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Feasibility Study and Deployment of Solar Photovoltaic System to Enhance Energy Economics of King Abdullah Campus, University of Azad Jammu and Kashmir Muzaffarabad, AJK Pakistan

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ABSTRACT As non-renewable energy sources become depleted, the world is transitioning toward renewable energy sources (RERs), which entail several significant advantages, including cost savings, large-scale availability, and minimal losses. Pakistan is sixth among the countries most affected by global warming and abrupt climatic changes. Severe floods, catastrophic rains, and wind gusts have created new challenges in the country regarding resilient and reliable power supply. Due to harsh weather conditions, the power shut down, blackouts, and prolonged fault in the transmission systems are common and cause millions of dollars in economic losses annually. The main challenge of providing a reliable power supply while satisfying the climatic conditions to use renewable energy resources has a global significance. This article aims to develop a hybrid power network (PV/Battery/Grid) for King Abdullah Campus, The University of Azad Jammu and Kashmir, Muzaffarabad, Pakistan. The results for the proposed system are compared with the existing system while they are supplying the same power to the load. The cost of energy (COE) from the existing on-grid Hybrid system is Rs.27.32/kWh. It can be seen that energy cost is minimized by up to Rs.0.251/kWh by the effective use of solar energy. Optimization results conclude that the on-grid hybrid (PV/Battery/Convertor/Grid) is more efficient than all other configurations. Therefore, it is concluded that the proposed hybrid power system for grid-connected sites is most efficient, stable, cost-effective, and environmentally friendly. The ultimate goal was to design an economically feasible hybrid power system and analyze the techno-socio impacts of the PV hybrid system for the campus. Data were initially collected for the desired site and then simulated via the HOMER simulation tool, which determined the net load and feasibility of the proposed system. This techno-economic analysis of the PV hybrid system will enhance the utilization of solar power in other educational or commercial facilities in the region may follow the path in the future.

INDEX TERMS Renewable energy sources, solar energy, HOMER, hybrid, diesel generator, grid.

I. INTRODUCTION

A. GENERAL

Electricity has become an essential parameter for the socio-economic development of the country. Due to technological and economic development, developing countries like Pakistan need more energy than they can produce to meet the growing energy demand. Consequently, these countries are facing energy shortages, and they need economical solutions to meet the energy deficit. Our planet's fossil fuel reserves are declining [1] day by day. This was considered inevitable at the turn of the century, and when that happened, electrical tools

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around the world would begin to rely on renewable energy resources (RERs) [2]. Research is seriously concerned with exploring the potential for renewable energy generation in each area, as it may help develop trends in the utilization of such resources in a given area [3]–[5]. Pakistan could be an area where researchers can explore renewable energy potential and its political aspects [6]–[8].

Although there are alternatives to RERs, if changes are to be significant, research should focus on eliminating such variations [9]. As a result, renewable energy is increasing the share of the energy production services market, and hence the distribution production system [10]–[13]. It encourages the usage of renewable energy (RE) with various hybrid energy configurations and energy storage technologies [14], [15]. The solar photovoltaic (PV) system is thought to be the most acceptable solution of energy than the other RERs [16]. The PV system is primarily centered on energy-saving and carbon dioxide (CO2) emission-reduction strategies.

Being a poor and densely populated country, Pakistan needs a consistent source of energy to keep its growth on track and offer a decent standard of living for its population [17], [18]. In contrast, the state cannot meet its primary energy needs and is experiencing a power crisis. The power sector is one of the sectors that have affected far more energy shortfall. Outages cover the difference between load and demand, and the nation is sometimes plunged into darkness for more than 12–14 hours every day [19], [20]. This situation which the country is experiencing did not happen suddenly. The main reason for this disaster may be traced back to years of mishandling, bad planning, and incompetence [21], [22].

The United Nations' new Sustainable Development Goals (SDGs) call for efforts that combine environmental protection with economic growth. The capacity of renewable energy to alleviate the effects of Carbon dioxide emission on socioeconomic development in thirty-one transitional markets is investigated in this study [23]–[26]. The findings back up the following claims: (i) Emissions of carbon dioxide have unmistakably negative repercussions for economic growth and human prosperity, and (ii) the overall implications of the interaction of sustainable energy and CO2 emissions on human socioeconomic development [27]–[31]. The government now confronts enormous challenges in guaranteeing its future energy sources. In these circumstances, attempts to investigate renewable energy sources to satisfy the government's deficit scenario have been stepped up.

Furthermore, all renewable energy sources, including photovoltaic (PV), biogas, wind, electricity, bioenergy from waste, and small and micro-hydropower, have tremendous potential in Pakistan. Pakistan, likewise, has solar irradiation of 5.5 Wh/m^2 per day with an average annual sunshine duration of 8–10 hours. Winds of 5–7 meters per second continue to blow near the coasts of Baluchistan and Sindh provinces, with the potential of creating more than 20,000 MW of economically viable wind power [32]–[34]. Renewable energy is becoming more popular worldwide, but Pakistan is still lagging in utilizing these abundant resources [35]–[38].

The waste heat to electricity company continues to have the capacity to generate large amounts of smooth strength in Pakistan, allowing it to overcome Pakistan's power deficiencies [39]–[41]. Researchers may be able to examine the potential of RE and its socio-economic implications in Azad Jammu and Kashmir. Solar power is one of the clean energy sources that does not harm the environment or contribute to global warming. Pakistan's estimated capacity is 1,600 GW per year, forty times greater than the projected energy generation potential [42].

Global warming has caused a significant rise in the temperature over the years that has changed the climatic conditions of the entire world. The climatic changes have brought new challenges in the shape of heavy rains, flooding, and heavy cyclones generally in the entire world and, more specifically, the countries most vulnerable to abrupt climatic changes.

On the other hand, to deal with global warming, swift mobility towards renewable power generation is the top priority at the global level. Thus, a global research question among the research community is how to make the power system more resilient and reliable while utilizing the renewable energy resources under the prolonged and harsh weather conditions that cause faults and blackouts.

Pakistan is at the sixth spot among the countries that are affected by global warming and abrupt climatic conditions. Severe floods, catastrophic rains and wind gusts have created new challenges in the country in terms of resilient and reliable power supply. Due to harsh weather conditions, the power shut down, blackouts, and prolonged fault in the transmission systems are common that cause millions of dollars in economic loss to the country annually. The local challenge of providing a reliable power supply while satisfying the climatic conditions to use renewable energy resources has a global significance.

This research article is aimed at developing a resilient hybrid power system using renewable energy resources to address the local challenge of reliable and resilient power systems that provide power under the prevailing weather conditions and to reduce the blackouts and prolonged faults which badly affect ongoing lab experiments and equipment, besides routine administrative and academic work of the King Abdullah Campus (KAC), University of Azad Jammu & Kashmir (UAJ&K).

B. RESEARCH CONTRIBUTION

This article explores the problem of lack of resilience in the hybrid power system using BSS systems PV, and diesel generator with the ultimate impact of mitigation in brownouts and power cuts in the AJK area of Pakistan. The case study particularly focuses on King Abdullah Campus at UAJ&K for this exploratory research. Hybrid power systems are considered a panacea for solving the problems of power shortages the world over, specifically in context of developing countries

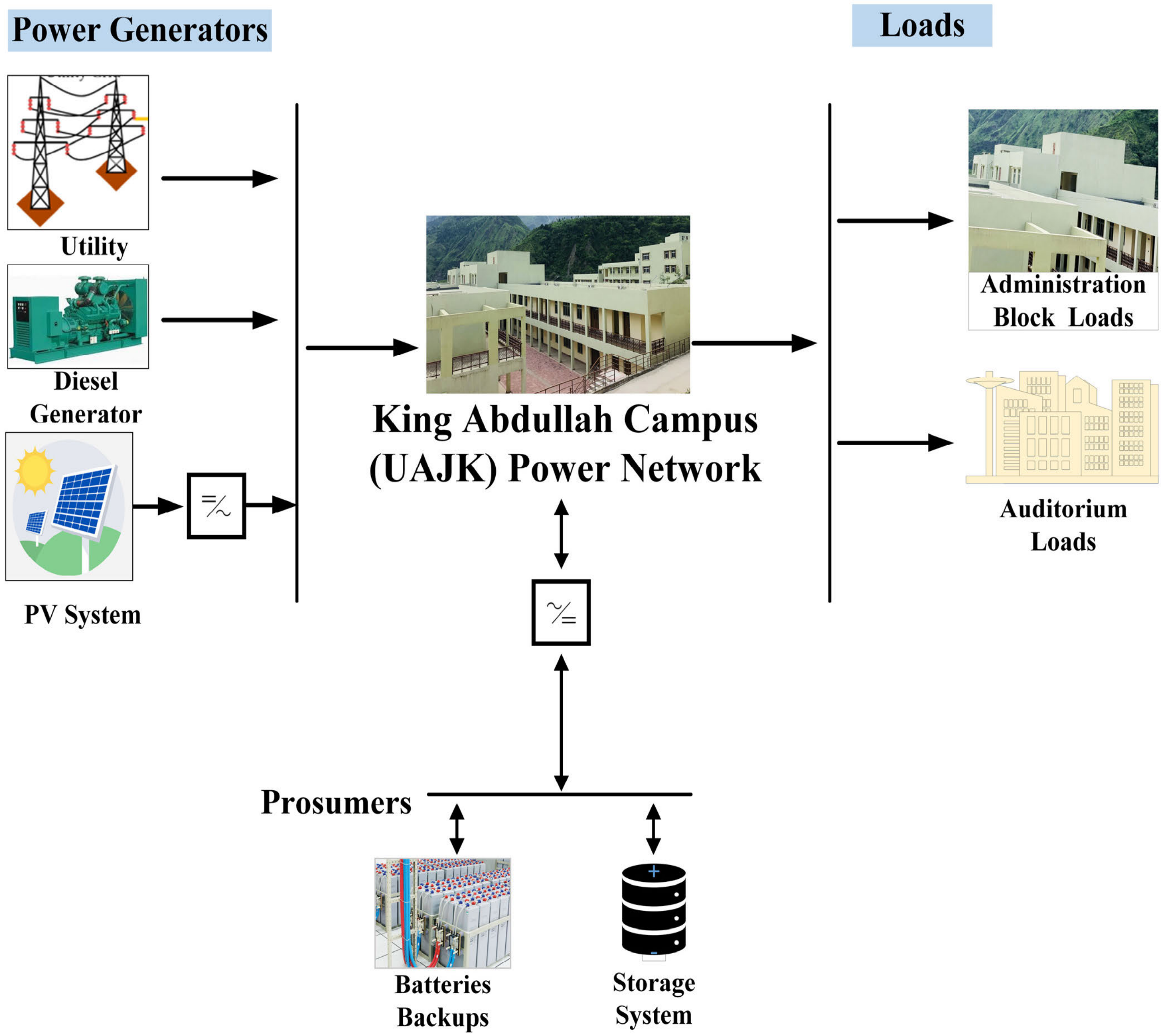

FIGURE 1. Proposed hybrid power system of king abdullah campus UAJ&K.

where power systems are not resilient enough. In this backdrop the power quality and economics of the system development takes center stage in addition to the system sizing and optimal operation. The main goal, thus, is to design a system which is economically feasible and then analyse the sociotechnical impact of the hybrid system on the community. This is done through a comparison of the current system with the proposed hybrid system. The proposed system is illustrated in Figure 1. The mix of social, economic, and technical system incorporates the following factors:

- PV hybrid system will alleviate the problem of power shortage hence facilitating the uninterrupted power supply for teaching, administration, and experimental activities at the campus.
- Since this technology is relatively unproven in AJK region, this research also provides additional real-world performance optimization for PV hybrid system and provides a guideline on energy-efficient, sustainable, and cost-effective design of PV for other educational or commercial facilities in the region, thereby providing a pathway to greater utilization of this technology.
- Determine the environmental and socio-economic impacts of solar power.
- The viable model design is established by extensive analysis in terms of cost reduction with low emissions.

The proposed PV hybrid system is designed via simulation tool HOMER microgrid. HOMER software is used for design optimization of microgrids in remote sites, islands, grid-connected sites, and isolated voltage. HOMER defines the quantity and suitable size and quantity of components for designing a power system. It is not easy to decide on the most suitable energy resources and their availability and cost variation. HOMER makes it easy to calculate the best possible system configuration by optimization and sensitivity analysis.

II. SITE DESCRIPTION

The study area here is King Abdullah Campus, The University of Azad Jammu and Kashmir, located in Muzaffarabad, Pakistan, which contains a hilly and plane area. There are two main types of sites: grid and off-grid site. The region where electricity from a grid source does not exist is called an off-grid site, and the area where electricity is available is called on grid site. Muzaffarabad is the capital of Azad Jammu & Kashmir, where off-grid and on-grid systems are under consideration. Latitude and Longitude of Muzaffarabad are 34N and 73E separately with time zone (UTC+05.00) Islamabad, and figure 2 portrays the area of the local destinations.

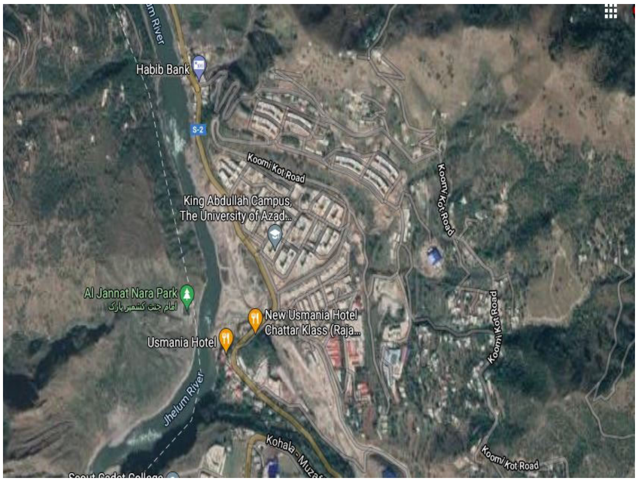

FIGURE 2. Site description.

A. OBJECTIVES

Pakistan is facing acute energy crises for the last two decades, which have become a bottleneck for the industrial, commercial, domestic, and educational sectors. In this scenario, sustainable and clean energy supply such as solar PV is a promising technology considering Pakistan's abundant solar potential. However, system sizing and performance optimization of the PV hybrid systems for Pakistan's conditions are very important in terms of economics and power quality. Hence, the ultimate goal is to design an economically feasible PV hybrid system and analyze its techno-socio impacts for King Abdullah Campus, The University of Azad Jammu & Kashmir, Muzaffarabad, Pakistan.

B. AVAILABILITY OF RENEWABLE RESOURCES

After the estimation of load, accessibility of RERs is examined for King Abdullah Campus, The University of Azad Jammu and Kashmir Muzaffarabad, Pakistan. There are many sources of energy, present at the site but it is most suitable for solar energy. All other sources are seasonal but solar energy present all over the year. However, after analyzing all the results we come to know solar is best source.

C. SOLAR RESOURCES

NASA's data on solar irradiation for the required area is used for the whole year. Data has been obtained from (July 1983 - June 2005). HOMER obtains all the necessary data from NASA's website. Global horizontal irradiance, clearance index, and temperature are the three primary components of solar radiation data. Figure 3 shows the monthly average worldwide horizontal irradiance as well as the clearing index. The monthly average PV radiation and clearness index are shown in Table 1. According to Table 1, the minimum amount of solar radiation in January is 2.95KWh/m2, while the highest value is 7.460 kWh/m2 in June. The annual average solar irradiation is 5.08 kWh/m2, making it excellent for PV system design.

TABLE 1. Clearness index, radiation and temperature.

MONTH	C-INDEX	RADIATION	TEMP
JAN	.568	2.950	5.450
FEB	.548	3.570	7.030
MAR	.549	4.550	12.040
APR	.588	5.880	17.700
MAY	.630	6.990	23.630
JUN	.647	7.460	27.430
JUL	.585	6.600	26.430
AUG	.573	5.940	24.460
SEPT	.644	5.700	22.030
OCT	.696	4.890	17.270
NOV	.674	3.690	12.150
DEC	.583	2.790	7.840
Average	.607	5.08	16.96 °C

The clearness index, which measures the proportion of sun rays that reach the earth's surface, has been used to measure the atmosphere's clarity. The solar index has a lower value on overcast days than bright days. Solar energy utilization is possible, as shown in Figure 3 of the clearness rating. Figure 4 shows that the average temperature for June is relatively high, but the average temperature for the winter season is relatively low.

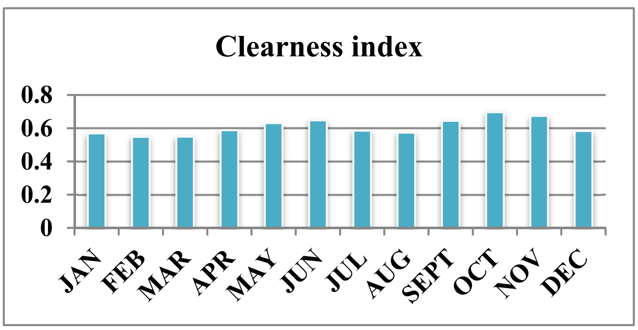

FIGURE 3. Characteristics of radiation and clearness index.

The average monthly temperature at King Abdullah Campus (KCA), UAJ&K Muzaffarabad, Pakistan, ranges from 5°C to 27°C, as seen in the graph below. The highest temperature is in June, the lowest in January, and the annual average temperature is 16.96 degrees Celsius.

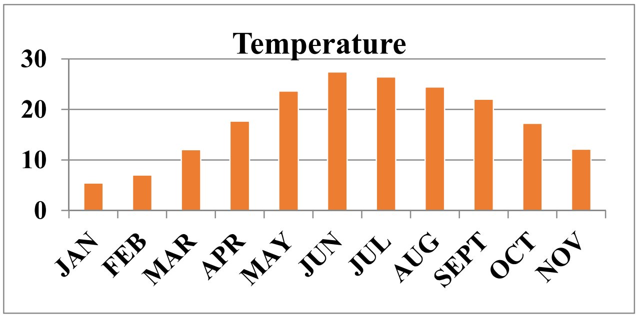

FIGURE 4. Characteristics of temperature.

D. INITIAL ASSESMENT

According to proper functioning, efficiency, and cost scenario, initial assessments for the power system are checked. The building is connected to a grid, and during load shedding special generator of 220KW is used. So that generator has a huge running and maintenance cost. The generator also emits a huge amount of polluted gases that are not environmental friendly. We have to take such a step that can reduce the cost of power generation and be reliable enough to run a load of Building during Load shedding.

HOMER determines various types of costs associated with the project such as capital cost (CC), replacement cost (RC), net present cost (NPC), cost of electricity (COE), operation & maintenance cost (OMC), and salvage value (SV). The economic feasibility of the proposed model can be evaluated with the help of these costs. The NPC of the system can be formulated as follows in equation (1).

$$NPC = \frac{TAC}{CRF} = CC + RC + OMC - SV \tag{1}$$

E. INITIAL CAPITAL COST

The total cost of all the components, including their installation cost, is called the system's capital cost. For a Hybrid power system, capital cost includes all the features of PV solar cell, Diesel engine, batteries, and initial convertor cost.

$$NPC = CC + RC + OMC + FC - SV \tag{2}$$

F. OPERATING COST

The operational cost is the expense that is essential for the overall running of a power system. It is also known as the operating cost. Different power systems have varied operational expenses depending on the active principles and practices. Compared to diesel and thermal power facilities, hydro and nuclear power systems offer lower operating costs. Similarly, all the infinite sources like sun-based, wind, etc. have low operational costs. Those resources having low operational cost are mostly preferred for energy production.

$$D_{grid} = \begin{cases} 0 & D \leq E_{gen} \\ D - E_{gen} & D \geq E_{gen} \end{cases} \tag{3}$$

G. NET PRESENT COST

Net present cost offers the main role in the cost calculation of a system. HOMER offers a high rank to NPC amongst the other cost standards. Overall, cost calculation can be tested by NPC. HOMER includes all types of costs for calculating NPC like functional cost, installation cost, replacement cost, maintenance cost, emission punishments, and energy cost throughout the task's life. NPC value should be small for a cost economic system, and if the value of the NPC is high, then it shows the system is uneconomical. The total NPC in a year is called the total annual cost. It is expressed as:

$$NPC = \frac{\left[i\,(1+i)^N - 1\right] Cann,\,tot}{1-(1+i)^N} \tag{4}$$

where i is represented the real discount rate, N is represented as the number of years in the project lifespan, and $C_{ann,tot}$ is the total annualized cost of all the system components. $C_{ann,tot}$ is expressed as follows:

$$C_{yr} = CRF\left(i, R_{plant-life}\right) \times C_{NPC,Total} \tag{5}$$

H. THE COST OF ENERGY (COE)

We mean the COE per unit of electrical energy, which is defined as the cost per kWh. The HOMER software calculates the average cost/kWh. Cost criteria are also available. The cost of energy, efficient, and cost-effective power systems with minimal energy costs is given in equation 6.

$$COE = \frac{C_{yr,total}}{AC_{load} + DC_{load}} \tag{6}$$

III. EXISTING POWER SYSTEM

Nonrenewable resources (RE) are those that the earth cannot reproduce. A diesel generator is an example of a nonrenewable energy system. The existing electricity grid is seen in Figure 5. The system is connected to the grid, and a 220KW generator is operated during load shedding hours. The diesel generator is coupled to the AC bus to supply direct electric power to the load. In Pakistan, the price of diesel is approximately Rs.125 per liter, and when the cost of fuel transportation is included, the total price of diesel rises.

During the load shedding hours, 220 KW generators run all the load of the system; during the usual situation on grid supply runs all load.

A. DETAIL DATA OF EXISTING SYSTEM

1) ELECTRICITY CONSUMPTION DEVIATION

The annual energy purchased from the grid is 338,892 kWh, and the yearly power sold to the grid is 2,420 kWh. This microgrid requires 1006 kWh/day and has a peak of 200 kW. In the proposed system, the following generation sources

TABLE 2. The yearly purchase and sale of energy.

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Load (kW)	Energy Charge	Total
January	26,334	1,265	25,069	150	Rs0.00	Rs0.00
February	21,799	0	21,799	150	Rs0.00	Rs0.00
March	23,979	0	23,979	150	Rs0.00	Rs0.00
April	32,443	1,155	31,288	200	Rs0.00	Rs0.00
May	34,268	0	34,268	200	Rs0.00	Rs0.00
June	31,288	0	31,288	200	Rs0.00	Rs0.00
July	32,778	0	32,778	200	Rs0.00	Rs0.00
August	34,268	0	34,268	200	Rs0.00	Rs0.00
September	29,798	0	29,798	200	Rs0.00	Rs0.00
October	25,069	0	25,069	150	Rs0.00	Rs0.00
November	23,979	0	23,979	150	Rs0.00	Rs0.00
December	22,889	0	22,889	150	Rs0.00	Rs0.00
Annual	338,892	2,420	336,472	200	Rs8.41M	Rs8.41M

TABLE 3. Component of existing system.

Component	Name	Size	Units
Generator	Auto size Genset	220	kW
Grid	Grid	999,999	kW
Dispatch Strategy	HOMER Load Following		

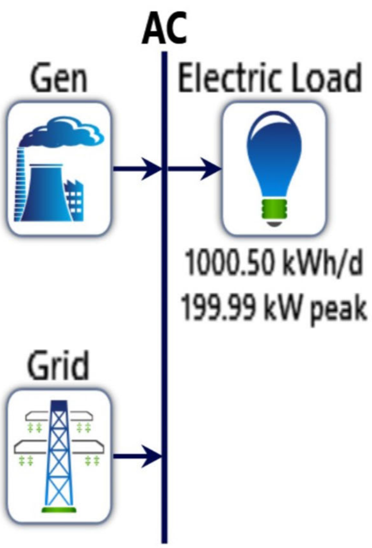

FIGURE 5. Schematic diagram of existing system.

serve the electrical load. The yearly purchase and sale of energy are given in Table 2, and annual production is shown in figure 6.

Table 3 describes the current system's size, including a grid supply and a 220KW generator utilized to meet load demand during load shedding hours.

Figure 7 depicts a cost summary of all the components in the existing system. All of the costs are represented in the picture with different color schemes.

Table 4 displays the net present cost of all components and the overall system.

The annualized cost of the existing system is shown in Table 5.

Table 6 depicts the generator properties in the existing setup.

Table 7 displays the generator's fuel consumption summary in the existing summary.

Table 8 describes the generator's operational characteristics.

Table 9 helps to explain the generator's fuel consumption characteristics.

Table 10 depicts the polluted gas emissions produced by the generator in the present system.

IV. PROPOSED POWER SYSTEM

Renewable energy resources are widely present in Pakistan. According to the feasibility study, solar energy has enormous potential for the examined location, and solar energy is employed as a renewable energy source in this suggested work. Solar power and storage system is used in combination with on-grid systems is shown in figure 8.

During the Load shedding Hours, electricity is provided through a diesel generator, having substantial operational costs. The complete structure of the project is shown in Fig. 9.

In the presence of the enormous potential of energy, extra energy will be stored in the batteries. This excessive energy can be used when the production of the solar panel is less. In the proposed system, grid and solar energy are used to run the load under normal conditions, as shown in figure 8.

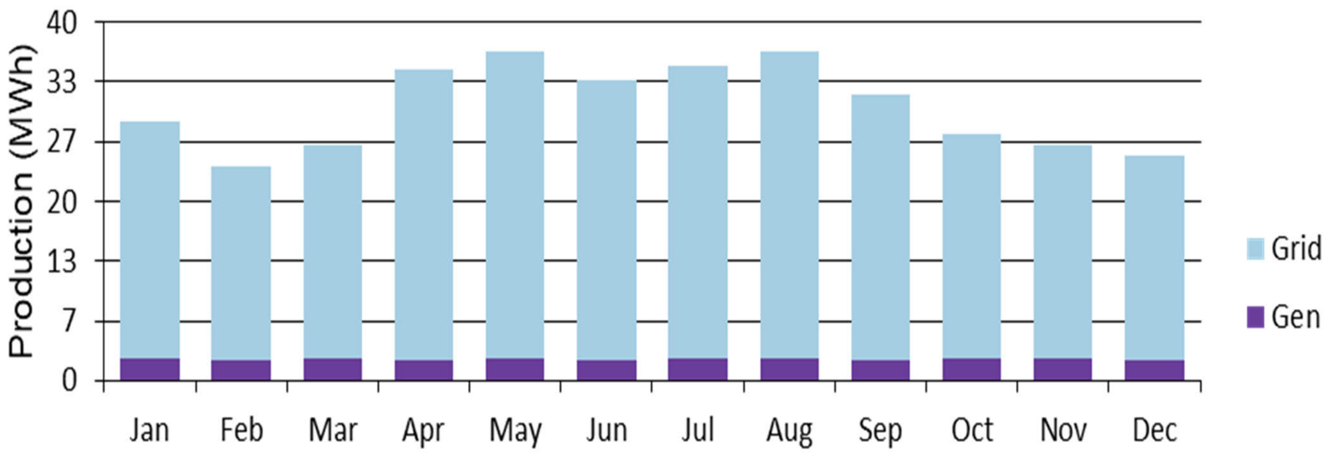

FIGURE 6. Annual energy production.

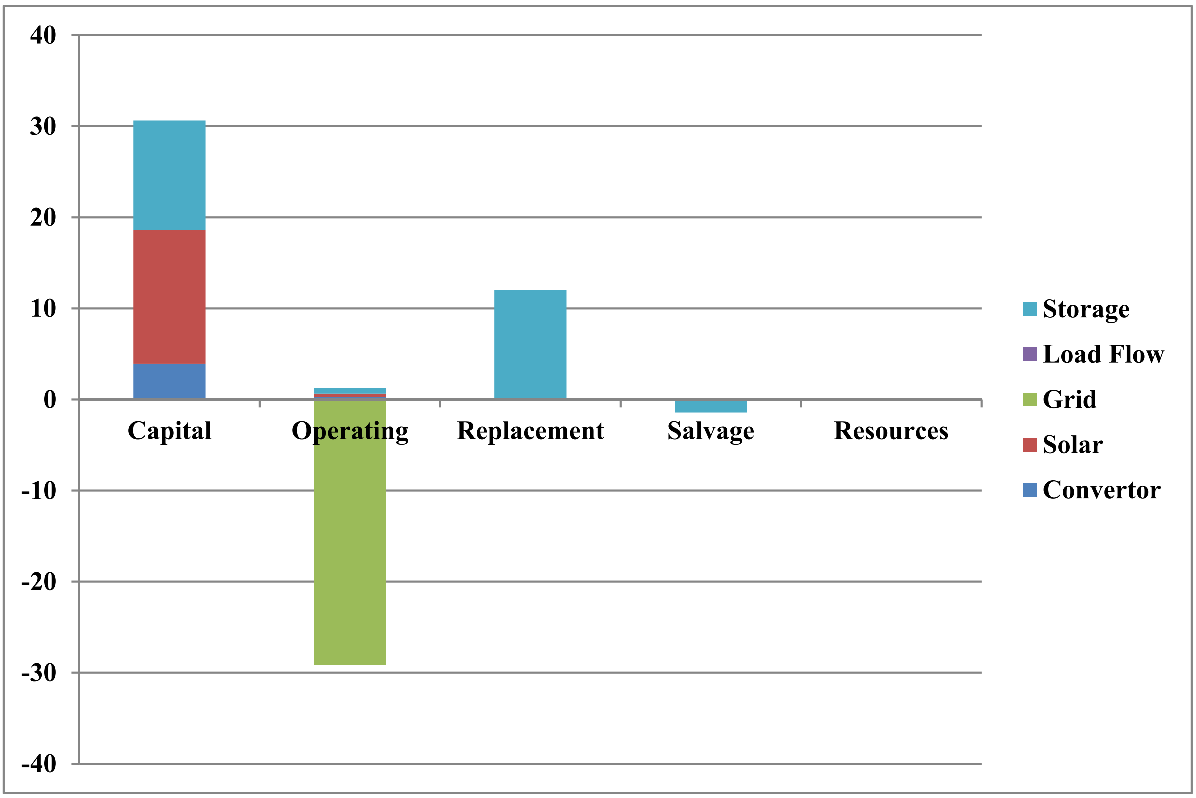

FIGURE 7. Cash flow.

TABLE 4. Net present cost.

Name	Capital (Rs)	Operating (Rs)	Replacement (Rs)	Salvage (Rs)	Resource (Rs)	Total (Rs)
Auto Size Genset	4.40 M	2.97 M	0.00	0.00	13.7 M	21.1 M
Grid	0.00	109 M	0.00	0.00	0.00	109 M
System	4.40M	112 M	0.00	0.00	13.7M	130 M

A. PROJECT DESCRIPTION

The Administration Block of King Abdullah Campus, The UAJ&K AJK Pakistan, has vast solar energy potential. Load Demand of the University is approximately 300 KW, met through grid supply. The block diagram of the proposed model is shown in figure 9.

TABLE 5. Annualized cost.

Name	Capital (Rs)	Operating (Rs)	Replacement (Rs)	Salvage (Rs)	Resource (Rs)	Total (Rs)
Auto Size Genset	340, 359	229,680	0.00	0.00	1.06 M	1.63 M
Grid	0.00	8.41 M	0.00	0.00	0.00	8.41 M
System	340, 359	8.64 M	0.00	0.00	1.06 M	10.0 M

TABLE 6. Auto size genset electrical summary.

Quantity	Value	Units
Electrical Production	28,710	kWh/yr
Mean Electrical Output	55.0	kW
Minimum Electrical Output	55.0	kW
Maximum Electrical Output	55.0	kW

TABLE 7. Auto size genset fuel summary.

Quantity	Value	Units
Fuel Consumption	9,642	L
Specific Fuel Consumption	0.366	L/kWh
Fuel Energy Input	94,875	kWh/yr
Mean Electrical Efficiency	30.3	%

TABLE 8. Auto size genset statistics.

Quantity	Value	Units
Hours of Operation	522	hrs/yr
Number of Starts	261	Starts/yr
Operational Life	28.7	yr
Capacity Factor	1.49	%
Fixed Generation Cost	1,044	Rs/hr
Marginal Cost	26.0	Rs/kWh

TABLE 9. Diesel consumption statistics.

Quantity	Value	Units
Total Fuel Consumed	9,642	L
Avg Fuel per day	26.4	L/day
Avg Fuel per day	1.10	L/hour

B. MODELING OF PROPOSED SYSTEM THROUGH HOME FRAMEWORK

The proposed system makes use of the HOMER microgrid software. The term HOMER refers to a hybrid optimization model for electrical renewables. Determining the most appropriate energy resources is increasingly challenging due to the abundance and variability of energy sources. HOMER makes it easy to develop the best possible framework by incorporating optimization and sensitivity analysis.

TABLE 10. Emissions statistics.

Pollutant	Quantity	Units
Carbon Dioxide	239,419	kg/yr
Carbon Monoxide	159	kg/yr
Unburned Hydrocarbons	6.94	kg/yr
Particulate Matter	0.964	kg/yr
Sulfur Dioxide	990	Kg/yr
Nitrogen Oxides	604	Kg/yr

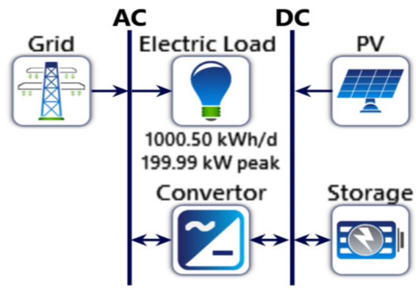

FIGURE 8. Schematic diagram of proposed system.

The HOMER software specifies how many, what size, and what grade of components are required to create a power system.

Start with the initial assessment; calculate the site load and rating of each load resource present on the site. After the initial assessment, HOMER takes the data, performs the techno-economic analysis, and generates the final results. The proposed framework of the HOMER operation is shown in figure 10.

C. LOAD ESTIMATION

The load data for the entire building is computed, and data is gathered for each room; the number of lights, fans, laptops, or other devices are carefully calculated. The daily load profile is shown in figure 11.

Grid-connected at King's Abdullah Campus, The University of Azad Jammu, and Kashmir Muzaffarabad, AJK Pakistan has a total load of 1000 kWh/d and peak load is 200 KW. Load of 1000kWh/d constantly used for 8 hours of the day, five days a week.

D. COST OF COMPONENTS

1) PHOTO VOLTAIC ARRAY

A photovoltaic array is a combination of PV modules that convert solar energy into electrical energy. The power

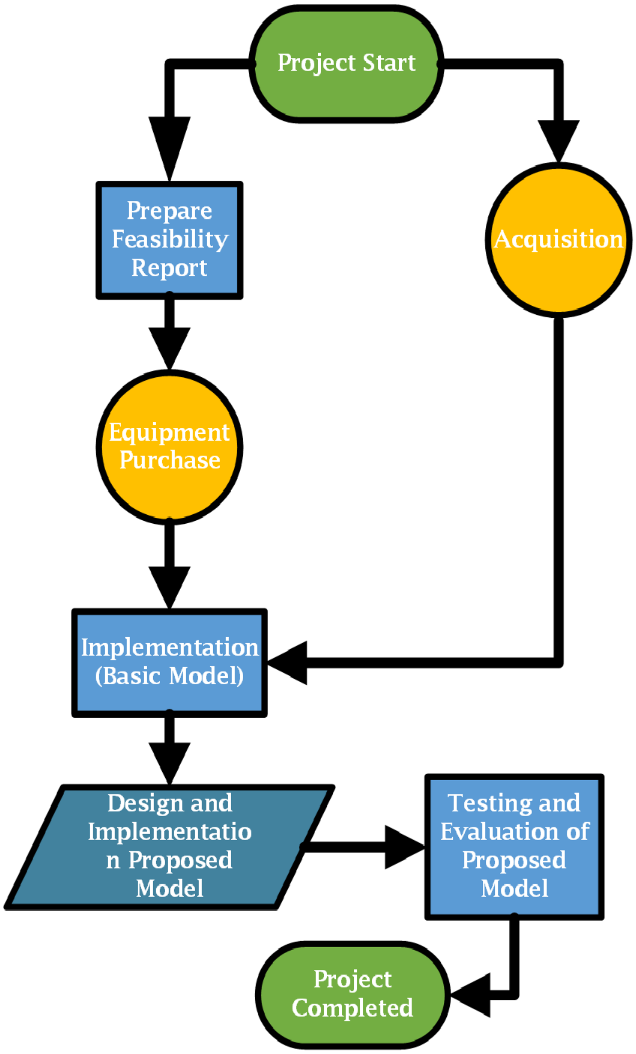

FIGURE 9. The block diagram of proposed project plan.

produced by photovoltaics is estimated using solar outputs and de-denominated in air temperature, as shown below.

$$P_{pv} = P_{Npv} \times \frac{G}{G_{ref}} \times \left[1+K_t \times \left(\left[T_{amb}+\frac{NOCT-20}{800}\right]\right)\right] \times G - T_{ref} \quad (7)$$

where PV is the photovoltaic range, g; Grief time tea and solar emissions under standard conditions, t_{umb}; Under normal conditions, the t_{ref} time T and the ambient temperature, the temperature coefficient of kt energy, and its value depend on the photovoltaic panel technology.

Below table 11 shows PV characteristics, Its instalment, and replacement cost and table 12 shows the characteristics of DG.

2) DIESEL GENERATOR (DG)

When the total power provided by traditional power and storage batteries is inadequate, a diesel generator is utilised as a hybrid power system to satisfy load needs. The equation (8) depends on the amount of fuel used by the diesel generator to generate electricity in each period.

TABLE 11. Characteristics of PV cell.

Technology	Generic Flat Plate
Installment Cost	Rs.50,000/KW
Replacement Cost	Rs.50,000/KW
Life Time	25 Years

$$F_{cons} = a.P_{DG} + b.P_{DG\_r} \quad (8)$$

where, $P_{DG}(t)$ is power generated by DG (kW) at hourly intervals (t), and F_{cons} is fuel consumption (liter/hour). The P_{DG_r} is rated power of DG produced at hourly (t), a, b are the coefficients (liter/kW).

TABLE 12. Characteristics of 250KVA generator.

Technology	Caterpiller
Installment Cost	Rs.20,000.00/KW
Operational and Maintenance Cost	Rs.0.5
Life Time	25 Years

3) CONVERTER

A converter is a device that converts electrical energy from AC to DC or vice versa. The equation. (9) calculates the rated maximum load decisions power. The efficiency of the converter is given in equation 9.

$$n_{cnv} = \frac{P_{output}}{P_{input} \ \ _{DG}} \quad (9)$$

where, P_{output} is represented as output power of the converter, and P_{input} is represented as input power of the converter.

TABLE 13. Characteristics of convertor.

Technology	Goodwe
Installment Cost	Rs.20,000.00/KW
Operational and Maintenance Cost	Rs1,00.00/yr
Life Time	25 Years

4) STORAGE AGENT

In this study, the battery storage agent is straightforward to link and have well energy productivity.

TABLE 14. Characteristics of convertor.

Parameters of Sensitivity	Specifications
Lifetime of Project (Years)	15,25
Demand of Electrical load (KWh/day)	898,929,940

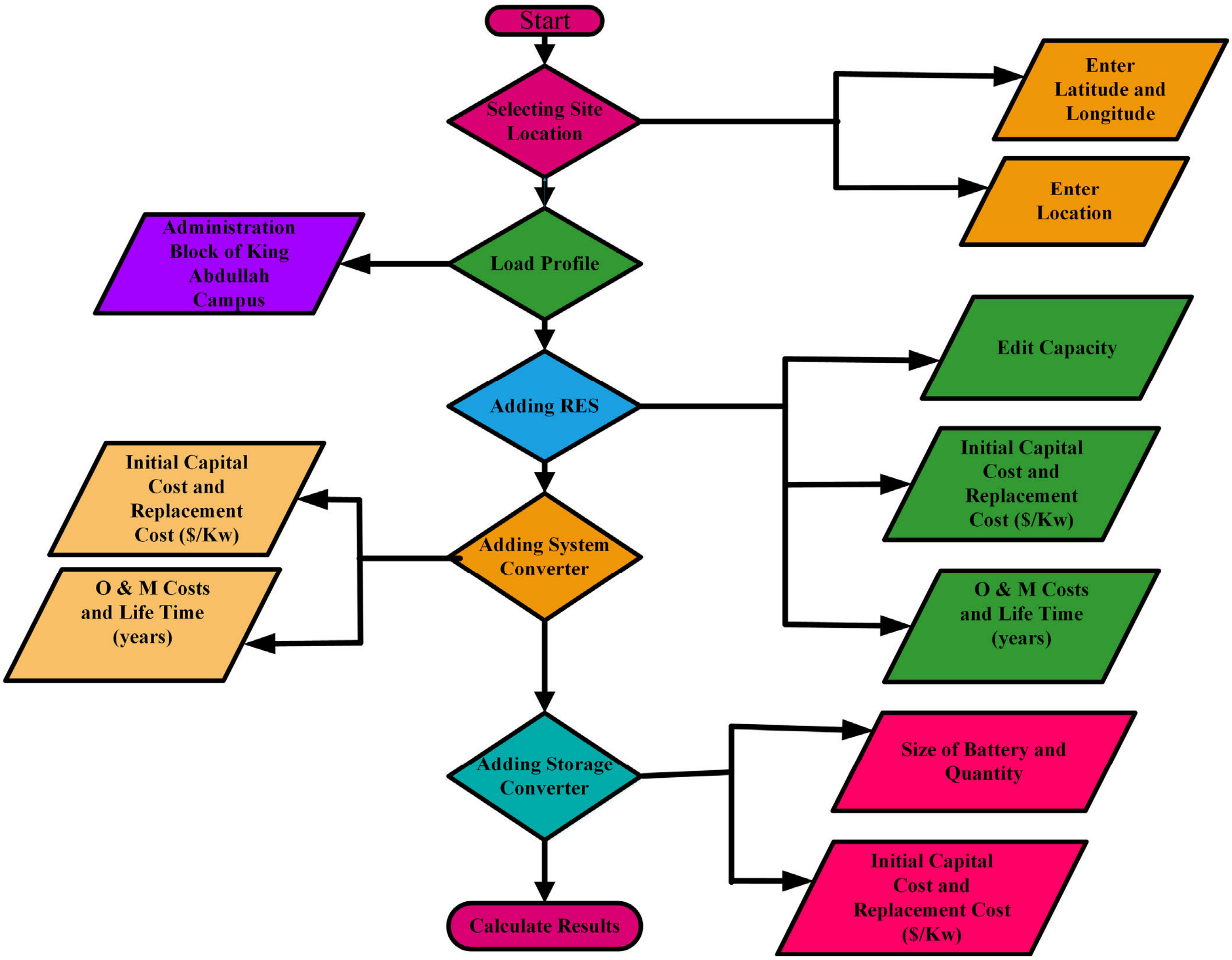

FIGURE 10. The proposed framework through HOMER.

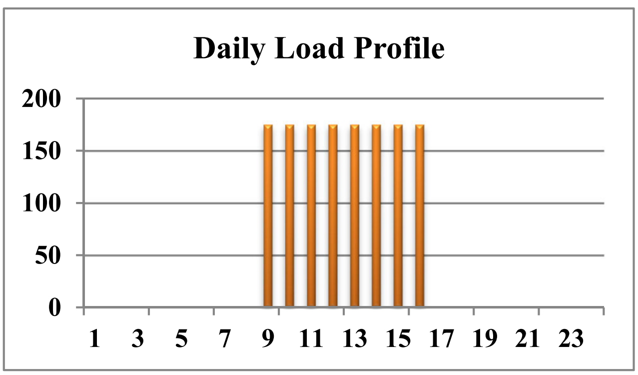

FIGURE 11. Load characteristic of king Abdullah Campus Azad Jammu and Kashmir university Muzaffarabad, AJK Pakistan.

High power from unconventional sources is used in case of power shortage. Eqs. (10) and (11) estimate the battery charge state at discharge and charge setting.

$$Eb\,(t+1) = Eb\,(t) \times (1-\sigma) - \left(\frac{E_t(t)}{n_{cnv}} - E_g\,(t)\right) \times n_{BD} \quad (10)$$

$$Eb\,(t+1) = Eb\,(t) \times (1-\sigma) - \left(E_g\,(t) - \frac{E_t\,(t)}{n}\right) \times n_{BD} \quad (11)$$

$$Eb_{min}$$

$$Eb_{max}$$

$$Eb_{min} \leq Eb(t) \leq Eb_{max} \text{ where } Eb_{min} = (1-DOD) \times Eb_{max} \quad (12)$$

The DOD represents the depth of discharge of the battery, which relies on the battery's technology.

TABLE 15. Characteristics of convertor.

Technology	IRON EDISON Re-VOLT
Capacity	48V, 189Ah
Installment Cost	Rs.1,197,910.00
Operational and Maintenance Cost	Rs.5,000.00 /yr
Life Time	10 Years
Replacement Cost	Rs.1,197,910.00

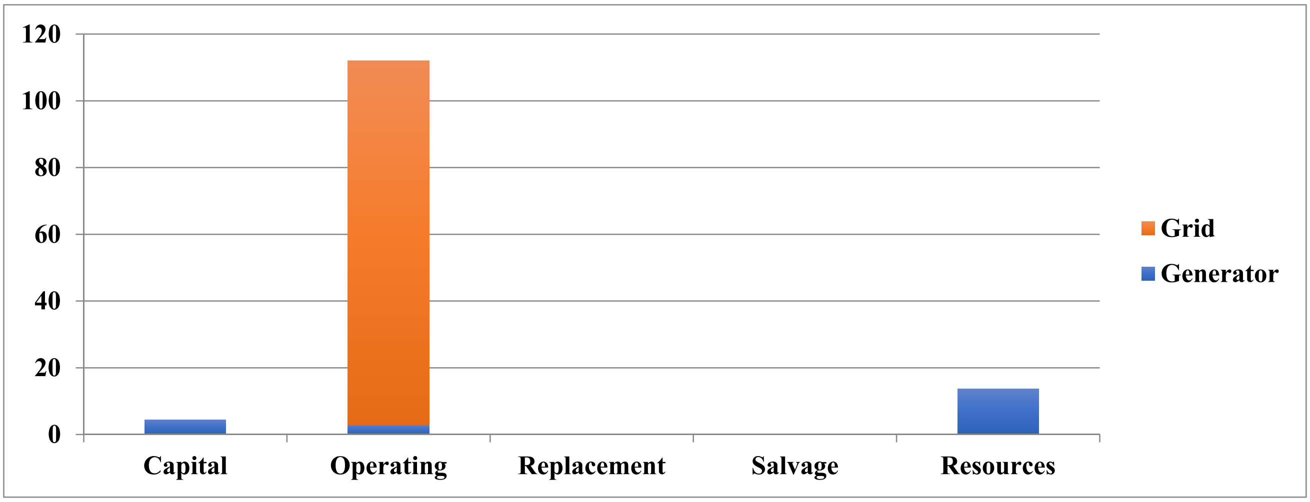

FIGURE 12. Annual production of proposed system.

V. OPTIMIZATION RESUTLS

A. HOMER OPERATION

First, data for the desired site is gathered and put into the HOMER software. All the energy sources are chosen under the specified paradigm. In this study, a solar source is included. Batteries along with converters are also added to the system. Finally, a configuration for the on-grid site is obtained. The annual production of the proposed system is shown in figure 12.

In the following stage, HOMER calculates the suggested site design and generates results in net present cost, cost of energy, Operating cost, and initial capital cost. In addition, HOMER calculates existing system parameters and provides findings for the same cost scenarios. The existing and proposed system results are then compared, and the best feasible option is determined.

The annual energy purchased from the grid is 105,712 kWh, and the yearly power sold to the grid is 196,201 kWh.

Table 17 shows the characteristics of all the system's components.

The cost summary graph of all the components is shown in the figure 13.

The net present cost of the proposed system is shown in Table 18.

The Generic PV system has a nominal capacity of 294 kW. The annual production is 497,242 kWh/yr.

B. OPTIMAL FRAMEWORK AND ANALYSIS OF DIFFERENT SCENARIOS

HOMER simulations are run with the provided data to acquire the best solution for the required hybrid system. Throughout the year, HOMER assesses input for each hour. The principal information for the proposed location is solar irradiation, whereas the remaining inputs are the same as in the existing system. The proposed system's outcomes are assessed and compared to the existing system for the same load. PV with varying loads and battery banks is simulated, resulting in thousands of results, although only classified findings are addressed practically.

In this section, simulated results of grid-connected units of different combinations are derived using HOMER. Solar energy is the primary power source at this grid-connected site, and when solar energy is unavailable, the electric grid and battery bank will deliver power to the load. As a result, the grid-connected photovoltaic panel is the most cost-effective and efficient alternative. HOMER tool will simulate hundreds of results in total. This image depicts the best suitable results of the grid site for varying configurations. There are four possible viable systems with PV/Grid/Convertor, PV/Battery/Grid/Convertor, and PV/Battery/Grid/Converter architectures.

1) EXISTING SYSTEM AND PROPOSED SYSTEM WITH THREE DIFFERENT SCENARIOS

Here are the results for an existing system is shown in figure 14. In the table below system has two probabilities either it can take the energy from the grid or use the combination of grid and generator. Here is the table in which cost comparison is given. Results show the Cost of Energy is Rs.25 when it is only connected to the grid, and the cost of Energy is Rs.27.32 when a combination of grid and generator is present.

After the optimization, HOMER shows the best result given below, but it has a battery backup of half an hour in this system. The three different scenarios with small, medium, and large backup are shown in figures 15,16, and 17.

The following are the outcomes of increasing battery backup for 0.653 hours is shown in figure 15.

Figure 16 shows the results achieved if the battery backup duration was extended to 1.31 hours.

TABLE 16. Annual energy production.

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Energy Purchased (kWh)	Peak Load (kW)	Energy Charge	Total
January	9,799	13,402	-3,603	148	-Rs90,076	-Rs90,076
February	8,177	13,539	-5,362	147	-Rs134,046	-Rs134,046
March	8,008	17,582	-9,574	148	-Rs239,344	-Rs239,344
April	9,237	15,129	-5,892	172	-Rs147,296	-Rs147,296
May	10,578	17,176	-6,598	183	-Rs164,941	-Rs164,941
June	8,920	17,830	-8,909	185	-Rs222,734	-Rs222,734
July	11,074	16,136	-5,062	183	-Rs126,547	-Rs126,547
August	13,251	15,230	-1,979	188	-Rs49,469	-Rs49,469
September	8,173	16,973	-8,800	177	-Rs220,008	-Rs220,008
October	3,982	20,739	-16,757	141	-Rs418,928	-Rs418,928
November	6,263	17,441	-11,178	149	-Rs279,462	-Rs279,462
December	8,250	15,024	-6,775	146	-Rs169,365	-Rs169,365
Annual	105,712	196,201	-90,489	188	-Rs2.26M	-Rs2.26M

TABLE 17. Components of proposed system architecture.

Component	Name	Size	Units
PV	Generic Flat plate PV	294	kW
Storage	LG Chem RESU10 [9.8kWh]	2	Strings
System Converter	Converter	196	kW
Grid	Grid	999,999	kW
Dispatch Strategy	HOMER Load Following		

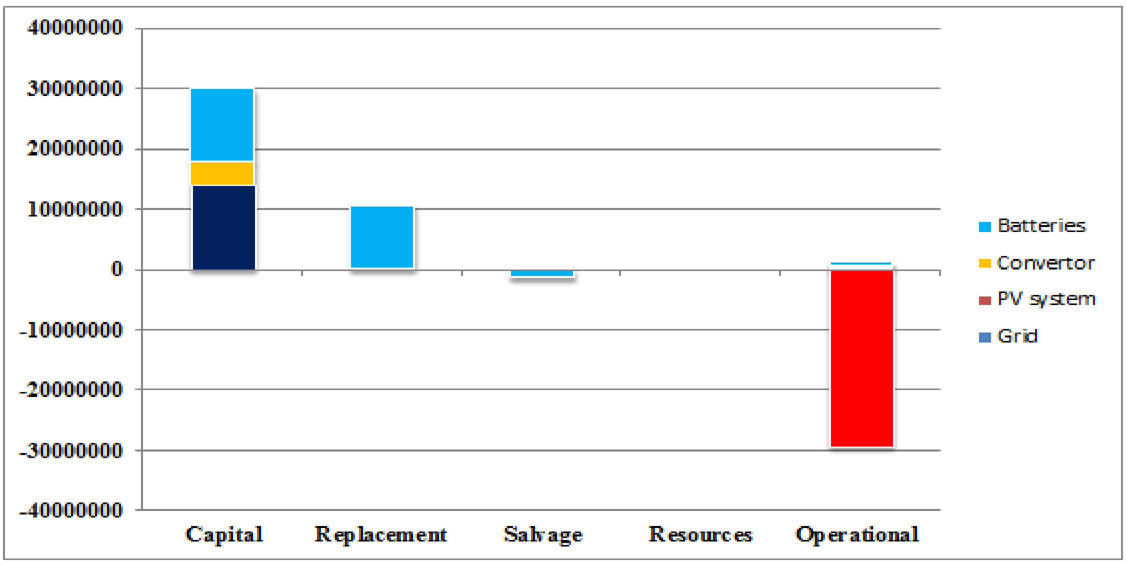

FIGURE 13. Cost summary of proposed system.

Figure 17 shows the results achieved if the battery backup duration was extended to 6.53 hours.

C. COMPARISON OF EXISTING AND PROPOSED SYSTEM

1) CASE 1: COST OF ENERGY

In the existing system, the cost of energy is Rs.27.09, while in the proposed system, the cost of energy is reduced by Rs..251 per kWh. The comparison of the cost of energy is given in Table 20.

2) CASE 2: NET PRESENT COST

In the existing system cost of energy is Rs.130M, while in the proposed system Net Present Cost is reduced to Rs.-1.84M. In the case of net present cost, the comparison of energy cost is given in Table 21.

3) CASE 3: INITIAL CAPITAL COST

In the Exiting system cost of Energy is **Rs.3.33M**, while in the proposed system Initial capital cost increased to **Rs.18.9M**.

TABLE 18. Net present cost of proposed system architecture.

Name	Capital (Rs)	Operating (Rs)	Replacement (Rs)	Salvage (Rs)	Resource (Rs)	Total (Rs)
Converter	3.92 M	253,164	0.00	0.00	0.00	4.17 M
Generic Flat plate PV	14.7 M	379,746	0.00	0.00	0.00	15.1 M
Grid	0.00	-29.2 M	0.00	0.00	0.00	-29.2 M
HOMER Load Following	5,000	0.00	0.00	0.00	0.00	5,000
LG Chem RESU10 [9.8kWh]	12 M	646,376	10.6 M	-1.43 M	0.00	21.8
System	30.6	-28.0 M	10.6 M	-1.43 M	0.00	11.8

TABLE 19. Annualized cost of proposed system architecture.

Name	Capital (Rs)	Operating (Rs)	Replacement (Rs)	Salvage (Rs)	Resource (Rs)	Total (Rs)
Converter	302,971 M	19,583	0.00	0.00	0.00	322,555
Generic Flat plate PV	1.14 M	29, 375	0.00	0.00	0.00	1.17 M
Grid	0.00	-2.26 M	0.00	0.00	0.00	-2.26 M
HOMER Load Following	386.77	0.00	0.00	0.00	0.00	386.77
LG Chem RESU10 [9.8kWh]	926,636	50,000	818,625	-110,991	0.00	1.68 M
System	2.37 M	-2.16 M	818,625	-110,991	0.00	910,511

Architecture		Cost					System	Gen					Grid	
Gen (kW)	Grid (kW)	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	O&M (Rs/yr)	Ren Frac (%)	Hours	Production (kWh)	Fuel (L)	O&M Cost (Rs/yr)	Fuel Cost (Rs/yr)	Energy Purchased (kWh)	Energy Sold (kWh)
	999,999	Rs118M	Rs25.00	Rs9.13M	Rs0.00	Rs9.13M	0						365,182	0
220	999,999	Rs130M	Rs27.32	Rs9.70M	Rs4.40M	Rs8.64M	0	522	28,710	9,642	229,680	1,060,595	338,892	2,420

FIGURE 14. Results for existing system.

Architecture				Cost					System	Storage	Grid	
PV (kW)	Storage	Grid (kW)	Convertor (kW)	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	O&M (Rs/yr)	Ren Frac (%)	Autonomy (hr)	Energy Purchased (kWh)	Energy Sold (kWh)
300		999,999	200	-Rs12.7M	-Rs1.74	-Rs2.45M	Rs19.0M	-Rs2.45M	82.1		101,633	201,817
300	5	999,999	200	-Rs1.84M	-Rs0.251	-Rs2.08M	Rs25.0M	-Rs2.43M	82.1	0.653	101,633	201,817

FIGURE 15. Results of proposed system with small backup.

Architecture				Cost					System	Storage	Grid	
PV (kW)	Storage	Grid (kW)	Convertor (kW)	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	O&M (Rs/yr)	Ren Frac (%)	Autonomy (hr)	Energy Purchased (kWh)	Energy Sold (kWh)
294	10	999,999	196	Rs11.8M	Rs1.62	-Rs1.46M	Rs30.6M	-Rs2.16M	81.2	1.31	105,712	196,201
250	10	999,999	167	Rs30.8M	Rs4.56	Rs233,731	Rs27.8M	-Rs473,902	74.1	1.31	135,385	158,008

FIGURE 16. Results for proposed system with medium backup.

Architecture				Cost					System	Storage	Grid	
PV (kW)	Storage	Grid (kW)	Convertor (kW)	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	O&M (Rs/yr)	Ren Frac (%)	Autonomy (hr)	Energy Purchased (kWh)	Energy Sold (kWh)
300	50	999,999	200	Rs96.1M	Rs13.12	Rs1.33M	Rs78.9M	-Rs2.20M	82.1	6.53	101,633	201,817
300	50	999,999	133	Rs121M	Rs17.84	Rs3.35M	Rs77.6M	-Rs190,673	73.4	6.53	139,339	158,699
200	50	999,999	200	Rs137M	Rs21.53	Rs4.90M	Rs73.9M	Rs1.36M	65.4	6.53	170,601	127,784
200	50	999,999	133	Rs140M	Rs22.17	Rs5.19M	Rs72.6M	Rs1.66M	63.6	6.53	177,270	122,331

FIGURE 17. Results for proposed system with huge backup.

TABLE 20. Cost of energy comparison.

Existing System	Proposed System (5 Battery)	Proposed System (10 Batteries)	Proposed System (50 Batteries)
No Backup	.653hr Backup	1.31hr Backup	6.53 hr Backup
Rs.27.32	Rs.-.251	Rs.1.61	Rs.13.12

TABLE 21. Cost of energy comparison.

Existing System	Proposed System (5 Battery)	Proposed System (10 Batteries)	Proposed System (50 Batteries)
No Backup	.261hr Backup	1.31hr Backup	6.53 hr Backup
Rs.130M	Rs.-1.84M	Rs.30.8M	Rs.96.1M

In the case of initial capital cost, the comparison of energy cost is given in Table 22.

TABLE 22. Cost of energy comparison.

Existing System	Proposed System (5 Battery)	Proposed System (10 Batteries)	Proposed System (50 Batteries)
No Backup	.261hr Backup	1.31hr Backup	6.53 hr Backup
Rs.4.40M	Rs.25M	Rs.30.6M	Rs.78.9M

VI. CONCLUSION

Prolonged energy crises, dwindling fuel supply, and growing environmental concerns, provision of reliable, economical, and sustainable power supply remains a significant challenge in Pakistan. Foregoing interrupted power demand for laboratory experiments and abundant solar potential available in the region is strategically vital to install PV hybrid Solar System in King Abdullah Campus the University of Azad Jammu and Kashmir Muzaffarabad. The annual energy acquired from the grid is 338,892 kWh; the present hybrid system consumes 1000 kWh per day and has a peak power of 200 kW. In our proposed framework, yearly energy acquired from the grid is 105712 kWh, and annual energy supplied to the grid is 196201 kWh. The total amount of electricity acquired from the grid is −90488 kWh.

The simulated results of grid-connected units of different combinations are derived using HOMER. Solar energy is the primary power source at this grid-connected site, and when solar energy is unavailable, the electric grid and battery bank will deliver power to the load. As a result, the grid-connected photovoltaic panel is the most cost-effective and efficient alternative. HOMER tool will simulate hundreds of results in total. The tables 20, 21 and 22 depicts the best suitable results of the grid site for varying configurations. There are four possible viable systems with PV/Grid/Convertor, PV/Battery/Grid/Convertor, and PV/Battery/Grid/Converter architectures.

This case study presents the economic analysis for the on-grid site of the Administration Block of King Abdullah Campus. Overall, this proposed system would provide real-world performance optimization for PV hybrid systems and alleviate the power shortage problem, hence facilitating the uninterrupted power supply for teaching, administration, and experimental activities at the campus. The proposed system's results are compared to the existing system's outcomes while giving the same power to the load. The COE from the current on-grid hybrid system is Rs.27.32/kWh, indicating that effective utilization of solar energy reduces energy costs by up to Rs.-.251/kWh.

VII. FUTURE WORK

- **Emergency Backup of Batteries** Stored Energy can also be provided to the Auditorium and other departments of King Abdullah Campus University of Azad Jammu & Kashmir Muzaffarabad according to its requirement.
- **Revenue Generation using Net Metering** It recovers the operational cost of PVs System generation by the revenues associated with providing energy stored in off-peak periods to the grid in peak power demand periods.
- **Rooftop Solar Charging Station**
  - ❖ We can use the electricity generated by solar power to make charging stations. We can use the charging station to provide a charging facility for electric bikes and EVs.
  - ❖ Financial sustainability
  - ❖ Smart Metering

- Establishing a sustainable power system supported by renewable energy sources (RES) that emit no carbon dioxide (CO2).
- The relevance of better health and smog reduction is measured in the cost-benefit analysis of sustainable development and air quality improvements while developing RES and EVs at the same time.

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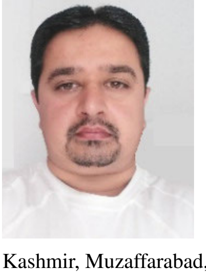

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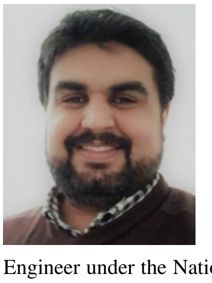

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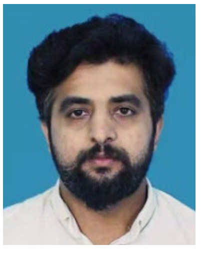

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