Turkish Online Journal of Qualitative Inquiry (TOJQI)
Volume 12, Issue 7, July, 2021:1427 – 1439

Hybrid Energy Network Systems using HOMER pro feasibility study of the Rural Networka case study

Vinod S. Patil [a], Gopalkrishna.D. Kamalapur [b]

[a] Assistant Professor Department of Electrical & Electronics Engineering. Jain College of Engineering. Belagavi.
[b] Professor,Department of Electrical & Electronics Engineering. SDM College of Engineering and Technology

Abstract

A vital part of rural infrastructure empowerment is rural electrification, and it is crucial for the development of the country as a whole. The welfare of the villagers is one of the essential goals of rural electrification. Compared with urban electrification, rural electrification is relatively costly. A practical microgrid approach is introduced for a particular geographic area utilizing locally accessible electricity supplies, given the current power demand. There have been many variations and diverse varieties of various energy mixes, such as photo-electric solar generators and diesel generators. In off-grid and on-grid networks, diesel generators, in addition to batteries, can be used as reserve resources. A detailed engineered analysis for the hybrid modeling of various electrical renewables HOMER-Pro simulation packages can be used to evaluate the optimum energy mix process, which is far-fetched in the existing literature analysis. The purpose of the simulation tool is to choose from the resources available in a given village the best possible combinations of HRES.

The study's detailed findings indicate that the majority of the power produced in both off/on grid situations is photo-electric solar power. In the off-grid environment, the renewable fraction is comparatively high, and it is varying from 92% - 100%, compared with perturbations around 63% - 80% in grid-tied systems. The outcomes also divulge that grid-tied systems levelized cost of power perturbs around Rs.0.18 ₹/kWh - Rs.1.39 ₹/kWh. Furthermore, Levelized electricity rates are too low in comparison to off-grid device prices of Rs.11.96 - Rs.18.47 /kWh. A resource and demand assessment are carried out in this study, and COE for different scenarios and configurations is also determined.

Keywords:

1. Introduction

The most emerging sources of energy aids in development of a strong economy,if they are reliable and ecologically friendly non depleting energy. Power from renewable energy sources, however, encounters some drawbacks when used in stand-alone use since they are sporadic in nature. The energy provided by a solar photovoltaic and wind turbine is mainly governed by environmental factors, although others need to be enriched with advanced technology to establish modern and expansive stand-alone approaches to rural energy demands. Some green energy sources have a vast range of prospectivealong with various benefits, such as high performance, zero emissions, and scalable structure. Wind and solar power energy resources are integrated with other sources or grids to prevail over these tribulations.

In FY 2020, the rise in electricity demand was confined to 1.2 percent, owing to low demand from the industries and, in large part, to unseasonal rains in August and September 2019, given the high economic downturn throughout this time[1].Total installed capacity as of 17.07.2020 in India is 370106.46 MW, a more significant part of power share is catered by thermal power station around 16 percent, nuclear energy contributes 2 percent, and hydropower contributes 12 percent. Energy from clean energy sources is 87027.68MW, accounting for just 25 percent of the total electrical energyproduced. Figure 1 shows the electricity generation segments from different energy sources in India in 2020[2].

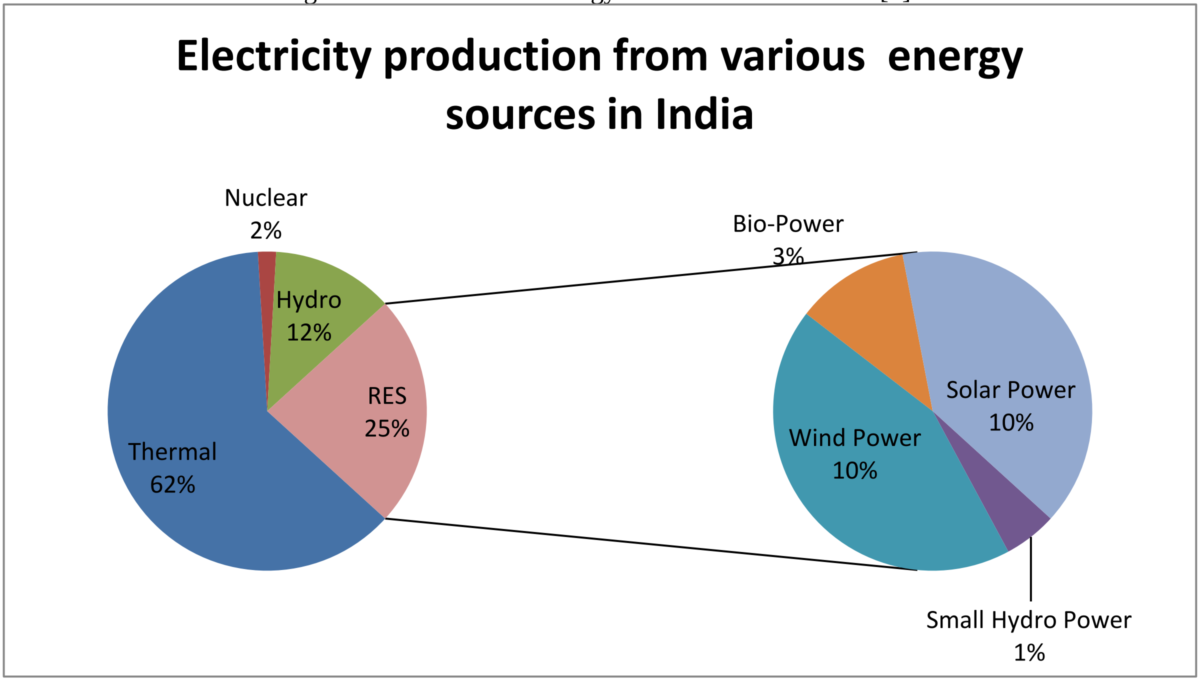

Figure 1: Electricity production from Renewable Energy sources

India has envisioned taking a sustainable track in the energy supply requirement for its development and has set a goal line for the usage of green energy by the expansion of renewable energy potential from 32 GW in 2014 to 175 GW in 2022, the increase is more than fivefold. Several objectives have already been described in the Intended Nationally Determined Contributions (INDC) by 2030, such as emissions reduction by 33-35 percent from 2005 onwards.The development of a peripheral carbon sink from the carbon footprint of 2.5 to 3 billion tons, and the need to generate 40% of the total power from renewable energy sources [3].After all, without adequate energy forecasting tools and involvement from all stakeholders (industry, domestic, government departments, educational institutions, and so on), meeting energy demands is impossible.

1.2 A Few early HOMER-based studies for HES feasibility studies

Electrical energy is very important,its projection from renewable energy is characterized by uncertainty at any time and it can only bea coherent projection using the analytical techniquesis illustrated in the study by the Prasad et al.[4][5]. Wide-ranging applications and methods based on a multi-criteria for energy forecasting is reviewed with a view of sustainable growth has been outlined [6]. There are several obstacles to the incorporation of distributed generations into the existing power structure that are detailed in [7]. There have been numerous research studies on microgrid design that emphasize renewable sources and employ various methods such as optimization techniques, soft computing techniques, and prominent analysis tools [8]. A comprehensive review of recent HOMER literary works for the techno-financial analysis of hybrid power systems is given in the coming sub-sections.1.3. A Hybrid Green Energy System is generated by increasing the amount of pooled sources of renewable energy.To gain top-class performance by best exploiting its characteristics to transcend its restrictions [9].Practical obstacles such as unnatural propagation, rough soil, and very remote areas contribute to electrification of rural areas with lesser populations, along with poor education, load density, and earnings. This article describes how to design rural electrification projects for integrated green energy power systems in remote places. Off-grid fusion facilities are always inexpensive; they are a durable electricity source and able to distribute the alternatives' best utilities. The emphasis on alternate energy generations such as hydro, wind, solar, tidal, biogas, etc. was accompanied by objectionable environmental consequences such as climate change, global warming, greenhouse gas pollution[10]. The use of renewable energy sources for electrification has become economically feasible due to the rapid growth of German technology in recent years[11]. Because of the inaccessibility of villages and other bodily limits, the inclusion of power grids and other infrastructure using traditional energy supply networks is either impractical or inefficient. Moreover, the lack of basic services in the rural and far-off areas are rising rapidly; the surge of metropolitanmigration is plunging the developing world. Such movements need to be halt and overturned efficaciously to avoid treacherous unstable growth. This is accomplished by providing electricity to the far-off and rural areas also in a sustainable manner. [12].In the coming years, the challenge will be to supply sufficient electricity to remote and rural areas while both enhancing the quality of care and slowing the rapid immigration.

To put it another way, instead of people going to cities where energy is available, power is projected to move to rural areas. Engineers must build broad and cost-based hybrid electric energy systems and maximize their standalone electrification applications in rural areas[13]. Provided an IREOM-based integrated green power system to define different direct expenses, such as net current costs and energy costs [14].Built numerous hybrid energy power system architectures for six Nigerian geopolitical territories. Using HOMER Stimulation Instances of NPC and COE of \$1.1–\$1.3/1, they found an economic viability solution. A comparative analysis of solar energy and wind energy capability for remote parts of Nigeria was also presented considering the availability of weather conditions. It uses HOMER software to design and size the optimal technological and economical hybrid energy system components[16].When the two better optimized system architectures, PV–wind–diesel–battery and PV-diesel-battery, were compared to the traditional system, they discovered that the DG (5.5 kW), PV array (10 kW) and battery (64 units) is by far the most cost effective alternative, with a COE of \$0.409/kWh and a TNPC of \$69,811[17]. For the development and production of rural micro-grids for developed countries with a view to sustainable development, a bi-level approach of strategic planning and multi-objective modelling was provided.

1.3 Outcomes from Literature

Most recently published research papers, scientists have upgraded hybrid green energy network simulations in numerous configurations using the HOMER method.This technique is used in a variety of renewable energy power system, for example small hydropower, solar photovoltaic, biomass generators, wind energy, biogas generators, natural gas or diesel generators (DG), and a variety of energy reservoir systems, such as a pumped hydroelectric energy storage system, fuel cell and flywheel and, engulfed in isolated or non-isolated connected power networks. The sizes and ratings of the bi-directional converters are also specified. The studies are often conducted based on location, year, design, and technological characteristics such as loading, ON/OFF grid systems, and the popular studiesassess HES on offered load data over the lifespan of the venture. The project period is projected to be between 20 and 25 years, with an estimate of the real costs incurred, in particular, by energy rates, which are mostly base on the presence of renewable resources. The length of the project is expected to be between 20 and 25 years, with an estimation of the actual costs incurred, in particular, by electricity prices, which are primarily dependent on the existence of renewable sources. The HRES consists of solar – wind – and batteries. A multifaceted HOMER program is projected to address size and financial problems. Device efficiency is analyzed and contrasted with several HRES combinations for optimum arrangements with minimalCOE and NPC values.The optimized scheme is less expensive, has fair environmental advantages, has a reasonable payback time, and emits less emissions. Changes in seasonal wind speed with power prices and total current costs are often subjected to sensitivity analysis.

2. HOMER (Hybrid Optimization using Multiple Energy Resources)

The National Renewable Energy Laboratory (NREL), a government lab in the USA, has published HOMER. It's got a lot of editions and various models. The HOMER software used during the study is (HOMER Pro 3.13.8). HOMER Pro may be specifically used to assess and analyze the techno-economic architectures of different hybrid electric energy systems, along with sustainable energy. HOMER Pro can simulate integrated hybrid energy systems made up of nine disparate components, including hydrogen, storage, biomass, solar, combined heat and electricity, hydro, wind, grid, load, and others. To comprehend the integration of renewable energy into hybrid electric power systems, a variety of software tools are provided[18]. One such software is the Hybrid Optimization Model for Multiple Energy Resources (HOMER), which is structured to conduct environmental and techno-economic studies to integrate renewable energy into electric power systems in various locations. [19][20].

HOMER is responsible for three crucial objectives: simulation of the system, optimization of the system, and sensitivity analysis. HOMER models the performance of a particular micropower network design for every hour, for the whole year during the simulation phase to determine its technical viability and life-cycle costs. HOMER simulates multiple design models during the optimization phase to find something which meets technical constraints while having the lowest lifespan. HOMER involves various modifications under multiple input conditions during the sensitivity statistical analysis to quantify the effects of uncertainty or adjustments in model inputs. The optimal values of the parameters managed by the design engineer, including the combination of elements that constitute the structure and the size or amount of every variable, are defined by optimization. The effect of volatility or changes in variables outside the designer's influence, such as the future fuel price or the average wind speed can be determined using sensitivity analysis. The relation between simulation of the hybrid electric system, optimization of the system, and sensitivity analysis of the system using HOMER is shown in Figure 2. The optimization oval encircles the simulation oval to reflect the fact that a single optimization is made up of several simulations. Similarly, since a single sensitivity analysis consists of various optimizations, the optimization oval is enclosed within the sensitivity oval.Sensitivity elements include the cost of wind turbines, world solar radiation, batteries and the price of biomass fuel, etc. HOMER evaluates the compositions of renewable sources identified in the research location, as shown in Figure 6: HOMER Hybrid Simulation Model. The Hybrid electric power system consists of a wind turbine generator (WTG), a solar PV generator(SPV) a battery (Batt), and grid systems.

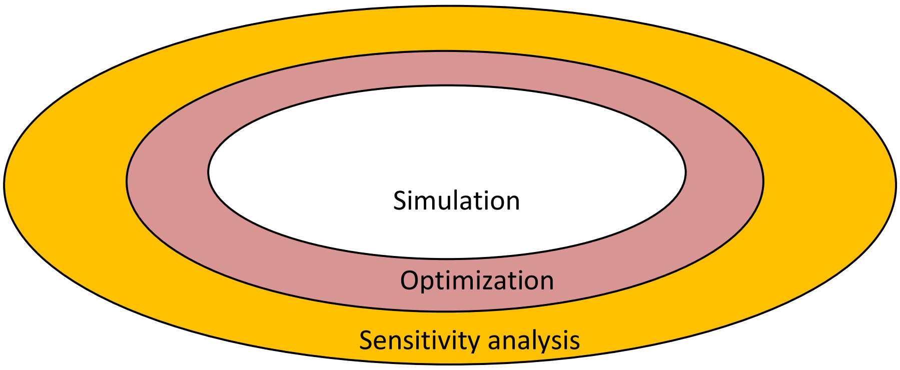

Figure 2 demonstrates the connection between simulation, optimization, and sensitivity analysis in the context of HOMER.

2.1. Mathematical concepts that have been used in research using Hybrid Optimization of Multiple Energy Resources (HOMER)

To estimate the project's economic feasibility, it was important to consider the variables which lead to the economic analysis.

Net present cost (NPC)

The actual net present expense of the device, including the element's running costs, is subtracted from the (Income) gain it generates over the project's lifespan, and this yields the project's profitability.

$$\text{NPC} = \sum_{t=0}^{t=n} \text{Total present cost} - \text{Profit incurred} \quad ..(1)$$

Annualized cost

The annual rate of the system is the cost of the system when factored out evenly for the duration of the project under consideration.

$$\text{Annualised Cost} = \frac{\text{Total cost of the project}\times\text{Discount Rate}}{1-(1+\text{Discount rate})^{-\text{Project life time}}} \quad ..(2)$$

Levelized cost of energy (LCOE)

It is the system's average cost of producing usable electrical energy. The LCOE iscalculated by dividing the annualized cost of generating electricity (the annual fixed cost minus the cost of servicing the thermal load) by the actual energy load handled using the equation below.

$$\text{LCOE} = \frac{\text{Total Annual electricity production}}{\text{Load served by the system}} \quad ..(3)$$

Renewable energy penetration (RP)

It is the sum of renewable energy used to power the load on an annual basis. RP ¼ Total power produced from renewable energy Total electrical load served

$$\text{RP} = \frac{\text{Total power Produced from Renewable Energy}}{\text{Total Electrical Load servedf}} \quad ..(4)$$

3. Description of the Jain College of Engineering campus

Populace and location

The Jain College of Engineering campus is located on the outskirts of Belagavi, in the village of Machhe, along the road to Jamboti, at 15.47.8 degrees north latitude, 74.2.4 degrees east latitude. The campus, which spans over ten acres, houses seven departments and four post-graduate learning centers that encompass all major engineering, scientific, and humanities disciplines. Around 3000 students, 120 faculty members, and 75 support personnel make up the campus workforce.

Feeder details connecting JCE campus

The electrical power to JCE is obtained from a substation located in the Machhe region near the Visvesvaraya Technical University of Belagavi. The substation has a transformation capacity of 80 MVA and the station has a 220 kV incoming line from 220 kV receiving station Hindal Belagavi also, the station has two 110kV incoming lines from the Vadgaon substation and Udyambag substation. The substation has four numbers of power transformer -2 numbers of 110/33kV 20 MVA transformer and two numbers of 110/11kV 20 MVA transformers. There are 21 outgoing feeders out of which one 110kV feeder is up to the Ashok Irons Industry. Four 33kV outgoing feeders and 16 other 11kV feeders extended to a residential area near Machhe. The station has a double bus scheme for power transfer with a single 110kV bus coupler. Feeder 11 is one of the 11 kV's extended from the station to the Peernwadi, with a total length of 11 kilometers. This feeder is having a total peak load of 120 amperes at 2MW. It's builtusing RABBIT – ACSR conductor having a nominal aluminum cross-sectional area of 50 mm². It has six aluminum strands of 3.35 mm diameter and one steel strand of 3.35 mm diameter. The current carrying capacity of the conductor is 190 amps. This feeder has 72 distribution transformers installed on which are used to step down the voltage from 11kV to 433V. Three-phase four-wire system is used to deliver power to all the residential loads. The feeder load is on the second bank of the 110/11kV 20 MVA transformer (Trf 2).

Electrical load demand of F-11 feeder

The electrical power supplied to the JCE campus is through Machhe substation from feeder number 11. With a peak load of 333.48 kW and an average demand of 100.92 kW, the scaled energy demand is approximately 2,422 kWh per day. Figure 2shows the sample feeder'sdaily load profile with hourly variance.

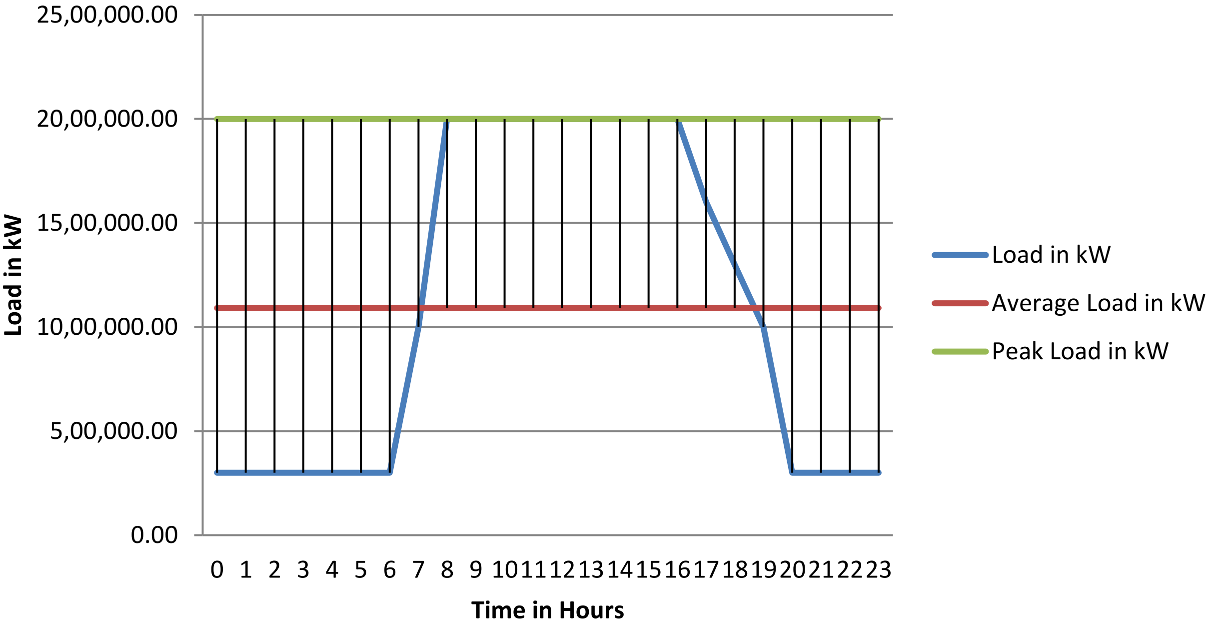

Figure 2 Load profile on Feeder No.11

Meteorological data of JCE campus

NASA-sponsored green energy resource website was used to collect the necessary meteorological data of the campus. With a solar clearness index of 0.5605, the average annual solar isolation was only about 5.32 kWh/m2/day. Figure 3 showsthe plot of clearness index and the average monthly profile of solar isolation.The wind capacity of the JCE Campus is outstanding, since it is surrounded by lush green mountains with a high average annual wind intensity estimated from NASA's metrological data base this is depicted in Figure 4

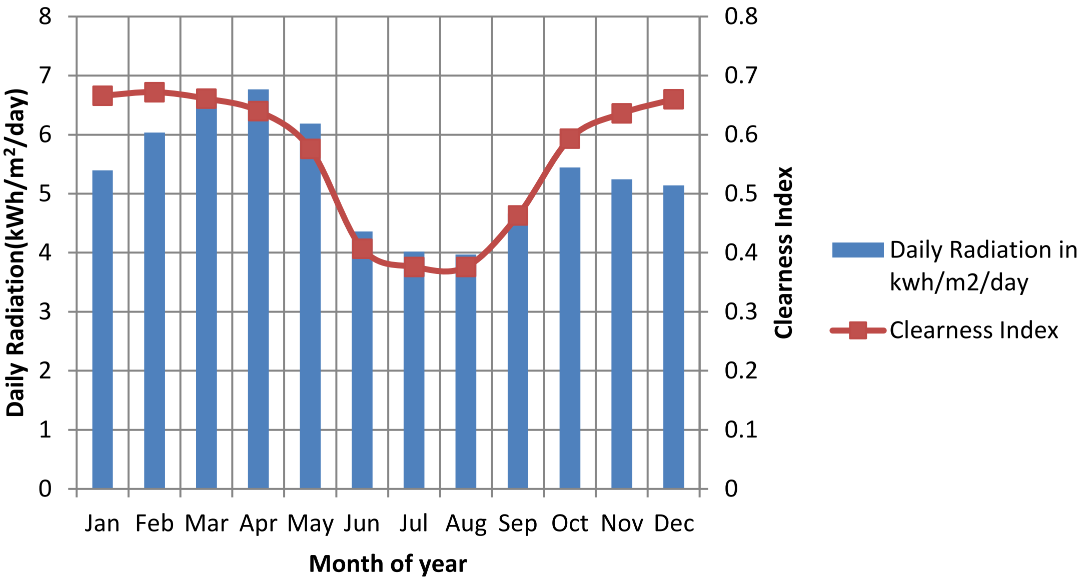

Figure 3 Monthly Average Solar Global Horizontal Irradiance (GHI)

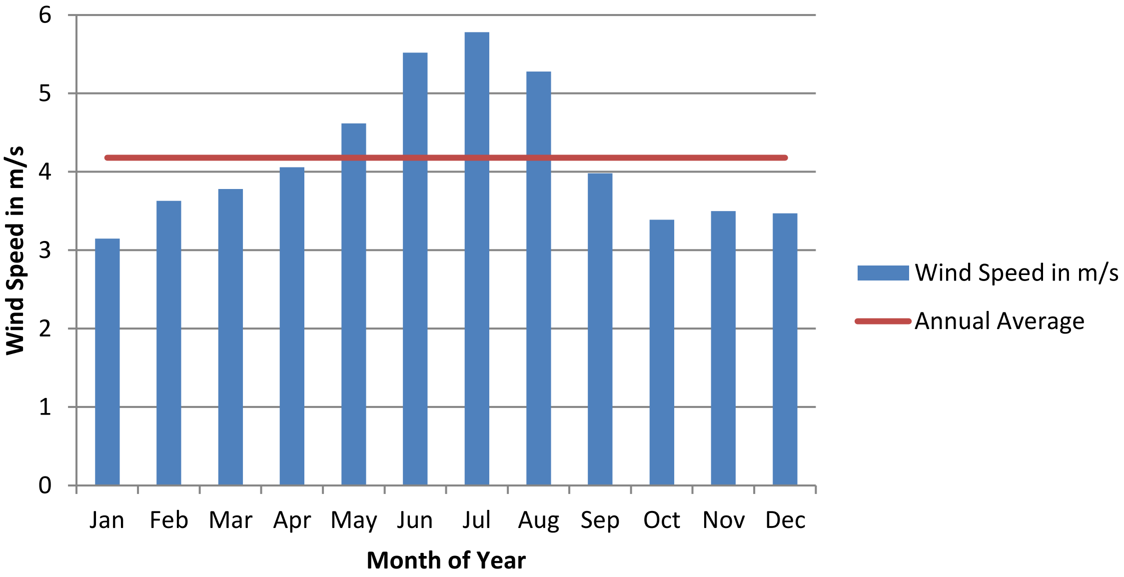

Figure 4 Data on Monthly Average Wind Speed

A load factor of 0.3 was assessed. The substation's typical power factor has been resolute to be 0.97.

4. Specifics of several microgrid essentials with their price

Sustainable energies like solar PV and wind generators are used for grid interconnection based on the availability of resources outlined in the preceding sections. Further, batteries are used to meet the load demand during the design of the microgrid. By using particulars of each module along with their mathematical modeling and diverse monetarist parameters are engaged in this study as outlined below:

Solar PV Panel or Solar Photovoltaic (SPV)

A specific type of solar PV system is chosen with an initial capital cost of Rs. 50,502/kW, and the Operation and maintenance expense is taken as Rs. 700/kW annually as per the yardstick of CERC. As stated in the introduction portion, the initial investment cost includes the cost of the module, mounting structures, construction and general works, evacuation cost and power conditioning unit, as well as preparatory & pre-operative expenditures as approved by CERC [21]. Equation 5 gives the photovoltaic power from the PV array scheme as computed in HOMER.

$$P_{PV} = Y_{PV} f_{PV} \left(\frac{\overline{G_T}}{\overline{G_{T,STC}}}\right) \left[1 + \alpha_p (T_C - T_{C,STC})\right] \quad ..(5)$$

where

Y_{PV} is the PVArray's rated power.

f_{PV} is the PV derating element in percentiles.

$\overline{G_T}$ is the incident solar irradiance on the PVarray.

$\overline{G_{T,STC}}$ is incident radiation under standard testing conditions.

α_p is temperature as a power coefficent

T_C is temperature of PVcell

$T_{C,STC}$ is temperature as standard testing conditions

Wind Turbine Generator (WTR)

With an initial capital cost of Rs 21,717/kW, a wind turbine generator is one of the sustainable power generators. The cost of replacement of Rs 20,000/kW is considered per the yardstick of KREC [22]. Further, the O & M expense is reserved as Rs 500/kW per year. As mentioned above in the introduction section, the capital cost includes module costs, mounting systems, constructional& general works, evacuation costs and power conditioning unit, preparatory and pre-operative expenses as approved by KREC[22].Every hour, HOMER performs a four-step cycle to measure the energy output of the wind generators. By referring the data of wind resource, the average wind speed is calculated for an hour at the height of the anemometer on the wind turbine. Secondly, byemploying either the power-law or the logarithmic-law , the factual wind speed is premeditated at the wind turbine's hub height utilizing equations 6 & 7.

$$\frac{U_{HUB}}{U_{ANEM}} = \left(\frac{\ln\left(Z_{HUB}/Z_O\right)}{\ln\left(Z_{ANEM}/Z_O\right)}\right) \quad ..(6)$$

$$U_{HUB} = U_{ANEM} \left(\frac{Z_{HUB}}{Z_{ANEM}}\right)^{\alpha} \quad ..(7)$$

Where

U_{HUB} is the wind speed at hub hight expressed in m/s

U_{ANEM}isthewindspeedatanemometer heightinm/s

Z_{HUB}isthe hub heightofwindturbinem

Z_{ANEM}isanemometer heighinm

$Z_O$isthesurfaceroughnesslengthinm

αisthepowerlawexponent

Thirdly, a locus is drawn on the power curve of the wind turbine to determine the wind speed needed to provide an average air density. Fourthly, to translate the power output value, the air density ratio, which is the ratio of actual air density to average air density, is computed. HOMER calculates the electrical power produced by the wind turbine generator system, is given in the equation 8.

$$P_{WTG} = P_{WTG,STP} \left(\frac{\rho}{\rho_O}\right) \quad ..(8)$$

P_{WTG} is Power output in kW

$P_{WTG,STP}$ *is* the capacity of the wind turbine at STP (in kW)

ρ is the actual air density kg/m^3

ρ_0 isthe air density at STP (1.225 kg/m^3)

Grid Charges with Net Metering (GCWNM)[23]

The energy charges in the net metering scheme are calculated by considering the monthly or yearly net generation using the following equations (9) and (10).

$$GEC_{NM(monthly)} = \sum_{K}^{rate} \sum_{l}^{12} \begin{cases} E_{m.net(grid),k,l.}gec_{grid,k} & if\, E_{m.net(grid),k,l\geq 0} \\ E_{m.net(grid),k,l.}gec_{sell,k} & if\, E_{m.net(grid),k,l<0} \end{cases} \quad ..(9)$$

$$GEC_{NM(annual)} = \sum_{K}^{rate} \sum_{l}^{12} \begin{cases} E_{annual.net(grid),k,l.}gec_{grid,k} & if\, E_{annual.net(grid),k,l\geq 0} \\ E_{annual.net(grid),k,l.}gec_{sell,k} & if\, E_{annual.net(grid),k,l<0} \end{cases} \quad .(10)$$

where $GEC_{NM\ (monthly)}$ is the monthly electricity prices in kWh, $E_{mnet(grid)k,l}$ is the gross electricity procured in kWh from the grid (grid buy subtracted by grid sells) in l month throughout the imposed rate of k, GEC_{sellsk} is the selling price for rate l in INR/kWh, and GEC_{gridk} is the grid power price for rate in INR/kWh, $GEC_{NM(annual)}$ is the monthly electricity prices in kWh, $E_{m.net(grid),k,l}$is the yearly total energy procured in kWh from the grid (grid buy subtracted by grid sells) during the applicable rate of k, $GEC_{sells,k}$ is the sales price for rate k in INR/kWh, and $GEC_{grid,l}$ is the grid electricity price for rate k in INR/kWh. Due to commercial tariffs and the lack of real-time schedule rates, a simple rate method that permits establishing a constant power rate and selling back rate in a gross billing method computed every month for on-grid systems is used in this study. The sell-back price to the grid is also assumed to be INR

Battery storage (LAB)

Storage is considered to be the high Tubular lead-acid battery, that has the cheapest cost/kWh and is especially useful for standalone or off-grid applications [104]. The storage device is designed using the Discover 12VRE-3000TF-L kinetic battery model. Table 2 displays many metrics as well as the battery's cost. The initial charge shall be 100 % of the string size of 25, and the minimum charge shall be 20%. The maximum discharging capacity of the battery cell is estimated using equation (12).

$$P_{Discharge} = \frac{-K_c Q_{max} + KQ_{initial} e^{-k\triangle t} + Q_{total} kc(1 - e^{-k\triangle t})}{1 - e^{-k\triangle t} + c(k\triangle t - 1 + e^{-k\triangle t})} \quad ..(12)$$

The maximum power which can be absorbed by the battery storage is calculated using equation (13) given below ,

$$P_{charge} = \frac{KQ_{initial} e^{-k\triangle t} + Q_{total} kc(1 - e^{-k\triangle t})}{1 - e^{-k\triangle t} + c(k\triangle t - 1 + e^{-k\triangle t})} \quad ..(13)$$

where $Q_{initial}$is the amount of power accessible in storage at the start of the time step in kWh, $Q_{max}$is the maximum capability of the battery bank in kWh, Q_{total} is the overall quantity of power accessible in the battery bank at the start of the time step in kWh, k is the rate characteristic of the battery bank (1/Hr), c is the efficiency coefficient of the battery bank, and t is the time step length in hours. The battery storage autonomy (AT_{bat}) in hours is computed using equation (14),Where N_{bat} is the maximum amount of cells in the storage device,Q_{nbat} is a single battery's nominal capacity in Ah, $V_{nbat}$is the battery's nominal voltage in volts, $Load_{prim,avg}$ is the mean primary demand in kWh/day, and SOC_{min} is the battery's minimal level of charge in percent value (%), and so on.

$$AT_{bat} = \frac{N_{bat} V_{nbat} Q_{nbat} (1 - {}^{SOC_{min}}/_{100}) \left({}^{24\ hrs}/_{day}\right)}{Load_{prim,avg} ({}^{1000Wh}/_{kWh})} \quad ..(14)$$

BIDIRECTIONAL CONVERTER (BCON)

Off-grid systems take into account a bi-directional converter (B_{Con}). CPC is estimated for being INR 10000/kW. Presently offered converters within the marketplace don’t need service and maintenance over the entire lifespan, so the operation and maintenance cost are nil. Table 2 shows the additional essential data evaluated for analysis.

SYSTEM CONTROLLER

During simulations, the HOMER PRO device controller enables consumers to choose how the device is set up and operated. To satisfy the load requirements, each controller will have its algorithms or system of regulations for controlling the multiple generators and store operations. HOMER can test and modify many controller models, as well as compare performance. In this investigation, two dispatch techniques, LF and CC, were used. In the LF, the power generation of the designed system, such as turbines, grids, etc. Firstly, for every time stage, serve the primary (main) load and thermal load at the least overall expense with maintaining the operational buffer needs. The RET sources are in charge of secondary targets like providing the deferrable demand or charging storage. It can, however, allow the generation of the generator to vend the energy to the grid if it is efficiently profitable. In the CC approach, on the other hand, the generator runs at maximum power output when supporting the principal load. After the requirement for the stated primary load is filled, the excess electrical production is directed forward into additional purposes like charging the storage bank, serving the deferrable load, and so on. Generators would not be permitted to create excess energy just for the purpose of dumping under the CC plan. The excess power produced must be used in HOMER PRO to work beyond the stages preferred to satisfy the primary load requirement. In the CC strategy, HOMER employs a two-step simulation process to supply configurable power sources (storage bank, generators, and grid). First, HOMER chooses the best mix of energy supplies to support both the primary load and thermal load at the lowest overall rate when complying with the operational reserve criteria. Second, it increases each generator's output in the maximum efficient arrangement to its maximum rated power, or as near as achievable without causing additional power.

Table 1 Component details and various expenses

S.N	Details about the components	Initial Cost (CPC) in (INR)	Replacement Cost (INR)	O&M Cost (INR)	Remarks
1	Solar PV fixed axis (SPV)	50,502/kW	50,502/kW	700/kW	Land cost not included
2	Wind generator	2171620/kW	2171620/kW	500.00/kW	Land cost not included
3	Lead Acid Battery (LAB)	7980	7980	2000	Capital cost & O&M cost is interpreted from discussion with venders
4	Bi-directional converter	10,000/kW	10,000/kW	0	

Important parameters and system settings utilized for simulations are described.

Nominal discount factor and inflation rates

According to the Ministry of Statistics and Programme Implementation's historic inflation data, an inflation rate [24] of 6.93 percent is taken into consideration annually for the lifetime of the project. According to CERC [25], the discount rate for all technologies using renewable energy sources is 10.41 percent.

Project lifetime

While constructing a hybrid electric power system depending on annual load growth, already mentioned in the introductory section, a longer project lifecycle has hurdles to consider in terms of economic and technical aspects. Other likely factors include RETs' reliance on the weather, a decline in their annual efficiency, changes in their O&M costs, and so on. Because of all of these difficulties, the project lifespan is projected to be 25 years in this analysis.

4.7.3. System fixed cost

The initial investment of the technologies evaluated in this research includes all expenses associated and is also included with particular RETs at the CERC-mandated rate. Following discussions with industry representatives and future project financiers, an additional INR 5000 is allocated to the fixed operation and maintenance cost to allow for minor repairs. The system's fixed rate is the rate at the start of a project without having any impact on the system's architecture and size. The systems operation and maintenance cost is the continuous annual cost that happens regardless of the architecture or size of the power system.

4.7.4 System configuration

Solar and wind energy, as well as the grid, were used in this study as renewable energy sources. A hybrid generating structure is composed of renewable energy sources, electrical load, and other system elements like wind turbines, PV, converters, and batteries. Figure 5shows the simulation of hybrid electric renewable system.

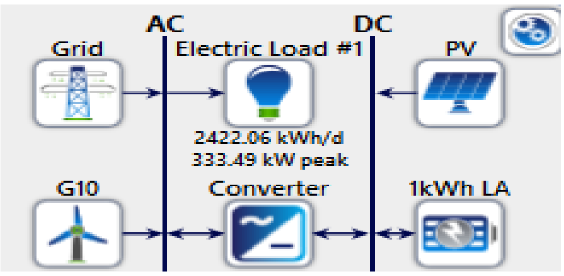

Figure 5: HOMER Simulation Model of hybrid system

The HOMER program was used in the current work for selecting and sizing the elements of a hybrid electric power system. HOMER is an overall designing tool that aids in the designing of hybrid electric power systems.

5. Simulation results

Table 2 shows the detailed specifications of the different elements. The overall price of the optimal electric systems in various microgrid situations is based on the microgrid design instances indicated in the simulations. The acquired results are shown below.

5.1 Technical results

Table 2 shows the ideal component sizes for various circumstances. Overall price of the optimal energy systems in various microgrid situations. Figure 6 depicts a graphical representation of the ideal component sizing in two microgrid situations under LF and CC dispatch strategies.

Table 2 shows overall ratings of optimal power systems in various microgrid situations.

Design scenario	Dispatch algorithm	Components				Grid		Over all Renewable fraction in %	COE in INR	Net present cost in INR
		SPV(kW)	Wind	BCon(kW)	LAB	Total energy purchased in (kWh/year)	Total energy sold in (kWh/year)			
1	LF	2172	1	1505	30	172,039	2,601,272	83.4	1.10	59,665,403.58
2	CC	2170	1	1503	25	172,039	2,601,272	84.2	0.8480	50,035,391.75

The component sizing of both scenarios is shown in Figure 6 when the simulations are carried out with LF dispatch algorithm and cycle charge. It is observed from Figure 7that in the on-grid scenarios load following based system when connected on the AC bus, scenario 1 (only SPV as generation unit) has the highest number of panels, battery converter and Lead Acid Batteryand SPV followed by 2nd scenario using cycle charge the number of components are fewer when compared to 1stscenario.Furthermore, both possibilities include a 100% renewable fraction.

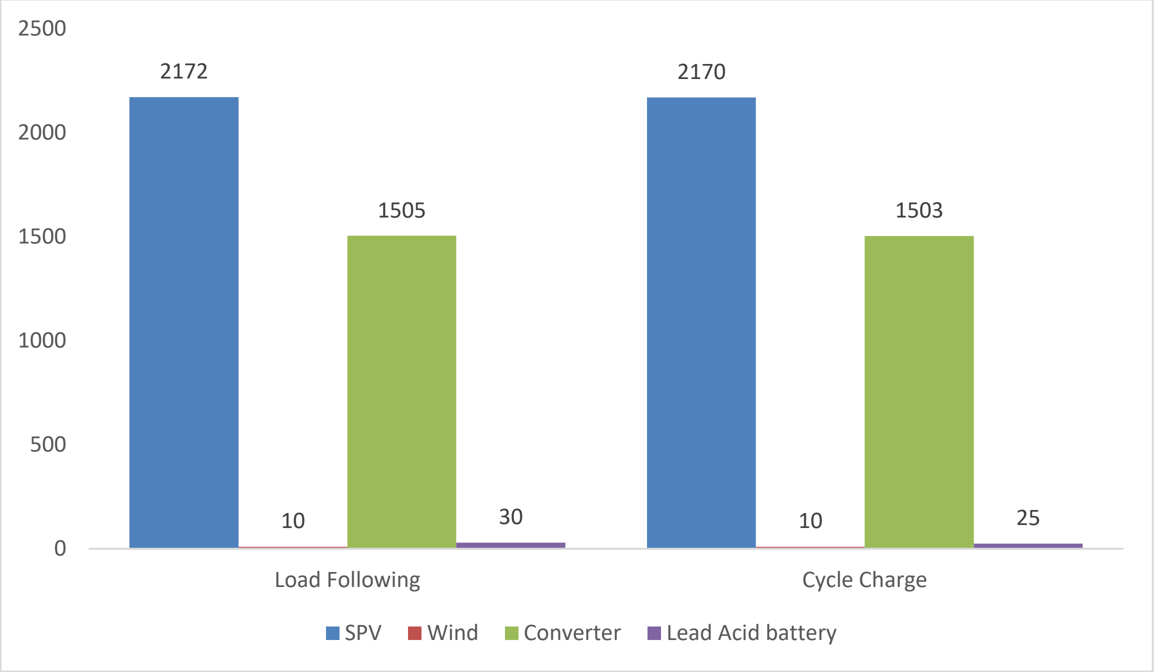

Figure 6: component sizing of hybrid system

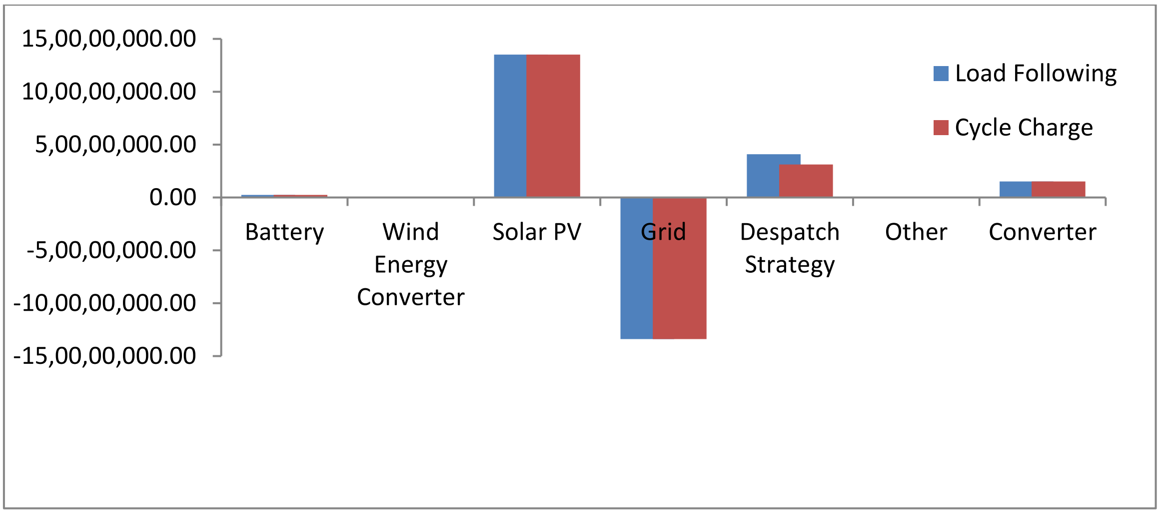

Figure 7: Total Cost breakup in rupees of grid connected system

6. Conclusion

This paper describes comparative research on an on-grid hybrid electric power system for two alternative charging methods in the Machee region of Belagavi district, Karnataka. The result of the HOMER-Pro software provides the detailed layout of the cash flow summary, the cost analysis, and the electric energy production of the suggested hybrid design. An on-grid hybrid electric power system necessitates a compact battery bank to supply a small amount of flexibility in the lack of renewables in steady-state conditions, and any extra power generated is fed back into the grid.When comparing the two systems, it's clear that the on-grid system with the cycle charge technique is the most efficient and cost-effective option in this case. HOMER-Pro software automatically recommends the best hybrid system configuration with the least COE and NPC. The Net Present Cost is estimated to be 50.31 million rupees, while the total Cost of Energy is estimated to be 0.848 rupees per unit. The PV/grid/Converter setup is the best based on the simulation results. This study emphasizes the significance of diverse alternatives for a certain load, as well as appropriate dispatch mechanisms when developing a renewable energy system, that will aid in preventing operational and economic errors

References

[1] Sabyasachi Majumdar, “India’s electricity demand to fall by 1 per cent, register 54 per cent PLF in 2020-21,” ET Energy, New Delhi, Apr. 30, 2020.

[2] M. of power Government of India,Central Eectricity Authority, “All India Installed Capacity (in Mw) of Power Stations Installed Capacity (in Mw) of Power Utilities in the States / Uts Located in,” Cent. Eectricity Authority, Minist. power, vol. 4, pp. 1–7, 2020, doi: http://www.cea.nic.in/reports/monthly/installedcapacity 2016 / installed_capacity-03.pdf.

[3] Y. K. Alagh, “India 2020,” J. Quant. Econ., vol. 4, no. 1, pp. 1–14, Jan. 2006, doi: 10.1007/BF03404634.

[4] R. D. Prasad, R. C. Bansal, and A. Raturi, “Multi-faceted energy planning: A review,” Renew. Sustain. Energy Rev., vol. 38, pp. 686–699, Oct. 2014, doi: 10.1016/j.rser.2014.07.021.

[5] R. D. Prasad, R. C. Bansal, and A. Raturi, “A review of Fiji’s energy situation: Challenges and strategies as a small island developing state,” Renew. Sustain. Energy Rev., vol. 75, no. July 2015, pp. 278–292, Aug. 2017, doi: 10.1016/j.rser.2016.10.070.

[6] R. Bansal, Handbook of distributed generation: Electric power technologies, economics and environmental impacts. 2017.

[7] C. Lupangu and R. C. Bansal, “A review of technical issues on the development of solar photovoltaic systems,” Renew. Sustain. Energy Rev., vol. 73, no. February 2016, pp. 950–965, Jun. 2017, doi: 10.1016/j.rser.2017.02.003.

[8] R. Baños, F. Manzano-Agugliaro, F. G. Montoya, C. Gil, A. Alcayde, and J. Gómez, “Optimization methods applied to renewable and sustainable energy: A review,” Renew. Sustain. Energy Rev., vol. 15, no. 4, pp. 1753–1766, May 2011, doi: 10.1016/j.rser.2010.12.008.

[9] V. Suresh, M. M., and R. Kiranmayi, “Modelling and optimization of an off-grid hybrid renewable energy system for electrification in a rural areas,” Energy Reports, vol. 6, pp. 594–604, Nov. 2020, doi: 10.1016/j.egyr.2020.01.013.

[10] A. Marneni, A. D. Kulkarni, and T. Ananthapadmanabha, “Loss Reduction and Voltage Profile Improvement in a Rural Distribution Feeder Using Solar Photovoltaic Generation and Rural Distribution Feeder Optimization Using HOMER,” Procedia Technol., vol. 21, pp. 507–513, 2015, doi: 10.1016/j.protcy.2015.10.036.

[11] M. Hossain, S. Mekhilef, and L. Olatomiwa, “Performance evaluation of a stand-alone PV-wind-diesel-battery hybrid system feasible for a large resort center in South China Sea, Malaysia,” Sustain. Cities Soc., vol. 28, pp. 358–366, Jan. 2017, doi: 10.1016/j.scs.2016.10.008.

[12] L. M. Halabi, S. Mekhilef, L. Olatomiwa, and J. Hazelton, “Performance analysis of hybrid PV/diesel/battery system using HOMER: A case study Sabah, Malaysia,” Energy Convers. Manag., vol. 144, pp. 322–339, Jul. 2017, doi: 10.1016/j.enconman.2017.04.070.

[13] A. B. Kanase-Patil, R. P. Saini, and M. P. Sharma, “Development of IREOM model based on seasonally varying load profile for hilly remote areas of Uttarakhand state in India,” Energy, vol. 36, no. 9, pp. 5690–5702, Sep. 2011, doi: 10.1016/j.energy.2011.06.057.

[14] L. Olatomiwa, S. Mekhilef, A. S. N. Huda, and O. S. Ohunakin, “Economic evaluation of hybrid energy systems for rural electrification in six geo-political zones of Nigeria,” Renew. Energy, vol. 83, pp. 435–446, Nov. 2015, doi: 10.1016/j.renene.2015.04.057.

[15] L. Olatomiwa, R. Blanchard, S. Mekhilef, and D. Akinyele, “Hybrid renewable energy supply for rural healthcare facilities: An approach to quality healthcare delivery,” Sustain. Energy Technol. Assessments, vol. 30, no. February, pp. 121–138, 2018, doi: 10.1016/j.seta.2018.09.007.

[16] L. Olatomiwa, S. Mekhilef, A. S. N. Huda, and K. Sanusi, “Techno-economic analysis of hybrid PV-diesel-battery and PV-wind-diesel-battery power systems for mobile BTS: the way forward for rural development,” Energy Sci. Eng., vol. 3, no. 4, pp. 271–285, Jul. 2015, doi: 10.1002/ese3.71.

[17] A. Kumar, A. R. Singh, Y. Deng, X. He, P. Kumar, and R. C. Bansal, “Integrated assessment of a sustainable microgrid for a remote village in hilly region,” Energy Convers. Manag., vol. 180, no. May 2018, pp. 442–472, Jan. 2019, doi: 10.1016/j.enconman.2018.10.084.

[18] D. Connolly, H. Lund, B. V. Mathiesen, and M. Leahy, “A review of computer tools for analysing the integration of renewable energy into various energy systems,” Appl. Energy, vol. 87, no. 4, pp. 1059–1082, Apr. 2010, doi: 10.1016/j.apenergy.2009.09.026.

[19] S. R. Pradhan, P. P. Bhuyan, S. K. Sahoo, and G. R. K. D. S. Prasad, “Design of Standalone Hybrid Biomass & PV System of an Off- Grid House in a Remote Area,” Int. J. Eng. Res. Appl., vol. 3, no. 6, pp. 433–437, 2013, [Online]. Available: https://www.ijera.com/papers/Vol3_issue6/BU36433437.pdf.

[20] A. Shiroudi, R. Rashidi, G. B. Gharehpetian, S. A. Mousavifar, and A. Akbari Foroud, “Case study: Simulation and optimization of photovoltaic-wind-battery hybrid energy system in Taleghan-Iran using <scp>homer</scp> software,” J. Renew. Sustain. Energy, vol. 4, no. 5, p. 053111, Sep. 2012, doi: 10.1063/1.4754440.

[21] G. B. Pradhan, “CENTRAL ELECTRICITY REGULATORY COMMISSION NEW DELHI order,” New Delhi, 2016. [Online]. Available: http://cercind.gov.in/2016/orders/sm_3.pdf.

[22] . S. D. Meena, “No. S/01/19 BEFORE THE KARNATAKA ELECTRICITY REGULATORY COMMISSION, BENGALURU Dated 27.” KARNATAKA ELECTRICITY REGULATORY COMMISSION, BENGALURU, BENGALURU, pp. 1–20, 2019, [Online]. Available: http://www.srpc.kar.nic.in/website/2019/meetings/occ/m156occm.pdf.

[23] HOMER Energy LLC, “HOMER Pro Version 3.7 User Manual,” HOMER Energy, no. August, p. 416, 2016, [Online]. Available: http://www.homerenergy.com/pdf/HOMERHelpManual.pdf.

[24] ियकसां, “(JULY भारत सरकार Government of India सां ियक और काय म काया वयन मं ालय Ministry of Statistics and Programme Implementation रीय सां ियकय काया लय National Statistical Office,” 2017. [Online]. Available: http://www.mospi.gov.in/sites/default/files/press_release/CPI Press Release July 2020.pdf.

[25] C. E. A. Monthly and E. Summary, “March 2020. The share of RES in total installed capacity has gone up from 10% to 24%, largely driven by various reforms introduced by the Government of India to provide necessary support for the growth of renewable energy-based generation in the country.,” 2020. [Online]. Available: http://www.cercind.gov.in/2020/draft_reg/EM-PMR-2020.pdf.