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# Design of hybrid power system for COMSATS University Islamabad using homer pro software

**Amir Rashid*, Muhammad Ehsan and Javid Rashid**

*Department of Electrical and Computer Engineering, COMSATS University Islamabad, PAKISTAN*
**Corresponding Author: e-mail: soomro1122@gmail.com, Tel +923322857303*
*ORCID iDs: http:/orcid.org/0000-0002-1708-1076 (Amir); https://orcid.org/0000-0002-1676-078 (Muhammad); https://orcid.org/0000-0003-4556-3766 (Javid)*

**Abstract**

More than a billion people do not have access o electricity, so it is important to find ways to generate power close to where they live. Hybrid energy systems can be made and used to generate electricity for homes and businesses that are not connected to national or regional power grids. Hybrid energy systems yield greater environmental and economic returns than stand-alone geothermal, solar, wind, or bigenerational systems. The goal of this paper is to simulate a hybrid power system for COMSATS University in Islamabad that is both technically and economically feasible and plays a big part to support clean energy production and safeguard the environment from toxic emissions. This paper provides a case study of COMSATS University Islamabad. The results showed that a hybrid system with a grid and a wind turbine that produced 1 MWh/yr was the best option. This study also provides a cost summary of PV panels, batteries, diesel generators, capital value, replacement, operation and maintenance (OM), fuel cost, and salvage value in dollars. In this study, a hybrid power system is designed that can provide us with a detailed analysis of power generation and consumption for the case study.

*Keywords:* Hybrid power; COMSATS University; Homer Pro; Power systems

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## 1. Introduction

In a time when technology and industry are growing and changing quickly, it is still hard to give everyone electricity that is both clean and affordable. More than a billion people do not have access to electricity, so it is important to find ways to generate power close to where people live. This is especially important for people who won't be able to connect to national or regional power grids for a while. But the number of people who don not have access to electricity has gone down a bit after years of hard work and is now less than one billion (Kabuye, 2021). Renewable energy sources like geothermal, small and large hydro, biomass, solar photovoltaic, solar thermal, and wind can provide long-lasting and cost-effective energy to all people, no matter where they live. Because these sources of energy can be shared, both single-source and hybrid power systems that connect to the grid can be made and used. A hybrid energy system is usually made up of two or more renewable energy sources that work together to make the system more efficient and keep supply and demand in balance. (Muljadi and Mckenna, 2001). The majority of us are already familiar with how a biomass, wind, or solar power generating system operates with some disadvantages. In the northern hemisphere, it is typically observed that during the rainy season, the biomass plant operates at complete capacity and on windy days, solar power is limited, and vice versa, during the summer, solar power is increased, allowing the power generation to be maintained in the afore mentioned condition. It is possible to reduce the cost of solar panels by employing mirrors and glass lenses to heat a fluid and rotate a common turbine that is used by wind and other sources of energy. During the colder months, the biomass reservoir may be heated with hydrogen in order to ensure that it produces the appropriate quantity of biogas for the generation of electricity. When there is the greatest amount of available wind and sunlight, the turbine works at its maximum capacity, and the additional power that is generated can be used to produce hydrogen.

A photovoltaic array and a wind turbine constitute yet another type of hybrid energy system. This would result in an increase in the output of wind turbines during the winter, while the solar panel output would reach its peak during the summer. The economic and environmental returns generated by hybrid energy systems are superior to those generated by stand-alone trigeneration, geothermal, solar, or wind energy systems. Solar panels and a wind turbine with a horizontal axis are mounted on a pylon for lighting in Weihai, Shandong, China. When combined, the anti-correlated power sources of wind and solar result in a more consistent output of electrical energy. Integration of renewable energy sources into the grid requires the use of both solar and wind power in tandem. In 2019, a hybrid system worth $5 million was installed in western Minnesota. Solar power of 500 kW is fed into the inverter of a wind turbine with a capacity of 2 MW, which results in an increase in capacity factor and a reduction in costs of $150,000 per year (Abd Ali et al., 2020). Up to five percent of a local distributor's sales can come from the distributor themselves. The Pearl River Tower in Guangzhou, China, will be an energy-positive structure thanks to the installation of solar panels on its windows and wind turbines on various floors of the building. Lighting pylons in various regions of China and India are topped with solar panels and wind turbines to generate electricity. When there are two energy production units that are complementary to one another, the space for lighting can be used more effectively (Li et al., 2020). The vast majority of models utilise wind turbines with a horizontal axis. However, models with vertical axis turbines utilising a helicoidal, twisted-Savonius system are beginning to appear. Solar panel installations on operational wind turbines produced glare so intense that it endangered nearby aircraft during testing. There was also the concept of a wind turbine with a vertical axis that was covered in solar cells and could take in light from any direction. Solar-wind hybrids are yet another type of hybrid. Combining solar and wind power has many benefits, one of which is that the two energy sources can complement each other thanks to their distinct periods of peak production. The hybrid system's power generation is more stable and has fewer fluctuations than those of either of its subsystems.

The Water and Power Development Authority (WAPDA), which is in charge of producing hydroelectricity, and the power distribution companies, which are part of the Pakistan Electric Power Company, are both vertically integrated public sector companies in Pakistan. Together, these two companies are in charge of making, sending, distributing, and selling electricity to consumers in the country (PEPCO). There are currently 11 distribution companies, one National Transmission and Dispatch Company (NTDC), and Karachi Electric (K-Electric) that serve Karachi and its surrounding areas, except for Karachi itself. There are approximately 42 independent power producers (IPPs) in Pakistan, each of which makes a sizeable contribution to the country's overall output of electrical power. As of the 5th of April 2021, the total installed capacity of Pakistan's power generation plants was greater than 40,000 MW (Ali et al., 2021). The primary resources are coal (26 percent), natural gas (12 percent), nuclear energy (equal parts solar and wind), renewable energy (solar and wind combined for 5%), furnace oil (15 percent), LNG (25 percent), and hydroelectricity (26 percent) (9 percent).

Islamabad is the capital of Pakistan. The Pothohar Plateau is where you'll find Islamabad. The history of this region can be found on the plateau, which is home to some of the world's oldest artefacts. These artefacts date back to the Stone Age and range in age from 100,000 to 500,000 years. A thriving civilization known as the Indus Valley Civilization existed in this region between the 23rd and 18th centuries BCE. Many powerful armies, such as those led by Zahiruddin Babur, Genghis Khan, Timur, and Ahmad Shah Durrani, travelled through this region while on their way to invade the Indian subcontinent. The urban form of the city was designed to be very dissimilar to that of typical South Asian cities. This was accomplished by constructing wide avenues in a setting that resembles a forest. Gio Ponti and Edward Durell Stone are just two of the many well-known architects and designers who have contributed to the development of the city. The city of Islamabad is located in the Islamabad Capital Territory at 33.43 degrees north latitude and 73.04 degrees east longitude. It is situated on the northern edge of the Pothohar Plateau and at the base of the Margalla Hills. Rawalpindi, the contemporary capital, and Gakhar, an ancient city, are both included in the metropolitan area known as the Twin Cities (Daechsel, 2015). Rawalpindi is considered to be the more modern of the two cities. The Rawal Dam can be found on the Kurang River, which is responsible for draining the undulating plain that is located to the city's south. The Rawal, Simli, and Khanpur Dams are the three reservoirs that are the result of human intervention and are responsible for shaping Islamabad's local climate. The record for the most rainfall in a single month was set in July 1995 with 743.3 millimetres (29.26 in).

Even though there has been snowfall at higher elevations on nearby hill stations like Murree and Nathia Gali, the temperatures in the city have remained relatively unchanged. During the winter, there is often thick fog in the mornings, but bright sunshine in the afternoons. The Indus Valley Civilization grew and thrived in this area between the 23rd and 18th centuries BCE (Galil et al., 2008). In later times, this area became home to an early Aryan settlement, which was established by people who had travelled from Central Asia to the region. Many powerful armies, like those led by Zahiruddin Babur, Genghis Khan, Timur, and Ahmad Shah Durrani, passed through this area on their way to invade the Indian subcontinent. The well-known Shrine of Meher Ali Shah was completed prior to the beginning of construction in Islamabad, which was intended to be the nation's capital. The design of Islamabad, which has wide streets and an environment that looks like a forest, was made to be very different from the design of most South Asian cities. The Greek architectural firm that was led by Konstantinos Apostolos Doxiadis was responsible for developing the city's master plan. They utilised a triangular grid with its apex facing the Margalla Hills to organise the city. At the start of the 1960s, the capital was moved to Rawalpindi for a short time. In 1966, after significant development work was finished, the capital was relocated to Islamabad (Jabeen, et al.,. 2009). A thriving civilization known as the Indus Valley Civilization existed in this region between the 23rd and 18th centuries BCE.

In later times, this area became home to an early Aryan settlement, which was established by people who had travelled from Central Asia to the region. Many powerful armies, such as those led by Zahiruddin Babur, Genghis Khan, Timur, and Ahmad Shah Durrani, travelled through this region while on their way to invade the Indian subcontinent. When Pakistan first gained its independence in 1947, the city of Karachi, which is located in the south of the country, was chosen to serve as the provisional capital of the country (Jabeen, et al.,. 2009). In 1958, a commission was established with the charge of selecting a suitable location for the national capital close to Rawalpindi. Among other considerations, the commission was tasked with giving special attention to location, climate, logistics, and defence requirements. Islamabad was recently selected as the location because of its proximity to both the army's headquarters in Rawalpindi and the contentious region of Kashmir, located in the north.

Islamabad has a climate that is a typical example of a humid subtropical climate. This climate features five distinct seasons: fall (September and October), summer (May and June), spring (March and April), rainy monsoon (July and August), and winter (November–February). June is typically the hottest month, with average high temperatures that routinely exceed 38 degrees Celsius (100.4 degrees Fahrenheit). July is the wettest month of the year, with heavy rainfall and evening thunderstorms that have the potential to cloud burst and cause flooding. The month of January is the coldest. Figure 1 illustrates the range of temperatures experienced within the city. The Rawal Dam, the Simli Dam, and the Khanpur Dam all serve as artificial reservoirs that help control the microclimate of Islamabad. Mornings during the winter months are typically marked by thick fog, while the afternoons are characterised by sunshine.

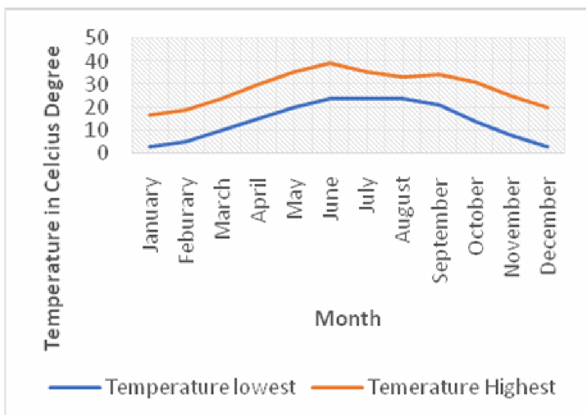


Figure 1. Temperature range in Islamabad, Pakistan

The main objective of this paper is to produce Hybrid power system for COMSATS university Islamabad the block diagram can be seen in Figure 2. The paper also shows the influence of diesel fuel price rise on four factors: costs, $CO_2$ emissions, renewable energy penetrations and electricity productions in each analyzed scenario by using HOMER Pro software.

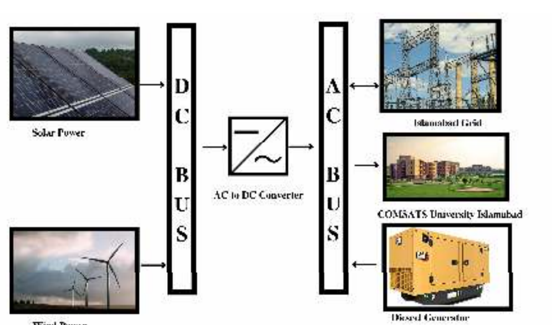


Figure 2. Proposed Hybrid power system for COMSATS University

## 2. Literature review

A literature review was conducted with the sole aim of establishing knowledge gap regarding designing the complete system and examining the performance of different grades of PV penetration at operating states. This helped in precisely quantify the characteristics of PV integration using HOMER. The review extends to the different configurations of the hybrid renewable energy systems for electric power generation. The strategies adopted for energy management attracted some attention for use in smart grids. The implementation of fuzzy logic systems was noted to attain energy management strategies. The investigation extended to the effectiveness assessment of hybrid PV–Wind–Diesel Battery configuration, which relied on hourly measurements of Adrar climate (southern Algeria) (Sarraj et al. 2020). The development of the hybrid configuration ascertains improved fuel saving at the same time maximizing renewable electricity use as an objective. The Homer software was used for design and simulation of hybrid system for research center in Iraq (Das and Zaman, 2021). It also used in Australia by taking climate of five different zones and design the system (Odou, Bhandari, Adamou, 2020). In Africa, (Benin) hybrid off grid system was design for rural area (Srivastava et al., 2016) In South Korea,(Suncheon), for offshore area hybrid system including solar and wind was design using Homer. In India, at Gorakhpur hybrid system was design for electrical department for Madan Mohan Malaviya University of Technology.

In 1993, the National Renewable Energy Laboratory in the United States made the software called HOMER. It is used to measure how well both systems work when they are connected to the grid and when they are not. HOMER does three things: first, it simulates, then it optimises, and finally, it does a sensitive analysis. In the simulation process, HOMER models the hybrid system for each hour of the year to find out if it is technically possible and how much it will cost over its whole life. HOMER figures out how much energy is needed and how much is available for each of the 8760 hours in a year. Then, HOMER figures out if a configuration is technically possible and estimates how much it will cost to install and run the system over the life of the project. During the optimization process, HOMER simulates all possible system configurations and shows a list of configurations that meet the technical constraints and are ordered by their Net Present Cost (NPC). The following equation is used by HOMER to figure out the total net present cost..

$$NPC = \frac{C_{tot}^{ann}}{CRF(i, Rp)} \tag{1}$$

where, NPC is the total annualized cost ($), i refers to the annual real interest rate (%) and Rp stands for the project life time in years.

## 3. Methodology

*3.1 Site Description*

COMSATS stands for the Commission on Science and Technology for Sustainable Development in the South, and it is an organisation that operates on a global scale. Through the implementation of beneficial applications of science and technology, it seeks to narrow the ever-widening gap that exists between the developed and developing worlds. The Third World Academy of Sciences (TWAS), which was led by Dr. Abdus Salam, a winner of the Nobel Peace Prize, was the organisation that first proposed the idea of COMSATS being established. The coordinates 33.6518 degrees north and 73.1566 degrees east are associated with COMSATS, which is located on Park Road in the Islamabad capital territory of Pakistan. The monsoon and the Western Disturbance are the two primary factors that are responsible for the changes in weather that occur in Multan; other than those two factors, continental air predominates throughout the rest of the seasons. Islamabad has a climate that is a typical example of a humid subtropical climate, and it has five distinct seasons: winter (November–February), spring (March and April), summer (May and June), rainy monsoon (July and August), and autumn (September and October). (September and October)

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*3.2 Resources Assessment*

Solar and wind are considered are the primary renewable energy sources. Solar radiation and the wind speed are obtained from the NASA Surface Metrology using Homer Pro software.

*3.2.1 Solar*

Solar Energy Irradiance and NASA Surface Meteorology data have been utilized in this research, due to the exact site latitude and longitude, the average level of solar radiation for the site is 4.35 kwh/$m^2$/day. The solar peak months are April to July. The range of solar radiations is 3.2-7.2 kwh/$m^2$/day. The average solar radiation on site can be seen in figure 3.

Hour angle (H) is calculated using

$$H = 15 \text{ deg x (time} - 12) \tag{2}$$

Time is the number of hours since midnight. Calculating the zenith angle (Z) involves

$$Z = Cos^{-1} (Sin X Sin Y + Cos X Cos Y Cos H) \tag{3}$$

The angle between the point directly overhead and the point where the sun is located in the sky is known as the zenith angle. Where Latitude, X Y: angle of solar declination H: the angle of the hour The solar declination angle is the angle formed by the earth's axis of rotation and the plane perpendicular to the incoming solar radiation. On the summer solstice, the solar declination angle is +23.5° deg, on the winter solstice, -23.5° deg, and on the vernal and autumnal equinoxes, it is (I) deg. The formula below can be used to calculate solar insolation (I).

$$I = S \cos Z \tag{4}$$

Where S is the solar constant, which is approximately 1000 W/m$^2$Z, according to the equation above.With the knowledge of latitude and the day of the year, the maximum amount of solar insolation on a surface at a particular tilt angle can be calculated using the equation of the sun's position in the sky throughout the year. Additionally, in order to use experimental data from sunshine hour recorders, these calculations are required..

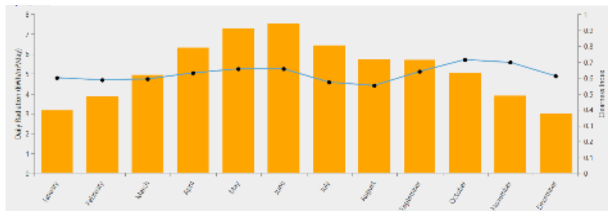

Figure 3. Average solar radiations on site

*3.2.1 Wind*

NASA Surface Meteorology data of wind speed applied by this paper depend on the site latitude and longitude. The average wind speed on site can be seen in figure 4. The simple formula for wind pressure P in imperial units (pounds per square foot) is

$$P = 0.00256\ V^2 \tag{5}$$

where V represents the wind's velocity in miles per hour (mph). Instead, use P = 0.613V$^2$, and measure V in metres per second to determine the pressure in SI units (Newtons per square metre). for our system the annual average wind speed has been calculated as 5.42 m/s.

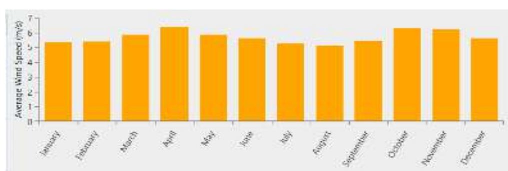

Figure 4. Average wind speed on site

*3.3 Component Schematics*

Both non-renewable (DG) and renewable (solar, wind, and hydro) energy sources are taken into consideration. The battery serves as a storage device. Due to the presence of both AC and DC components, a converter is included to act as an interface between the two currents, enabling the AC load to be supplied first before the batteries are charged. Figure 5 shows the schematic of Hybrid system model in Homer Pro software.

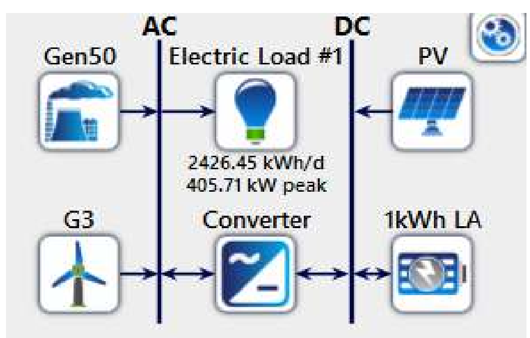


Figure 5. Schematic model for Hybrid system in Homer

*3.4 Load Profile*

The average electrical load of the center was calculated. It was observed that the maximum electric load recorded was in the summer period. Whereas winter is the lowest level of electric load. On the other hand, the average daily electrical base line load was about 2426.4 kWh/d over a full year, while 150kW recorded as the maximum for electric load. The Figure 6 shows daily load profile for January.

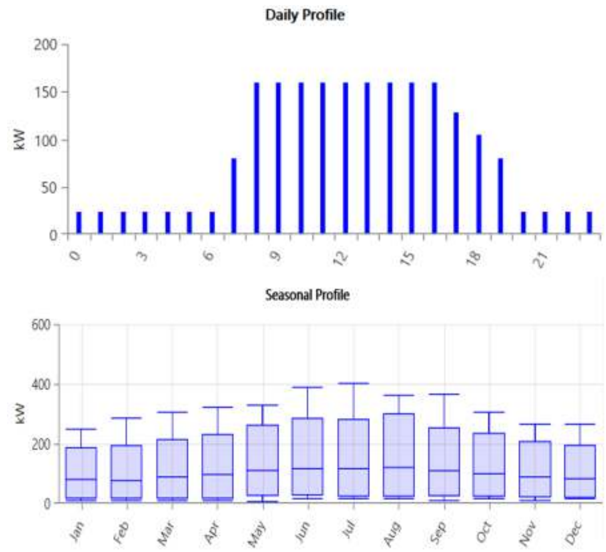


Figure 6. Daily load profile and seasonal load profile

*3.5 Components and performance characteristics*

It includes the cost summary, operational and maintenance cost, life time of components used in the system like PV panel, Generator, Wind turbine etc. PV panel cost obtained from market 2500$. Temperature effects on PV module are modelled in Homer. The PV array sizes of 1kw are considered. Wind turbine of 10kw with height of 100m are used. The cost of the turbine is obtained from market. Diesel Generator (DG)(25kw) of caterpillar company having capital cost obtained from capital market is 44630.7$. The operational and maintenance cost is 3% of capital cost. Cost of diesel is 1$/L. Lead acid batteries of 83.4Ah/12V types are used for this study with throughput of 1kWh. Maximum charge current is 16.7A and efficiency is 80%. The cost of the battery is obtained from solar systems market. The nominal discount rate is 8%, the inflation rate is set to be 13% and lifetime of project is set to be 25 years. The cycle charging (CC) delivery strategies have been considered. The generators will operate at full capacity in the CC strategy and the battery bank will be charged using excess power.

## 4. Results and discussion

The three components of the output of the optimization are the architectures, costs, and some system variables. The most effective controller strategy depends on the configuration, whether it be CC or LF. 5 are carefully examined, including: Solar/DG/Battery, Wind/Solar/DG/Battery, Solar/Battery, Wind/Solar/Battery, Wind/DG/Battery as shown in Figure 7. Project lifetime of 25 years.

| PV (kW) | G3 | Gen50 (kW) | 1kWh LA | Converter (kW) | Dispatch | COE ($) | NPC ($) | Operating cost ($/yr) | Initial capital ($) | Ren Frac (%) | Total Fuel (L/yr) | Hours | Production (kWh) | Fuel (L) | O&M Cost ($/yr) | Fuel Cost ($/yr) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,207 | | 50.0 | 2,661 | 380 | CC | $0.629 | $5.45M | $152,745 | $3.95M | 74.2 | 70,823 | 5,066 | 228,805 | 70,823 | 7,599 | 70,823 |
| 1,504 | 4 | 50.0 | 1,243 | 384 | CC | $0.640 | $5.55M | $122,787 | $4.34M | 75.6 | 67,170 | 4,911 | 216,363 | 67,170 | 7,366 | 67,170 |
| 1,809 | | | 4,682 | 577 | CC | $0.835 | $7.23M | $115,501 | $6.10M | 100 | 0 | | | | | |
| 1,973 | 5 | | 3,983 | 457 | CC | $0.850 | $7.37M | $103,495 | $6.35M | 100 | 0 | | | | | |
| | 338 | 50.0 | 19,875 | 438 | CC | $2.05 | $17.8M | $568,320 | $12.2M | 71.0 | 78,840 | 5,266 | 256,963 | 78,840 | 7,899 | 78,840 |

Figure 7. Optimize result of Hybrid power system using Homer

Based on these parameters, the hybrid Solar/Battery/DG system has the lowest Net Present Cost NPC of all the system architectures at $5.45M. The Cost of Energy COE, initial capital cost, and Operation and Maintenance O&M costs are $0.629, $3.95M, and $152745, respectively. It's important to note that none of these various costs include any grants or other forms of funding. Due to its lower COE, the system Solar/Battery/DG is more economical than PV/DG/Wind/Battery. The system has a 95% penetration of renewable energy.

*4.1 Economics*

By comparing with the system economics, the feasible system for electricity is Solar/Battery/DG, The present worth of system is $4,660, amount receives in return on investment is 32.4% and the cost of our project is completed in 4.91 years. The economics of system can be seen in Figure 8.

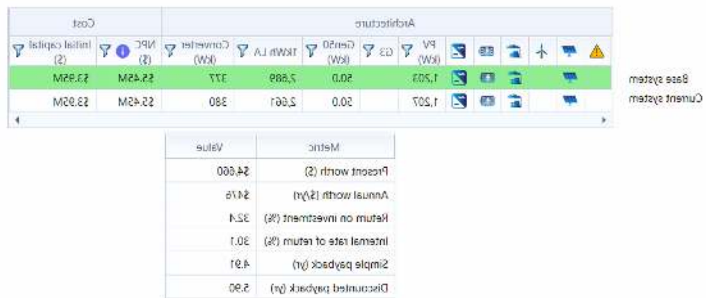


Figure 8. Economics of system

*4.2 Electrical perspectives of system*

Figure 8 shows the electrical statistics of system, 90.5% produced from solar and 9.5% from DieselGenerator to meet demand. The excess electricity receives is 59.8%. the overall load is 825366 KW. The renewable fraction 72% which means our 72% of our load will be on our renewable sources i.e, solar, wind and batteries.


Figure 9. Electrical statistics of system

The carbon emission from DG IS 98091kg/yr, SO2 emission is 240kg/yr, NO emission is 575kg/yr as shown in table no 1.

Table 2. Emissions of gases

| Quantity | Value | Units |
|---|---|---|
| Carbon Dioxide | 98.091 | Kg/yr |
| Carbon Monoxide | 612 | Kg/yr |
| Unburned Hydrocarbons | 27.0 | Kg/yr |
| Particulate Matter | 3.67 | Kg/yr |
| Sulfur Dioxide | 2.40 | Kg/yr |
| Nitrogen Oxides | 575 | Kg/yr |

*4.3 Cost Summary*

Figure 10 shows the overall cost summary for distributed COMSATS University Islamabad which contain diesel generator, PV, Lead acid batteries, System converter. The total cost contains capital value, replacement, Operation and maintenance (OM), fuel cost and salvage value in dollars. For lead acid batteries the total cost will be $1340136 which contain no fuel charges. Similarly, the total cost for 50KW fixed generator set $860037.91. for Generic flat PV plate which contain no any replacement charges, fuel charges and salvage value the total amount for PV plates will be $3134660.45. the system converter cost will be $113992. The most of the load will be produced by PV panels.

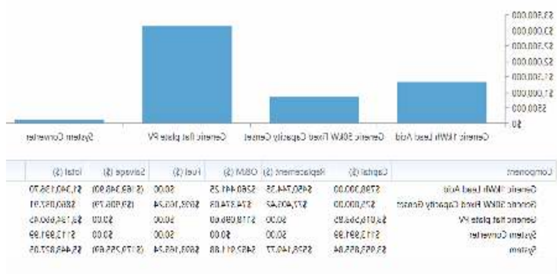

Figure 10. Overall cost summary for distributed COMSATS University Islamabad

## 5. Conclusion

In this paper, the conclusion is that for design of COMSATS University Islamabad, the Solar, DG and battery system is sufficient. Because of its net present cost and initial capital cost. By using the Homer software, the system covers its cost within 7.6 years. No need of wind power plant and grid. After 25 years the system gives the salvage value. Future research is described for the following aspects:

| *Research Area* | *Description* |
|---|---|
| Field Testing | Conducting field testing to validate the simulation results of the hybrid power system design. |
| Optimization of Battery Storage | Optimizing the size, type, and number of batteries used in the hybrid energy system to maximize efficiency and reduce costs. |
| Integration of Smart Grid Technologies | Exploring the potential benefits of integrating smart grid technologies such as energy storage management systems, demand response systems, and advanced metering infrastructure. |
| Environmental Impact Assessment | Evaluating the environmental impacts of the hybrid power system and identifying ways to reduce its carbon footprint. |
| Economic Viability Analysis | Conducting a thorough economic analysis that takes into account the lifecycle costs of the hybrid power system, including capital expenditures, operation and maintenance costs, and replacement costs. |
| Integration of Other Renewable Sources | Exploring the potential benefits of integrating other renewable energy sources such as solar or biomass into the hybrid power system to increase its efficiency and reliability. |

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**Biographical notes**

**Amir Rashid, Muhammad Ehsan and Javid Rashid** are of the Department of Electrical and Computer Engineering, COMSATS University Islamabad, Pakistan