Hybrid Energy System Modelling for Oil & Gas Fields: A Case Study of Pasakhi Satellite Oil & Gas Complex

Fahim Mustafa[1], Anwar Ali Sahito[2], Shoaib Ahmed Khatri[2] and Laveet Kumar[1,*]

[1]*Department of Mechanical Engineering, Mehran University of Engineering & Technology Jamshoro, Pakistan*
[2]*Department of Electrical Engineering, Mehran University of Engineering & Technology Jamshoro, Pakistan*
E-mail: laveet.kumar@gmail.com
[*]*Corresponding Author*

Received 11 May 2021; Accepted 18 August 2021;
Publication 15 October 2021

Abstract

Energy is needed for all community activities, the production of all goods, and the provision of all services. It is extremely important to a country's economy and wealth. Currently, conventional fossil fuels provide most of the world's energy. In case of oil and gas fields their energy consumption is totally off-grid, their generation depends upon fossil fuels, the cost of energy consumption of oil and gas fields are too high because operational work of the field is totally depending upon fossil fuels. The development of off-grid renewable energy generation technologies offers the opportunity for tackling these challenges. This study provides a techno-economic feasibility analysis of an off-grid hybrid renewable energy system [HRES] for Pasakhi Satellite Oil & Gas Field, Tando Jam, Hyderabad, Sindh, Pakistan. The proposed hybrid energy system designed for field consists of the different combination of solar Photovoltaics [PVs], wind turbines, batteries, and generator to meet

Distributed Generation & Alternative Energy Journal, Vol. 37_2, 281–310.
doi: 10.13052/dgaej2156-3306.37210

the required energy consumption demand. The renewable hybrid energy system is model and optimized configuration through powerful simulation software Hybrid Optimized Model for Electric Renewable [HOMER] Pro. The optimized configuration of the hybrid system consists of solar PV's (50 kW), Wind turbines (60 kW), 40 lead-acid batteries (165 Ah and 12V each), 30 kw generator and 100 kW converter. The simulation results show that the proposed system can meet the power requirements of 250 kWh/day primary demand load with 40.21 kW peak load. This system configuration has the Capital Cost $71040, the Net Present Cost [NPC] of $253,159 and Cost of Energy [COE] of 0.215$/kWh. Furthermore, the results of the present study are compared with the literature because of which a cost-effective HRES with a low COE has been established.

Keywords: Hybrid energy system modelling, oil & gas fields, HOMER-Pro.

Nomenclature

HOMER	Hybrid Optimized Model for Electric Renewable
kW	Kilowatts
MW	Megawatts
MWh/day	Megawatt-hour/day
NPC	Net Present Cost
COE	Cost of Energy
PV	Photovoltaics
kWh/day	Kilowatt-hour/day
CO_2	Carbon di oxide
HPS	Hybrid Power System
HRES	Hybrid Renewable Energy System
GW	Gigawatts
O&M	Operation and maintenance
NASA	National Aeronautics and Space Administration
RES	renewable energy sources
NREL	national renewable energy laboratory

1 Introduction

Energy is needed for all community activities, the production of all goods, and the development of all services. It is extremely important to a country's economy and wealth. Currently, conventional fossil fuels provide most of the world's energy. The demand for energy is growing every day as the world's population grows and people's materialistic desires grow. As a result, these services will be limited at some stage. Because of the increased use of electricity, energy generation will become the most serious problem on the planet [1]. The cost of producing electricity from fossil fuels is a major contributor to global warming [2, 3]. The release of significant quantities of carbon di oxide [CO_2] is responsible for the contamination. CO_2 levels in the atmosphere have increased by 40% since the beginning of the industrial revolution [4]. Pakistan is a substantial republic in South Asia, both geographically and strategically. Pakistan is experiencing an energy crisis due to a variety of factors, including population growth, rising energy demands, and reduced power output. The global temperature is rising, fossil fuel prices are rising, and fossil fuel supplies are running out. A solution to both challenges in electricity supply was proposed, and it was based on a green and environmentally sustainable solar energy generation scheme. Renewable energy sources such as solar and wind, along with a diesel generator and battery storage, will assist rural areas in addressing their energy needs [5]. Hybrid power system [HPS] is a set of various renewable energy options, such as wind and solar systems, combined with a conservative energy basis, such as a diesel generator. The success of hybrid solar-wind systems is due to advancements in technology and rising fossil fuel prices. This system uses two renewable energy sources, which improves system proficiency and power reliability while lowering energy storage requirements for standalone systems [6]. In comparison to standalone solar or wind systems, standalone hybrid renewable energy schemes have a lower cost and higher consistency. Solar-wind-battery and solar-diesel-battery systems are often used [7]. South Africa and South Asia both have energy shortages but abundant solar resources. The lack of energy in Pakistan, especially in those communities that are located far from the grid, can be addressed using hybrid renewable energy techniques [8]. This study concentrates on HRES modelling for oil and gas fields that depend solely on fossil fuels for power generation. As backup sources for renewable energy, this model includes solar PVs, wind turbines, batteries, and a generator.

In oil fields the source of power generation are mostly generators, supplying electricity all around the year. The operating cost of generators at Pasakhi oil field ranges from 10 to 12 million rupees/year excluding the fuel prices. Increasing fuel prices as well as rapidly exhausting resources of fossil fuel, increase in environmental CO_2 and rising global temperature has led to increase the motivation to minimize the dependence on these sources.

Pakistan has a lot of potential for renewable energy resources. Solar, geothermal, wind, hydro, and biomass are all renewable energy sources in

Pakistan. In Pakistan, the capacity for generation of hydroelectricity is over 60 GW, and an average potential of energy from solar PVs is approximately 2.142 kWh/day solar irradiance/m^2/year, with nearly 50000 GW coming from solar and wind energy. Pakistan will grow a substantial portion of these renewable energy potentials from hydro energy potential through 2022 [9]. Solar energy is widely available in many regions of the United States. The global radiations falling average daily value on the horizontal surface is about 200 to 250 $W/d \times m^2$. This equates to approximately 6840 to 8280 MJ per m^2. Solar energy is abundant in our provinces. The average amount of solar energy available is approximately 5.5 kWh/m^{2}d, with an average sunshine period of 8–10 hours per day. The wind strip along the coasts of Sindh and Baluchistan has extremely high speeds, ranging from 4–9 m/s at a height of 10 metres to 12 m/s at a height of 50 metres [10]. In the literature, some researchers have presented various hybrid energy modelling and optimization techniques such as cost of energy, net present cost, renewable fraction, percentage of renewables, energy generation and energy consumption. Generations of energy derived from natural sources face several challenges, including rising fuel costs, diminishing fuel resources, pollution of the environment, and global warming. Many studies on stand-alone hybrid systems have been conducted locally as well as globally, with the conclusion that this system is economical, environmentally friendly, and suitable for communities that are not reachable via grid, as well as in areas where energy is generated using diesel generators. Standalone power systems based on renewable energy systems [RES] backed by RES or mixed systems can provide the greatest quality and consistency of electricity for lighting, communication, water supply, and other essential need. Our study is aimed to decrease in total system and energy cost and will reduce the environment contamination to some extent [11–25].

Pakistan is rich in natural resources as well as renewable energy resources; however, it is difficult to claim that Pakistan has a strong renewable energy potential while still failing to implement these free energy resources. Total electricity generation (2019–2020) was 134,745.70 GWh, with renewable energy generation is just 4,151.91 GWh. It means that renewable energy accounts for just 3.081% of total electricity production [26]. Pakistan must transition toward clean energy opportunities that are abundant in nature and all around us and are environmentally sustainable.

The rest of the paper is organized as follows. The methodology of the proposed system is discussed in the Section 2. Modelling of Hybrid energy system is discussed in Section 3. Results and discussions will be presented in the Section 4. Conclusion of the proposed system is mentioned in the Section 5.

2 Methodology

2.1 Location of Site

The Pasakhi Satellite Oil & Gas Complex is in Tando Jam with coordinates (25.406263716541037, 68.56630202729063). Tando Jam is a town in Pakistan's Sindh province that is about 12 kilometres east of Hyderabad. Villages and fields are surrounded by the selected location of study area. The CO2 gas emitted by the generators, which run 24 hours a day, is extremely harmful to all living things in the Pasakhi Satellite Oil & Gas Complex's vicinity.

2.2 Site-Visit for Finding the Energy Consumption

Since information on the Pasakhi Satellite Oil & Gas Complex's energy use was difficult to come by, a survey was conducted to gather the required data. The inspection was held to collect data for future green energy updates as well as to detect energy patterns in the oil and gas fields. The sample of Questionary is in Appendix-A. Because they are completely cut off from the grid, they rely solely on generators, i.e., fossil fuels, to generate electricity. Finally, the survey's results were unexpected, given that their daily electricity consumption is 0.5 MWh, as mentioned in the previous topic. It required a massive amount of space to install a 0.75 MWh/day mean 22.5 MW hours per month microgrid, which is almost equivalent to a middle-class community's monthly average electricity usage. As a result, we reduced our study to just 250 kWh per day.

2.3 Energy Audit and Estimation of Load

The purpose of Pasakhi oil and gas energy auditing is to detect energy dynamics and evaluate energy usage to create sustainable energy systems. To learn about the consumption of electricity and watts of power using components such as lights, fans, and so on, the method of arranging an easy audit, room to room data collecting was implemented. The daily average requirement for power-consuming equipment, as well as the winter and summer circumstances, are assessed based on the working hours of home appliances. The estimation of load is done for a whole year during audit that is conducted through a questionnaire survey in Appendix A. To find the daily and monthly load Equations (1) and (2) is used as shown below.

Total Load Estimation of a Day

$$(BL \times TQ \times DU) = \text{Total Load/day} \quad (1)$$

Where:
BL (watts) = Base Load
TQ = Total Quantity
DU = Daily Usage
Total Load Estimation of a Month

$$(BL \times TQ \times DU \times TLD) = \text{Total Load/Month} \quad (2)$$

Where,
BL = Base Load
TQ = Total Quantity
DU = Daily Usage
TLD = Total Load/Day

2.4 HYBRID Energy System Modelling

A hybrid system combines two or more technologies, such as solar PV panels and a wind turbine or generator. South Africa and South Asia all have energy shortages but abundant solar power. In Pakistan, especially in those areas far from the grid, there is a shortage of electricity. This problem may be solved by using a HRES [8]. The oil and gas fields are mostly off the grid, relying solely on turbines for electricity production. If we use an HRES system of generators, we will save money on electricity and reduce CO_2 emissions in some way. Through integrating Solar PV, Wind Turbines, and Batteries with generators, 50% of the load would be transferred to renewables, resulting in cost savings and a low-cost HRES grid. If solar irradiance is unavailable during rainy or windy seasons, wind turbines will supplement the system with generators, and if neither solar PV nor wind turbines are available, a generator will supply electricity. In general, a hybrid system is the simplest and most cost-effective alternative for remote areas. For modelling of the HRES HOMER-Pro software is used.

2.4.1 Software used for modelling

HOMER (3.14.4 edition) the entire study relies on this software, which has been downloaded by millions of people in 193 countries around the world and was developed for the National Renewable Energy Laboratory [NREL] in the United States by Mistaya Engineering in Canada, which uses Windows as a programming language. The software performs three principal tasks are simulation, optimization and sensitive analysis. Simulation, optimization, and sensitive analysis are the three main functions of the programme. This software is primarily intended for optimization and simulation of a variety of renewable energy sources using NPC [27]. It uses input of electricity consumption in kWh of whole year to run the model, which displays the approximate cost as well as the energy source's efficiency. For simulations of the various system architectures as well as the development of data, which can be represented as a collection of suitable configurations sorted by NPC.

2.5 Available Resource Calculations

2.5.1 Radiation data of solar energy

National Aeronautics and Space Administration [NASA] meteorological surface and solar energy databases provided the monthly solar radiations and clearness index data. Solar radiation is approximately 5.27 kWh/m^2/day on an annual basis in Pasakhi Satellite Oil & Gas Complex, Tando Jam district, Hyderabad. The highest solar radiation is observed from April to June, ranging from approximately 6.41 kWh/m2/day to 6.98 kWh/m^2/day. The monthly average solar radiation and the clearance index are shown in Figure 1.

2.5.2 Data of wind energy

The NASA Prediction of Worldwide Energy Resources [POWER] database is also used to obtain the average wind speed for Pasakhi Satellite Oil & Gas Complex. Throughout the year, the wind intensity ranges from 5.252 m/s

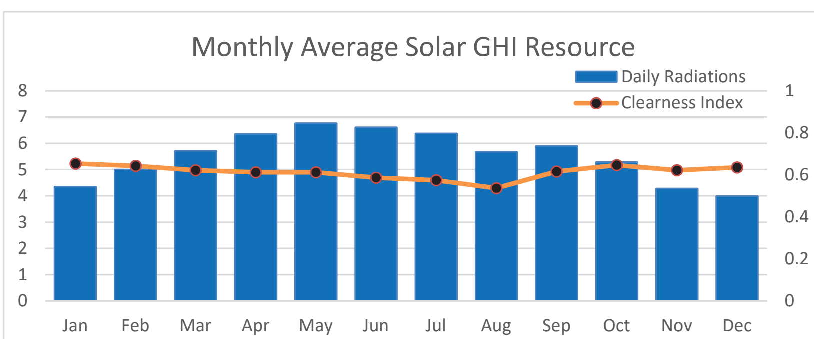

Figure 1 Radiation and clearance index of solar energy.

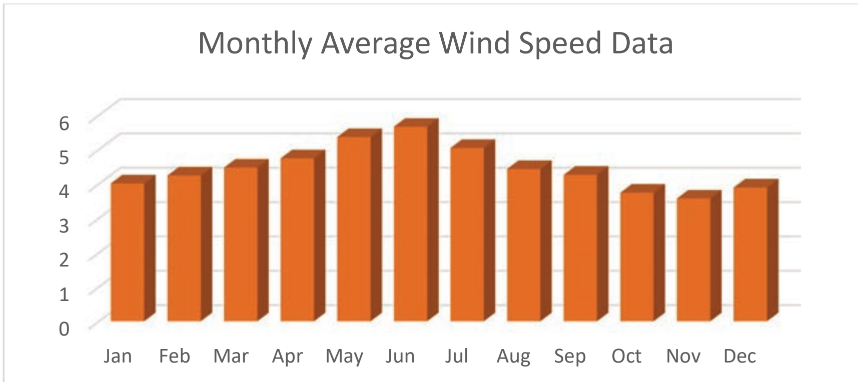

Figure 2 Data of wind energy.

to 8.20 m/s. The average annual wind speed for the chosen research area is 5.98 m/s.

2.6 Components Used to Designed the System

Solar PV, Generators, Batteries for backup, Converters, and Wind Turbines are the five primary elements. The aim of this study is to create a cost-effective HRES that can meet the energy needs of Pasakhi Satellite Oil & Gas in Tando Jam. This section provides a concise overview of each part, which includes field data testing for the generation of renewable power sources in the proposed scheme.

2.6.1 Converter

It is a series of electrical devices that converts alternating current to direct current voltage. A system converter is needed for any system that uses both alternating and direct current. Converters may be found in a variety of systems. The converter used in this method is a multi-portable unit called a (100 KW Pure Sine Wave) converter. The converter's initial cost is $23,040, with a depreciation cost of $23,040, and an operating and repair cost of $517 because it requires cleaning and wiring because the chosen location is dusty. The converter (100 KW Pure Sine Wave) can be used for both systems (on-grid & off-grid). Table 8 (Appendix B) will give complete details of the Converter Specifications. The specifications of a component used in the HOMER software is shown in Figure 3.

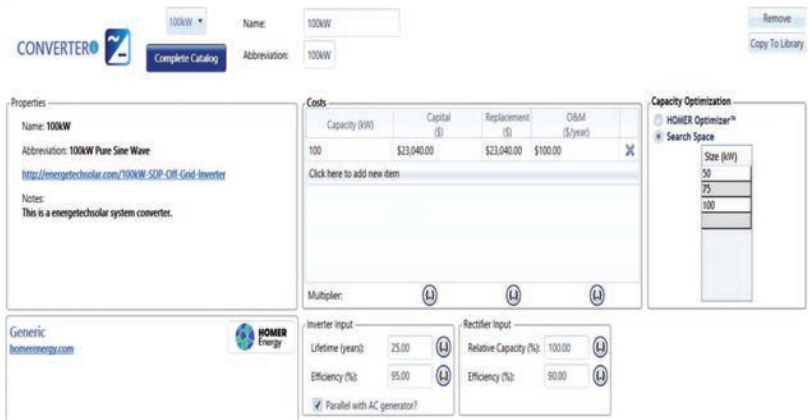

Figure 3 Specification of converter.

2.6.2 Battery storage system

A refillable battery or storage space consists of one or more cells that convert chemical energy to electrical energy and then use that electricity as a power source. In this system, battery backup is used for power storage, particularly when the system is not receiving energy from solar panels. When selecting a storage component in HOMER, the storage page assists you in selecting a storage system from the Homer software library by examining the battery system's specifications and costs. We can add our own battery model if we do not want to use the Homer Software-provided battery system. Also available in the HOMER library are idealised batteries, generic lead-acid batteries, kinetic batteries, supercapacitors, and adapted kinetic batteries. The number of batteries obtained corresponds to the amount of storage selected in HOMER Software, every single storage battery has a capital cost of $175, a replacement cost of $150, and an operating and maintenance cost of $10. The initial cost includes the installation fee. Storage batteries are selected at a price that is competitive with the industry. This device uses the AGS 12V 165 AH (40) battery system because it allows energy to be powered and calculated independently, the description of a battery is mentioned in Table 9 (Appendix B). Figure 4 shows the complete internal specification of batteries used in HOMER software.

2.6.3 Solar photovoltaic panels

Solar PV panels are used to convert solar energy into electricity and store it. PV systems are becoming increasingly common as a source of energy,

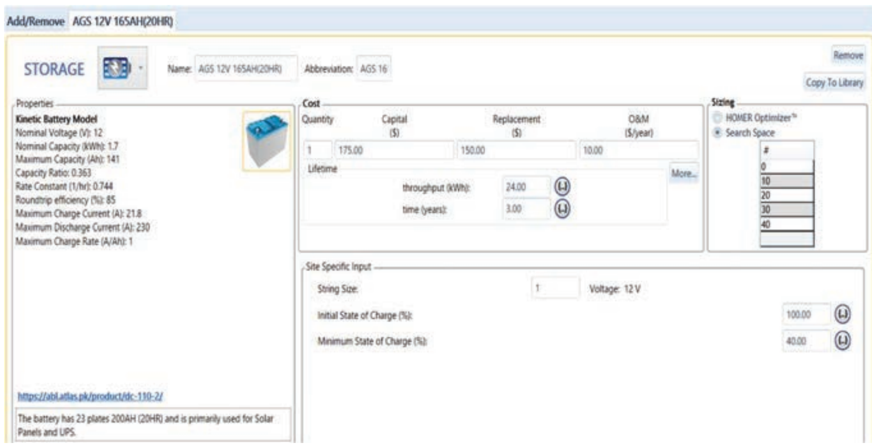

Figure 4 Specification of battery.

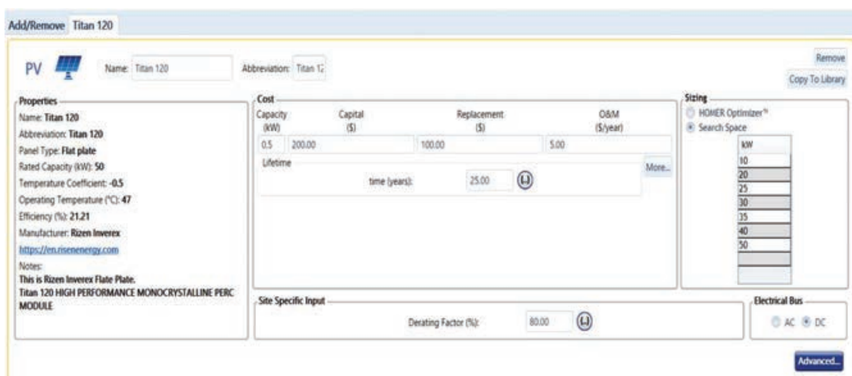

Figure 5 Specification of solar PV.

especially in rural areas. This technique would be able to satisfy electricity demand in a cost-effective and consistent way. Since the HOMER Pro simulates equations for 1 kW, the cost of a PV system is dictated by the output of the panels, which is calculated in kW. The initial cost of the panel is $1,000, which covers the cost of the panels and cables, depending on retail costs per 1 kW module. The operation and maintenance costs are fixed at $1,000 over a 25-year term, with annual O&M costs of $10, their specification is shown in Table 10 (Appendix B). Figure 5 shows the internal specification of solar PV used in HOMER software.

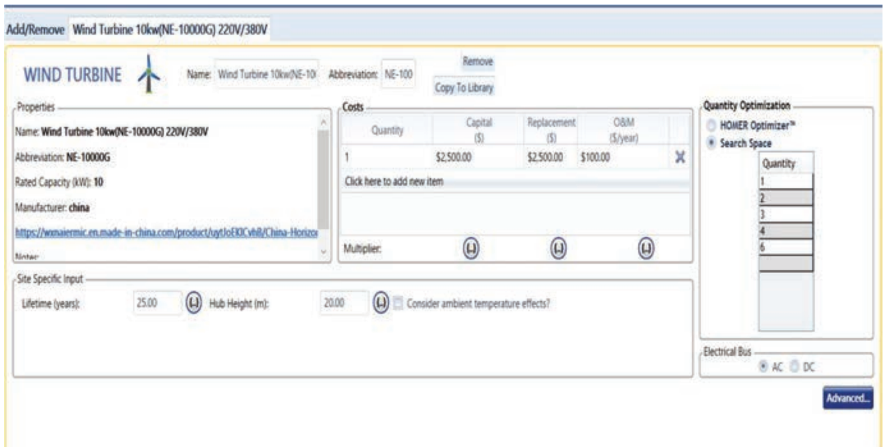

Figure 6 Specification of wind turbine.

2.6.4 Wind turbine

Wind energy is a system that converts the kinetic energy of the wind into electrical energy to meet the need for electricity. In comparison to other fossil fuel generation systems, wind energy is a renewable energy source that produces electricity without emitting any emissions. Because of the economic and environmental gains, countries are changing their energies to renewables. Wind turbines can be used to generate electricity reliably in both off-grid and on-grid situations. Based on the demand in the selected region, the HOMER software library is used to pick a wind turbine (NE-10000G) with a rated power of 10 kW for the proposed hybrid system. The cost of one wind turbine is $2500, the cost of repair is $2500, and the annual operation and maintenance cost is $100. The specification of the wind turbine is shown in Table 11 (Appendix B). Figure 6 shows the internal specification of wind turbine.

2.6.5 Generator

A generator is a system that converts mechanical energy into electrical energy. A generator can generate electricity using fossil fuels. In this proposed scheme, we used a generator with a rated power of 50 KW and an operational and maintenance cost of $2 per hour. The generator is used as a backup source in the study region when renewables are not usable, and minimal load is transferred to generator. Table 12 (Appendix B) will define

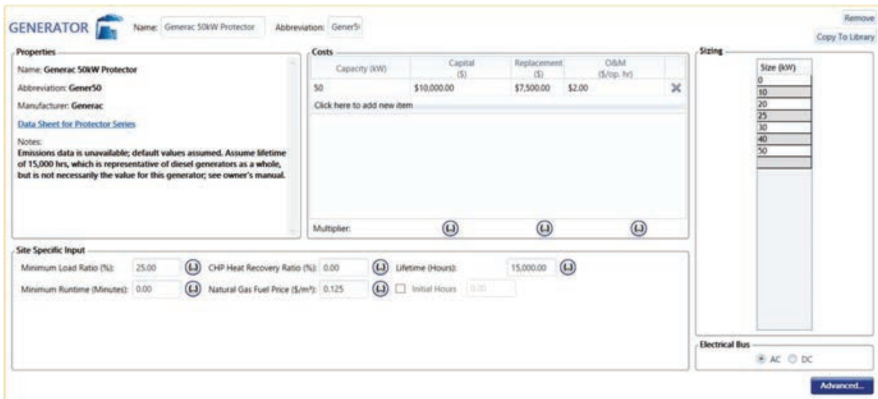

Figure 7 Specification of generator.

the generator's specifications. Figure 7 shows the internal specification of generator used in HOMER software.

3 Results and Discussions

This thesis included optimization outcomes. Any green energy configurations discovered in the HOMER software. To decide the most cost-effective configuration system, the HOMER software computes the energy balance for each configuration system. The system should be able to meet the demand for electricity under defined conditions. The Homer software findings will be comprehensive, covering everything from the regular average load of the Pasakhi satellite to all components of the wind, battery, and solar PV system. It discusses, among other items, electricity generation, optimization, technological criteria, power storage battery measurements, solar PV panels, and wind turbines. It contains Homer Software simulations such as NPC, Levelized CEO, Operating cost, and Initial capital cost.

3.1 Average Load Estimation

The evaluation of the residential area of the Pasakhi Satellite Oil & Gas Complex, Tando Jam, revealed nearly all the energy-consuming components. Table 1 depicts the energy-consuming appliances that are often used in the residential setting. The area's electricity demand is split into two categories: residential energy consumption and plant energy consumption. The plant's energy consumption is steady, at 500 kWh per day. The residential side

Table 1 List of appliances

S. No	Appliances	Wattages
1	Air Conditions (A.C)	1200
2	Ceiling Fans	75
3	Energy Savers (CFL)	24
4	Heaters	1500
5	Oven	2400
6	Juicer Machine	400
7	Fridge	150
8	Lights	50
9	Exhaust Fan	100

Table 2 Seasonally residential load

Seasons	Load
Summer	249.94 kWh
Winter Season	99.16 kWh

consumes 486 kWh of electricity per day as well. After surveying the site, we discovered that there was only a small amount of room available to instal the HRES model, so we limited our exploration and took only half of the residential area load. It may range from 50% to 40%, and we also consider approximately 40% surplus energy that will participate in the load that is not chosen for testing.

These artefacts were chosen later after understanding energy consumption to connect them with the hybrid model, which was meant to be the baseline load. To measure the capability of everyday operating equipment such as refrigerators, energy savers, and ceiling fans, the HOMER needs the average hourly data of a full year in months. The load was split into two parts, one for summer and one for winter. The watts are calculated by calculating the baseload of the materials, which is dependent on the goods' normal and hourly use. The load is entered into the HOMER programme in kW, so after determining the base load, we must translate it to kW Seasonal baseload assessment. The real load of the residential area would vary marginally since the above load is theoretical, and as we all know, realistic results differ slightly from theoretical results. Table 2 shows the average residential load during the summer and winter seasons.

3.2 Scaled Daily Load Profile

A residential load profile was chosen after integrating the load into the HOMER software. When a residential area's base load is entered, the results show that the average load of the residential area is 173.56 kWh/day, as seen in Table 3. The average load is 7.23 kW, the peak load is 27.91 kW, the load factor is 0.26, and the scaled annual average for the residential area is 250 kWh/d, with the load increased by 10% if there is any variance.

It is normal for the demand for energy usage to be lower in the morning hours than in the evening hours. Figure 8 depicts the residential area's regular scaled load profile.

3.3 Modelling of Hybrid Energy System

In this section, the results of HOMER software's modelling of the HRES (Solar PV system, Rechargeable batteries, and wind turbines) without grid connection are prearranged. Figure 9 shows the Schematic Design of the proposed model to satisfy the Pasakhi Satellite Oil complex residential area's electricity requirement. In the following section, we will go into in depth how each component is used to model the structure. The solar PV system, and

Table 3 Annual baseline & scaled average load

Mertic	Baseline	Scaled
Average (kWh/d)	173.56	250
Average (kW)	7.23	10.42
Peak (kW)	27.91	40.21
Load Factor	0.26	0.26
Scaled Annual Average (kWh/d)	250	

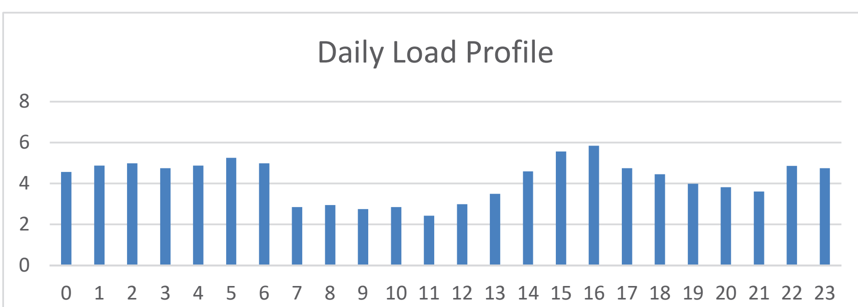

Figure 8 Daily scaled load profile.

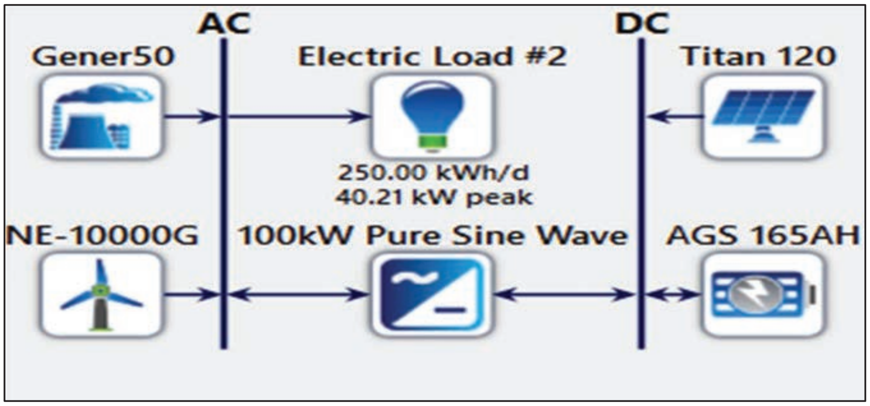

Figure 9 Homer block diagram of hybrid renewable energy system.

batteries are all connected to the DC bus. The wind turbine and generator are connected to the AC bus. To satisfy the need for electricity, they all work together. If sun and wind are not usable, the batteries can be used to compensate. If solar, wind, and storage batteries are not available, the produced energy can be used in their place. The HOMER Pro software was used to determine the most technically and economically viable hybrid energy mixture device. The model classified the outcomes based on their starting costs, NPC, COE, capacity deficit, dispatch types, and green energy fraction.

When evaluating the grid-free Hybrid setup, a cohesive composition was designed that is comprised of Wind Turbines, PV panels, Converters, batteries, and a generator for system backup. Figure 9 depicts the concept diagram in its entirety.

3.4 Optimization Results of Modelling Hybrid System

Various configuration systems were examined to achieve the most optimised HRES; many configuration systems are capable of meeting the need for energy consumption. HOMER will disregard all configuration systems that are not feasible and categorise the various feasible outcomes in ascending order based on the method NPC and COE. Using NPC as a criterion for comparison, the most optimal outcomes from HOMER are Solar PV, Generator, Wind Turbine, and battery as the base case.

The most integrated facility to satisfy the energy demand had 50 kW of solar PV, 60 kW of wind turbine, 40 batteries, 100 kW of converter, and 50 kW of generator. The proposed model's COE and NPC are $0.215 and

Table 4 Optimization results

		Architecture						Cost				System
		Solar PV (kW)	Generator (kW)	Wind Turbine (kW)	Battery	Converter (kW)	Dispatch	NPC ($)	COE ($)	O&M ($)	Initial Cost ($)	Renewable Fraction
1		50	30	6	40	100	LF	$253,159	$0.215	$14,088	$71,040	43.0%
2		10	50	1	0	100	LF	$397,866	$0.337	$27,718	$17,750	0

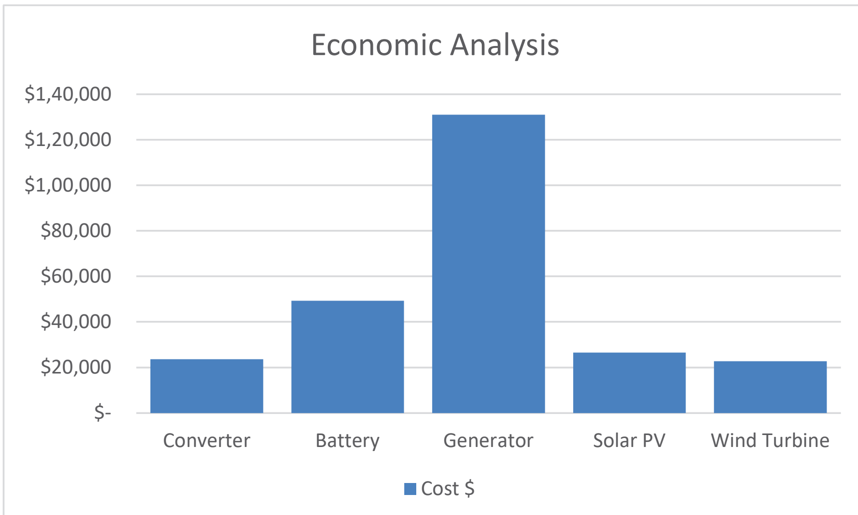

Figure 10 Cost summary of the components.

$253,159, respectively. This suggested model is the most realistic of the 1218 HOMER models.

3.4.1 Economic analysis

Table 4 depicts the rigorous economic research results for the most cost-effective hybrid energy scheme. When compared to the other proposed models, the chosen proposed model has the lowest NPC, COE, and O&M. Figure 10 depicts a cost breakdown of the materials.

The estimated NPC of the system is $253,159, and the prices of the wind turbines, solar PVs, generator, converter, and batteries are $22756.51, $26463.76, $131033.70, $23557.1, and $49348.03, respectively. The cost of the generator is the largest, accounting for 51.57% of the total cost of the system. The materials used in this analysis are readily available on the local market. The chosen model has a quick payback time of 2.2 years.

Table 5 Cost summary of the system

Components	Capital $	Replacement $	O&M $	Fuel $	Salvage $	Total $
Converter	$23,040.00	$0.00	$517.10	$0.00	$0.00	$23,557.10
AGS	$7,000.00	$37,478.21	$5,171.01	$0.00	−$301.18	$49,348.03
Generator	$6,000.00	$17,939.40	$77,456.51	$30,369.04	−$731.25	$131,033.70
Solar PV	$20,000.00	$0.00	$6,463.76	$0.00	$0.00	$26,463.76
Wind Turbine	$15,000.00	$0.00	$7,756.51	$0.00	$0.00	$22,756.51
System	$71,040.00	$55,417.61	$97,364.88	$30,369.04	−$1,032.43	$253,159.1

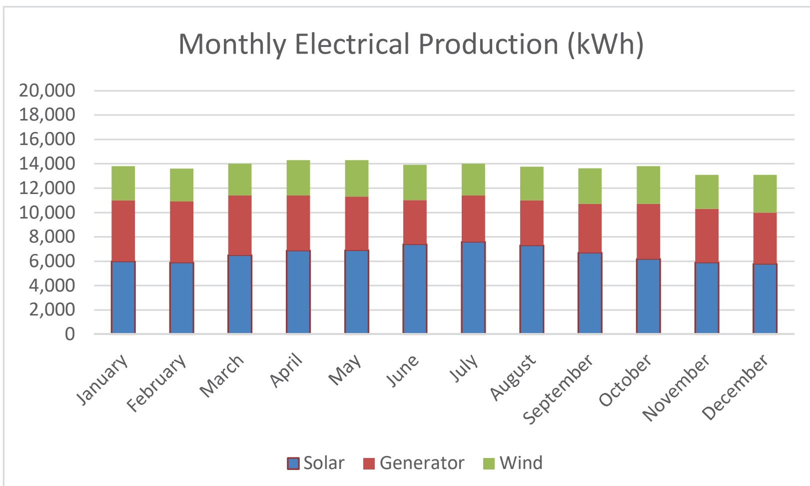

Figure 11 Monthly electric production of the HRES model.

Table 6 Annual production and consumption of electricity

Production	kWh/year	%
Solar PV	79,094	47.8
Generator	52,016	31.5
Wind Turbine	34,189	20.7
Total	165,299	100

3.4.2 Technical analysis

Figure 11 describes the HRES model's monthly electric production.

Figure 11 shows the proposed HRES system's electric output. Table 6 shows that the annual electricity generation is 165,299 kWh and the annual electricity load demand is 91,250 kWh.

Table 7 Comparison of results with previous studies

Hybrid Systems	Country	Power Consumption kWh/day	Peak Load kW	Initial Cost ($)	COE ($)	NPC ($)	O&M ($)	Electricity Production/yr
PV/Wind /DG/Battery [22]	China	564	70	396008	0.285	691427	22852	434448
PV/Wind/Batt [23]	India	151.650	30.5	166000	0.288	228000	4944	204408
PV/wind/Batt [24]	Bangladesh	213	30	126586	0.161	224344	5007	152035
PV/Wind/Diesel/Battery [25]	Comoros	159	9.3	133000	0.665	412009	26137	129707
The current Study	Pakistan	250	40.21	71040	0.215	253159	14088	165299

As seen in Table 6, the module produces more energy than the amount of energy needed, which is referred to as excess electricity. In this proposed report, the surplus power is 72578 kWh/year, and the energy deficit is 1.34 kWh/year.

4 Comparison with Previous Studies

Table 7 describes the comparison of current study results with literature in terms of NPC, COE, O&M, Production per year and power consumption. The highest COE 0.665 $/kWh was obtained from Aboudou and Ganaoui [25] study, due to less renewable energy resources available. Whereas the lowest COE 0.161 $/kWh obtained from the study of Das and Himadry Shekhar [24] with compare to the study of Krishna and Om [23] they both are using the system that consists of PV, wind and battery, the power consumption of Krishna and Om [23] is lower as compared with Das and Himadry Shekhar [24] i.e. 151.650 kWh/day, peak load is nearly same but the initial cost of Krishna and Om [23] study is higher, COE is very high as compared with Das and Himadry Shekhar [24] study, because both studies only contains PV, wind and battery no primary power resources available in the study. However, in our study the COE is 0.215 $/kWh as compared with the study of Aboudou and Ganaoui [25] and Li and Jinze [22] COE is very is very low and the operation and maintenance cost is also lower then both studies, the lowest COE and NPC obtained from the current study due to the better optimization and high availability of renewable energy resources.

5 Conclusion

To meet the energy needs of the Pasakhi Satellite Oil & Gas Complex in Tando Jam, Hyderabad, the current study established a design of a hybrid renewable energy system that involves wind turbines, solar PV, and batteries, as well as a generator backup. According to the HOMER Software, the green fraction of the planned model is 43.9%. The generator used in Pasakhi oil and gas field residential area is (CAT 3306) with power rating (220 kWh) fuel used is Diesel, average consumption of a generator at 75% of load is nearly 4-5 gallons/hour and a large amount of CO_2emissions discharged in the environment, the Pasakhi oil and gas complex is surrounded by villages and fields, it is mentioned in the Table 6 that the electrical generation from Generator usage per year is only 31.5% and from renewables it is 68.5%, very huge amount rate of CO_2will decrease. That is why the proposed system is beneficial to global scenario. These configurations were determined to achieve the most efficient device based on the COE and NPC, thus considering various susceptibility parameters such as wind speed, solar radiation, and system costs. The study investigated the viability of a hybrid off-grid renewable energy arrangement scheme for electrifying the Pasakhi Satellite Oil & Gas Complex in Tando Jam, Hyderabad. According to a survey of the region, the projected demand for energy consumption in the residential area for the summer season is 486.6 kWh/day and for the winter season is 275.6 kWh/day, but there is not enough space left to instal the microgrid for this energy consumption. As a result, we restrict our research to 250 kWh per day in the summer and 100 kWh per day in the winter. The simulation tools looked at a few different architecture choices for the HRES (HOMER). This HRES model has the lowest energy cost of $0.215. The HRES model is a low-cost, dependable approach for oil and gas fields that also benefits the environment. The energy cost for such an HRES model will be minimised even more. The oil and gas fields are surrounded by fields and villages, and more HRES models can be developed if there is enough space available.

6 Appendices

6.1 Appendix-A: Survey Questionnaire

Energy is needed for all community activities, the production of all goods, and the provision of all services. It is extremely important to a country's economy and wealth. Currently, conventional fossil fuels provide most of the world's energy. In case of oil and gas fields their energy consumption is totally off-grid their generation is only depends upon fossil fuels, the cost of energy consumption of oil and gas fields are too high because operational work of the field is totally depending upon fossil fuels. The development of off-grid renewable energy generation technologies offers the opportunity for tackling these challenges. This study provides a techno-economic feasibility analysis of an off-grid hybrid renewable energy system for Pasakhi Satellite Oil & Gas Field, Tando Jam, Hyderabad, Sindh, Pakistan. For economic growth and stability of country we must find cheap, reliable, and abundant energy resource. This questionnaire is developed after critically reviewing the literature, past studies, international guidelines concerned with dispute resolutions around the globe. Apart from the literature, several unstructured interviews were the part of this research. First part of this questionnaire is concerned about the demographic information of respondents.

Personal Information

First Name __________________

Last Name __________________

Mobile NO __________________

Instructions

Please, answer among the options provided for each question (one or more). Please write N/A if the question is not applicable to you.

Rank your preferences (1, 2, 3...) where required – 1 as the highest rank and so forth.

General information of households

1. Total number of members in the Room:

Members	Number
Adults above 40	
Adults between 30 and 40	
Adults between 20 and 30	
Total	

2. What are your priorities **for annual income expenditure**? Rank your options with 1 for the most important.

Items	Ranking
Food	
Education	
Energy	
Clothes	
Health care	
Religious functions	
Entertainment	

3. Please indicate which of the following items you have in or around your home.
   (Select all that apply)
   ☐ Stand-alone freezer ☐ Gas clothes dryer
   ☐ Laptop ☐ Electric dispenser
   ☐ Solar electric (PV) panels ☐ Refrigerator
   ☐ Water well with electric pump
4. Do you have water dispenser in your room?
   ☐ Yes ☐ No
5. What is the wattage of your water dispenser?
   ☐ 250 watts to 500 watts ☐500 watts to 750 watts
   ☐750 watts to 1100 watts
6. Do you have Laptop?
   ☐ Yes ☐ No
7. How many of each of the following items do you have in your room?.
   ☐ Plasma TV ☐ LCD TV
   ☐ Standard Tube TV ☐ Desktop Computer
   ☐ Laptop Computer ☐ Printer
   ☐ Wireless Modem/Router ☐ Cell Phone/Smart Phone

Room Heating System

1. What type is your main heating system?
   ☐ Electric room heater
   ☐ Electric heat pump
   ☐ Gas room heater
2. What type of fuel does your primary heating system use?
   ☐ Natural gas
   ☐ Kerosene Oil
   ☐ Electricity
   ☐ Wood
   ☐ Other

Water Heating System

1. Do you have water heating system?
   ☐ Yes ☐ No

2. What type of fuel do you use for heating of water?
   ☐ Natural gas
   ☐ Kerosene Oil
   ☐ Electricity
   ☐ Wood
   ☐ Other

Lighting

1. Please complete the following information about your home lighting. Please note that when you are asked the 'Number of bulbs', don't forget to count each bulb in every fixture.

   INDOOR LIGHTING

Type of Lighting	Number of bulbs	Average hours per day
Small incandescent* (< 40 Watts)	† ( )	† ( )
Medium incandescent (100 Watts)	† ( )	† ( )
Compact fluorescent (15 watts)	† ( )	† ( )
LED lights (5 to 10 watts)	† ( )	† ( )

2. Which of these fuels do you use for lighting? Please, specify the amount of fuel you consume each month.

Type of Source	Amount
Kerosene	liters/month
Solar	kWh/month
Car Batteries	Amp-Hour
Dry Batteries	Amp- Hour
Candles	nos/month
Diesel (Generator)	Liters/month
Other (Specify)________	

Kitchen Appliances

1. Which fuel type do you use for cooking in your kitchen?
   ☐ Electricity ☐ Natural gas ☐ Liquefied petroleum gas.
   ☐ Wood fuel ☐ Coal.
2. Did you use electric stove to cook meals in your kitchen?
   ☐ Yes ☐ No
3. Write down the amount of fuel used in your kitchen?

Fuel type	Kerosene (liter)	LPG (cylinder)	Firewood (kg)	Dung (kg)	Agricultural waste (kg)	Coal (kg)	Charcol (kg)
Amount of consumption							

Air Conditioning – Main Cooling

1. Do you have air conditioning system?
   ☐ Yes ☐ No
2. What type is your home's main cooling system?
   ☐ Window or wall mounted air conditioner unit
   ☐ Ceiling/room/whole house fans
   ☐ Central air conditioner
   ☐ Don't have cooling system
   ☐ Other
3. Do you have ceiling fans in your home?
   ☐ Yes ☐ No
4. No of ceiling fans in each of your room?
   ☐ 1 ☐ 2 ☐ More then 2 ( )
5. Do you have table fans in your home?
   ☐ Yes ☐ No
6. No of table fans in each of your room?
   ☐ 1 ☐ 2 ☐ More then 2 ( )

Green and Renewable Energy Services

1. If all or part of your electricity could be provided by "carbon neutral/green" energy sources, which one would you prefer?
   ☐ Wind power
   ☐ Solar power
   ☐ Hydro-electric power (dams)
   ☐ Nuclear power
   ☐ Other
   ☐ Do not have a preference.
2. Will you pay extra bill for renewable energy setup?
   ☐ Yes ☐ No

6.2 Appendix-B: Rating of the Equipment's

Specification of Converter

Table 8 Specification of converter

S. No	Converter Specification	
1	Converter Model	100KW Pure Sine Wave
2	Range of input voltages	285–400VDC
3	Range of Output voltage	220–240VAC
4	Operating Temperature Range	−41 to +61
5	Power Factor	Adjustable −0.85, +0.85
6	Method of heat ejection	Natural Convection
7	Minimal output frequency	50/60 Hz
8	Subjective efficiency	99%
9	Warranty	25 years

Specification of Battery

Table 9 Specification of battery

S.NO	Specification of battery used	
1	Model	AGS 12V 165AH (20)
2	Designed voltage	12V
3	Extreme capacity (Ah)	141
4	Capability ratio	0.363
5	Rounded trip efficiency	85%
6	Highest charge current	21.8A
7	Highest discharge current	230A
8	Highest charge rate	A/Ah

Specification of Solar PV's

Table 10 Specification of solar PV module

S.no	Solar PV Specification	
1	Solar PV Module	Titan High Performance Monocrystalline Perc Module (RSM120-8-580-650)
2	Designed Watts	550 W (0.55 KW)
3	Glass	3.2 mm solar glass with anti-titreflection surface treatment
4	Size (L×W×H) & Weight	2172×1303×35 mm & 31.5 Kg
5	Lifetime	25
6	Amps	13.91 A
7	Nominal operational temperature	-44 to $+44(-+2°\text{C})$
8	Maximum System Voltage	1500 VDC
9	Product warrant	20 years
10	linear power output warranty	25 years

Specification of Wind Turbine

Table 11 Specification of wind turbine

S.no	Specification of Wind Turbine	
1	Model	NE-10000G
2	Rated power	10000 W
3	Max power	11000 W
4	Rated voltage	220/380 V
5	Start-up wind speed	3 m/s
6	Rated wind speed	12 m/s
7	Safety Wind speed	45 m/s
8	Net weight	365 kg
9	Blades Rotor Diameter	6.3 m
10	Tower height	12/15 m

Specification of Generator

Table 12 Specification of generator

S. No	Specification of Generator	
1	Model	Generac 50 KW Protector
2	Rated Capacity	50 KW
3	Manufacture	Generac
4	Initial Cost	$10,000
5	Replacement Cost	$750
6	O&M	$2 operation/hour
7	Fuel used	Natural Gas
8	Lifetime	25 Years

References

[1] M. Mehrpooya, M. Mohammadi, E. J. S. E. T. Ahmadi, and Assessments, “Techno-economic-environmental study of hybrid power supply system: A case study in Iran,” vol. 25, pp. 1–10, 2018.

[2] P. A. Owusu and S. J. C. E. Asumadu-Sarkodie, “A review of renewable energy sources, sustainability issues and climate change mitigation,” vol. 3, no. 1, p. 1167990, 2016.

[3] M. A. Ramli, A. Hiendro, and S. J. R. E. Twaha, “Economic analysis of PV/diesel hybrid system with flywheel energy storage,” vol. 78, pp. 398–405, 2015.

[4] D. Moreira and J. C. J. B. T. Pires, “Atmospheric CO2 capture by algae: negative carbon dioxide emission path,” vol. 215, pp. 371–379, 2016.

[5] F. Mohammed and S. J. A. A. S. Gupta, “Analysis and Optimization of a Hybrid PV-Wind-Diesel Standalone System with Battery Storage Using HOMER,” 2019.

[6] W. Zhou, C. Lou, Z. Li, L. Lu, and H. J. A. E. Yang, “Current status of research on optimum sizing of stand-alone hybrid solar–wind power generation systems,” vol. 87, no. 2, pp. 380–389, 2010.

[7] J. L. Bernal-Agustín, R. J. R. Dufo-Lopez, and S. E. Reviews, “Simulation and optimization of stand-alone hybrid renewable energy systems,” vol. 13, no. 8, pp. 2111–2118, 2009.

[8] A. Iqbal and M. T. J. I. J. O. P. Iqbal, “Design and Analysis of a Stand-Alone PV System for a Rural House in Pakistan,” vol. 2019, 2019.

[9] H. Ullah, I. Kamal, A. Ali, and N. J. R. E. Arshad, “Investor focused placement and sizing of photovoltaic grid-connected systems in Pakistan,” vol. 121, pp. 460–473, 2018.

[10] A. Ghafoor, T. ur Rehman, A. Munir, M. Ahmad, M. J. R. Iqbal, and S. E. Reviews, “Current status and overview of renewable energy potential in Pakistan for continuous energy sustainability,” vol. 60, pp. 1332–1342, 2016.

[11] K. K. Sharma et al., “Economic evaluation of a hybrid renewable energy system (HRES) using hybrid optimization model for electric renewable (HOMER) software—a case study of rural India,” 2021.

[12] S. Kumar, P. Chinnamuthan, and V. J. J. O. G. E. Krishnasamy, “Study on renewable distributed generation, power controller and islanding management in hybrid microgrid system,” vol. 8, no. 1, pp. 37–70, 2018.

[13] J. Ahmad et al., “Techno economic analysis of a wind-photovoltaic-biomass hybrid renewable energy system for rural electrification: A case study of Kallar Kahar,” vol. 148, pp. 208–234, 2021.

[14] O. Ekren, C. H. Canbaz, and Ç. B. J. J. o. C. P. Güvel, “Sizing of a solar-wind hybrid electric vehicle charging station by using HOMER software,” vol. 279, p. 123615, 2021.

[15] S. U. Rehman, S. Rehman, M. Shoaib, I. A. J. E. P. Siddiqui, and S. Energy, "Feasibility Study of a Grid−Tied Photovoltaic System for Household in Pakistan: Considering an Unreliable Electric Grid," vol. 38, no. 3, 2019.

[16] H. U. R. Habib, S. Wang, M. Elkadeem, and M. F. J. I. A. Elmorshedy, "Design Optimization and Model Predictive Control of a Standalone Hybrid Renewable Energy System: A Case Study on a Small Residential Load in Pakistan," vol. 7, pp. 117369–117390, 2019.

[17] M. J. Khan, A. K. Yadav, L. J. R. Mathew, and S. E. Reviews, "Techno economic feasibility analysis of different combinations of PV-Wind-Diesel-Battery hybrid system for telecommunication applications in different cities of Punjab, India," vol. 76, pp. 577–607, 2017.

[18] M. Z. K. Kakar, K. Harijan, and L. J. I. J. O. R. E. R. Kumar, "Load Assessment of Solar PV System: Case Study of Tor Tang Village of Baluchistan," vol. 8, no. 2, pp. 29-35, 2019.

[19] A. Singh, P. Baredar, B. J. E. C. Gupta, and Management, "Techno-economic feasibility analysis of hydrogen fuel cell and solar photovoltaic hybrid renewable energy system for academic research building," vol. 145, pp. 398–414, 2017.

[20] J. Reddy and N. J. J. O. G. E. Sudhakar, "Design and Analysis of a Hybrid PV-PEMFC System with MPPT Controller for a Three-Phase Grid-Connected System," vol. 8, no. 2, pp. 151–176, 2018.

[21] A. Jain, S. Shankar, and V. J. J. O. G. E. Vanitha, "Power generation using permanent magnet synchronous generator (PMSG) based variable speed wind energy conversion system (WECS): An overview," vol. 7, no. 4, pp. 477–504, 2017.

[22] J. Li, P. Liu, and Z. J. C. E. T. Li, "Optimal design and techno-economic analysis of off-grid hybrid renewable energy system for remote rural electrification: A case study of southwest china," vol. 81, pp. 115–120, 2020.

[23] O. Krishan and S. J. J. O. E. S. Suhag, "Techno-economic analysis of a hybrid renewable energy system for an energy poor rural community," vol. 23, pp. 305–319, 2019.

[24] H. S. Das, A. Dey, C. W. Tan, and A. J. I. J. O. R. E. R. Yatim, "Feasibility analysis of standalone PV/wind/battery hybrid energy system for rural Bangladesh," vol. 6, no. 2, pp. 402–412, 2016.

[25] K. M. Aboudou and M. J. I. J. R. El Ganaoui, no, "Feasibility study for the production of electricity using a hybrid PV-wind-generator system in a remote area in Comoros," pp. 22–36, 2017.

[26] N.E.P.R.A, "State Industry Report 2020," 2021.
[27] A. Demiroren, U. J. R. Yilmaz, and S. E. Reviews, "Analysis of change in electric energy cost with using renewable energy sources in Gökceada, Turkey: An island example," vol. 14, no. 1, pp. 323–333, 2010.

Biographies

Fahim Mustafa received the bachelor's degree in Mechanical Engineering from Nazeer Hussain University Karachi, Pakistan in 2018, currently enrolled in Master of Engineering in Energy System Engineering from Mehran University of Engineering & Technology Jamshoro, Pakistan.

Anwar Ali Sahito received the bachelor's degree in Electrical Engineering from Mehran University of Engineering & Technology Jamshoro, Pakistan, the master's degree in electrical power system engineering from NED University Karachi, Pakistan, and the philosophy of doctorate degree in Electrical-Electronics & Computer Engineering from Mehran University, respectively.

He is currently working as an Associate Professor at the Department of Electrical Engineering, Faculty of Engineering, Mehran University. He has also experience of working in power distribution utilities for seven years. He has more than twenty research papers in international and national research journals. He also has three conference papers in IEEE conferences. His research areas include Power Electronic Converters, FACTS, Power System Analysis and Distributed Generation.

Shoaib Ahmed Khatri received the bachelor's degree in Electrical Engineering from Mehran University of Engineering & Technology Jamshoro, Pakistan, the master's degree in Electrical Power Engineering from Mehran University and enrolled in the philosophy of doctorate degree in Energy Systems Engineering from Mehran University, respectively. He is currently working as an Assistant Professor at the Department of Electrical Engineering, Faculty of Engineering, Mehran University. His research areas include Energy systems and energy management covering their technology, policy and economic aspects for Small-medium industries, Transportation Office and domestic levels.

Laveet Kumar received his B.E in Mechanical Engineering in 2015 and M.E in Energy System Engineering. He joined Department of Mechanical Engineering, Mehran University of Engineering and Technology, Jamshoro as Lecturer in 2016. Currently he is pursuing PhD at UM Power Energy Dedicated Advanced Centre (UMPEDAC), University of Malaya, Malaysia fully funded by Higher Education Commission of Pakistan