Modeling / Optimization and Effect of Environmental Variables on Energy Production Based on PV / Wind Turbine Hybrid System

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ABSTRACT

The use of fossil fuels to supply human energy needs is increasing day by day, which contributes to environmental pollution. In addition, they have a limited supply and are not continuously being made, or they are made very slowly. Thus, to reduce human dependence on this type of energy, the use of renewable energy sources is increasing, which has problems because of the high cost of investment and the stochastic nature. In this study, a sensitivity analysis of renewables was conducted to evaluate the impact of these resources on the costs of hybrid power plants based on renewable energies. In this regard, the amount of wind and intensity of sunlight was studied in the Kermanshah region. Significant results can be attributed to a reduction in the rate of return of capital to 9.22 years for the radiation intensity of 4.5Kwh / m^2 / d. Then, by Sensitivity analysis to wind intensity, the Optimal wind turbine speed was 4.99 m/s, for COE 0.93($/Kwh).

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1. INTRODUCTION

Given the importance of using renewable energy sources in the energy supply, the use of renewable and endless energy sources is gradually increasing today [1][2][3][4]. Energy experts believe that the use of renewable energy production systems will reduce risks such as reduced fossil fuels and environmental pollution. In addition, fossil fuels such as oil, gas, and coal will eventually come to an end, and civilization that is directly dependent on non renewable energy will end up with a new and larger challenge [5][6][7]. This has led industrialized and developed countries to take more serious action in using other energy sources, particularly renewable energies [8][9][10][11]. The use of solar energy, wind and sea waves, geothermal, hydrogen, biomass, and so-called renewable energies requires a lot of research, and research must be done before use. Renewable energies, especially for developing countries, are more attractive. Therefore, international programs and policies, including those of the United Nations, have been assigned a special role in the context of sustainable global development of renewable energy sources [12][13]. However, there are problems with integrating these systems with current systems. Because of this, extensive research has been done on renewable systems.

Some of the research in this area are mentioned: Elbaz and et al. [12] have provided research titled Multi-Objective Optimization Method for Proper Configuration of Grid-Connected PV-Wind Hybrid System in Terms of Ecological Effects, Outlay, and Reliability. Nyeche and et al. [13] have provided research titled Modelling and optimization of a hybrid PV-wind turbine-pumped hydro storage energy system for mini-grid application in coastline communities. Anoune and et al. [14] have provided a research titled Sizing methods and optimization techniques for PV-wind-based hybrid renewable energy system: A review. Mayer and et al. [15] have provided a research titled Environmental and economic multi-objective optimization of a household level hybrid renewable energy system by genetic algorithm. Salameh and et al. [16] have provided research titled Techno-economical optimization of an integrated stand-alone hybrid solar PV tracking and diesel generator power system in Khorfakkan, United Arab Emirates. Alayi and et al. [17][18] Provide research in the field of hybrid systems based on renewable energy systems. Adefarati and et al. [19] have provided research titled Techno-economic analysis of a PV–wind–battery–diesel standalone power system in a remote area. Maatallah and et al. [20] have Provide research data in the field of hybrid wind and solar systems. Vasel and et al. [21] have provided research titled the effect of wind direction on the performance of solar PV plants.

In the present study, the impact of these resources on investment cost and rate of return on capital has been investigated in order to prevent unexpected events from decreasing or increasing wind speed and intensity of solar radiation.

2. RESEARCH METHOD

Bistoon Thermal Power Plant Iran is located at Shahrak-e-Bistoon, Kermanshah, Iran. It has a design capacity of 640 Mw with two steam units of 320 MW on land with an area of 130 hectares. Location coordinates are: Latitude= 34.3468, Longitude= 47.3575. In Fig. 1 and Table 1, the geographical characteristics of this area can be seen. It has a latitude of 37.8^0 and a longitude of 45.20^0.

Table 1. Geographical characteristics of the studied

Parameter	Quantity
Latitude	37.8^0
Longitude	45.20^0

Fig. 1. Geographical specifications of Kermanshah city

2.1. Solar Radiation

In this research, information about the intensity of solar radiation in Kermanshah for the years 2017-2018 is taken from NASA and is used as inputs to Homer software. According to this, the amount of average radiation of the sun in this area was 5.08 kWh/ m^2/ d. the relative diagram can be seen in Fig. 2.

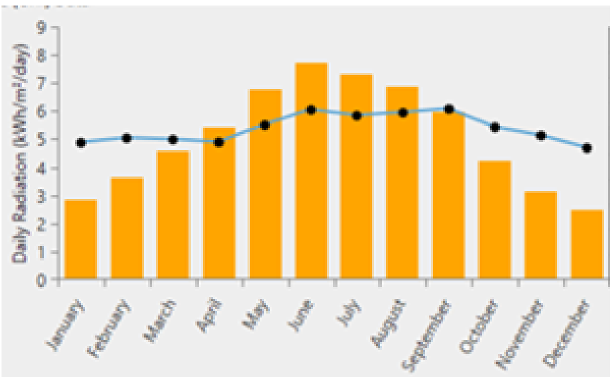


Fig. 2. Daily radiation (Kwh/m^2/day) for the studded site

As can be seen from Fig. 2, the highest intensity of solar radiation is related to the month of June with an average of 7.7 KWh/m^2/day, which reaches its lowest value in the year in December, i.e. 2.3 KWh/m^2/day.

2.2. Wind Speed

In this section, the wind speed has been extracted in the desired site, and the amount of wind at the height of 50 meters can be seen in Fig. 3 for one year. From the chart in Fig. 3, it can be seen that the average wind speed in this region is 4.99 meters per second, which shows the high potential of this region for exploitation. The highest and lowest winds are in July and January, with 5.9 and 4.22 meters per second, respectively. Fig. 2 and Fig. 3, which show the potential of this city to use solar and wind-based technologies.

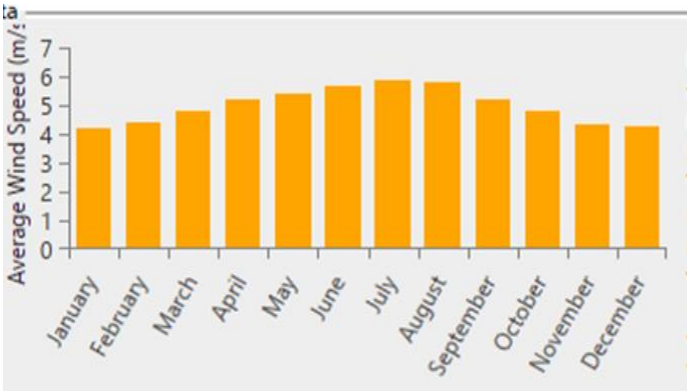


Fig. 3. Average wind speed (m/s^2) for the studded site

According to Fig. 3 shows the average wind intensity for different months of the year. The highest average wind intensity is related to the month of July with the value of 5.8 m/s, while the lowest value is related to the month of January with the value of 4.15 m/s.

2.3. Electrical Load

To simulate more accurately and to achieve more realistic results, the amount of electric load supplied by the power plant is provided. The total amount of electrical load is 24000 kwh/d, and the peak load is 1833 kW, which can be seen in detail in Fig. 4 [http://www.ttbp.ir].

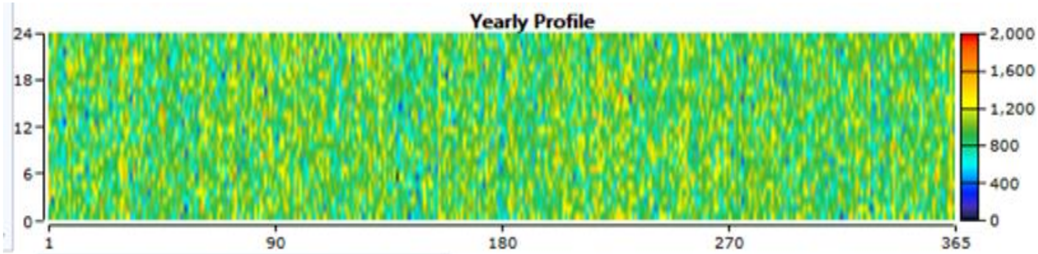


Fig. 4. electric load for Bistoon Thermal Power Plant

2.4. Model of the System Under Study

Photovoltaic cells and battery storage systems are connected to the DC load bus. The total output power of these units is connected to the AC bus by a DC / AC converter for consumer use. By applying the information to the software as well as the cost of the tools used in the hybrid system, the configuration can be considered as in Fig. 5.

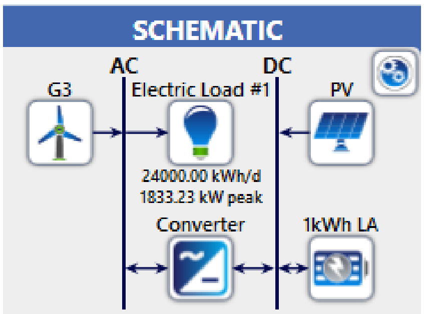


Fig. 5. General schematic of the solar and wind hybrid system with battery storage

As can be seen from Fig. 5, the system under study consists of equipment such as wind turbine, photovoltaic cells, batteries, and converters. In Table 1, the economic specifications and lifespan of each of these equipment can be seen. For wind turbine and photovoltaic cells, two characteristics of longevity and economic considerations are given, and in addition to the characteristics of longevity and economy in the converter, the amount of efficiency in different modes is also determined.

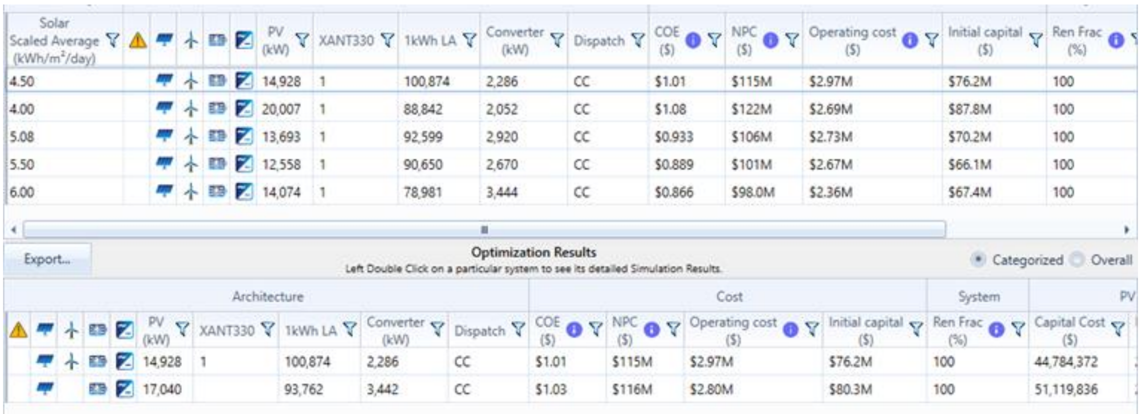
Table 2. Information on equipment requirements of the system under study

Equipment	Cost($)			Other information
	O&M	Replacement	Capital	
G3	2600	26000	130000	Life time: 20yr
PV	10	3000	3000	Life time: 25yr Derating factor: 80%
Converter	5	300	300	Life time: 20yr Inverter $_{eff}$: 95% Rectifier $_{eff}$: 90%
Generic 1kWh Lead Acid	10	300	300	Life time: 10yr Throughput (Kwh): 800

3. RESULTS AND DISCUSSION

3.1. Sensitivity Analysis on the Intensity of Sunlight

Considering that the intensity of the sun may vary in the next few years and it changes the mean value, so it can be made to reach the system with high reliability that can be made. Sensitivity analysis was performed on the intensity of the solar radiation is shown in Fig. 6.



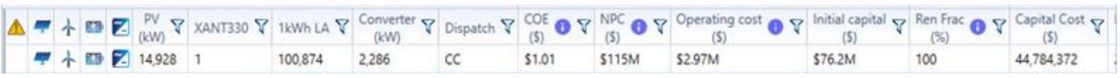
Solar Scaled Average (kWh/m²/day)	PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
4.50	14,928	1	100,874	2,286	CC	$1.01	$115M	$2.97M	$76.2M	100
4.00	20,007	1	88,842	2,052	CC	$1.08	$122M	$2.69M	$87.8M	100
5.08	13,693	1	92,599	2,920	CC	$0.933	$106M	$2.73M	$70.2M	100
5.50	12,558	1	90,650	2,670	CC	$0.889	$101M	$2.67M	$66.1M	100
6.00	14,074	1	78,981	3,444	CC	$0.866	$98.0M	$2.36M	$67.4M	100

Export... Optimization Results
Left Double Click on a particular system to see its detailed Simulation Results. Categorized Overall

Architecture					Cost				System	PV
PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)
14,928	1	100,874	2,286	CC	$1.01	$115M	$2.97M	$76.2M	100	44,784,372
17,040		93,762	3,442	CC	$1.03	$116M	$2.80M	$80.3M	100	51,119,836

Fig. 6. Results from the sensitivity analysis on the intensity of the solar radiation

In economic analysis, the parameters of Net Percent Cost (NPC) and cost of energy (COE) are very important. Considering two economic indicators and the reliability of the electricity for different cases, the best state of the radiation intensity is 4.5(KWh/m^2/day) with the results obtained in Fig. 7.



PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)
14,928	1	100,874	2,286	CC	$1.01	$115M	$2.97M	$76.2M	100	44,784,372

Fig. 7. Results from the sensitivity analysis on the intensity of the solar radiation

As shown in Fig. 7, for a solar radiation of 4.5 KWh/m^2/day, the optimal solar radiation of the system was determined. To provide the required electrical power with the lowest investment cost, the system needs 1 wind turbine and 14928 kW photovoltaic cells to generate power. To convert power to AC power to 2286 kW converter with 100874 kVA battery is needed to store excess energy. For the system in Fig. 7, the effective economic indicators in the selection of equipment are listed in Table 3.

As can be seen from Table 3, considering the sensitivity analysis on solar radiation, economic parameters will also change so that for the optimal solar radiation, the rate of return on investment by considering two cases in interest and non-interest costs is 9.50. And 9.22 years. The amount of electric power produced for the intensity of the solar radiation can be observed in Fig. 8.

Table 3. Economic effective indicators in the selection of mode system equipment

Indicator	value (yr)
return of capital with no interest	9.22
return of capital by considering interest	9.50

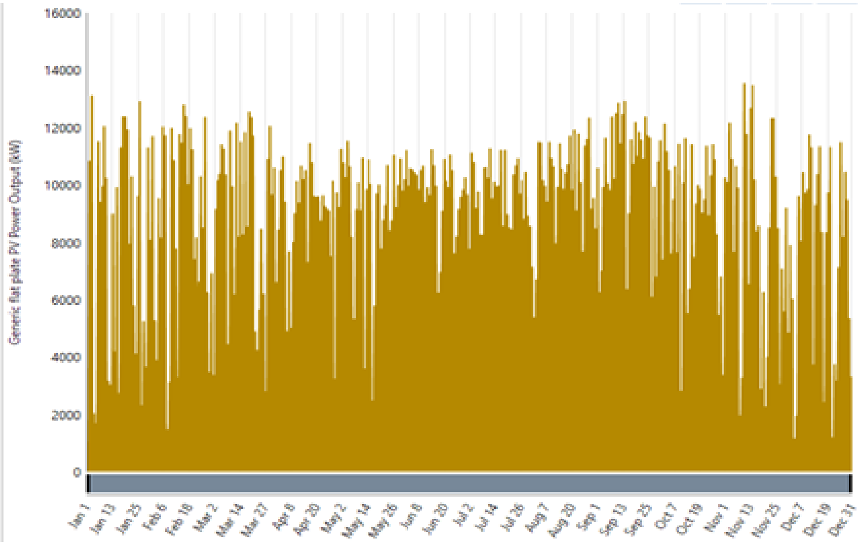


Fig. 8. The amount of power produced by the photovoltaic cell for optimal radiation intensity

3.2. Sensitivity Analysis of Wind Speed

Considering that the intensity of the wind may vary in the next few years and it changes the mean value, so it can be made to reach the system with high reliability that can be made. Sensitivity analysis was performed on the intensity of the wind. Considering two economic indices and the reliability, reliability of various states, the best state corresponds to the mean density of 4.99 m / s with the results obtained in Fig. 9.

Export... Export All... **Sensitivity Cases** Left Click on a sensitivity case to see its Optimization Results. Compare Economics Column Choices...

Sensitivity	Architecture					Cost					System
Wind Scaled Average (m/s)	PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)
4.99	13,693	1	92,599	2,920	CC	$0.933	$106M	$2.73M	$70.2M	100
4.00	13,709	1	94,573	4,884	CC	$0.952	$108M	$2.80M	$71.4M	100
5.50	13,580	1	91,568	1,895	CC	$0.920	$104M	$2.70M	$69.2M	100
6.00	14,841	1	84,804	6,306	CC	$0.931	$105M	$2.56M	$72.3M	100

Export... **Optimization Results** Left Double Click on a particular system to see its detailed Simulation Results. Categorized Overall

Architecture					Cost				System	PV
PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)
13,693	1	92,599	2,920	CC	$0.933	$106M	$2.73M	$70.2M	100	41,078,228
13,157		101,161	2,550	CC	$0.961	$109M	$2.96M	$70.6M	100	39,469,520

Fig. 9. Results from sensitivity analysis on the severity of the wind

According to Fig. 9, which has different wind speeds for the studied system, the optimal wind intensity in terms of two economic elements and maximum production capacity is related to the value of 4.99 m/s, which is considered as the wind speed. Input to the turbine The amount of investment cost and the amount of production capacity of the whole system can be seen in Fig. 10.

PV (kW)	XANT330	1kWh LA	Converter (kW)	Dispatch	COE ($)	NPC ($)	Operating cost ($)	Initial capital ($)	Ren Frac (%)	Capital Cost ($)
13,693	1	92,599	2,920	CC	$0.933	$106M	$2.73M	$70.2M	100	41,078,228

Fig. 10. Results from sensitivity analysis for the most optimal wind intensity

As shown in Fig. 10, for a wind speed of 4.99, the optimal wind speed of the system was determined. To provide the required electrical power with the lowest investment cost, the system needs 1 wind turbine and 13693 kW photovoltaic cells to generate power. To convert power to AC power to 2920 kW converter with 92599 kVA battery is needed to store excess energy. For the system in Fig. 10, the effective economic indicators in the selection of equipment are listed in Table 4.

Table 4. Economic effective indicators in the selection of mode system equipment

Indicator	value (yr)
return of capital with no interest	9.01
return of capital by considering interest	9.12

As can be seen from Table 4, considering the sensitivity analysis on wind intensity, economic parameters will also change so that for the optimal wind intensity, the rate of return on investment by considering two cases in interest and non-interest costs is 9.12. And 9.01 years.

4. CONCLUSION

In the present study, the impact of these resources on investment cost and rate of return on capital has been investigated in order to prevent unexpected events from decreasing or increasing wind speed and intensity of solar radiation. After a sensitivity analysis, the optimum intensity of the radiation to obtain the lowest cost of the radiation intensity was 4.5 (KWh/m^2/day). In order to achieve the highest efficiency, the highest intensity of radiation is the most optimum. Considering the two economic indices and the reliability of a power system for different states, the best condition for the average blowing intensity of blowing meter per second was achieved. According to the economic results, the highest cost component of batteries can be considered as a cost-saving technology, which has a significant role in the total economic cost.

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