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Design and Techno-Economic Analysis of Small-Scale Hybrid Power System Connected To Grid System

Abraham Alem Kebede[1]
[1](*Faculty of Electrical & Computer Engineering, Jimma Institute of Technology/ Jimma University, Ethiopia)*
Corresponding Author: Abraham Alem Kebede

ABSTRACT: *Now a days renewable energy sources are becoming dominant in the world. The use of these energies with utility network results in enhancement of overall power transfer, voltage stability profile, uninterrupted power supply, etc. But even though this sources have a number of advantages, it also have negative impact un less continuous evaluation have been made. Therefore renewable energy sources will be evaluated both technically and economically. In this research first feasibility of each potential resources have been analyzed. Technical and Economic impacts will be analyzed by considering possible combinations of plants deploying for typical loads estimated initially. The first is when renewable energy sources are working independently, and second is when this sources are combined together with grid system. After identifying the most reliable combination, design and modeling part of the power grid connected hybrid system will be done using HOMER software. In order to design the size of solar panel, first all available load requirements have been determined. Design parameters which are determined mathematically, are fed to the software and therefore the optimization and sensitivity parameters are evaluated. From the simulation results it is found that the optimization results have been analyzed for all possible combinations and hence the designed system is cost effective. Compared to grid availability the total power produced from the solar system is Around 10.5 KW peak power and hence, 5.2 KW is delivered to the load and the remaining 5.3 KW is fed to the utility network.*
KEYWORDS: *Renewable Energies, Solar PV, Diesel Generator, HOMER, Utility Grid, Optimization, Sensitivity Parameter..*

I. INTRODUCTION

With the serious problem of environmental pollution caused by fossil fuel, and with rapid depletion of fossil fuel reserves, it is feared that the world will soon run out of its energy resources. This is a matter of concern for developing countries whose economy heavily leans on its use of energy. Under the circumstances it is highly desirable that renewable energy resources should be utilized with maximum conversion efficiency to cope with the ever increasing energy demand. Since wind and sunlight are free and inexhaustible, the price of wind and solar photovoltaic power is stable, as compared to the diesel generator [1]. Diesel depends on fuel whose price is costly and may vary considerably. Nevertheless, the major challenge of wind and solar photovoltaic power source is that they are intermittent power supplies, because wind doesn't always blow and sometimes there may not be sunlight. Therefore, before the installation of these renewable energies there should be assessment of resources at selected site where these plants are going to be installed. This research focus on the feasibility study, techno- economic aspect and Design of small-scale Renewable power plant inter-connected to power grid. Even though the hybrid energy system to be applied to the network is small, the integration of this renewable energy sources may have significant impact on the optimum power flow, transmission congestion, power quality issues, and system stability [2]. So, in order to avoid this effect, the technical properties of renewable energy sources must be considered on power system plan and operation in depth. In order to assess the feasibility of this hybrid energy system, all the required data's will be collected for specific site and then analyzed using HOMER software. Technical and Economic impacts will be analyzed by considering possible combinations of plants. The first is when renewable energy sources are working independently, and second is when this sources are combined together with grid system. After identifying the most reliable combination, design and modeling part of the power grid connected hybrid system will be done using HOMER software.

II. RENEWABLE ENERGY SYSTEMS

Photovoltaic and solar thermal systems are the two basic ways used to generate electricity from sunlight. Pphotovoltaic means the direct conversion of light into electrical energy using solar cells. Semiconductor materials such as silicon, gallium arsenide, cadmium telluride or copper indium di selenide are used in these solar cells. Basically the amount of power available from a PV device is determined by Intensity of sun light, type and area of the PV material, and also wave length of Sun light. So, while designing of the system all this factors should be taken in to account. In line with the PV panel designing components line Battery, charge controller, Inverters are among the different components which should be considered.

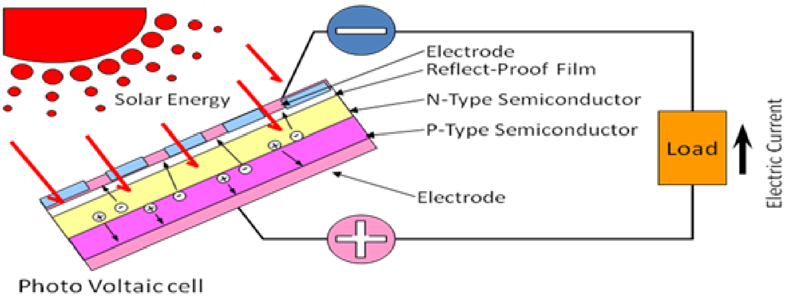

Fig. 1 Schematic block diagram of a PV cell

Among different renewable energy resources, Wind Energy system is also the one which is extensively used, especially for rural electrification. The wind energy conversion system is composed of the tower, the yaw, turbine blades and the nacelle, which accommodates the gear box and generators. The Towers are made from tubular steel, concrete, or steel lattice which holds the main part of the wind turbine and keeps the rotating blades at a height to capture sufficient wind power. Even though the nature of the wind is intermittent, with the help of frequency converters its variable frequency can converted in to stable and operating frequency.

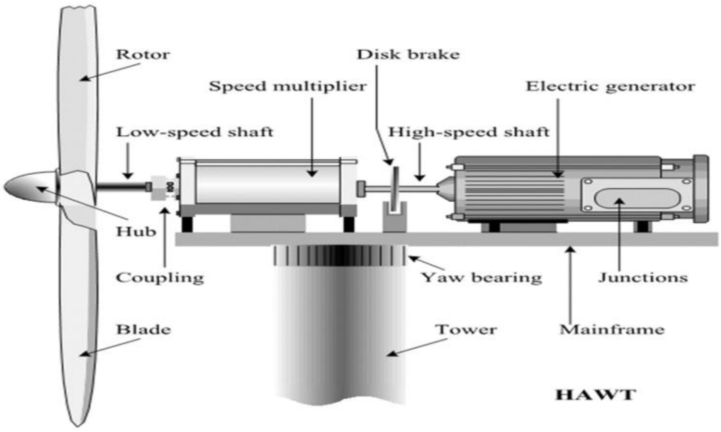

Fig. 2Wind energy conversion system block diagram [3]

III. METHODOLOGY AND ANALYSIS

A. *Site mapping and Data collection*

Jimma zone as well the city is one of the richest place in renewable energy sources, in particular solar energy potential. To solve the problem of electricity shortage, use of this solar energy plays a great role. In order to analyze the design and economic aspect of renewable energy resources, first data is going to be collected for the nearest place to the selected site. The primary sources for data collection are, NMA, SWERA, and NASA, which provides the data for solar radiation, wind speed and direction. Direct measurement is an alternative mechanism for collecting data's. For modeling or Design of the small scale RES, first load estimation should be considered by selecting typical loads. Technical properties of solar and wind resources are compared for studying their efficient operation.

Kito Furdissa is found in Jimma city which extends between 7°13' to 8°56' North latitudes and 35°49' to 38°38' east longitudes. And also it is located in the south western part of Oromia. The altitude range of Kito Furdissa is around 1673 – 1780 m. For the sizing of the solar panel the primary load profile considered are, personal computers used in the school of electrical and computer engineering. The numbers of computers are estimated to be 30 PCs in number (almost one computer laboratory).

B. Data collection of solar & Wind energy resources

Month	***Daily solar radiation horizontal,*** *$kWh/m^2/d$*	***Wind speed*** *m/s*
January	*5.43*	*3.1*
February	*6.42*	*3.0*
March	*6.5*	*2.8*

April	*5.64*	*2.8*
May	*5.39*	*2.5*
June	*4.87*	*2.4*
July	*4.5*	*2.1*
August	*4.64*	*1.9*
September	*5.21*	*2.0*
October	*5.39*	*2.4*
November	*5.40*	*2.9*
December	*5.41*	*3.1*
Annual	*5.5*	*2.6*

Table 3.1. The average solar radiation and average wind speed data of Jimma city as per estimation of NASA is shown below.

C. Solar Radiation data of the selected site

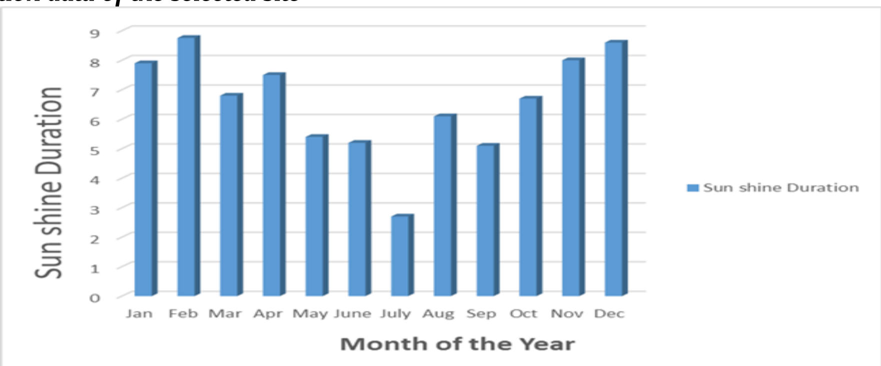

Fig. 3.1 Monthly average Sunshine hours of Kito Furdissa

D. Determination of solar radiation by analytical method

Using Angstrom modelling formula the collected and measured sun shine hour datas from NMA, are converted to solar radiation in KW/m2/day. Angstrom model formula used is shown below,

$$H = H_0\left[a + \frac{s}{s_0}b\right] \quad 3.1$$

Where,

H = monthly average daily radiation on horizontal surface (MJ/m2),

H0=is monthly average daily extraterrestrial radiation on a horizontal surface (MJ/m2)

S_O= monthly average of the maximum possible daily hours of bright sunshine

S = monthly average daily number of hours of bright sunshine

a and *b* are regression coefficients which can be obtained using the following equations for M number of data points.

$$a = \frac{\sum\frac{H}{H_o}\sum\left(\frac{S}{S_o}\right)^2 - \sum\frac{S}{S_o}\sum\frac{S}{S_o}\frac{H}{H_o}}{M\sum\left(\frac{S}{S_o}\right)^2 - \left(\sum\frac{S}{S_o}\right)^2}$$

$$b = \frac{M\sum\frac{S}{S_o}\frac{H}{H_o} - \sum\frac{S}{S_o}\sum\frac{H}{H_o}}{M\sum\left(\frac{S}{S_o}\right)^2 - \left(\sum\frac{S}{S_o}\right)^2}$$

Daily extraterrestrial radiation on a horizontal surface is given by

$$H_o = \left[\frac{24x3600}{\Pi} I_{SC}\right] x \left[1.0 + 0.0033cos\left(\frac{360N}{365}\right)\right] x \left[cos\phi cos\partial sin\omega_S \frac{\Pi}{180}\omega_S sin\partial sin\phi\right]$$

Where:

n_d = day number starting from January 1st as 1,

G_{SC}(the solar constant) =1367 W/m2,

ϕ = Latitude of the location,

δ= Declination angle (^{0})

ω_s= Sunset hour angle (^{0})

The declination angle and sun set hour can be calculated by the day of year using the following equation (Cooper's equation),

$$\delta = 23.45\frac{\pi}{180}sin\left(2\pi\left(\frac{284+n}{365}\right)\right) \quad 3.2$$

Where, *n* is the day number counted from January first throughout the year.
ωs = the sunset hour angle (^{0}), which is given by equation below
$\omega s = cos^{-1}(-tan\phi tan\delta)$
The maximum possible sunshine duration (monthly average day length, S_O) is given by $S_O = (2/15)\omega s$. Anywhere in the world, the regression coefficients given by the following equation [4].

$$\frac{H}{H_O} = 0.23 + 0.48\frac{S}{S_O}$$

Using the above formulas the respective calculated values of different parameters are summarized below.
Table 3.2. Calculated date in month, declination angel, hour angle and day of the year.

Month	Jan	Feb.	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov
Date In Month	17	16	16	15	15	15	17	16	15	15	14
Day Of The Year ,N	17	47	75	102	130	162	199	229	251	281	316
Declination(δ^o)	-20.92	-12.94	-2.41	9.41	18.79	23.05	18	13.46	2.22	-9.59	-18.91
Hour Angle (ω_s)	86.22	87.65	89.57	91.7	93.49	94.39	93.35	92.46	90.39	88.26	86.63
Length Of The Day (Hour)	11.31	11.69	11.73	12.23	12.26	12.18	12.35	12.33	12.05	11.77	11.55
H0 In Kwh/M2/Day	8.93	9.54	9.3	10.02	8.88	9.31	9.89	9.29	9.38	9.65	9.08
Calculated, H In Kwh/M2/Day	5.37	6.23	6.32	5.12	5.14	5.13	4.83	5.08	4.95	5.27	5.37
NASA H In Kwh/M2/Day	5.43	6.42	6.5	5.64	5.39	4.87	4.5	4.64	5.21	5.39	5.40

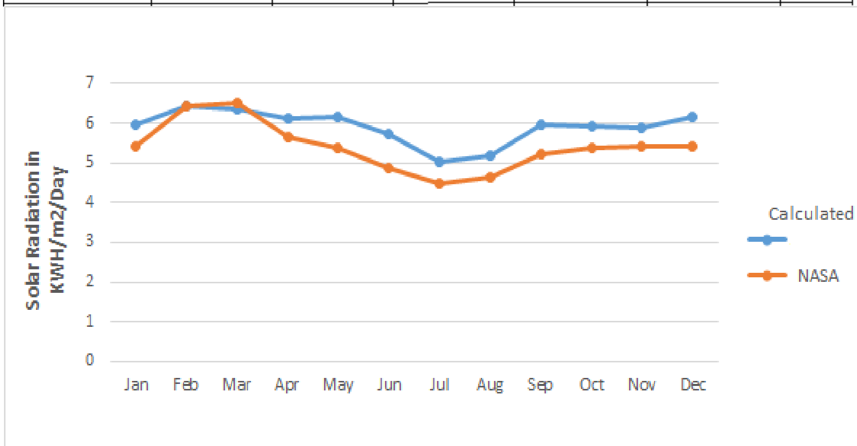

Fig. 3.2. Comparison of calculated solar radiation data with NASA

The monthly average clear ness index can be calculated from the ratio of H monthly average daily radiation to that of H0 monthly average daily extra-terrestrial radiation on a horizontal surface (MJ/m2).
K = H/ H0.

The values of H and H0 from the above table are taken and then their ratio are fed to the Homer software for each respective months. The results are summarized as shown below.

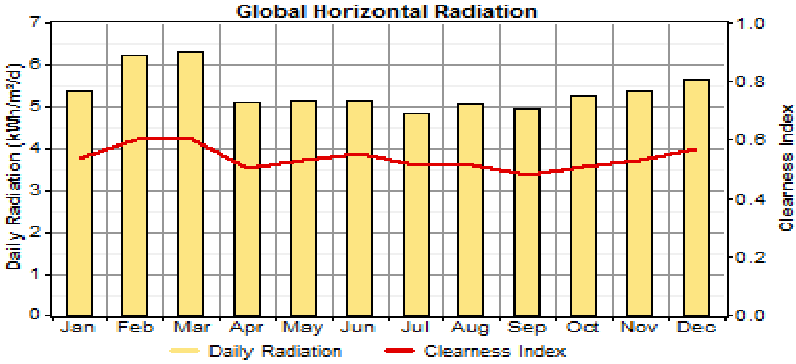

Fig 3.3 **Daily Available Solar Insolation Data for the Selected site Using HOMER**

E. Wind Resource Assessment of the Selected Site

The wind speed data of the study site have been taken from a nearby metrological station (Jimma station) which is measured at 10 meter height. In order to estimate the wind speed at selected turbine hub height, the following equation has been used.

$$V(Z)\times\ln\frac{(Z_r)}{Z_o}=V(Z_r)\times\ln\left(\frac{Z}{Z_o}\right) \quad 3.3$$

Where z_r is the reference height (10m), z is the new hub height, z_o is the roughness length, which is 0.1–0.25 m , V(z) and V(z_r) is the velocity at height z and z_r respectively.

The Average monthly wind resource of the selected site is shown below.

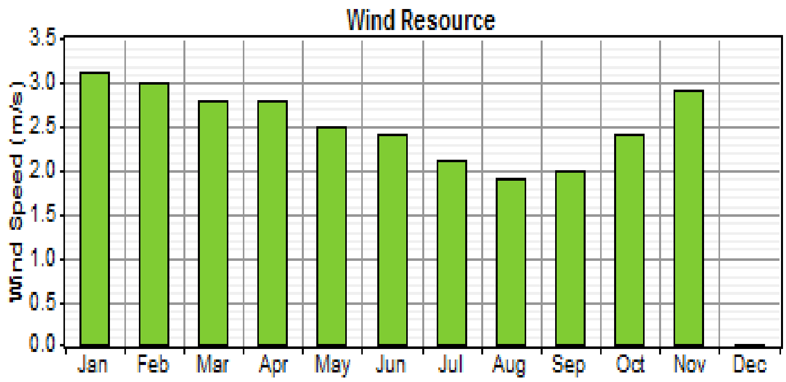

Fig. 3.4 Average wind speed (m/s) of the selected site.

From the resource assessment output of the software, it can be seen that the majority of average wind speed is less than the cut in wind speed (3 m/s). Hence, wind energy resource is not feasible for hybridization as compared to the solar energy resource comparing for the same power production.

F. ELECTRICAL LOAD PROFILE ESTIMATION

It is known that before the detail design of Grid connected Hybrid Renewable Power System, the primary task to be done is estimation of the load profile. This intern enables to determine the size of system components accurately. For the sake of minimizing the complexity in estimating the electrical load (Primary load) of the selected site, around 30 PCs with an average size of one laboratory class,Including fluorescent lighting lamps and fans (Deferrable Load) are assumed in this study. Based on the collected load profile data, the hourly load of the room has been calculated.

Table 3.3. SUMMARY OF Load Data

Category of load consideration	Name of items	No. of items (N)	Rated Power (W)	Total Rated Power(KW)	Daily Usage, in hrs	Daily Required energy in (KWh)	Remark
Laboratory	Personal computer (Pc)	30 PCs	150	4.5	16	72	Day & Night
	In door lamps, (fluorescent)	20	16	0.32	10	3.2	Night
	Corridor lamp	3	16	0.048	12	0.576	Night
	Fans	4	75	0.3	10	3	
Total				5.168		78.776	

The system load have the energy demand of 78.776 KWh/day with peak load of 4.5 KW. Therefore, the daily load to be supplied can be computed as:

78.776 KWh*1.3 (fudge factor) = 102.408 KWh/m^2.day.

So it can be seen from the above table that almost the remaining 5.3 KW generated power from PV will be supplied to the utility network- Grid connected system.

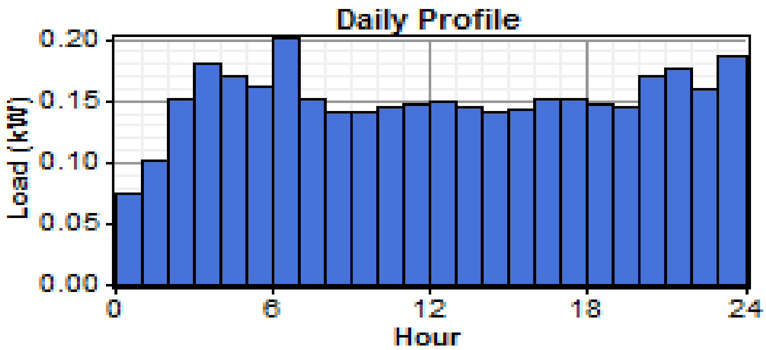

Fig.3.5 Daily load profile of primary load HOMER output.

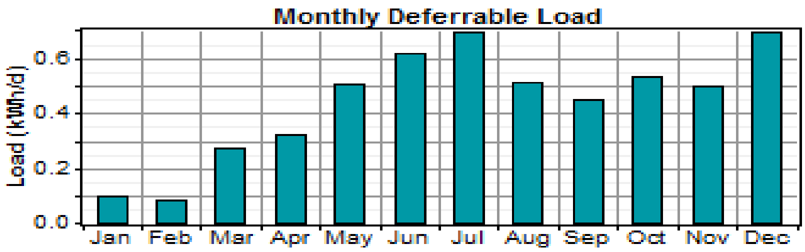

Fig.3.6 Monthly deferrable load profile data HOMER output.

IV. DESIGN AND MODELING OF POWER GENERATION SYSTEM

A. Configuration of Grid connected Hybrid Energy System

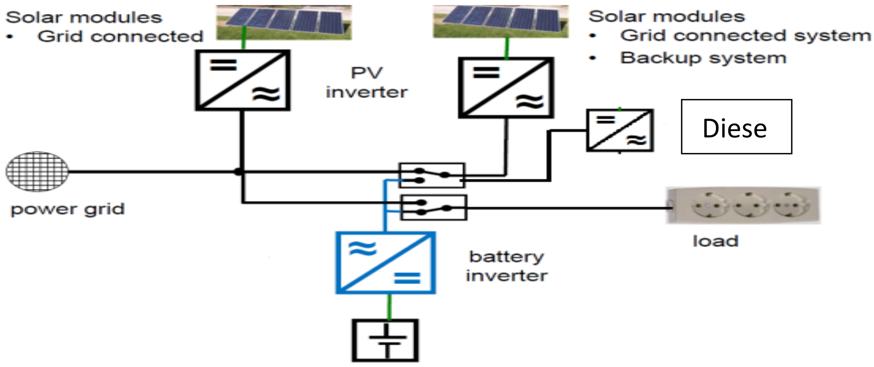

Fig 4.1Model of grid connected hybrid system

B. Solar PV System Sizing

For proper sizing and designing of the PV system, the load profile has been estimated initially. Accordingly, the equivalent parameters of a PV module is selected as follows.

Table 4. 1. Standard Parameter of chosen PV module (one module)

Nominal Peak Power	175 W
Nominal Voltage	35.57 V
Open Circuit Voltage	44.5 V
Nominal current	3.2 A
Short circuit	5.4 A
Maximum system voltage	1000 V DC
Voltage temperature coefficient (α)	-0.37%/^{0}C
Current temperature coefficient (β)	0.035%/^{0}C
Power temperature coefficient (k)	-0.5%^{0}C
Efficiency	15

C. Procedures followed for designing of the solar system

In any PV system sizing the first step is obviously determination of the load profile. The load size has been determined in chapter three and it is found as 102.408 KWh/m^2.day.

The average load energy can be given as follows:

$$P_{av} = \sum_{0h}^{24H} \frac{P_L Whrs}{24} \quad 4.1$$

$$= \frac{102.408 \text{ KWh/m}^2\text{.day}}{24} = 4.267\text{Kwh}$$

Taking into consideration the temperature losses, battery efficiency, and wiring losses, the PV cell rating, should be increased the typical percentage losses in a PV system are 90 %, 85 % and 97 % for temperature, battery and wiring losses respectively as provided by the manufacturer. So the total number of PV module is given by:

$$\textit{The optimal number of PV module} = \frac{P_{PV}}{\textit{Standard PV module rating}} \quad 4.2$$

Where $P_{pv}$is the PV cell rating.

The design of components of solar PV system is computed using the following steps for different varying daily load energy requirement.

Total energy demand per day = 102.408 kWh/day

Battery round trip efficiency is 0.96 (table 4.2, shown below) used for this study from the selected battery specification.

Required array output per day. The watt-hours required by the load are adjusted (upwards) because batteries are less than 100% efficient. Dividing the total energy demand per day by the battery round trip efficiency determines the required array output per day. That is,

Required array output per day =

$$\frac{\text{Total energy demand/day}}{\text{battery round trip efficiency}} = 106.67\ kWh$$

Energy output of the module per day =Selected PV module garneted power output * PSH

= 210 W*9.52 h = 1999 Wh

Module energy output at operating temperature is determined by multiplying the derating factor (DF) by the energy output module establishes an average energy output from one module. Since the DF value is 0.8 and 0.9 for the hot climates and critical loads, and for moderate climates and non-critical applications respectively. 0.9 D F is used in this study. So, Module energy output at operating temperature =1999 Wh*0.9 =1.799 kWh.

Number of modules required to meet energy requirements are obtained as by dividing the required array output per day by the module energy output at operating temperature. i.e.

Number of modules required to meet energy requirement

$$= \frac{\text{required array output/day}}{\text{module energy output at operating temp}} = 60\ modules$$

The battery bus voltage for this study is 48V. Which corresponds to the required DC input voltage for the inverter.

$$\text{Number modules required per string} = \frac{Batter\ \ bus\ voltage}{Selected\ \ Vmp\ @STC 80.85} \quad 4.3$$

$$= \frac{48V}{27.3V} = 1.7 = 2\ modules$$

$$\text{Number of strings in parallel} = \frac{Number\ of\ \ modules\ required\ to\ meet\ energy\ requirement}{\text{Number modules required per string}} = 30\ strings$$

Number of modules to be purchased: multiplying the number of modules required per string by the number of strings in parallel determines the number of modules to be purchased.

Area of the array will be the multiple of total number of modules by area of one module. Since the corresponding dimension of the selected module is approximated to length of 1.625m and width is 1m. Its area will be,

$L \times w = 1.625\ m^2$

Then the area of the array will be,

Array area = 1.625*1* = 97.5 m^2

Nominal rated PV module output: The rated module output in watts as stated by the manufacturer. It is obvious that PV modules are usually priced in terms of the rated module output (birr/watt). The selected PV module for this study is rated as 175 W.

Hence, Number of nominal rated array output

= 60 * 175 W = 10.5 kW

A. **Battery sizing**

The battery type recommended for using in solar PV system is Hoppecke, deep cycle battery. Deep cycle battery is specifically designed for to be discharged to low energy level and rapid recharged or cycle charged and discharged day after day for long period of time. The size of battery is calculated based on the standard data sheet shown in the table below.

Table. 4.2. Battery Specification for the Site

Battery description	
Battery description in(Ah)	3000
Nominal Voltage in(V)	6
Round trip efficiency (%)	96
Minimum state of charge (%)	30
life in (years)	20
Max. charge current in (A)	16

The battery should be large enough to store sufficient energy to operate the appliances at night and cloudy days.

$E_b = \frac{E_u}{\eta_b} = \frac{78.776}{0.96}$ = 82.058 kWh/day (Assuming efficiency of battery to be 96%)

Assuming that the working voltage for direct current is 12V (Vcc), then, the net capacity that the battery can store in Ah/day will be

$C_{bn} = \frac{E_b}{V_{cc}}$ = 6.838 KAh/day

The net capacity of the battery depends on the depth of the discharge of the battery (DDP), and the depth of discharge determines the life cycle of the battery. Deep cycle lead acid battery can store 30% to 80% depth taking an assumption of DDP = 60%

Then the total commercial capacity of the battery is calculated as:

$C_b = \frac{C_{bn}}{DDP}$ = 11.4 kAh /day

This value is correct, if and only if there is no cloudy days. Considering cloudy days, let us assume the battery have energy demand of three (the number of days that need the system to operate when there is no power produced by PV panels) to get the required Ampere-hour capacity of deep-cycle battery days.
C_b= 11.4 kAh/day x 3 day of autonomy =34.2 KAh.
So the battery should be rated 12 V, 34.2 KAh for 3 day autonomy
Determine the number of battery in parallel,

$$\frac{\text{required battery capacity}}{\text{capacity of selected battery}} = \frac{34.2\text{KAh}}{3\text{KAh}} = 12 \text{ batteries} \qquad 4.4$$

Determine the number of battery in series

$$=\frac{\text{system voltage}}{\text{Nominal battery voltage}} = \frac{12V}{12V} = 1 \text{ battery}$$

Finally, determine the total number of battery as,
Number of battery in parallel X the number of battery in series
= 12 batteries.

B. **Inverter sizing**

Total Watt of all appliances = 5.168 kW
For safety, the inverter should be considered 25-30% bigger size. The inverter size should be at least 7 kW.

C. **Solar charge controller**

The Solar charge controller rating = Total short circuit current of PV array x 1.3
Solar charge controller rating = (30 strings x 5.4 A) x 1.3 = 210.6 A. So, the solar charge controller should be rated to standard 215 A at 12V or greater.

D. **Diesel Generator**

Based on the peak load demand consideration, a generic 10 KW fixed capacity generator set is used as a backup with respective cost of 1 Dollar per litter. When the power from the PV, the grid and battery is not available, the diesel will be connected to the load via Interlocking switch. Hence, the system is secured.

E. **Economic Evaluation & Cost Analysis**

1. Capital cost of PV array = No of modules * price of modules
=US$0.55/W *175W*60 modules = US$5775 = 115,500 Birr
(Currency exchange rate of commercial bank of Ethiopia, $1=20.00)
2. Capital cost of battery bank = No of battery * price of each battery
= US$ 0.21*3000Wh*12battries = US$7560 =151,200.00 Birr
3. Capital Cost of Inverter = US$ 0.711/W* 7 kW
= US$4.977 = 99.54 birr

- LCC Replacement cost of Inverter

$$= \sum Item\ cost * [1 + i]^{n-1}$$

4.Cost of charge controler
=US$5.93/A*211A =US$1,251.23=25024.6 birr.

Besides PV module ,battery ,inverter and charge controler ,complete pv system also uses wire ,swithches fuses ,lamps and miscellaneous part ,we uses factor of 10% cover balance of the sysem installation.the tax and transporation cost 20% and 10% respectively.
Hence, Total initial capacity cost for the system (P_i) is
= (115,500 +151,200 + 99.54 +25024.6)*1.4 = 408,553.796 Birr
The annual maintenance and operation cost is about one percent per year of initial cost, and salvage value (S) system after 30 years is taken about 15% from initial cost.

I. MODELING & SIMULATION RESULT OF GRID CONNECTED HYBRID ENERGY SYSTEM

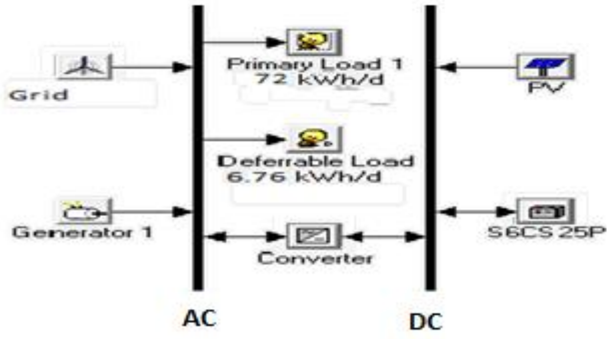

Fig. 5.1. Homer software Model of grid connected hybrid system

Based on the modeling done using HOMER software,simulation output the cost analysis, Optimization and Sensitivity results are summarized as follows.

Optimization Results

Table 5.1 Optimization result summary

PV (kW)	Label (kW)	S4KS25P	Converter (kW)	Grid (kW)	Initial capital	Operating cost ($/yr)	Total NPC	COE ($/kWh)	Batt. Lf. (yr)
10	0	144	7	1000	$ 96,500	2,527	$ 128,807	7.159	12.0
15	0	144	7	1000	$ 99,387	2,349	$ 129,413	7.193	12.0
5	0	144	7	1000	$ 93,612	2,876	$ 130,375	7.246	12.0
20	0	144	7	1000	$ 102,275	2,263	$ 131,203	7.292	12.0
30	0	144	7	1000	$ 108,050	2,198	$ 136,142	7.567	12.0
10	20	144	7	1000	$ 106,500	2,385	$ 136,990	7.614	12.0
15	20	144	7	1000	$ 109,387	2,207	$ 137,595	7.648	12.0
5	20	144	7	1000	$ 103,612	2,734	$ 138,558	7.701	12.0
20	20	144	7	1000	$ 112,275	2,121	$ 139,385	7.747	12.0
10	30	144	7	1000	$ 111,500	2,314	$ 141,081	7.841	12.0
15	30	144	7	1000	$ 114,387	2,136	$ 141,687	7.875	12.0
5	30	144	7	1000	$ 108,612	2,663	$ 142,649	7.929	12.0
20	30	144	7	1000	$ 117,275	2,050	$ 143,476	7.975	12.0
30	20	144	7	1000	$ 118,050	2,055	$ 144,325	8.022	12.0
10	40	144	7	1000	$ 116,500	2,243	$ 145,173	8.069	12.0
15	40	144	7	1000	$ 119,387	2,064	$ 145,778	8.102	12.0
5	40	144	7	1000	$ 113,612	2,591	$ 146,740	8.156	12.0
20	40	144	7	1000	$ 122,275	1,979	$ 147,568	8.202	12.0
30	30	144	7	1000	$ 123,050	1,984	$ 148,416	8.249	12.0
30	40	144	7	1000	$ 128,050	1,913	$ 152,507	8.476	12.0
10	0	288	7	1000	$ 187,220	5,695	$ 260,015	14.452	12.0
15	0	288	7	1000	$ 190,107	5,516	$ 260,620	14.485	12.0
5	0	288	7	1000	$ 184,332	6,043	$ 261,583	14.539	12.0
20	0	288	7	1000	$ 192,995	5,430	$ 262,410	14.585	12.0
30	0	288	7	1000	$ 198,770	5,365	$ 267,349	14.859	12.0
10	20	288	7	1000	$ 197,220	5,552	$ 268,197	14.907	12.0

Categorized results

Table 5.2 Categorized result summary of HOMER output

PV (kW)	Label (kW)	S4KS25P	Converter (kW)	Grid (kW)	Initial capital	Operating cost ($/yr)
10		144	7	1000	$ 96,500	2,527
10	20	144	7	1000	$ 106,500	2,385

Sensitivity result

Table 5.3 Sensitivity result summary

PV (kW)	Label (kW)	S4KS25P	Converter (kW)	Grid (kW)	Initial capital	Operating cost ($/yr)
10	20	144	7	1000	$ 96,500	2,527

Cost Analysis Summaryfrom HOMER

The economic analysis and cost summary result which is found from HOMER is approximately equivalent to the manually estimated values of the power plant components.

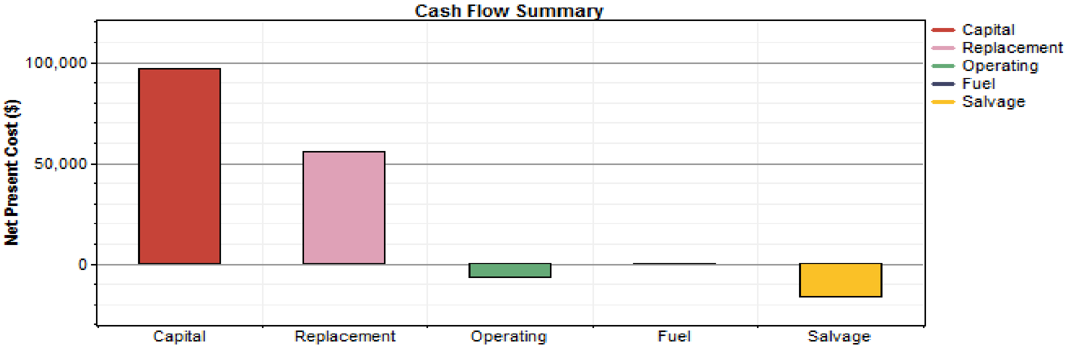

Fig. 5.2. Homer software Model of grid connected hybrid system

PV Array Data

PV array data considering a derating factor of 90% and 25 years lifetime was considered as shown in figure 5.3

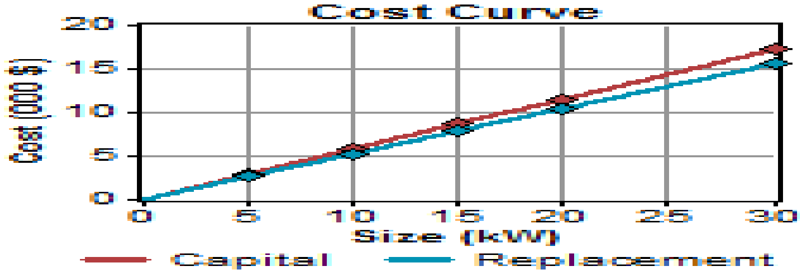

Fig.5.3 Photovoltaic solar output using HOMER

Battery Data

The battery chosen has a nominal voltage of 6 Volts and nominal capacity of 3000Ah (18 kWh) and 15 year life time. Six batteries were considered by HOMER in the simulation shown in Figure 5.4.

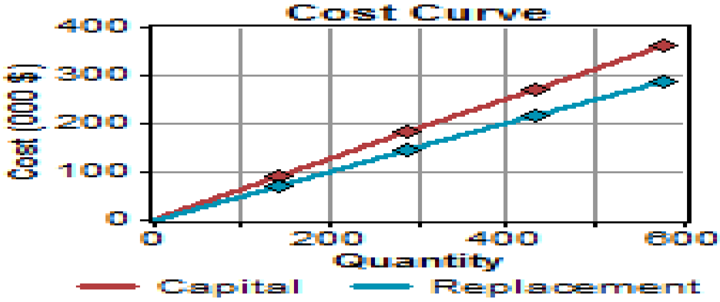

Fig. 5.4Storage batteries output using HOMER

Inverter Data

The inverter efficiency was assumed to be 95% for all the size considered. The size considered is 7 kW the converter input is shown in Figure 5.5

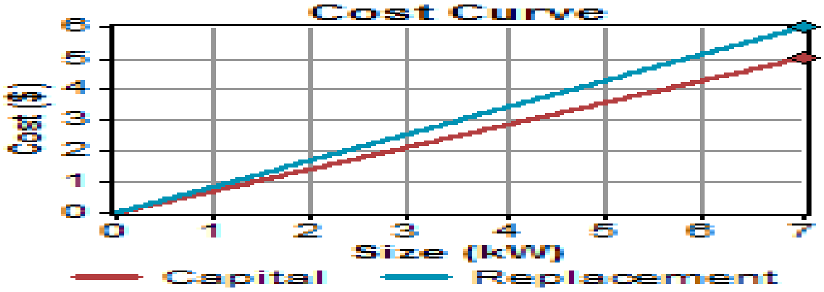

Fig. 5.5 Converter output using HOMER

Grid extension comparison

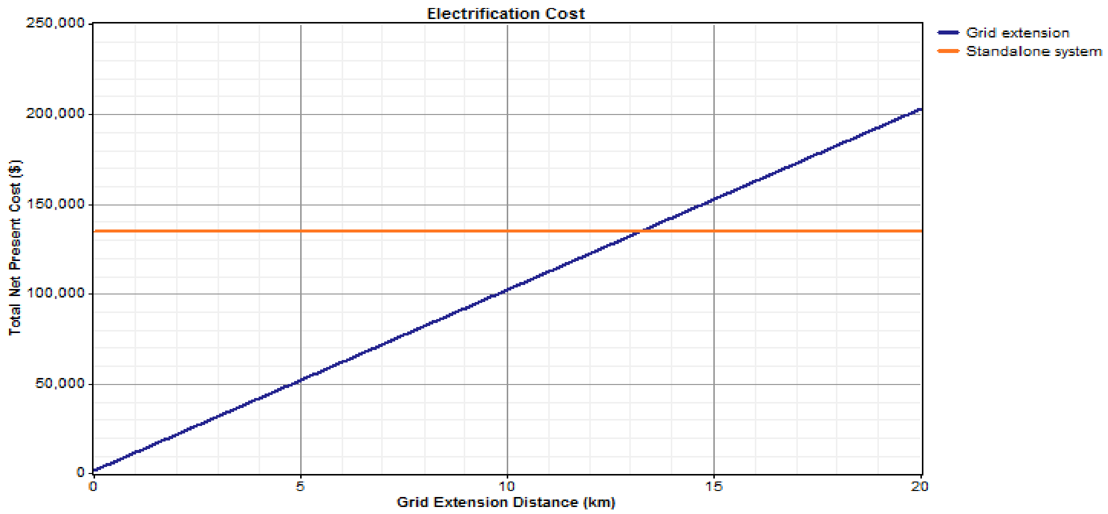

Fig.5.6. Grid extension comparison

V. CONCLUSION

In order to design the size of solar panel, first all available load requirements have been determined. Design parameters which are determined mathematically, are fed to the software and therefore the optimization and sensitivity parameters are evaluated. From the simulation results it is found that the optimization results have been analyzed for all possible combinations and hence the designed system is cost effective. Compared to grid availability the total power produced from the solar system is Around 10.5 KW peak power and hence, 5.2 KW is delivered to the load and the remaining 5.3KW is fed to the utility network.Simulation results shows both sensitivity and optimization output for all possible combinations and the results found are acceptable compared with grid availability. Besides the overall cost summary have been considered for comparison purpose.

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