Intended constraints for system

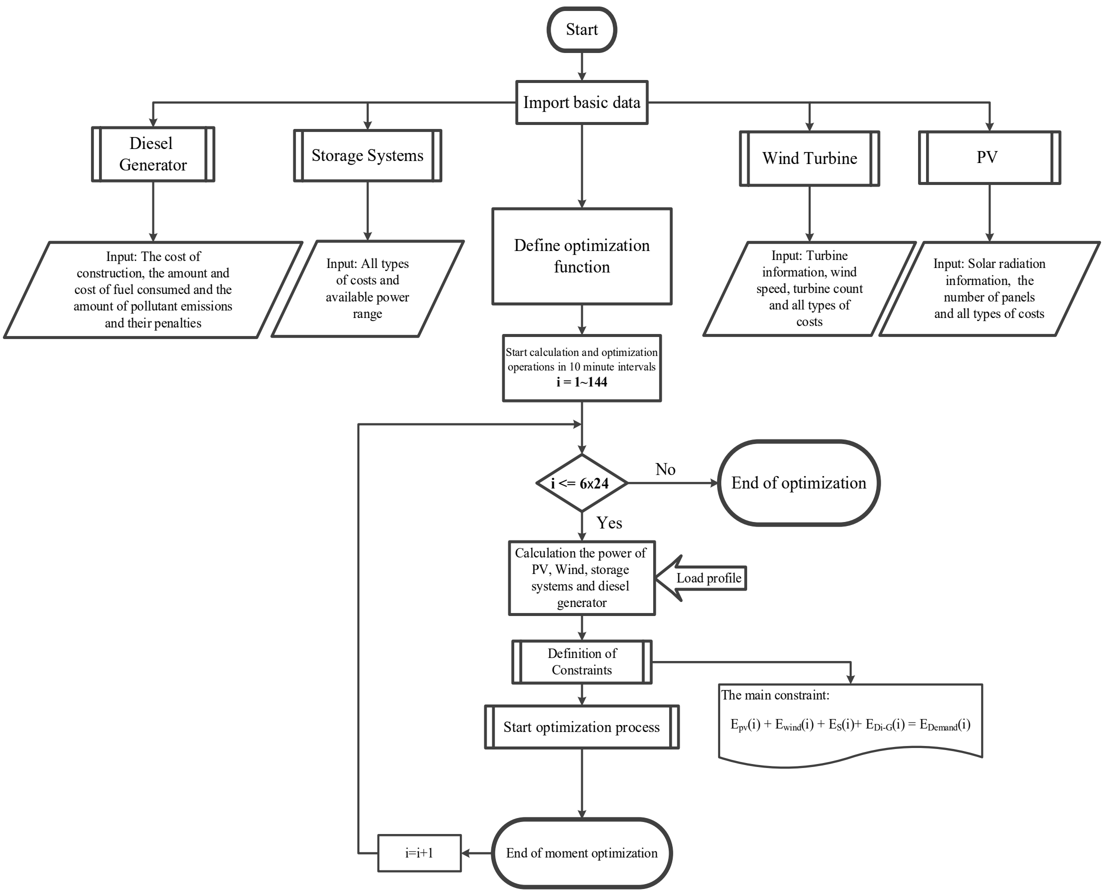

Figure 10. Flowchart of the genetic algorithm

Figure 10 shows the flowchart of the problem and how to solve that as well as Figures 11 to 14 which show the convergence process for the first, fiftieth, one hundred and one hundred forty-four states (i.e., the first ten-minute, the fifties, the hundredth, last the last ten-minute), for example. Table 4 also shows the cost of optimal system design for all steps (times). As mentioned earlier, the only criterion for selecting and using the power of any power supply is only if the power is available and economical. In the following, after applying the genetic algorithm and determining the optimal cost of the system in each case, we examine the daytime power output by each source. It is clear, according to the main constraint of system design, Equation (3); total power produced by the resources must be equal to the amount of demand at any given moment.

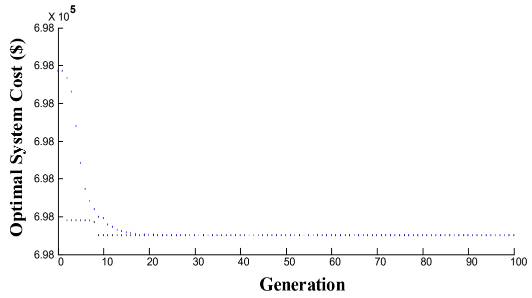

Figure 11. Convergence process for the first state

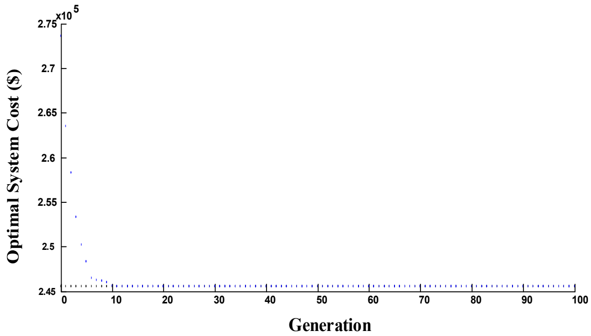

Figure 12. Convergence process for the fiftieth state

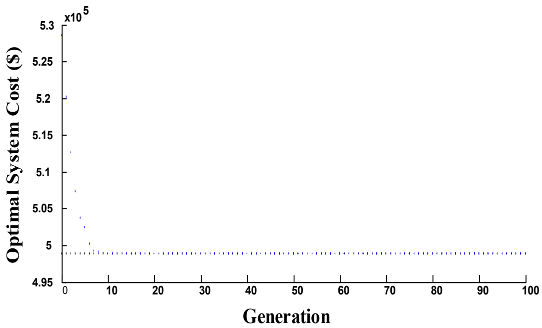

Figure 13. Convergence process for the one hundred states

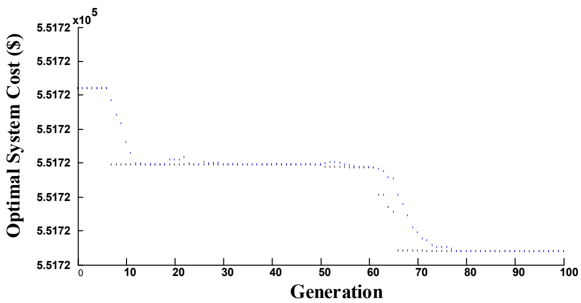

Figure 14. Convergence process for the one hundred forty-four states

Figure 15 shows the charging and discharging states related to daytime energy storage. Figure 16 to 19 represent the power diagram used by solar panels with demand, the power diagrams used by wind turbines with demand, the power diagrams used by the total capacity of storage resources (batteries, CAES and PHS) with demand and also power generation diagrams used by diesel generator with demand, respectively.

Figure 20 also shows the sum of the productive power of the resource and the diagram of the demand. It is clear that with respect to Equation (3), in Figure 20 we have to see the two graphs' overlap.

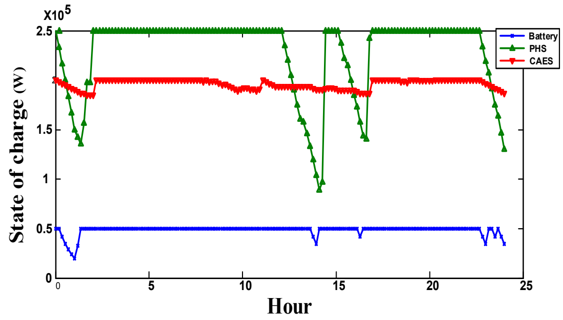

Figure 15. Charging and discharging states

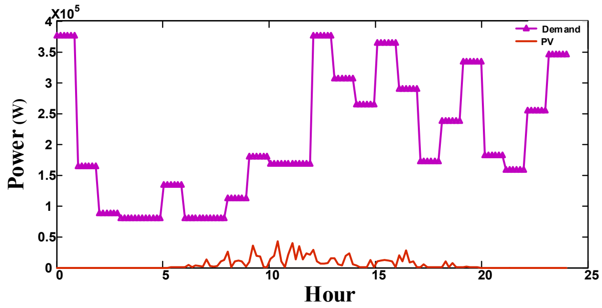

Figure 16. The power diagram used by solar panels with demand

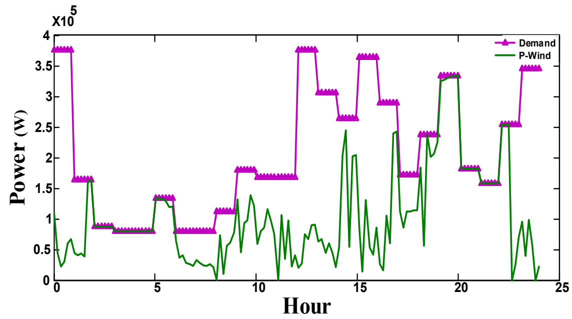

Figure 17. The power diagrams used by wind turbines with demand

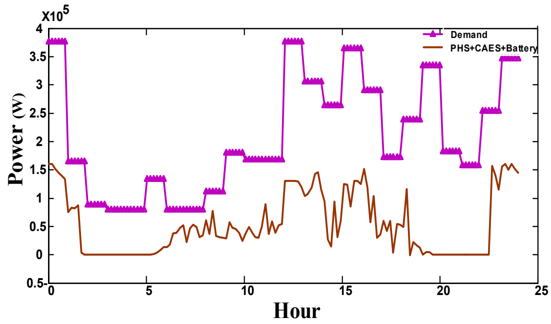

Figure 18. The power diagrams used by the total capacity of storage resources (batteries, CAES and PHS) with demand

Table 4. Optimal system cost for each scenario

Optimal System Cost ($)	"*i*" ten minutes	Optimal System Cost ($)	"*i*" ten minutes	Optimal System Cost ($)	"*i*" ten minutes	Optimal System Cost ($)	"*i*" ten minutes
476616.92	109	569426.15	73	185758.69	37	698005.55	1
420239.71	110	561164.46	74	147962.86	38	601076.88	2
573128.38	111	629046.58	75	145088.41	39	571446.25	3
545796.99	112	617388.16	76	125358.21	40	586984.87	4
520726.76	113	651342.44	77	117342.34	41	637205.65	5
548733.50	114	653518.53	78	108146.64	42	649429.01	6
782110.58	115	505827.46	79	155359.47	43	323726.86	7
790013.69	116	507578.65	80	113138.10	44	300806.65	8
789511.50	117	499678.84	81	105896.78	45	287658.71	9
792390.57	118	551566.75	82	130859.07	46	290410.41	10
795212.49	119	560952.92	83	172990.99	47	400402.26	11
795548.75	120	500463.04	84	164816.23	48	404548.75	12
445948.75	121	421446.57	85	196107.25	49	229748.75	13
445948.75	122	523839.99	86	245546.14	50	229748.75	14
445948.75	123	591030.45	87	180686.36	51	229748.75	15
445948.75	124	421859.90	88	241428.88	52	229748.75	16
445948.75	125	580808.74	89	245288.36	53	229748.75	17
445948.75	126	524548.74	90	215244.748	54	229748.75	18
390748.75	127	626086.76	91	403811.04	55	211348.75	19
390748.75	128	535205.13	92	274863.56	56	211348.75	20
390748.75	129	603709.03	93	373029.46	57	211348.75	21
390748.75	130	593510.14	94	374939.93	58	211348.75	22
390748.75	131	573775.01	95	353067.86	59	211348.75	23
390748.75	132	586049.62	96	330879.01	60	211348.75	24
611548.75	133	509630.84	97	279910.27	61	211348.75	25
611548.75	134	471720.28	98	343828.01	62	211348.75	26
611548.75	135	464286.70	99	311524.04	63	211348.75	27
431725.09	136	498899.24	100	373352.62	64	211348.75	28
454698.47	137	654949.93	101	282135.36	65	211348.75	29
482651.70	138	616600.59	102	340983.89	66	211348.75	30
644526.15	139	312948.74	103	280248.18	67	335548.75	31
570613.018	140	287700.85	104	368605.69	68	335548.75	32
659607.82	141	312948.74	105	263786.07	69	333532.06	33
598060.71	142	339430.43	106	356375.11	70	328906.74	34
514874.56	143	316611.30	107	264202.38	71	311149.70	35
551723.34	144	331978.35	108	226077.22	72	317824.50	36

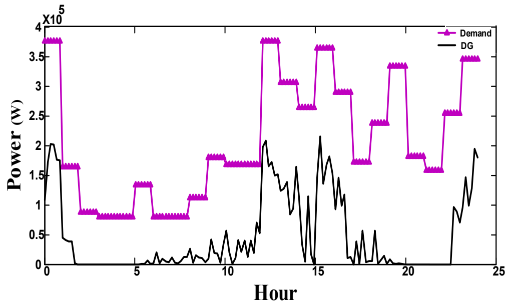

Figure 19. The power diagrams used by diesel generator with demand

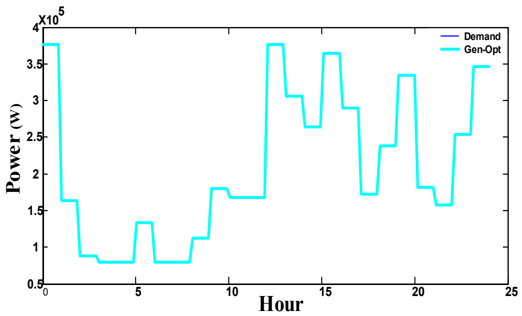

Figure 20. The sum of the productive power of the resource and the diagram of the demand

4. CHALLENGES AND PROSPECTS FOR THE FUTURE

Although electricity supply through hybrid systems based on renewable energy sources has many advantages, there are also challenges and problems associated with these systems and renewable sources, which each of them can be considered as a research topic for the development of hybrid systems. Some of the future challenges and prospects for hybrid systems are as follows:

- The making-cost of renewable energy components and equipment requires a substantial devaluation. Since the high-cost of investment delays the return on investment. Reducing costs will undoubtedly increase the incentive for entrepreneurs to implement these systems.
- Low efficiency of photovoltaic systems is a main obstacle in exhorting the use of these systems.
- The use of hybrid systems requires a certain set of safeguards. Therefore, appropriate protective equipment must be installed to protect these systems.
- Given that the islanded hybrid systems have the least amount of load oscillations, high load variations and lack of proper control may cause the whole system to collapse.

- A significant amount of energy is wasted in the process of energy conversion in hybrid systems.
- Access to storage systems such as batteries and so on is one of the major concerns for manufacturers.
- Development of smart grids consisting of different generators that complement each other.
- The need to manage time in hybrid systems using a number of existing standards, such as the IEEE 1557 and IEC 61850 standards, is essential for fast and reliable communication between different systems components.
- Deploying hybrid systems based on renewable energy sources as micro-grids requires a robust energy management method.
- Hydrogen production as well as hydrogen-based economy should be a constant topic for future researches; because a breakthrough in this field can lead to a change in lifestyle.
- Sensitivity and transient analysis in hybrid systems considering changes in parameters such as solar radiation, wind speed, load demand, etc.
- Utilization of nanotechnology is one of the important issues for research in order to improve the different components of hybrid systems.
- Although the losses preoccupied in power-electronic converters have been diminish to a suitable rate, it must still be safeguarded that the energy losses in these converters are minimized.
- Due to the development of appliances that are powered by DC voltage, technical and economic feasibility in this field should be fully realized.
- The widespread use of hybrid systems will undoubtedly require government subsidies for renewable energy equipment.
- Manufacturing of new equipment and parts using new semiconductors such as Gallium-Nitride is progressing rapidly that undoubtedly produces compact parts and equipment (with the least occupancy), high-frequency operation, and so on. Therefore, it requires increasing research activities in this field.
- Further study in storage resources such as batteries and hydrogen storage systems are needed to reduce energy storage costs.

5. CONCLUSIONS

Renewable energy-based nexus systems are one of the most efficient methods of generating electricity due to the increasing need for energy and the problems of conventional power plants. Optimal sizing as well as synthesis of nexus systems is essential for efficient and cost-effective utilization, and there are several methods available for this purpose. Choosing the right method for optimal system sizing is of great importance. Each of the sizing methodologies, has its specific features but hybrid methods, supply the maximum malleability among the other sizing methodologies and they can obviate the constraints of a specific method by adding some good features of other appropriate methods.

In this paper, the optimal combination of a typical nexus system that is capable of supplying load at any moment according to load profile using genetic algorithm have been achieved which also is economically optimal. There is no limitation to the type of energy source in the implemented method and could be applied to all situations.

NOMENCLATURES

1. Acronyms

GA	Genetic algorithm
HRES	Hybrid renewable energy system
PV	Photovoltaic
WT	Wind turbine
CAES	Compresses air energy storage
PHS	Pumped hydro storage
DG	Diesel generator
ESS	Energy storage system

2. Symbols / Parameters

C_T: Total cost of system
C_{cpt}: Capital cost
C_{Mtn}: Maintenance cost
P: Initial investment cost
A: Annual investment cost
E_{pv}: Energy-generated by the PV system
E_{wind}: Energy-generated by the wind-turbines
E_{Batt}: Energy-generated by the battery system
E_{CAES}: Energy-generated by compresses air energy storage
E_{PHS}: Energy generated by the pumped hydro storage
$E_{Di\text{-}G}$: Energy generated by the diesel generator
F: The amount of consumed fuel
P_{rated}: Rated power
N_{WT}: Number of wind turbines
N_{Sol}: Number of solar panels

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