Bulletin of Electrical Engineering and Informatics
Vol. 4, No. 2, June 2015, pp. 120~129
ISSN: 2089-3191

Integrated Alternative Source of Energy System with Grid Substation

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Abstract

This paper discusses the modeling, simulation and optimization of integrated alternative source of energy system with grid substation. When there is a lack of energy in grid substation to meet the demand of customer load then alternative source of energy compensates energy deficiency and after that if there is excess energy available then remaining energy is stored in battery bank or sells to grid according to need. In another case when required energy is not generated by alternative sources then remaining energy is purchased from the grid and if the grid substation hasn't available these remaining energy to meet the customer load demand during the peak load then stored battery energy is also active. The size of integrated alternative source of energy system may vary from few hundred watts to ten or hundreds of MW. The possible sources of alternative energy like solar, wind and biomass are considered under this paper. Study location, Muzaffarpur district of Bihar (India), is taken because there is good potential of energy generation from alternative source of energy and still there is no any wind and solar energy power plant. The modeling and simulation of the system is done by using HOMER software and the software solve the optimization problem to minimize the total cost of system and maximum utilization of alternative source of energy.

Keywords*: Integrated power system, wind energy system, P-V system, biomass energy system, HOMER software*

1. Introduction

India's significant and sustained economic growth is placing enormous demand on its energy resources. However, there is a pervasive demand-supply imbalance that necessitates serious efforts by the government of India to augment energy supplies. The country imports about 80 percent of its oil. With the threat of a further increase in oil prices, serious problems with regard to energy security is anticipated. India also runs the substantial risk of lesser thermal capacity being installed. While dependence on imported coal is increasing, supply of indigenous coal is likely to decrease in the coming years because of production and logistic constraints [1]. Economic growth, increasing prosperity and urbanization, rise in per capita consumption, and spread of energy access are the key factors that would be responsible for substantially increasing the total demand for electricity. Thus there is an emerging energy supply-demand imbalance. According to a Central Electricity Authority report, the anticipated energy and peaking shortage in the country is estimated to be 10.3 percent and 12.9 percent, respectively, in 2011 and 2012.

Muzaffarpur district of Bihar state, India as the study area there is still a wide demand-supply gap that needs to be bridged, one glaring proof of the same is the fact that Bihar's power system has a peak of about 1500 MW under the constrained demand scenario and the availability is about 950 MW. Only 52.8 % of villages and 6 % of households of the state are electrified, leaving about 85 % of the population with no access to electricity [2]. The Bihar state government still totally dependent on thermal and hydro power plant to overcome this energy shortage but there is a good potential to generate power from alternate source of energy like solar and biomass because there is good annual average solar radiation (5.27kWh/m^2/d) and abundant in biomass residue respectively. As per C-WET'S India wind atlas, Bihar lies in low wind zone and no wind power density is observed at more than 200 watts per square meter at 50 meter hub height which is minimum requirement for installation of large wind power plant. As

Received November 3, 2014; Revised December 18, 2014; Accepted January 18, 2015

per MNRE guidelines, for small wind plants minimum wind speed required is 4.17 m/s (or 15 KMPH) at 20 meter hub height. Muzaffarpur and some other district of Bihar is close to minimum wind speed requirement for small wind system [3]. Muzaffarpur is suitable for small wind power generation. Integration of alternative source of energy with grid substation is best to overcome this energy deficiency. Hence it is necessary to integrate alternative source of energy and alternative units can chosen so that they satisfy the customer load demand in remote area at minimum cost all the time and maximum utilization of alternative sources.

The integrated power systems which utilize renewable energy generators can be classified into two basic configurations: Series hybrid system and Parallel hybrid system [4]. Both the systems have their own characteristics. The proposed scheme is based on parallel hybrid system a shown in Figure 1.

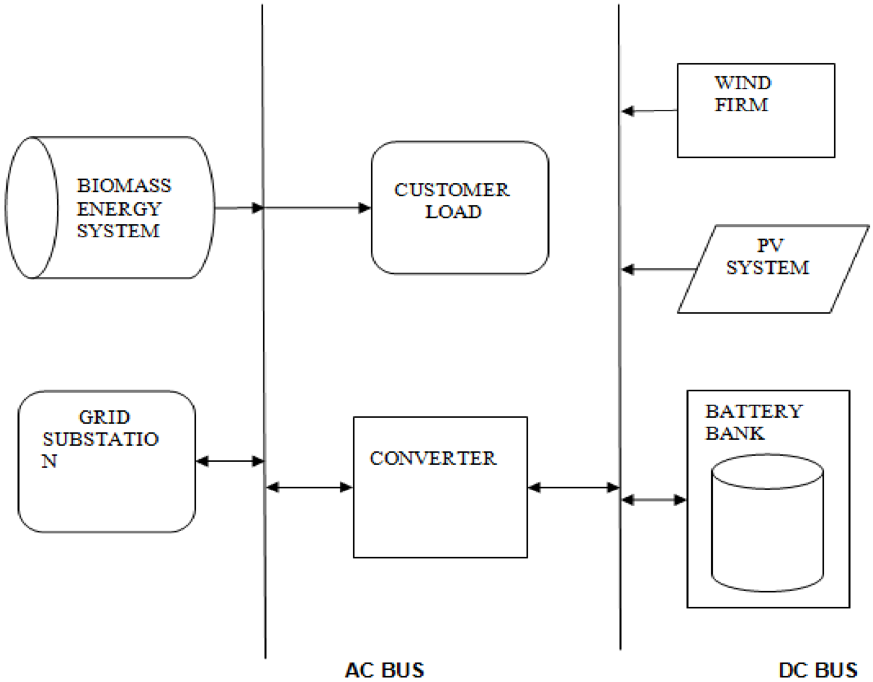

Figure 1. Parallel integrated power system

Many hybrid systems have been proposed in the past for electrification of remote areas or grid connected sites. Many tools are also available for sizing and simulation of a hybrid system. But fewer include biomass resources. The performance of integrated power system is dependent on climate condition and availability of biomass resources.

In designed system biomass power plant is largest supplier of energy and it is active in all possible condition which we have got in simulation model. In our simulation model primary load is variable and average demand is 2.3 MWh/d and peak demand is 225kW. Data of annual wind speed and solar radiation of Muzaffarpur is taken from [5] [6]. Wind speed vary seasonally from (3.1 - 4.3) m/s.

All Analysis is doing by using HOMER software means hybrid optimization model for electrical renewable [7] [8]. Our propose model shows how much percentage contribution of alternative sources in total power generation and how it make us partially independent on conventional energy sources. In case of PV/biomass integrated system we have got 65% renewable fraction means 65% of total energy generated by alternative sources but in case of PV/wind/biomass integrated system we have got 70% renewable fraction but NPC of this system is 13% more than the PV/biomass integrated system. But for optimum utilization of alternative sources NPC doesn't matter so much; if we consider conventional sources are no longer uses because of its limited amount. We have also study how energy purchasing and selling from the grid vary month by month. Since in cloudy day sun light effect has become lesser so we have not got sun light properly. So that in the month of July, August and September net energy purchasing is more as compare to other months and at the same time it is depends on the availability of biomass resources and wind speed

2. Integrated Power System (IPS) Configuration

The configuration of hybrid system depends on three factors: resource (renewable sources), load, and cost (initial capital and operating cost) [9]. The major problem faced by power generation using the integrated system is the variation in load and alternative resources (solar radiation, wind speed and biomass production). Therefore, the major concern in the design of an electrical power system that utilizes alternative energy resources is the accurate selection of system components that can economically satisfied the load demand.

In the above optimization problem, integrated power system sizing is done with the aim of maximizing renewable fraction. The purpose of this paper is to explore the possibility of integrated power system with grid substation through design and optimization of PV/Wind/Biomass integrated system using a computer based design optimization. To demonstrate the potential of alternative source of energies to less dependent on grid substation as a source of energy for customer load. This study will provide energy system solution that can reduce customer load dependency on grid substation and maximum utilization of alternative sources which are environmental friendly.

3. System Specifications

3.1 Homer

HOMER (hybrid optimization model for electrical renewable) simulation simulates the operation of a system by making energy balance calculation for each of the 8,760 hours in a year. For each hour HOMER compare the electrical and thermal load in the hour to the energy that the system can supply in that hour. For system that includes batteries, HOMER decides for each hour how to operate the generators and whether to charge or discharge the batteries. If the system meets the loads for the entire year, HOMER estimates the life cycle cost of the system, accounting for the capital, replacement, operation and maintenance, fuel and interest cost [10].

3.2 Study Location

Muzaffarpur (Latitude $26^0\ 04'N$, Longitude $85^0\ 36'\ E$) city of Bihar, India has taken for study. The district occupies an area of 3173 km² and has a population of 3,743,836 (as of 2001).

3.3 Load Profile

A typical daily and annual electrical load profile are shown in Figure 2 and Figure 3 respectively. Muzaffarpur district has been considered for load analysis. For a particular area we consider home, shops, street, schools and other some load.

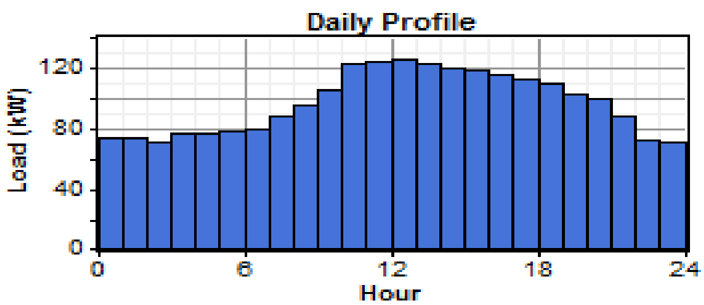

Figure 2. Daily Load Profile of City

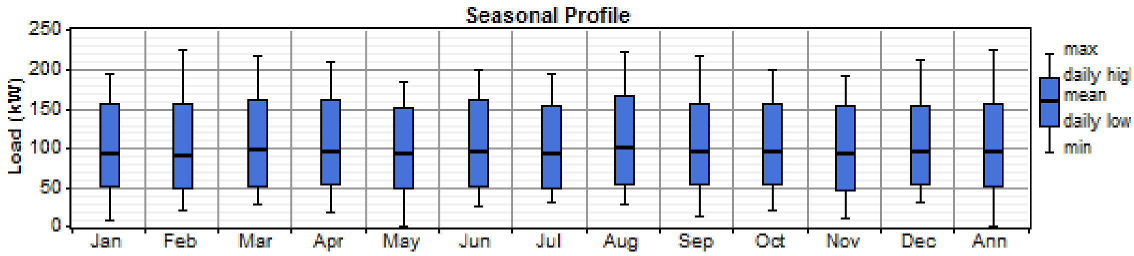

Figure 3. Annual load profile of city

Majority of load occurs between 11 A.M to 8 P.M with average load 96.6 KW and peak load 225 KW.

3.4 System Components

3.4.1 Solar Photovoltaic (PV) System

Solar energy is the most promising of the renewable energy sources in view of its apparent unlimited potential. The sun radiates its energy at the rate of about 3.8 x 1023 kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m^2 at the boundary of the atmosphere. After traversing the atmosphere, a square meter of the earth's surface can receive as much as 1kW of solar power, averaging to about 0.5 over all hours of daylight. Solar radiation details of study area is taken from [5] is given in Figure 4.

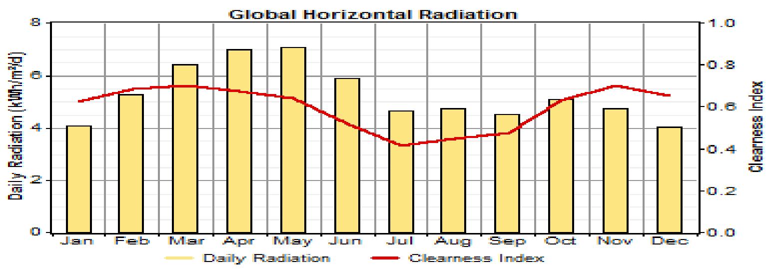

Figure 4. Annual solar radiation and clearness index data profile

3.4.2 Wind Energy System

The energy available in the wind depends on the density and air velocity. The density, as any other gas, changes with the temperature and pressure which varies with the high level of the sea. The energy of a mass of air which is displaced is determined by the Kinetic Energy (K.E) flux [11]. The hub height of the wind turbine system is 20m and altitude (m above the sea level) of Muzaffarpur is 46. Wind speed details of study area are taken from the website [6] which is given in Figure 5.

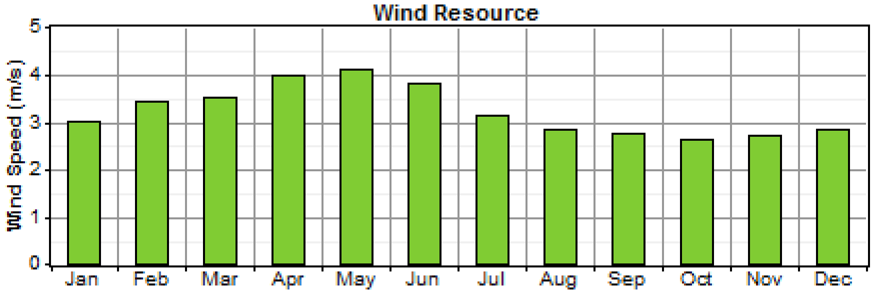

Figure 5. Annual wind speed data profile

3.4.3 Biomass Energy System

Biomass energy system converts biomass energy into electrical energy. The energy availability is depends on the type and the quantity of biomass residue. The main biomass residue in this region is rice husk, rice straw, paddy straw, maize cobs and municipal solid waste. The annual production of biomass residue of Muzaffarpur district is given in terms of M.T./year is taken from [11]. Therefore annual average biomass production is 176 tones/day. Annual biomass production profile is shown in Figure 6.

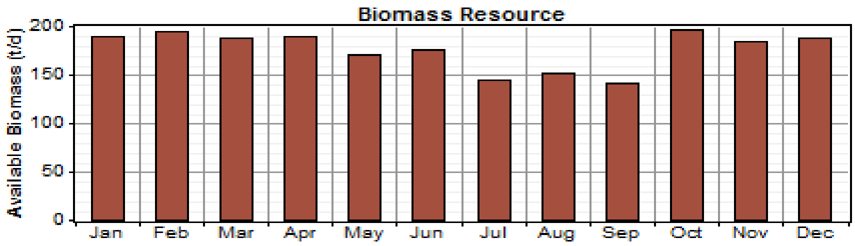

Figure 6. Annual biomass production profile

3.4.4 Battery Storage System

Battery bank is a conventional approach to store electrical energy with high efficiency. Its discharging level cannot exceed a minimum limit defined as depth of discharge. The capacity of the battery is so designed so as to supply the primary load during the non-wind and non-solar hours.

3.5 System Constraint

The constraints which are given in Figure 7 are conditions that system meet to be feasible. Infeasibility systems do not include operating in the sensitivity and optimization analysis [12].

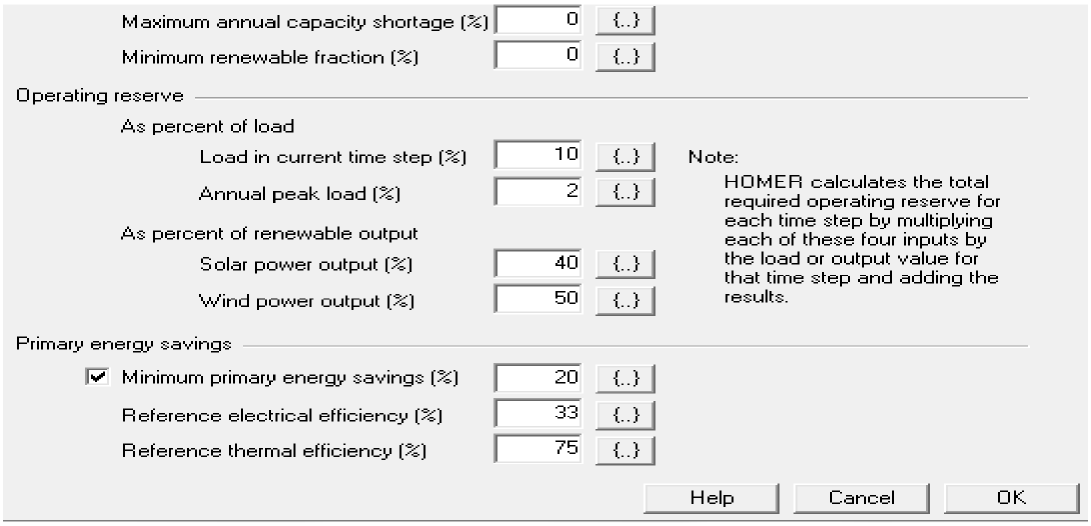

Figure 7. System constraint

4. HOMER Simulation and System Architecture

HOMER helps determine how different conventional, renewable, and hybrid systems interact with primary load demand. Based on availability and potential of alternative sources in the study area, an integrated power system is modeled consists of a photovoltaic, wind power system, and biomass plant. Battery is used for back-up and storage system. The project life time is estimated at 25 years. The Figure 8 shows an integrated alternative source of energy system with grid substation.

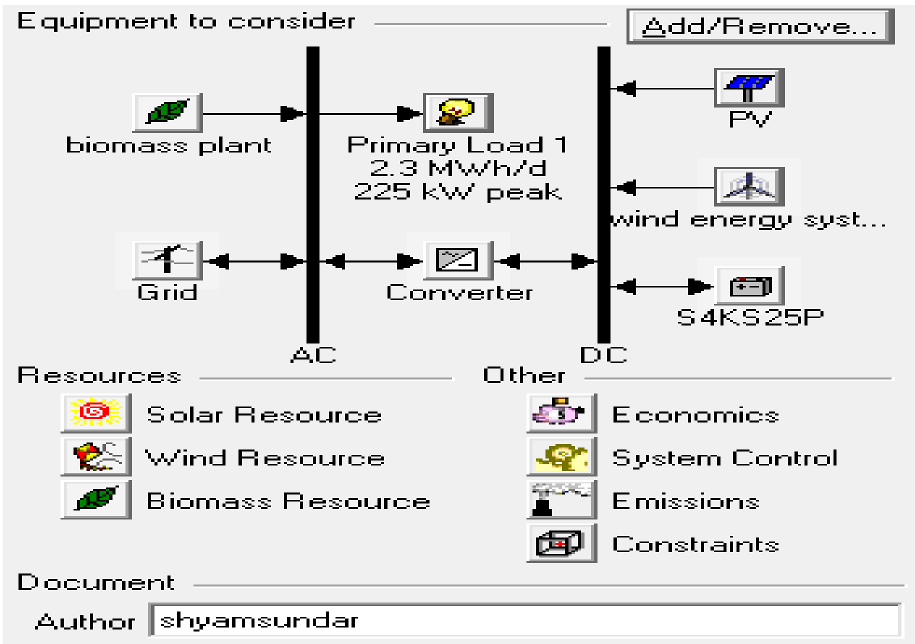

Figure 8. Integrated alternative source of energy system with grid substation

Table 1. System architecture of integrated energy system

PV Array	80 kW
Wind turbine	12 wind energy system
biomass plant	80 kW
Grid	100 kW
Battery	75 Surrette 4KS25P
Inverter	100 kW
Rectifier	100 kW
Dispatch strategy	Cycle Charging

5. Result and Analysis

Homer simulates system configuration with all of the possible combinations of components that are specified in the component input. Homer performs hundreds or thousands of hourly simulations (to ensure best possible matching of supply and demand) and offers a list of possible schemes ranked on the basis of NPC(net present cost). The system is design in such a way that the power generated from this integrated system to meet the load demand. The integrated alternative source of energy system with grid substation evaluated to determine the feasibility of the system. The system is also simulated in order to evaluate its operational characteristics, renewable fraction, grid sold and purchased energy table, namely annual electrical energy production, annual electric load served, capacity shortage, and unmet electric load as shown in Figure 9 to Figure 15.

In the month of July, August and September due to cloudy day the generation of power through PV system is less so that energy purchased from grid in this month is high as compared to other months. In the month of May total energy purchased is very less because solar radiation is maximum (7.070 kWh/m^2/h) as compare to other months. The maximum energy generation from wind plant in the month of April, May and June due to good wind speed. The maximum energy generation from biomass power plant of an average 79.9 kW. In this paper we are mainly focus energy optimization so that renewable fraction should be high and net energy purchases is low then our system would be most effective.

ble click on a system below for simulation results. ◉ Categorized ○ Overall

PV (kW)	WPP	BMPP (kW)	S4KS25P	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Net Purchases (kWh/yr)	Ren. Frac.	Biomass (t)	BMPP (hrs)
80		80	75	100	CC	100	$ 264,700	54,749	$ 964,577	0.084	265,051	0.65	1,135	5,840
80	12	80	75	100	CC	100	$ 444,700	52,099	$ 1,110,701	0.093	196,763	0.70	1,134	5,840
	12	80	75	100	CC	100	$ 404,700	64,044	$ 1,223,402	0.109	319,583	0.60	1,135	5,840

Figure 9. The simulation result of integrated PV/wind/biomass energy system with grid substation

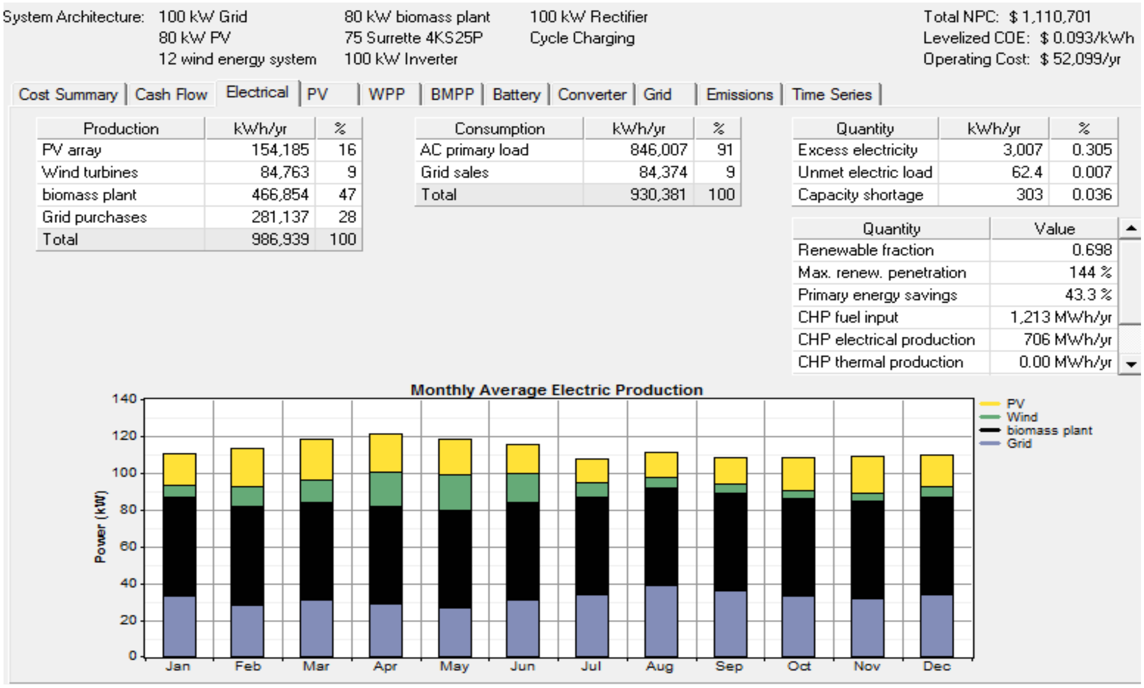

Figure 10. Contribution of electrical energy production by PV/wind/biomass/grid substation

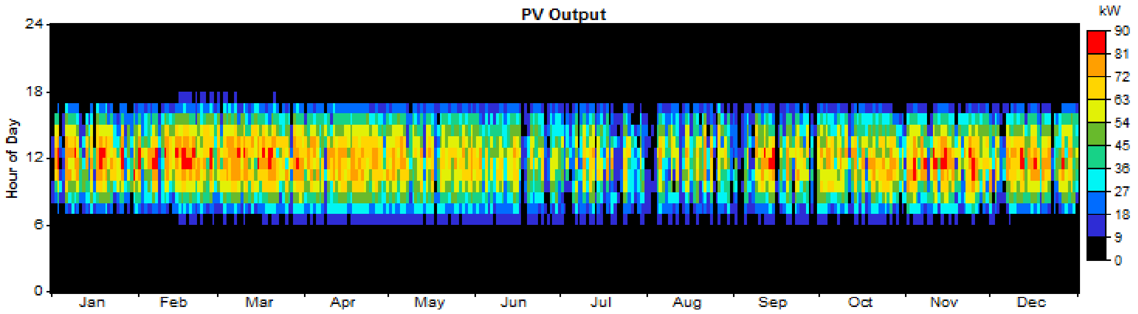

Figure 11. Annual electric energy production by PV system

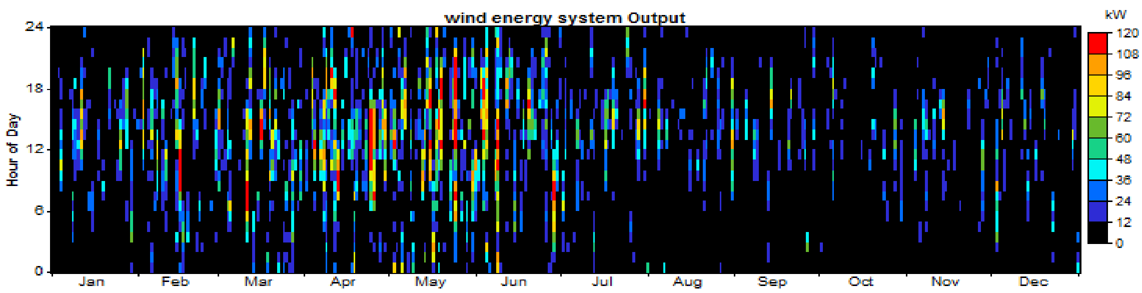

Figure 12. Annual electric energy production by wind energy system

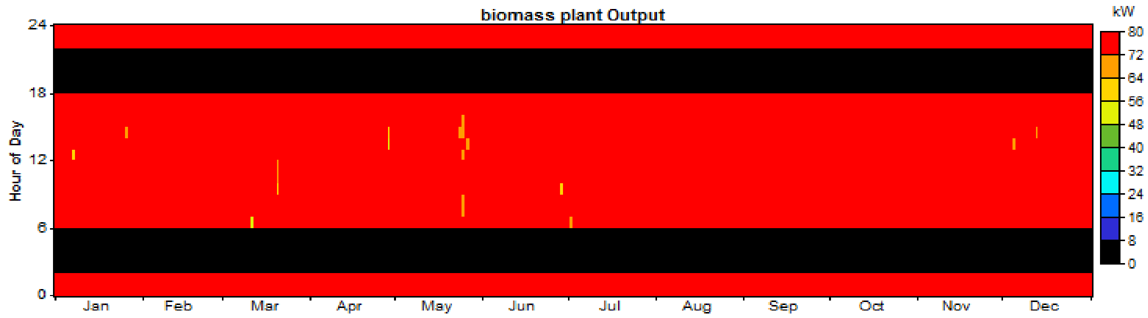

Figure 13. Annual electric production by biomass energy system

Quantity	Value
String size	1
Strings in parallel	75
Batteries	75
Bus voltage (V)	4

Quantity	Value	Units
Nominal capacity	570	kWh
Usable nominal capacity	342	kWh
Autonomy	3.54	hr
Lifetime throughput	792,645	kWh
Battery wear cost	0.106	$/kWh
Average energy cost	0.026	$/kWh

Quantity	Value	Units
Energy in	20,152	kWh/yr
Energy out	16,023	kWh/yr
Storage depletion	120	kWh/yr
Losses	4,009	kWh/yr
Annual throughput	17,915	kWh/yr
Expected life	12.0	yr

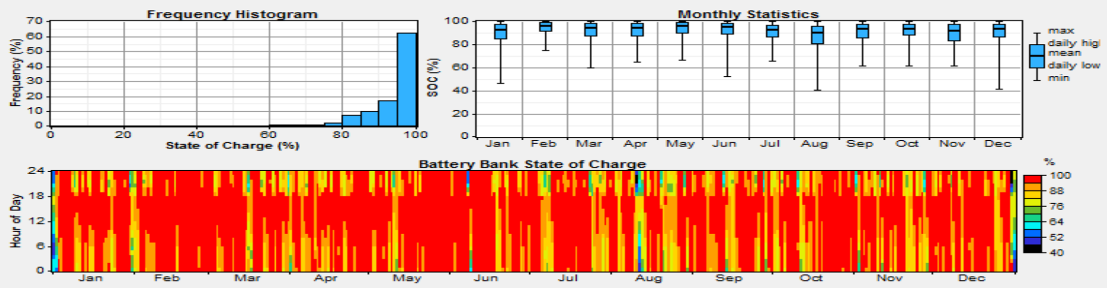

Figure 14. Statistical result of battery system

Quantity	Inverter	Rectifier	Units
Capacity	100	100	kW
Mean output	22	1	kW
Minimum output	0	0	kW
Maximum output	100	23	kW
Capacity factor	21.9	0.9	%

Quantity	Inverter	Rectifier	Units
Hours of operation	6,765	1,007	hrs/yr
Energy in	239,936	9,560	kWh/yr
Energy out	191,950	8,126	kWh/yr
Losses	47,987	1,434	kWh/yr

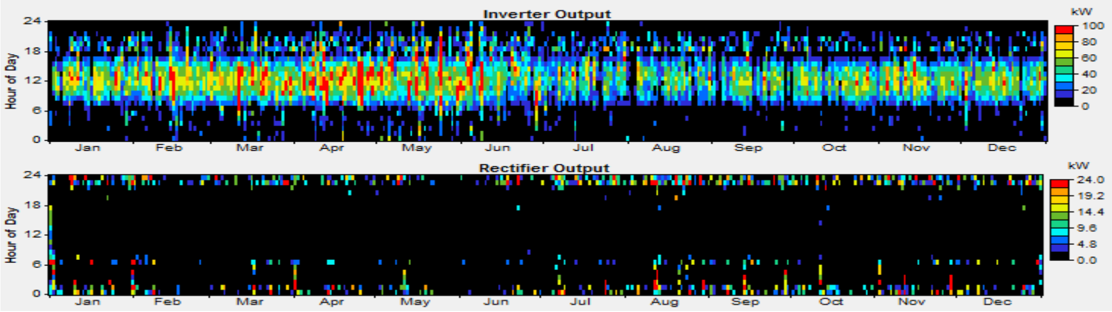

Figure 15 Statistical result of converter

Table 2. Annual grid energy purchased and sold data table

System Architecture: 100 kW Grid, 80 kW PV, 12 wind energy system, 80 kW biomass plant, 75 Surrette 4KS25P, 100 kW Inverter, 100 kW Rectifier, Cycle Charging

Total NPC: $ 1,110,701
Levelized COE: $ 0.093/kWh
Operating Cost: $ 52,099/yr

Cost Summary | Cash Flow | Electrical | PV | WPP | BMPP | Battery | Converter | Grid | Emissions | Time Series

Month	Energy Purchased (kWh)	Energy Sold (kWh)	Net Purchases (kWh)	Peak Demand (kW)	Energy Charge ($)	Demand Charge ($)
Jan	24,765	6,809	17,956	100	1,796	10
Feb	18,961	8,793	10,168	100	1,017	10
Mar	23,046	7,977	15,069	100	1,507	10
Apr	20,850	10,333	10,517	100	1,052	10
May	19,544	11,930	7,614	100	761	10
Jun	21,988	7,496	14,492	100	1,449	10
Jul	25,010	5,435	19,575	100	1,957	10
Aug	28,847	3,362	25,485	100	2,549	10
Sep	25,956	4,086	21,870	100	2,187	10
Oct	24,541	5,357	19,184	100	1,918	10
Nov	22,599	6,604	15,995	100	1,600	10
Dec	25,031	6,193	18,838	100	1,884	10
Annual	281,137	84,374	196,763	100	19,676	120

6. Conclusion

The proposed integrated system is designed and optimized using HOMER software to supply energy to primary load and in case of base load excess energy generated by alternative sources sold to the grid substation. The monthly variation of net purchased energy is given in Table 2. Which shows that how climatic condition change the energy generation by alternative sources. our main focus is not a NPC (net present cost) of the system but maximum utilization of alternative sources which is environmental friendly and we can easily see in Figure 7 how second row system (PV/wind/biomass integrated energy system) maximize the energy utilization by 70% through alternative sources as compare to other two sources and net purchased energy (kWh/yr) from grid substation is also low as compare to other two systems in which either PV or wind is not included. Battery storage system is also important which stored energy in case of low demand and excess generation of electricity and it gives to supply in case of peak load demand. The total energy IN and OUT from the battery is given in Figure 12, where energy IN mean excess generation and energy OUT means stored energy supplied to load in case of peak load demand or low power generation. Thus battery utilize 20,152 kWh/yr energy which may be loss during the excess generation of electricity.

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