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Optimizing the Potential of the Feasible Combination for Electrification through Renewable Resources in Commercial and Urban Areas †

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Abstract: According to the global perspective, overpopulated urban areas require increased electric utility and demand. The national and regional energy supply and distribution companies find it difficult to fulfill this increasing demand. This study involves a proper optimization of regional solar potential and capacity for a possible hybrid model in the light of variable renewable energy and optimized software-based results, including the Net Present Costs (NPC) and Cost of Electricity (COE) that have been analyzed within HOMER simulations, in light of system performance and system's durability, operation and maintenance cost, derating factor, lifetime, revenue, and their efficiency including the solar irradiance potential, as an application of electrical energy. Our results showed that if we implement a design of this hybrid model that is analyzed for different plant capacities of 50 MW, 100 MW, 150 MW, and 200 MW and draw a comparative analysis having a lifetime of 25 years, the system with the total power-generating capacity of 200 MW will be the most cost-effective and profitable system. It generates a profit which is four times more than the profit generated by 50 MW and has a lifetime of 25 years.

Keywords: HOMER; PV; technical analysis; economic analysis

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1. Introduction

According to the reports of The World Bank, Pakistan has only used 0.071% of its total solar potential as a source of renewable energy and has recommended increasing its utility by 20% till 2025 and up to 30% by 2030, to decrease the fossil fuel combustion, air pollution, and threatening effects on climate and global warming [1]. For this purpose, many new inventions and research are taking place. In the vast number of research work, different tools are used for modeling and optimization purposes. HOMER has been widely used all over the world, as it is user-friendly and fast processing [2].

In this paper, we considered HOMER as a source of making a hybrid model for an overpopulated, commercial urban area of Peshawar, a major city of Khyber Pakhtunkhwa. We took the annual data of load, the peak load months, and then, the genetic algorithm of homer software was used for optimizing it. All load calculations and components pricing details were included through the load profile provided by their local energy distribution company for fulfilling the energy demand for community load which greatly affects the environment. We have performed other comparative analyses that proves increasing the total capacity of the system will decrease the total cost of the system and also the power generation efficiency of the PV module increases with the increasing total capacity of the system, whereas the grid purchases decrease and vice versa.

2. Methodology

For techno-economic analysis and the variable renewable energy sources optimization through our data collections, we used "HOMER" software developed by NREL (National Renewable Energy Laboratory, USA). We studied the optimization of our desired hybrid system for electricity production (solar, diesel, wind, etc., with storage) of Peshawar (Pakistan) using HOMER software [3]. The load profile for this hybrid configuration was taken from Industrial Grid, Kohat Road, Peshawar, Pakistan. Solar irradiance data and wind energy potential of our region were taken from USAID reports performing techno-economic analysis [4]. The simulation framework followed in the current study is shown in Figure 1.

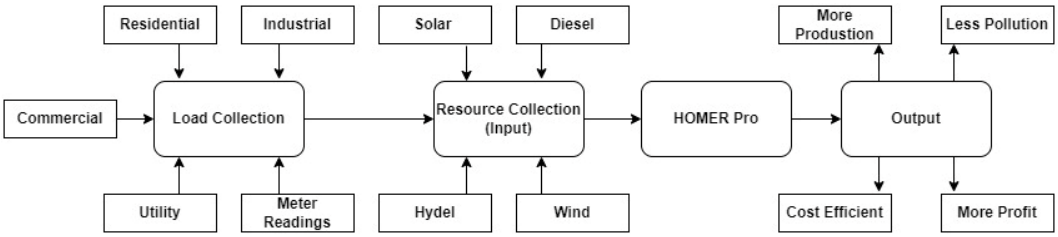


Figure 1. Simulation framework in HOMER software.

2.1. Technical Analysis

Figure 2 shows a schematic diagram that we designed for the optimization of components in HOMER for analysis. We took a wind turbine, a DC-to-AC converter, load data from a grid, a PV system, and a backup electricity connection from the grid, so whenever there is a lack of solar power, i.e., at night or the cloudy day, the power is taken from the grid. However, when there is excess solar power, it is sold to the grid for net metering purposes. A generator is also connected, as it is one of the feasible sources that we have installed from our side as a non-renewable source for low-load levels to get an optimized solution in HOMER.

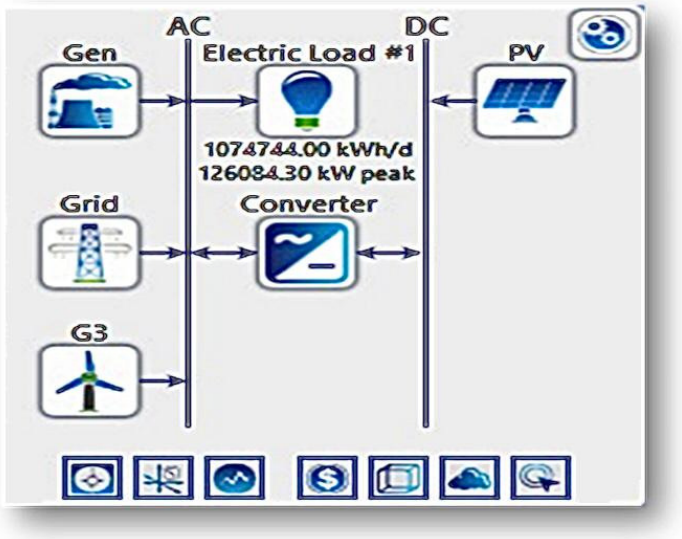


Figure 2. Schematic diagram of the optimized hybrid system.

2.2. Parameters for 50 MW, 100 MW, 150 MW, and 200 MW Capacities of the Power Plant

Comparing the unit price of electricity generated from the hydel power station and distributed by the grid station for the residential area as 0.110 ($/kWh) = 17.9 (Rs/kWh) [5] and assuming the dollar rate to be 157 PKr in June 2021, we offer a single unit of electricity generated by our hybrid system (Figure 3) for Rs-9 for the upcoming 25 years.



Figure 3. Schematic diagram of the optimized hybrid system.

All the components are installed with the rated capacities of 50 MW, 100 MW, 150 MW, and 200 MW.

- In case of the wind power plant, the capital cost is taken from the reference of a 100 kW wind turbine as $400,000, a replacement cost as $400,000, and an operation and maintenance cost as $4000 per year in HOMER.
- The complete solar power plant's capital cost is $283,268 and the same replacement cost with operation and maintenance cost is $8055, which are the same for the 100 MW, 150 MW, and 200 MW systems, where the lifetime of the PV plate is 25 years, and the derating factor is 80%.
- A converter is used for the conversion of generated DC to the AC to operate the given AC load. The cost of a single converter of 500 kW is taken as $40,000, and the replacement cost is $40,000 with no operation and maintenance cost.
- A generator is also installed in our system for optimization purposes. The cost of a single generator with a capacity of 50 MW is $80, and the replacement cost is $80 with operation and maintenance costs as $0.25. For 100 MW, 150 MW, and 200 MW capacities, we increase the number of generators according to the rated capacity.

2.3. Solar Radiation

Figure 3 is made from the data provided by the USAID measured in 2019 with the help of ADB in USPCASE UET Peshawar [6]. As is shown in Figure 4, the peak of solar radiation in Peshawar is in the month of June, which is about 7.028 kWh/m^2/day. It starts increasing from April, i.e., 5.762 kWh/m^2/day, to August and the mid of September, i.e., 5.4 kWh/m^2/day.

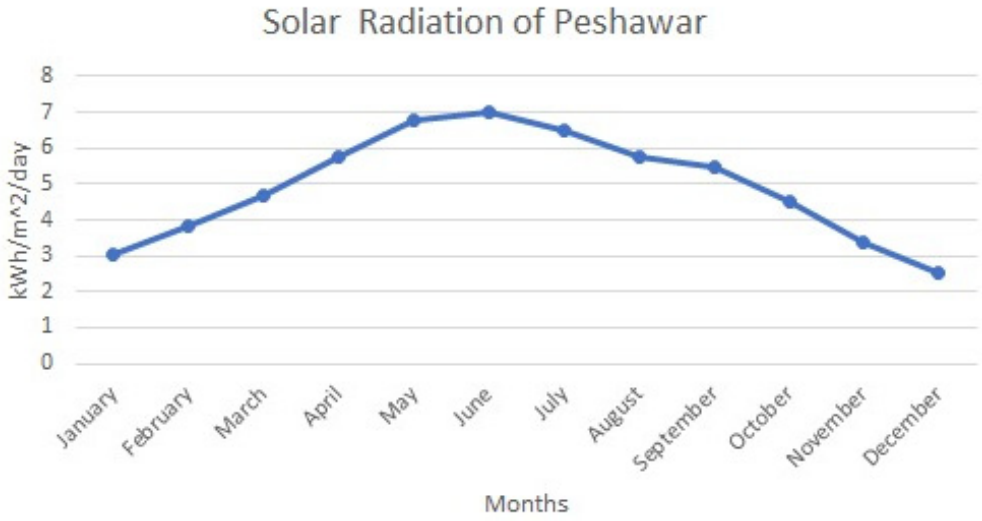


Figure 4. Annual solar radiation graph of Peshawar.

2.4. Load Profile of the Industrial Grid

The yearly load profile was taken from Industrial Grid, Kohat Road, Peshawar. Figure 5 shows the daily profile, the seasonal profile, and the annual load profile. The seasonal

profile shows that the load increases from May till September. The yearly profile shows that after 130 days of the year the peak load starts building up till 250 days of the year.

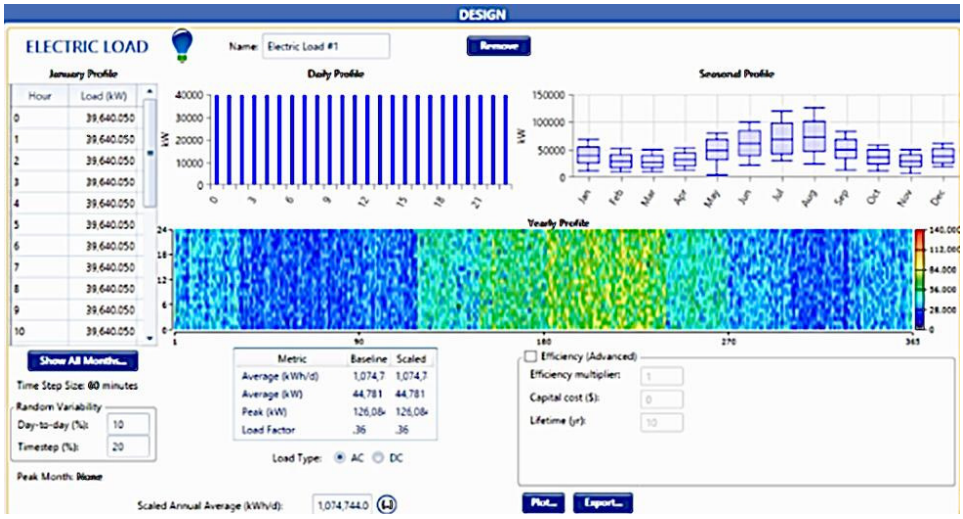


Figure 5. Overall load profile.

3. Results and Discussions

3.1. Economic Analysis

Table 1 shows that for the least capacity of plant, i.e., 50 MW, the capital cost is lower, but the total cost that includes the replacement cost, operation and maintenance costs, fuel costs (diesel), and a salvage value of the system as a whole is higher, while for the maximum capacity of the plant, i.e., 200 MW, the initial cost is more, but the total cost of the system reduces about five times for a lifespan of five years, considering homer's currency unit in dollars.

Table 1. Comparison of economics.

System	Initial Cost ($)	Total Cost ($)	COE ($)
50 MW	18,163,449	435,824,746.83	0.139
100 MW	36,326,898	313,814,594.22	0.135
150 MW	54,490,347	191,804,441.62	0.132
200 MW	72,653,796	83,330,884.72	0.307

3.2. Effective Generation of the PV Vs. Grid Purchases

Here, we can observe that the electricity generation from the PV was least for a smaller capacity system with about 50 MW, whereas for the grid purchases electricity generation from the PV was more, which would result in expensive energy production and generation, as shown in Table 2. For a bigger power plant with 200 MW, the PV generation capability and efficiency increase to about 64.8%, and the grid purchases decrease to about 35.2% within 25 years of the lifetime of the system. It is one of the key findings of our system.

Table 2. PV efficiency vs. grid purchases.

System	PV Efficiency (%)	Grid Purchases (%)	Total (%)
50 MW	36.4	63.6	100
100 MW	45.5	54.6	100
150 MW	57.1	42.9	100
200 MW	64.8	35.2	100

3.3. Profit Analysis

It is evident that for the 200 MW plant capacity, the overall project profit gains four times that procured for 50 MW plant capacity for a lifespan of 25 years, as given in Table 3, where we plan to sell a single electricity unit for $0.05. In the case of 50 MW, 100 MW, 150 MW, and 200 MW, the cost of electricity is $0.132, $0.135, $0.232, and $0.307, respectively.

Table 3. Savings from hybrid plants.

System	Total Revenue ($)	Total Expenditure ($)	Overall Profit ($)
50 MW	155,734,020.89	25,693,489.61	130,040,722.35
100 MW	311,468,041.71	51,386,979.26	260,081,081.56
150 MW	467,202,061.14	77,080,468.83	390,121,592.27
200 MW	607,570,900.72	102,773,958.43	504,796,942.31

4. Conclusions

This study presents a hybrid model, the 200-MW-capacity plant with the best-optimized results and techno-economic feasibility for about 25 years, which increases PV generation and reduces grid purchases, saving electricity costs. Peshawar's load was used as a reference in our study of the industrial grid. This proves that the bigger plant will generate higher revenues and bigger profits. The project presents the best optimized solution with all the details of attributes and methods, including cost analysis, generation capacity, environmental feasibility, and overall profitability. Our study proved that solar energy is not only an environment-friendly source of energy, but also a profitable source of energy production. Thus, we concluded that solar is not only a clean and green energy source and it has no residue that can cause any environmental degradation and guarantees the minimum cost-effective prices for investment projects for the installation of solar panels with handsome revenues and related features. This study highlights the importance of investment in clean energy sources and its need for its long-term benefits.

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