International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-9, July 2020

Cost Optimization of Hybrid Energy System in Afghanistan using HOMER

Saadatullah Hamkar, Anand Mohan

Abstract: ***This paper presents the Cost Optimization of hybrid energy systems in two of the most important provinces of Afghanistan, electrification of Khulm district (Uljato) for Balkh province and Zendeh Jan district (Hotel Safid) for Herat province is purposed in this study. HOMER (Hybrid Optimization Model for Electric Renewables) pro version 3.23.8 is used for optimization, simulation and sensitivity analysis, HOMER is a great software to design and evaluate technically and financially the options for off-grid and on-grid power systems. Renewable resources for selected areas are analyzed in Global Solar atlas (GSA) and Global wind atlas (GWA} the result is compared with the meteorological tower data set, the GSA/GWA is the online website that provides a summary of solar potential, solar resources, wind speed, wind density, and other related factors globally. it is provided from World Bank Group with funding from the Energy Sector Management Assistance Program (ESMAP). The modeling of the hybrid system is purposed as grid-connected for both sites, the system is designed for 2.348MW and 1.622MW for Khulm and Zendeh Jan district respectively, and 10% of load variability is considered. as a result of the study, the Levelized cost of energy (LCOE) from the hybrid system is obtained 0.0566 USD/kWh and 0.0537 USD/kWh for Khulm and Zendeh Jan district respectively which will be 30 to 50 percent cheaper than the price of electricity that is imported from neighboring countries. The total electricity generation for Khulm and Zendeh Jan districts from solar and wind are 7,988,376 kWh/year and 6,218,710 kWh/year respectively. Accessibility of electricity is the important factor for the economic growth of Afghanistan, more than 1000MW of electricity is imported from neighboring countries that are not sustainable and reliable, while Afghanistan has a great potential of renewable energy sources (REs) whose utilization could help to lessen future supply gaps at a cost level that are economically and financially attractive The development of domestic generation is vital for Afghanistan and renewable energy sources (RES) with great potential can successfully be harnessed to meet these two requirements. Besides these renewable energies (REs) are clean energies, friendly with the environment, free of harmful emissions, and have a great impact on the reduction of global warming and climate change.***

Keywords: Afghanistan, HOMER, Hybrid system, Solar, Wind

I. INTRODUCTION

Afghanistan is a non-coastal country located in South East Asia surrounded by Tajikistan, Uzbekistan, Turkmenistan, Iran, Pakistan, and china. It is located between latitude 29° 35’ and 38° 40’ degrees north and longitude 60° 31’ and 75° 00’ east. Its total land area is 652,864 km^2, in 2018, the total population was 37.7 million [1].

Since, four decades of war and conflicts caused enormous damage to the energy infrastructures, generations, transmissions, and distributions in the country. The power demand is increasing year by year, meanwhile, the primary source of the electricity supply is insecure and expensive [2]. In 2009, electricity consumption was 49kWh per capita In 2020, it’s approximately 195kWh per capita which still it is very low compared to South Asian countries that are 667kWh per capita per year and the global average is about 3100kWh per capita per year [3].

The available electricity power volume in the country is about 1627MW and about 600MW is generated inside the country where the main generation of electricity is from hydropower plants that account for 53% domestic power source followed by thermal fuel, diesel generators, and solar panels. Approximately 1000MWs of energy are imported from neighboring countries like Uzbekistan, Tajikistan, Turkmenistan, and the Islamic Republic of Iran[4].

The imported power created technical, environmental, and economic issues. Technically, they are not operating in a synchronized system as each power system of the neighbor countries supplies a separate region in Afghanistan. Nine geographically distinct power networks in the country are divided by four significant grids [5] as follow:

1. North East Power System (NEPS): NEPS is supplied by four different asynchronous power generations which are one domestic power generation and three outsourced from Tajikistan, Uzbekistan, and Turkmenistan.
2. Southeast Power System (SEPS): SEPS included the Kandahar and Helmand region power grid which is supplied by domestic power plants.
3. Herat Power System (HPS): HPS is supplied by three different asynchronous power generations sources in which one source is domestic and two other sources are imported from Iran and Turkmenistan.
4. Nimroz Power System (NPS): NPS is supplied by imported power from Iran.Additionally, in each center of the provinces, there are separate power grids that are not connected to the aforementioned nine geographically separate power networks [6], [7]. According to the power system master plan, the net demand would be increased six times by 2032 and the proposed new hydropower generation also cannot meet the load requirements [8]. There was a growing gap between demand and supply specifically between 2010 to 2015,

Revised Manuscript Received on July 30, 2020.
* Correspondence Author
Saadatullah Hamkar*, Department of Electrical Engineering, AP Goyal Shimla University, India.
Dr. Anand Mohan, Professor, Department of Electrical Engineering, AP Goyal Shimla University, Shimla, India.

the number of household connections to the grid increased by 60 percent and total connections by 57 percent, households dominate the customer base, representing almost 93 percent of the total connections, while commercial customers represent just under 7 percent and government agencies less than 1 percent.

The most recent and widespread forecast of electricity demand in Afghanistan was developed as part of the research of the Afghanistan Power Sector Master Plan (APSMP), and therefore the net demand was projected to increase from almost 2,800 GWh in 2012 to 15,909 GWh in 2032 [9].

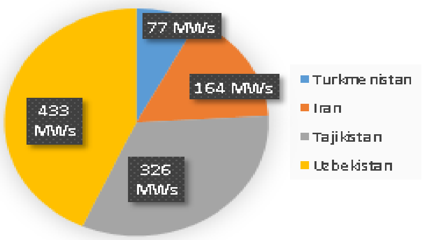

Figure 1. Imported energy in Megawatts [10]

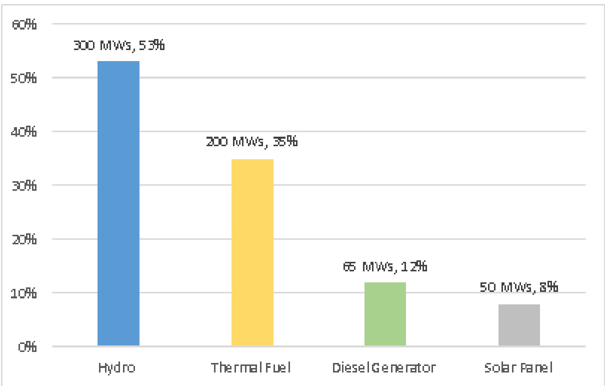

Figure 2. Domestic power generation

The main objective of this study is to determine and evaluate the domestic generation of electricity from RES mainly hybrid system solar and wind in Balkh and Herat provinces.

- Increase domestic generation
- Reduce the imported power from neighboring countries
- Become self-reliant in the power sector in the coming decades.

II. RENEWABLE ENERGY SOURCES OF AFGHANISTAN

The usage of renewable energies to reduce carbon emission is significantly increased worldwide [11] and became the primitive target of all countries [12]. Energy access and energy security are two key prerequisites for the socio-economic growth of Afghan societies. Renewable energy resources with their enormous potential in Afghanistan can successfully be harnessed to meet these two requirements [13]. Rural areas considered as the low access to electricity because the extension of the electricity network is economically impossible due to rough terrain and remoteness of the location and the best way to electrify the rural regions would be the implantation of REs [14], [15]. Afghanistan has potential that can produce around 300,000 MW of electricity utilizing available renewable energy sources. This energy production could potentially divided as follow: solar (222,000 MW), wind (66,000 MW) hydro (25,000 MW), geothermal (3,000-3,500 MW) and biomass (4000 MW) [16]–[20]. Afghanistan has 300 days of sunshine each year, its average solar potential GHI is estimated at 6.5 kWh/m^2/day, And Direct Normal irradiances is 1,022 kWh/m^2/year. Kandahar, Helmand, Farah, and Herat enjoy high Solar irradiation even northern provinces where average irradiation is 4.5 kWh/m^2/day electricity generation is feasible [4], [20].

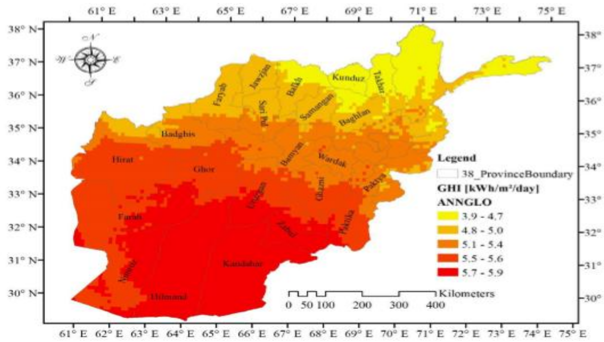

Figure 3. Global Horizontal Irradiance (GHI) map of Afghanistan

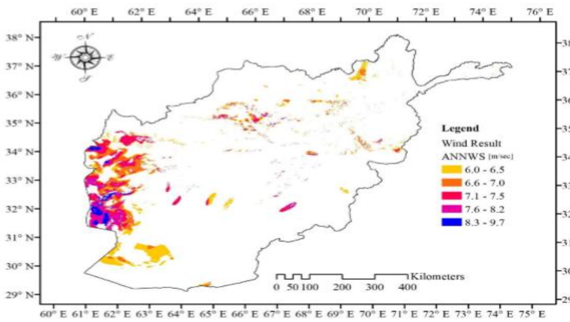

Figure 4. Wind map wind power map of Afghanistan

III. LITERATURE REVIEWS

In 2019, MD Nurunnabi and his colleagues studied sizing optimization and sensitivity analysis of hybrid Wind/PV microgrid for 5 different areas of Bangladesh. As a result of their optimization for Magnama, the minimum NPC and LCOE are from Wind and Generator, for Kuakata Wind/PV and generator are more feasible and cost-effective [21]. Moreover, in 2018, a hybrid PV-wind stand-alone system was designed by Fulzele et al and they concluded that the simulation result indicates that a hybrid energy system consisting of 225kW PV panels, one unit of wind generator of 50 kW, 2500 units of batteries and 150kW of the inverter would be the economical solution for the generation of electric energy for Dhudhagon village [22],

Furthermore, Sawle and his team investigated the socio-economic design of hybrid renewable energy systems using optimization techniques (2018), They presented the optimal hybrid power system design including the various configuration of renewable energy generation the design consideration of hybrid system using a novel particular matter factor, human health impacts are directly shown whereas pollutant emission is measured in the hybrid system design based on the minimum value of multi-objective function optimal values are decided for objective indices for optimal configuration including the various combination of wind, PV, diesel generator, biomass and battery bank separate cases hybrid systems are tested [23].

In the northern rural region of Togo, Este and his colleagues designed a hybrid system for electrification and Upliftment of the area. Este and his team used HOMER software to optimize the operation cost of the photovoltaic and biodiesel generator that served as a stand-alone power system. As a result of his optimization, the electricity produced by hybrid system PV/BG is economical than the PV system alone and economical than BG alone [24].

On the contrary, Obaid and his colleagues constructed a wind-fuel-cell-solar hybrid electric boat power with the Maximum Power Point Tracking (MPPT) System. their proposed design using PV panels with Maximum Power Point Tracking (MPPT) system battery bank wind turbine asynchronous generator, Polymer Electrolyte Membrane (PEM) fuel cell with electrolyzing and hydrogen tank were all renewable sources and that was an advantage for the proposed design and had continues operation and stable speed regardless of wind speed and solar irradiance variations [25].

Anwarzai Mohammad has researched and analyzed Afghanistan's wind, solar, and geothermal resources potential. He analyzed briefly all the prospective of the renewable energy sources in the country using Geographical Information System (GIS) application and Multi-Criteria Decision Analysis (MCDA) software. Additionally, he described site selection criteria for solar panels as well as wind turbines [4].

Saudi Arabia's all electricity generated from conventional sources to reduce the environmental impact of using fossil fuels Yahya Z. has studied about using different renewable energy sources and has developed a grid-connected solar PV-Wind hybrid system for different locations of Saudi Arabia using HOMER Pro software [26]. A study has been done in Catalonia, Spain by González, A. and his team as a result of their study they believed that grid-connected Hybrid Renewable Energy System (HRES) of Windpower and PV are more economical and profitable in the rural township of Mediterranean and add it that grid-connected system needs less initial investment due to less requirement of components [27]

Dihrab and Sopin presented a hybrid system of solar and wind in 3 locations in Iraq, it is found that the PV and wind power are more in Basrah rather than Baghdad and Mosul [28]. And many other types of research have been done to calculate the sizing of (PV) photovoltaic and wind energy systems using linear programming [29]–[31]. And some software is available for optimization of the hybrid system mainly HOMER has been used in renewable energy systems [32]–[34]. Graphic construction and artificial intelligence method also presented for the optimization technique of hybrid system case studies [35], [36].

IV. METHODOLOGY

The proposed methodology for cost optimization of hybrid energy systems has been given in Figure 5 In this study, Afghanistan's renewable energy resources are reviewed and analyzed and the power sector has been studied thoroughly. the solar and wind energy-producing countries like India, Brazil, the US, Australia, and Germany's information have been reviewed to develop and define appropriate criteria for suitable site selection in Afghanistan [37]–[43]. To measure the wind for 12 months, the initial data were collected from the ACEP survey which was funded by USAID back in 2012. The data were collected from six selected sites using NREL's modeled wind resource map and global solar horizontal irradiation was also measured [44]. For data validation, the meteorological tower data of the selected sites by ACEP were compared with GSA and GWA data. The GSA is provided by the World Bank Group and funded by the ESMAP and through the GSA portal a summary of solar potential and solar resources are provided globally whereas, the GWA provides the potential wind resources information [45], [46]. Following the data validation process, in this study, it was tried to select economic and reliable technology for solar panels and wind turbines for better functioning and power generations. The more cost-effective renewable technologies are the cheaper the power production would get and subsequently would encourage a higher shift towards utilizing renewable energy projects and ultimately reduce global warming caused by fossil and thermal energy productions in the country. The HOMER software is used for the design of on-grid, off-grid, and hybrid power systems for remote, stand-alone, and distributed generation applications. HOMER software is developed by the National Renewable Energy Laboratory in the United States it allows you to consider a large number of conventional and non-conventional technologies. Using this software, the economic factors of the project's annual interest rate, project lifetime, system's capital cost, Operation a& Maintenance (O&M) cost, replacement cost, and LCOE is defined in HOMER software. HOMER does sensitivity analysis, Optimization as well as Simulation [47]–[51].

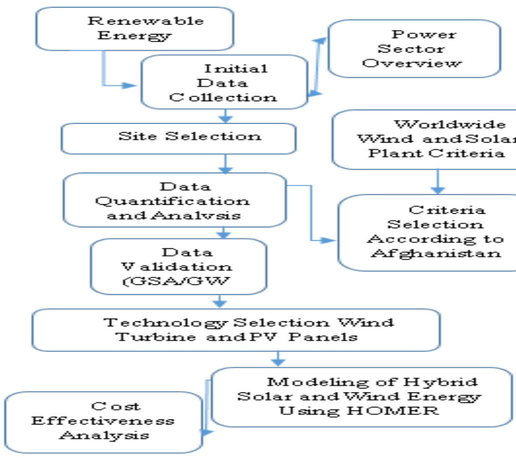

Figure 5. Methodology for Cost optimization of the hybrid energy system

A. *Case Study 1 Uljato (Khulm District, Balkh)*

Khulm or Khulmi is one of the districts of Balkh province, in 2012 the population was estimated 68,900 [52]. Khulm district is also known as Tashqurghan and it is an ancient town located on the productive lands that agriculture is considered the main occupation of their people and it is known as the center for trading the sheep and wood [53].

Khulm has 91 villages, 7 primaries, 13 secondaries, 7 high school, and 4 health centers [54].

The total load demand in this district is 21,820 kWh/d [12]. And the system is designed for the peak load of 2348.24 kW.

B. *Case study Hotel Safid (Zendeh Jan District, Herat)*

Zendeh Jan district is located in the central part of Herat province, in 2012 the total population was estimated 55,500 [55].

Zendeh Jan district has 22 Schools and 157 villages, most of the people are busy in agriculture, their saffron is well known in the world [56].

The load demand is estimated at 17,720 kWh/d with 10% variability and the system is designed for the peak load of 1662.2 kW. It is worth mentioning that for Zendeh Jan district it is not the actual load, estimation is done by the author.

C. *Site Selection Criteria for Wind and Solar (PV)*

Site selection criteria are crucial for any kind of Energy generation and installation. Applicable environment, technical and economic factors are considered for site selection for getting the best result of generation.

There are some constraints for installation for both wind turbines and solar PV panels like locations with lower solar irradiance or less wind speed these are the main constraints that such installation would not be profitable and beneficial [57].

As the purpose of this study is the modeling of the hybrid system so we have to select the best and suitable area where the installation of both wind turbines and PV panels is applicable.

The wind speed for both selected areas Uljato and Hotel Safid are more than 6m/s and the annual global horizontal irradiation is also greater than 3.5 [kWh/m²/day].

Meanwhile, the slope angle is also less than 5% for both sites [58], Afghanistan is a mountainous, less developed country and transportation is difficult so we select areas that the slope is less than 10%.

However, in the United States of America and United Kingdom fields with less than 19% are considered suitable for the installation of wind farms [59].

The wind speed for both selected areas Uljato and Hotel Safid are more than 6m/s and the annual global horizontal irradiation is also greater than 3.5 [kWh/m²/day].

Meanwhile, the slope angle is also less than 5% for both sites [google earth pro], Afghanistan is a mountainous, less developed country and transportation is difficult so we select areas that the slope is less than 10%.

Table I: Site selection criteria for wind turbines and PV panels

Criteria	Wind Turbines	PV Panels
Resources	Annual wind speed > 6m/s at 50m height	Annual global horizontal irradiation > 3.5[kWh/m²/day] [60]
Slope area [61]	Less than 10%	Less than 5%
Land Use [62]–[64]	Rock outcrop/bare soil, Sand covered area Rangelands (grassland, forbs, low shrubs) Rain-fed crops (sloping and flat) Rock outcrop/bare soil, Sand covered area	Rock outcrop/bare soil, Sand covered area Rock outcrop/bare soil, Sand covered area
The fruit trees and gardens	Should not be install	Should not be install
Natural Disaster area	Should not be install	Should not be install
Large hills and mountains [65]	Should not be install	Should not be install
Settlements [66]	Not within 2000m	Should be 10km around the urban/cities
Roads [67]	The area within 10km of road	Areas within 10km of roads
Airport [68]	Not within 3500m	Nor applicable
Required area minimum [69]	4km²	0.4km²

D. Solar irradiation in Uljato (Balkh) and Hotel Safid (Herat)

The study areas of this paper are two important provinces of Afghanistan Uljato for Balkh with a latitude of 36° 43.27' and longitude 67° 37.33' and Hotel Safid for Herat province with latitude 34° 24.32' and longitude 61° 49.35’.

The solar and wind data from GSA, GWA, and NREL are assessed compared with meteorological wind tower measurement data.

Table II: NREL, GSA, and Meteorological data comparison in Uljato and Hotel Safid [44], [45]

Name	Latitude (°)	Longitude (°)	Annual GHI [kWh/m²/day]		
			NREL	TOWER	GSA
Uljato	36.7212	67.6222	4.78	3.29	5
Hotel Safid	34.4054	61.8226	5.39	13.15	5.63

For Uljato, Balkh there are slight differences between tower, NREL, and GSA.

Hotel Safid, Herat enjoys high solar irradiance and there is much difference between tower and GSA but hopefully, the irradiation is more than 5 [kWh/m²/day].

Table III: Annual site information at Uljato and Hotel Safid

Site Information		Uljato	Hotel Safid
Specific photovoltaic power output	PVOUT Pacific	1599 kWh/kWp	1839 kWh/KWp
Direct normal irradiation	DNI	1583 kWh/m²	2150 kWh/m²
Global horizontal irradiation	GHI	1794 kWh/m²	2055 kWh/m²
Diffuse horizontal irradiation	DHI	782 kWh/m²	707 kWh/m²
Global tilted irradiation at an optimum angle	GTI OPTA	2029 kWh/m²	2336 kWh/m²
The optimum tilt of PV modules	OPTA	32 / 180	32 / 180
Air Temp	TEMP	18.6 °C	17.5°C
Terrain elevation	ELE	395m	861m

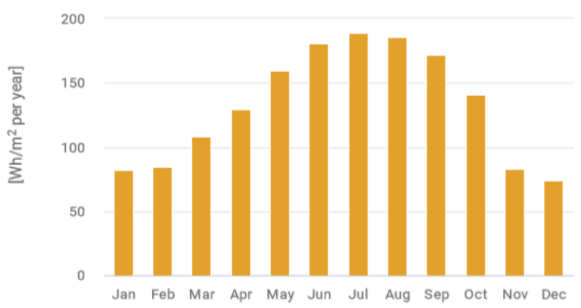

Figure 6. Monthly average profile DNI [Wh/ m²*]* per year in Uljato, Balkh.

DNI is the amount of solar energy that always held straight or perpendicular. In Uljato May to Oct is the highest and for Hotel Safid Jan to Dec, it is fairly good.

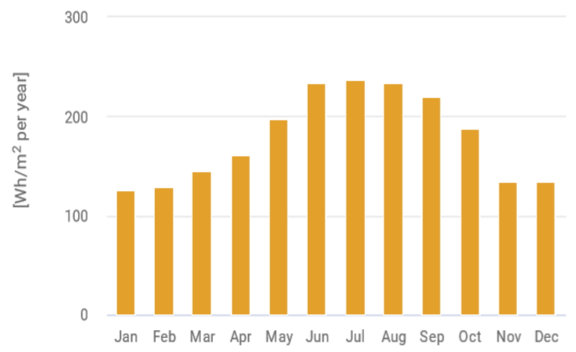

Figure 7. Monthly average profile DNI [Wh/ m²] per year in Hotel Safid, Herat.

In Hotel Safid, the DNI is better between April to October, while it decreases from November to February.

D. *Wind Resources in Uljato (Balkh) and Hotel Safid (Herat)*

The Afghan clean energy program (ACEP) conducted wind monitoring operation to measure the wind data, wind speed, wind direction in elevation of 20m, 30m, and 50m. six sites were selected by NREL's Modeled wind resource Fortunately, the two sites that are purposed in this paper are also included in that six selected sites of the NREL, and among the six sites, Uljato for Balkh and Hotel Safid for Herat has the highest annual average wind speed [22].

Table IV: Wind resources in Uljato and Hotel Safid at different heights

Specification	Uljato			Hotel Safid		
Height	10m	50m	100m	10m	50m	100m
Wind Speed [m/s]	4.91	7	7.69	6.25	8.28	9.41
Power Density [W/m^2]	237	443	594	405	862	11.51
Roughness Length RL[m]	0.005	0.005	0.005	0.1	0.1	0.1
Mean Air density	1.157 kg/m^3			1.081 kg/m^3		

the mean wind speed, power density Roughness length and mean air density is studied in 10m, 50, and 100m above the ground for both Uljato and Hotel Safid using the GWA, Hotel Safid, Herat province has ideal wind speed in each height above the ground and the roughness length is 0.1 but for Uljato roughness length is 0.05 and wind speed is getting better after 50m height for a good power generation.

Table V: GWA, NREL, and Meteorological tower average wind speed (m/s) In Uljato and Hotel Safid [45], [46]

Province	Name	Latitude(°)	Longitude(°)	Height (m)	Average Annual Wind Speed [m/s]		
					NREL	TOWER	GWA
Balkh	Uljato	36.7212	67.6222	50	6.51	6.20	7.00
Herat	Hotel Safid	34.4054	61.8226	50	6.77	9.09	8.28

The annual wind speed is better for both sites, while, Hotel Safid enjoys high wind speed compare to the Uljato

V. ECONOMIC MODELING OF THE HYBRID SYSTEM

For economic modeling of the hybrid system, the annualized cost of the system (ACS), NPC, and the cost of energy is indispensable [70]. In this study the cost of the solar panel is estimated at approximately 1340 USD/kWp with 20 years of warranty [24], 67% of the total cost is estimated for the replacement cost for O&M 10 USD/kWp is calculated. 214USD/kW is estimated for a converter for replacement and O&M costs 199.02$/kW and 2.57$ is calculated respectively. A wind turbine is estimated at 251759USD/100kW 75% of the total cost is estimated as replacement cost and 2% is estimated O&M cost [21]. The wind turbine's cost includes the installation, transport, and the manufacturing cost[71]. the discount rate is considered 8%, and the inflation rate is considered 2%.

Table V: Wind turbine and PV module parameter [21], [24]

PV Parameters	**Value**
Manufacturer	Suntech
Maximum Power at STC (Pmax)	370
Optimum Operating Voltage (Vmp)	26.4 V DC
Dimension	1482 × 992 × 35mm
Derating Factor	90%
Open Circuit Voltage	>40
Short Circuit Current	7.95 A
Warranty	25 years
Wind Turbine Parameters	**Value**
Manufacturer	Kingspan Renewables Ltd.
Rated Power	5.2kW
Peak	6.1kW
Cut-in Speed	3.5 m/s
Cut-out Speed	N/A (continues operation)
Survival Wind Speed	70m/s
Lifetime	25years

A. Cost of Operating Energy (COE)

To calculate the COE, HOMER divides the annualized cost of producing electricity (the total annualized cost minus the cost of serving the thermal load) by the total electric load served, using the following equation:

$$COE = \frac{C_{ann,tot} - C_{boiler} H_{served}}{E_{served}} \quad (1)$$

$C_{ann,tot}$ is the total annual cost of the system [$/kWh] and C_{boiler} is the boiler marginal cost [$/kWh], H_{served} is the total thermal load served [kWh/year], and E_{served} total electric load served [kWh].

B. Net Present Cost (NPC)

The NPC of a system is the present value of all the costs the system incurs over its lifetime minus the present value of all the revenues it earns over its lifetime. Costs include capital costs, replacement costs, O&M costs, fuel costs, emissions penalties, and the costs of buying power from the grid. Revenues include salvage value and grid sales revenue. HOMER calculates the total NPC by summing the total discounted cash flows in each year of the project lifetime. The total NPC is HOMER's main economic output, the value by which it ranks all system configurations in the optimization results, and the basis from which it calculates the total annualized cost and the LCOE[72].

C. Solar PV Modeling

HOMER uses the following equation to calculate the output of the PV array:

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{G_T}{G_{T,STC}}\right)[1+ \alpha_P (T_c - T_{c,STC})] \quad (2)$$

Whereas, the descriptions of the abbreviations are as follow: Y_{PV} is the rated capacity of the PV array, meaning its power output under STC[kW], f_{PV} is the PV derating factor [%], G_T is the solar radiation incident on the PV array in the current time step [kW/m^2], $G_{T,STC}$ is the incident radiation at standard test conditions [1 kW/m^2], α_P is the temperature coefficient of power [%/°C], T_c is the PV cell temperature

in the current time step [°C], and $T_{c,STC}$ is the PV cell temperature under standard test conditions [25°C].

D. Wind Turbine Modeling

Calculating Hub Height Wind Speed in each time step, HOMER calculates the wind speed at the hub height of the wind turbine using the inputs you specify in the Wind Resource Inputs window and the Wind Shear Inputs window. If you choose to apply the logarithmic law, HOMER calculates the hub height wind speed using the following equation [72]:

$$U_{hub} = U_{anem} \frac{\ln\left(\frac{Z_{hub}}{Z_0}\right)}{\ln\left(\frac{Z_{anem}}{Z_0}\right)} \quad (3)$$

U_{hub} is the wind speed at the hub height of the wind turbine [m/s], U_{anem} is the wind speed at anemometer height [m/s], Z_{hub} is the hub height of the wind turbine [m], Z_{ane} is the anemometer height [m], Z_0 is the surface roughness length [m], and l_n is the natural logarithm.

E. Grid Parameter

In Afghanistan, the COE for domestic is 0.0823 USD/kWh and for commercial it is about 0.23 USD/kWh [15]. This research is also carried out by estimating the fixed rate of the country, and the sell-back price is set at 0.06 USD/kWh. Grid power is supplied when there is no power from renewable energy sources to meet demand. Furthermore, when there is much generated from renewable energies it delivers to the grid.

International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-9 Issue-9, July 2020

VI. HYBRID SYSTEM COMPONENTS

Hybrid solar photovoltaic (PV) and wind energy systems are an effective solution in particular for standalone and grid-connected applications. Integrating the two sources of energy can provide better reliability [73]–[75]. The drawback of all renewable energies is their intermittency [76] and hybridization of renewable energies reduce this drawback since the weakness of one system can be complemented by the strength of another one

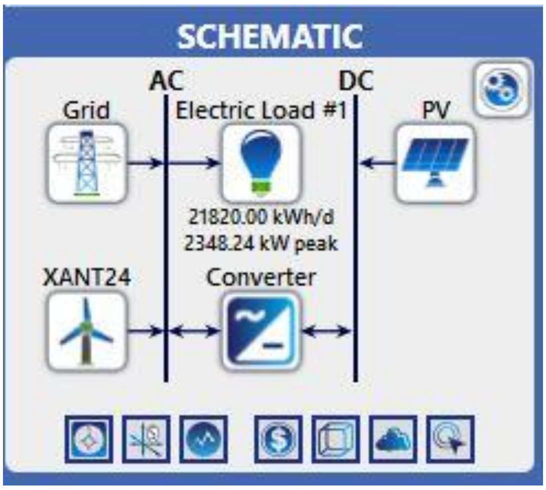

Figure 8. Block diagram of hybrid system on-grid mode in Uljato (Khulm), Balkh

The system is designed for the peak load of 2348.24 kW for Khulm district, as total load demand is 21820 kWh/d in Khulm [12].

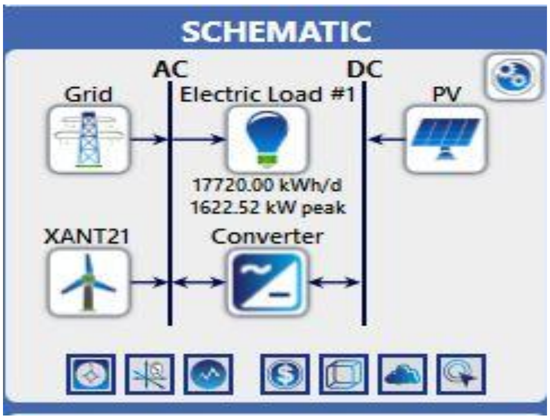

Figure 9. Block diagram of the hybrid system on-grid mode in Hotel Safid (Zendeh Jan), Herat

The load demand is considered 17720 kWh/day and the system is designed for the load of 1622.52 kW for Zendeh Jan district, 10% of load variability is considered for both sites. In this system, the on-grid of RE is designed by HOMER Pro to meet the load demand of selected areas. The solar irradiance and wind speed are considered as sensitivity variables. The search space for solar PV is ranged from 0 to 2500 kW, for wind turbines ranged from 0 to 10 turbines 100kW and for converter 0 to 2500kW is considered as optimization variables.

A. Simulations

To select the techno-economically system configuration PV-Grid, Wind-Grid, PV-Wind-Grid, and Grid alone are considered, then for best integration of the system simulation based on NPC, COE, operating cost, and Initial cost has been done.

Table VI: Simulation result based on NPC, COE, Operating cost, and Initial cost

Model	Site	NPC (USD)	COE (USD/kWh)	Operatin g Cost (USD)	Initial Cost (USD)
PV-Grid	Uljato	8.19 M	0.0666	349,751	3.67 M
Wind-Grid	Uljato	8.07 M	0.0758	429,342	2.52 M
PV-Wind-Grid	Uljato	8.13 M	0.0566	141,977	6.30 M
Grid	Uljato	8.47 M	0.0823	655,462	-
PV-Grid	Hotel Safid	6.89 M	0.0674	283,029	3.03 M
Wind-Grid	Hotel Safid	6.69 M	0.0662	276,843	2.52 M
PV-wind-Grid	Hotel Safid	5.95 M	0.0537	127,039	4.31 M
Grid	Hotel Safid	6.89 M	0.0823	532,600	-

VII. RESULT AND DISCUSSION

A. Result Case 1 Uljato (Khulm), Balkh

The analysis performed for four different configurations: PV/Grid, Wind/Grid, PV/Wind/Grid and Grid alone for both Uljato and Hotel Safid and the result is presented in Table VII it shows the minimum and economically feasible generation of electricity cost for Uljato is given by the hybrid system of PV-Wind-Grid model, for Uljato the NPC is USD 8.13M and the COE is 0.0566 USD/kWh.

In all different cases that have been studied, the cost of the hybrid system remains optimal, the COE and NPC remain lower than the grid alone. remains below the COE from the grid only and the operating cost of the system also remains less than other considered configuration for the hybrid system. In Uljato The PV power output is 4,652,563 kWh/year and 9953kWh/d the Windpower output is 3,606,232 kWh/year and 12,747kWh/d, the system is designed as net metering when there is more generation from renewable energies the grid is feed by them.

B. Result case 2 Hotel Safid (Zendeh Jan), Herat

Hotel Safid, Herat that enjoys high wind speed and GHI the generation capacity can be increased up to a high level, using the hybrid system of PV and wind turbines all over the year. The economic electricity generation cost for Hotel Safid is given by the hybrid system of PV-wind-grid model, the NPC is USD 5.95M and COE is 0.0537 USD/kWh. The PV power output is 3,045,633 kWh/year and 8344 kWh/d and the Windpower output is 3,173,077 kWh/year and 8679.6 kWh/d in Hotel Safid. For both sites, the renewable energy fraction is more than 70%.

Retrieval Number: I7013079920/2020©BEIESP
DOI: 10.35940/ijitee.I7013.079920
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

As a result of this analysis, it has been cleared that the hybrid system for both sites the NPC, the cost of energy, and other economic parameters are feasible and economical. In Uljato, PV-Grid would be feasible when the wind speed is decreased but for completing the weakness of each other the integration of both systems is purposed, and the significance of hybrid system in Uljato, Balkh is the high GHI in summer and high wind speed in winter that makes the system better. At all the PV-grid and wind-grid would be 10 to 20 percent costly compare to the hybrid solar and wind energy on-grid. The COE for PV-wind-grid would be 10 to 30 percent cheaper compared to the grid alone and other analyzed models.

C. Sensitivity Analysis

Table VIII: Sensitivity analysis for different GHI, wind speed, and hub height

Site	GHI [kWh/m²/day]	Wind speed (m/s)	Hub Height (m)	NPC USD	COE kWh/USD
Uljato	4.83	7	50	8.23M	0.0593
Uljato	5	5.48	31.8	8.19M	0.0666
Uljato	5	7	50	8.13M	0.0566
Hotel Safid	5	7.5	31.8	6.63	0.0615
Hotel Safid	5	7.5	50B.	6.38M	0.0638
Hotel Safid	5.5	7.5	31.8	6.28M	0.057
Hotel Safid	5.5	8	31.8	6.12M	0.0545
Hotel Safid	5.5	8	50	5.95M	0.0537

The main purpose of the sensitivity analysis is to find the economical and feasible model, different values are considered in this study, In Uljato when the GHI is 4.83 [kWh/m²/day] at a wind speed of 7.00 m/s, the COE is 0.0593 USD/kWh in 50m height of hub, 5.00 [kWh/m²/day] GHI and the wind speed of 7.00 m/s and 50m hub height is the COE comes 0.0566 USD/kWh and the NPC also comes less than the other sensitivity analysis in Uljato. the economical and feasible parameter for Uljato is when the GHI is more than 4.5 [kWh/m²/day] and wind speed 6.00 m/s. more than 6.00 m/s but if it decreases from these ranges the NPC cost increases and the feasibility of the system also come down as the generation decreases. Hotel Safid enjoys high GHI and wind speed in each month the feasibility of the system is much higher when the GHI 5 [kWh/m²/day] and the wind speed is 7.5 m/s at 31.8m hub height the COE comes 0.0615 USD/kWh. For 7.5 m/s wind speed and 5.5 [kWh/m²/day], GHI at the hub height of 31.8m even the COE comes 0.057USD/kWh and the NPC USD6.28M. and the most economical parameter in Hotel Safid is with 5.5 [kWh/m²/day] GHI 8.00 m/s wind speed at hub height 0f 50m the COE is 0.0537 USD/kWh and the NPC is also much lower than models. As the Hotel Safid site has good potential for wind and solar energies for future studies it can be increased by size to generate much electricity to electrify whole the province.

VIII. CONCLUSION AND FUTURE SCOPE

This paper is conducted on the cost optimization of the hybrid system and explores the power output of the hybrid system at two different locations in Afghanistan. for both sites hybrid of solar and wind energy systems connected to the grid was feasible and economical. For economic comparison and finding the cost-effectiveness of the HREs configuration, the key performance factors like NPC, COE, and several sensitivity analyses such as GHI, Wind speed, and Hub height have been studied. The result of optimization reveals that using the RES can decrease the price of electricity up to 30% and 50% compare to the imported power. As renewable energies are the clean energies and pollution-free implementation of them would be beneficial both economically and environmentally for both districts.

There are so many aspects that are necessary for future scope in the power sector of Afghanistan, as Afghanistan is blessed with vast REs every province of the country has its potential for electricity generation, so it needs for academic researches and investment then the country could be self-reliant in the power sector. For further analysis of the wind potential, additional meteorological towers should be installed, more accurate, economic, and implementable areas for wind and solar energies inside the country should be studied. This paper can be used as a guideline on the modeling of hybrid systems in Afghanistan and also it would be applicable in different regions around the world with similar resources

REFERENCES

1. "World Bank, World Development Indicators Database, Country profile,Afghanistan;http://databank.worldbank.org/data/Views/Reports/ReportWidgetCustom.aspx?Report_Name=CountryProfile&Id=b450fd57&tbar=y&dd=y&inf=n&zm=n&country=AFG
2. "Energy-Development-Security Nexus, in, Afghanistan."-http://www.ensec.org/index.php?option=com_content&view=article&id=386:energy-development-security-nexus-in-afghanistan&catid=130:issue-content&Itemid=405 (accessed May 17, 2020).
3. "'IRENA, Renewable Energy country profile – Afghanistan,' 2015. [online].Available:http://resourceirena.irena.org/gateawy/countrySearch/?countrycode=AFG [Accessed:2019]
4. "Anwarzai, M. A., & Nagasaka, K. (2017). The utility-scale implementable potential of wind and solar energies for Afghanistan using GIS multi-criteria decision analysis. Renewable and Sustainable Energy Reviews, 71, 150–160.
5. "Jim Liston: Central Asia-south Asia connectivity; Impact of Afghanistan Power Master Plan on Regional Interconnection, IEA Training, Bangkok, Nov 2013
6. "Energy Charter Secretariat: Occasional Papers, Regional Electricity Cooperation in Central and Southern Asia, Belgium, 2007.
7. "John Irving & Peter Meier, Afghanistan Resource Corridor Development: Power Sector Analysis, Australian AID, 11 July 2012.
8. "FICHTNER, Islamic Republic of Afghanistan: Power Sector Master Plan, ADB, Project Number: 43497, May 2013
9. "Afghanistan's Power Sector Master Plan .pdf.". [online]. Available:[Accessed:NOV.2019],http://www.adb.org/sites/default/files/project-document/76570/43497-012-afg-tacr.pdf.
10. "Afghan Energy Information Center, Power Production and Supply Statics." Access[online]. Available: http://aeic.af/en/ppi. [Accessed: 26-Nov-2019]
11. "Lund H, Kempton W. Integration of renewable energy into the transport and electricity sectors through V2G. Energy Policy 2008;36:3578–87.
12. "IRENA. REmap Roadmap for a Renewable Energy Future. 2016 ed. Abu Dhabi: International Renewable Energy Agency.
13. "Lopezet al.–2012–U.S.Renewable Energy Technical Potential A GIS- Available .pdf."

14. "Haanyika CM. Rural electrification in Zambia: policy and institutional analysis. Energy Policy 2008;36:1044–58
15. "Mainali B. Renewable energy market for rural electrification in developing countries: country case Nepal. [Licentiate thesis] Division of energy and climate studies, KTH, Haanyika, 2008, Mainali;
16. "Akash Kumar Shukla, K. Sudhakar *, Prashant Baredar Energy Centre, Renewable energy resources in South Asian countries: Challenges, policy, and recommendations Maulana Azad National Institute of Technology Bhopal, Bhopal, India Received 22 November 2016; received in revised form 10 December 2016; accepted 11 December 2016 Available online
17. "National Renewable Energy Laboratory (NREL), Focus on creative answers to today's energy challenges to transforming the way the world uses energy. Available at: 〈http://www.nrel.gov/〉
18. "Garg P, Kandpa TC. Renewable energy education in developing countries. In: Proceedings of 2nd world renewable energy congress; 1992.
19. "Muneer T, Asif M, Munawwar S. Sustainable production of solar electricity with particular reference to the Indian economy. Renew Sustain Energy Rev 2005;
20. "David S. Renne, Richard Perez, Solar and wind resource, assessment for Afghanistan and Pakistan. In: Proceedings of the ISES Solar World Congress, Solar Energy and Human Settlement. pp. 134–140; 2007
21. "MD. NURUNNABI 1, NARUTTAM KUMAR ROY1,2, (Member, IEEE), EKLAS HOSSAIN 3,4, (Senior Member, IEEE), AND HEMANSHU ROY POTA2
22. "J. B. Fulzele, M. B. Daigawane, and P. M. Daigawane, 'Design of hybrid PV-wind stand- Alone renewable energy system: Case study,' J. Inf. Optim. Sci., vol. 39, no. 1, pp. 345- 335 Jan. 2018
23. "Y. Sawle, S. C. Gupta, and A. K. Bohre, 'Socio-techno-economic design of hybrid sys- Renewable energy system using optimization techniques,' Renew. Energy, vol. 119, pp. 459-472, Apr. 2018
24. "K. Etse, A. Mohan, and A. Sharma, 'Hybrid system for Electrification and Upliftment of Northern Rural Region of Togo,' vol. 8, no. 1, p. 9, 2019.
25. "W. Obaid, A.-K. Hamid, and C. Ghenai, 'Wind-Fuel-Cell-Solar Hybrid Electric Boat Power Design with MPPT System,' in 2019 8th International Conference on Modeling Simulation and Applied Optimization (ICMSAO), 2019, pp. 1-5.
26. "Alharthi, Y., Siddiki, M., & Chaudhry, G. (2018). Resource Assessment and Techno-Economic Analysis of a Grid-Connected Solar PV-Wind Hybrid System for Different Locations in Saudi Arabia. Sustainability, 10(10), 3690. DOI:10.3390/su10103690
27. "González, A., Riba, J.-R., Rius, A., & Puig, R. (2015). Optimal sizing of a hybrid grid-connected photovoltaic and wind power system.Applied,Energy,154,752–762.DOI:10.1016/j.apenergy.2015.04.105
28. "Dihrab SS, Sopin K. Electricity generation of hybrid PV/wind systems in Iraq. Renew Energy 2010;35(6):1303–7.
29. "Cormio C, Dicorato M, Minoia A, Trovato M. A regional energy planning methodology including renewable energy sources and environmental constraints. Renewable & Sustainable Energy Reviews 2003;7(2):99–130.
30. "Blankenship RE, Tiede DM, Barber J, Brudvig GW, Fleming G, Ghirardi M, et al. Comparing photosynthetic and photovoltaic efficiencies and recognizing the potential for improvement. Science 2011;332(6031):805–9.
31. "Woo CK, Zarnikau J, Moore J, Horowitz I. Wind generation and zonal-market price divergence: evidence from Texas. Energy Policy 2011;39(7):3928–38. ome&ie=UTF-8 (accessed May 18, 2020).
32. "Khan MJ, Iqbal MT. Pre-feasibility study of stand-alone hybrid energy systems for applications in Newfoundland. Renewable Energy 2005;30(6):835–54.
33. "Zoulias EI, Lymberopoulos N. Techno-economic analysis of the integration of hydrogen energy technologies in renewable energy based stand-alone power systems. Renewable Energy 2007;32(4):680–96
34. "Dufo-López R, Bernal-Agustín JL. Design and control strategies of PV–diesel systems using genetic algorithms. Solar Energy 2005;79(1):33–46.
35. "Yang HX, Lu L, Zhou W. A novel optimization sizing model for hybrid solar– wind power generation system. Solar energy 2007;81(1):76–84.
36. "Yang HX, Zhou W, Lu L, Fang ZH. Optimal sizing method for a stand-alone hybrid system with LPSP technology by using a genetic algorithm. Solar Energy 2008;82(4):354–67.
37. "Bhattacharya M, Paramati SR, Ozturk I, Bhattacharya S. The effect of renewable energy consumption on economic growth: evidence from top 38 countries. Appl Energy 2016;162:733–41.
38. "Bureau of Resources and Energy Economics. Asia Pacific Renewable Energy Assessment. 2014 ed. Canberra.
39. "Bureau of Resources and Energy Economics. Energy in Australia 2014. 2014 ed. Canberra.
40. "Geoscience Australia and Bureau of Resources and Energy Economics. Australian Energy Resource Assessment. 2014 ed. Canberra.
41. "Environmental Report for Danish electricity and CHP – Summary of the status year 2014, Energinet.DK" (PDF).
42. "Share of renewables in energy consumption in the EU rose further to 16% in 2014. Eurostat News Release, 10 February 2016".
43. "Schavan, A. (2010). Germany's Energy Research Plan. Science, 330(6002), 295–295. :10.1126/science.1198075 -
44. "Afghan Clean Energy Program, Wind Resource Assessment Summary, USAID, April 2012
45. "Global Solar Atlas, 'Uljato and Hotel Safid,' Solar Resources, 2020.-[Online].Available:https://globalsolaratlas.info/detail?s=34.4054,61.8226&m=bookmark. [Accessed 18 3 2020].
46. "Global Wind Atlas, 'Uljato And Hotel Safid,' Wind Resources, 2019. [Online]. Available: https://globalwindatlas.info/. [Accessed 30 3 2020].
47. "O. Hafez and K. Bhattacharya, '"Optimal planning and design of a renewable energy-based supply system for microgrids,"' Renew. Energy, vol. 45, pp. 7–15, Sep. 2012. doi: 10.1016/j.renene.2012.01.087.
48. "P.M.Murphy,S.Twaha,andI.S.Murphy,'"Analysisofthecostofreliable electricity: A new method for analyzgrid-connectedcted solar, diesel and hybrid distributed electricity systems considering an unreliable-electric-grid,withexamplesinUganda,"'Energy,vol.66,pp.523–534,Mar.2014.doi:10.1016/j.energy.2014.01.020.
49. "M. A. M. Ramli, A. Hiendro, K. Sedraoui, and S. Twaha, '"Optimal sizing of grid-connected photovoltaic energy system in Saudi Arabia,"' Renew. Energy, vol. 75, pp. 489–495, Mar. 2015. doi: 10.1016/j.renene.2014.10.028.
50. "K. Y. Lau, M. F. M. Yousof, S. N. M. Arshad, M. Anwari, and A. H. M. Yatim, '"Performance analysis of hybrid photovoltaic/diesel energy system under Malaysian conditions,"' Energy, vol. 35, no. 8, pp. 3245–3255, Aug. 2010. doi: 10.1016/j.energy.2010.04.008.
51. "G. M. Shafiullah, M. T. O. Amanullah, A. B. M. S. Ali, D. Jarvis, and P. Wolfs, '"Prospects of renewable energy—A feasibility study in the Australian context,"' Renew. Energy, vol. 39, no. 1, pp. 183–197, 2012. doi: 10.1016/j.renene.2011.08.016.
52. "'Settled Population of Balkh Province' (PDF). Central Statistics Organisation. Retrieved 28 July 2015.
53. "'District Names'. National Democratic Institute. Archived from the original on 29 January 2016. Retrieved 28 July 2015.
54. "'Summary of District Development Plan' (PDF). Khulm District Development Assembly. Retrieved 28 July 2015.
55. "'Settled Population of Herat Province' (PDF). Central Statistics Organization. Retrieved 28 January 2016.
56. "Zendeh,Jan-Wikipedia."https://en.wikipedia.org/wiki/Zendeh_Jan (accessed Jun. 18, 2020).
57. "R. Mahtta, P.K. Joshi, A.K. Jindal, Solar power potential mapping in India using remote sensing inputs and environmental parameters, Renewable.Energy(2014),https://doi.org/10.1016/j.renene.2014.05.037.).
58. "Google,Earth."https://earth.google.com/web/@0,0,0a,22251752.77375655d,35y,0h,0t,0r?utm_source=earth7&utm_campaign=vine&hl=en (accessed May 21, 2020).
59. "USEPA (United State Environmental Protection Agency), Screening Sites for Wind Energy Potential.
60. "Manwell, J. F., McGowan, J. G., & Rogers, A. L. (2009). Wind Energy Explained. Chichester: John Wiley & Sons Ltd.,
61. "M.L. Sabo, N. Mariun, H. Hizam, M.A. Mohd Radzi, A. Zakaria, Spatial matching of large-scale grid-connected photovoltaic power generation with utility demand in Peninsular Malaysia, Appl. Energy 191 (2017) 663e688, https://doi.org/10.1016/ j.apenergy.2017.01.087
62. "M. Uyan, GIS-based solar farms site selection using analytic hierarchy process (AHP) in Karapinar region, Konya/Turkey, Renew. Sustain. Energy Rev. 28 (2013) 11e17,

https://doi.org/10.1016/j.rser.2013.07.042.

63. “M. Tahri, M. Hakdaoui, M. Maanan, The evaluation of solar farm locations applying Geographic Information System and Multi-criteria decision-making methods: case study in southern Morocco, Renew. Sustain. Energy Rev. 51 (2015) 1354e1362, https://doi.org/10.1016/j.rser.2015.07.054.
64. “J. Ara´n Carrio´n, A. Espı´n Estrella, F. Aznar Dols, M. Zamorano Toro, M. Rodrı´guez, A. Ramos Ridao, Environmental decision-support systems for evaluating the carrying capacity of land areas: optimal site selection for grid-connected photovoltaic power plants, Renew. Sustain. Energy Rev. 12 (2008) 2358e2380, https://doi.org/10.1016/ j.rser.2007.06.011..
65. “J.M. Sa´nchez-Lozano, J. Teruel-Solano, P.L. Soto-Elvira, M. Socorro Garcı´a-Cascales, Geographical Information Systems (GIS) and Multi-Criteria Decision Making (MCDM) methods for the evaluation of solar farms locations: case study in southeastern Spain, Renew. Sustain. Energy Rev. 24 (2013) 544e556, https://doi.org/ 10.1016/j.rser.2013.03.019.
66. “Baban Serwan MJ, Parry Tim. ‘Developing and applying a GIS-assisted approach to locating wind farms in the UK’, Renew Energy 2001; 24:59–71.
67. H.A. Effat, Selection of potential sites for solar energy farms in Ismailia Governorate, Egypt using SRTM and multicriteria analysis, Cloud Publ. Int. J. Adv. Remote Sens. GIS 2 (2013) 205e220.
68. 68. “James Perry and Andrew Biss, Wind Farm Clutter Mitigation in Air Surveillance Radar, IEEE A & E SYSTEM MAGAZINE, JUNE 2007.
69. “Doug Dahle, Dennis Elliott, Donna Heimiller, Mark Mehos, Robi Robichaud, Marc Schwartz, Byron Stafford, and Andy Walker, Assessing the Potential for Renewable Energy Development on DOE Legacy Management Lands, DOi/GO-102008- 102435; February 2008.
70. “S. Charfi, A. Atieh and M. Chaabene: ‘The effect of batteries DOD range setting values on diesel engine generator pollution and overall cost of a hybrid solar/diesel/battery system,’ 2016 International Renewable and Sustainable Energy Conference (IRSEC), Marrakech, 2016, pp. 956-960.
71. “International Renewable Energy Agency. Wind Power. Renewable Energy Technologies: Cost Analysis Series. [Online]. Available: https://www.irena.org/documentdownloads/publications/re_technologies _cost_analysis-wind_power.pdf
72. “HOMER pro 3.13.8, ‘HOMER Software library,’ HOMER ENERGY,8.5.2020-[Online].Available:https://www.HOMERenergy.com/products/pro/docs/latest/library.html. [Accessed 8 5 2020].
73. “Chadjivassiliadis J. Solar photovoltaic and wind power in Greece. IEE Proc A Phys Sci, Meas Instrum, Manage Educ – Rev 1987;134:457–63.
74. “Giraud F, Salameh ZM. Steady-state performance of a grid-connected rooftop hybrid wind-photovoltaic power system with battery storage. IEEE Trans Energy Convers 2001;16:1–7.
75. Kimura Y, Onai Y, Ushiyama I. A demonstrative study for the wind and solar hybrid power system. Renew Energy 1996;9:895–8.
76. “S. Bahramara, M. P. Moghaddam, and M. R. Haghifam, ‘“Optimal planning of hybrid renewable energy systems using HOMER: A review,”’ Renew. Sustain. Energy Rev., vol. 62, pp. 609–620, Sep. 2016. doi: 10.1016/j.rser.2016.05.039.

AUTHORS PROFILE

Saadatullah Hamkar Graduated from international Mazar-e Sharif Afghan Turk High School, and he has received his B. tech from chemical technology faculty of Engineering from Balkh University, Afghanistan. He has been certified as Design Engineer of Solar Power from Advance Electrical Design and Engineering institute, Delhi. currently He is pursuing Master of Technology (M. Tech) at department of Electrical engineering from AP Goyal Shimla University, India. He is an active member of the institute for Engineering and Research Publication (IFERP). His current research interests include integration of renewable energies, Solar PV cells and analysis and design of renewable energy generation system

Dr. Anand Mohan is currently working as a Professor in the Department of Electrical Engineering, underneath the School of Technology and Sciences at AP Goyal Shimla University, Shimla, India. He is also looking after for School of Technology and Sciences as Dean. He has more than 15 Years for academic, administrative, and industrial experience in various renowned organizations of India. He has written more than 15 research manuscripts in International and National Journals and conferences. He has been the reviewer of many journals of repute in India as well as abroad. He has got his Ph. D in the field of Power System Engineering from the University of Petroleum and Energy Studies, Dehradun, India. He is a member of many Technical Societies like The Institution of Engineers and IAENG etc. Recently has been invited as Speaker in the International Conference on Machine Learning and Intelligent Systems (MLIS 2019) at National Dong Hwa University, Taiwan. He also expressed in the 6th Annual World Congress of InfoTech-2019, with the theme of “Launch a New Era of 5G and Global Future Network”, held on May 10-12, 2019 at Nanjing, China. He was the Specially invited member of the Board of Studies of Electrical Engineering for HPTU, Hamirpur. He is the regular speaker in the Short Term Courses organized by of National Institute of Technical Teacher Training and Research (NITTTR), Chandigarh.