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Designing Off-Grid and On-Grid Renewable Energy Systems Using HOMER Pro Software[#]

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Abstract: The limited amount of fossil fuel, increasing demand of energy and global environmental issues for electricity generation is the main consideration for exploitation of renewable energy resources (RE). Improvements in photovoltaic technologies and wind turbine generators have given different opportunities for utilizing these renewable resources for electricity generation. The purpose of this paper is to calculate the energy demand, optimization, economic viability of system and evaluation of designs for both off-grid and on-grid connected power systems for a range of applications and in order to know the cost of solar PV system by using Homer (Hybrid Optimization Model for Electric Renewable) software developed by National Renewable Energy Laboratory (NREL), USA for the Economically, clean power and optimum utilization of renewable energy sources for Institute of Environmental Engineering & Management MUET Jamshoro Pakistan.

Keywords: *Optimization, Hybrid system, on-grid system, off-grid system*

Introduction

Electricity perform an essential part in national growth and in the economic development of any county but unfortunately in world about 1.3 billion people live without electricity, these challenges have been faced globally and is the one of the major problem which is faced in the world. Although with that the grid extension is still the most chosen mode for the electricity generation due to several energy related mishaps, including the oil crises faced globally and accidents in nuclear power plants like in Fukushima nuclear plant. If we talk about Pakistan, Pakistan is facing the worst energy crises but in past Pakistan has the potential for producing up to 60 MW of electricity to fulfill the energy demand of 31.5 million people but now crisis has increased due to the electricity shortage and cause of it people are facing load sheading issues, rise in fossil fuel prices, legal commitment of reducing the carbon emission which is effecting the environment therefore people are moving towards the renewable energies to meet the load demand.

The main reason of doing literature review is to explain the knowledge gap which justifies the need of this work and apart from it by the helps in methodology like to compare this study with other reviews and gives information.

HOMER software has been used to perform different tasks like to find out the feasibility of the system, do cost analysis for the system with that the sensitivity and sustainability for the system the renewable technologies choose for system is PV, wind turbines, generator and diesel generators to know the sustainability of hybrid system for the primary AC load for 24 hours. The result shows that the excess load is just 5% with no storage. The payback time of whole system is 15 years with that it is environmental friendly with less emission as compare with the grid station (Hoque *et al*., 2012)

Perform most select arrangement and possibility Study for rural society by allowing for photovoltaic, biomass, Hydro and diesel as income to produce electricity for the peak load of 55.49 kW, as the results shows that the system designed for the rural society is well designed with proper economic analysis according to the area as compare to the electricity from the grid (Bhatt et al., 2016)

The hybrid system is designed for fulfilling the load demand of the Manit Bhopal, energy central. For the designing of the hybrid system, the HOMER Pro version is used where the AC primary load is given of 101 kWh/day and maximum 5 kW is load demand and the results also shows that the system is able to fulfil the electricity demand in all seasons with an interruption (Phrakonkham).

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It is obvious that rely-able deliver of electricity during utilize of hybrid energy system can develop the regular of living and cost-effective actions of the rural and semi-urban habitants in the district of Bizerte. In addition, using hybrid energy system can decrease the greenhouse gas emissions (Maatallah *et al*., 2016)

In this study, the authors performed a cost assessment investigation of grid and the result shows that grid electricity is cheaper form an off grid system than a grid based supply if it is beyond 44 km reserve (Munuswamy *et al*., 2011)

This paper focus on selecting an appropriate standalone power supply arrangement for a small and far-off off-grid town in Western Australia. To maximize the price of power supply and to suggest the most cost-effectively feasible way out for this town, different systems are considered. Varied from a diesel-generator-based alternative towards a hybrid system collected of a diesel producer, wind turbine, a photovoltaic system and battery energy storage are analyse by the help of HOMER software (Ali *et al.*, 2016).

In this paper, two real micro grid systems one interconnect and another independent, are evaluated by an economic point, this study gives concepts of technical and economically feasibility for operation of the current and the new grid systems. The results tells that both the systems can be improved like for interconnected system the installation of PVs and wind turbines are required for more effective output and for independent system installation of PVs and only one wind turbine is required for economically viable (Papaioannou *et al*., 2010).

Selection of right equipment and many more problems accurse for that different software are used for designing the perfect and economical system for that different software tools are used like HOMER, Hybrid2, RETScreen, iHOGA, INSEL, TRNSYS, iGRHYSO, HYBRIDS, RAPSIM, SOMES, SOLSTOR, HySim, HybSim, IPSYS, HySys, Dymola/Modelica, ARES, SOLSIM, and HYBRID DESIGNER as far in this study after reviewing the 19 software at different locations world widely the research come to the point that HOMER is one of the best software with lots of software tools and options for designing the hybrid system with exact cost analysis figure (Sinha *et al*., 2014).

Firstly, in beginning home application checks the feasibility of the whole system that either the system can fulfill the load demand or not, then secondly, it estimates (NPC) the total net present cost of the system with that it estimates the (IC) initial setup cost and after that it estimate the replacement cost, maintenances and operation cost with that the fuel and purchasing power cost from the system (Li *et al*., 2013).

Evaluated the EC analysis and the feasibility for using the solar and wind energy with hydrogen as a backup unit for standalone system with the combination of grid based electricity by using Homer software, the results shows that the grid combined system with hybrid system 100% renewable system have more possibility than the stand alone system. In calculation it shows the PV, wind and the grid is the most feasible option (Türkay *et al*., 2011).

HOMER Pro Software

Software which is used in this thesis is HOMER Pro (3.11.2 version), HOMER (Hybrid optimization of multiple Electrical Renewable) this software has been downloaded more than 80,000 people in 193 countries in a world. It was developed for nation renewable energy laboratory USA by Mistaya Engineering in Canada. For describing cost components and availability of the resource, Homer runs the model with the input. For simulations of the different configuration of the system and for generation of the results, which can be display as a list of reasonable configuration sorted by net present cost? HOMER can simulate a system for 8760 hours in a year and part from it simulates the system by calculation of energy to balance it in each step of year. After simulation it display the list of the configuration which helps to take proper decision of selection best options by comparing the lists and results and apart from list t also display or simulates the results in graphs and tables for evaluating them on their financial and technical qualities.

Study Area

The study area for this proposed project is Institute of Environmental Engineering & Management (IEEM), Mehran University of Engineering and Technology Jamshoro, which is one of the largest University of Sindh, Pakistan, located in Jamshoro about 15 km from Hyderabad on the right bank of river Indus, with the latitude and longitude 25° N, 68° E.

Solar Resources of the Study Area:

For designing solar system of IEEM, firstly solar resources have been downloaded from National Renewable Energy Lab (NREL) database for the selected study area. The annual average of solar radiation is scaled 5.54 (kWh/m^2/day) as shown in Figure 1 below. That's means the solar radiation are obtainable throughout the year thus substantial quantity of PV power can be achieved.

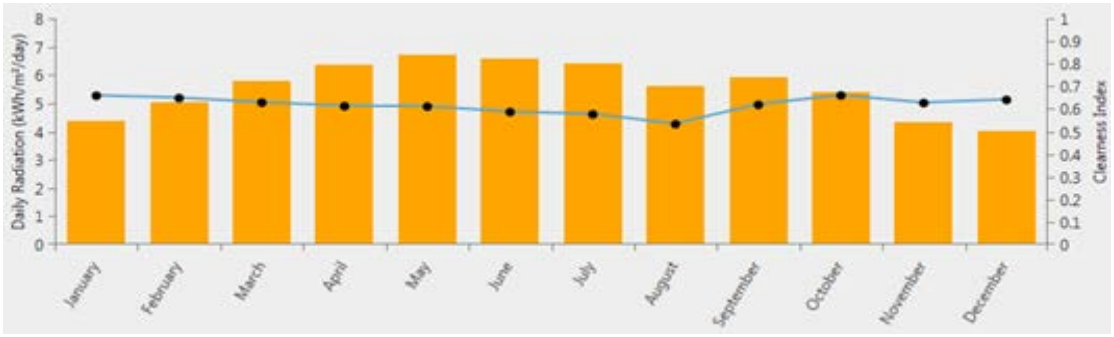

Figure 1. Solar resource for the selected area from HOMER software

Load Assessment of the study area.

The assessment of load is done carefully, firstly the base load as shown in table:1 of IEEM was selected which should be converted on PV system then assessment of load was done by calculating the working hours of institute, according to the working hours the seasonally assessment of load was carried out, cause during the winter and summer break and on weekends institute is close and with that in winter the consumption of electricity is less than summer.

Table 1. Base total of IEEM

SNO	Base Load	Base Load in watt	Total quantity
1	Small Tube lights	20	524
2	Tube lights	40	28
3	Pedal fans	150	5
4	Wall fans	80	68
5	Energy savers	12	78
6	Ceiling fans	120	7
7	Projectors	840	4

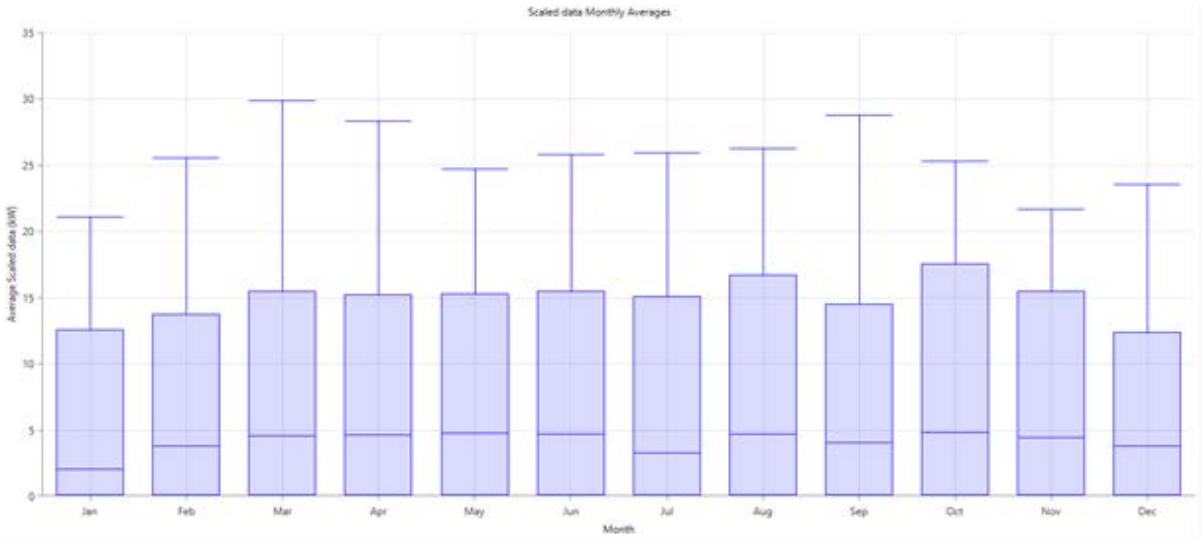

Figure 2. Monthly Average load of IEEM

After inputting the assessed load in HOMER software it was found average energy required is 98.03 kWh/d and peak load is 29.90 kW as shown in the Figure 2.

Designing off-gird and on-grid renewable systems for IEEM:

The components are selected from HOMER Pro software for designing the off-grid and on-grid solar system. Figure: 3 shows the grid connected or on-grid system which consists of PV array, converter, and grid for backup system. Figure: 4 shows the off-grid or without grid designed system which consist of PV array, converter, and batteries for backup system.

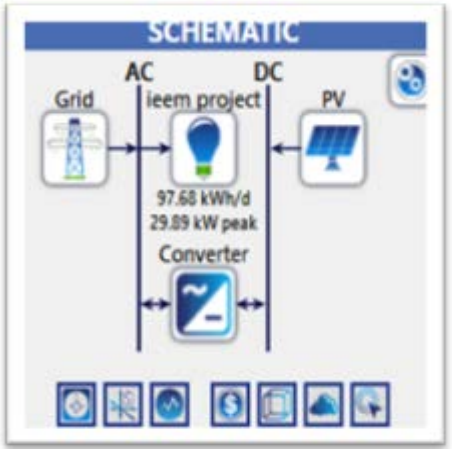

Figure. 3 on-grid solar PV system

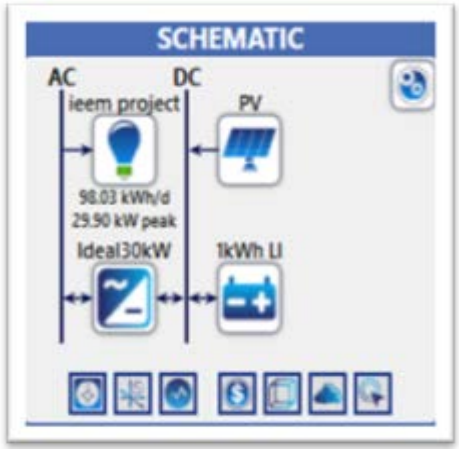

Figure. 4 off-grid solar PV system

The main components which are used in both off-grid and on-grid systems are analyzed economically by inputting installation cost, replacement cost and operation & maintenances cost of all the components as shown in the figure 3 & 4 above. For economic analysis the following values are used.

Photovoltaic Array

The model selected from HOMER library is Generic Flat Plate PV which is manufacture by the Generic lifetime is about 25 years. Where the installation cost is assumed as 65520 RS which includes the cost of panel and wiring, mounting hardware, Replacement cost is assumed as the 50,000 RS and O & M cost is assumed as 4000 RS.

Converter

The model which is selected from HOMER library is System Converter which is manufactured by Generic. Its efficiency is about 90% and lifetime is about 20 years the capital and replacement cost of 1 kW converter is 16,666RS and O & M is zero.

Battery or Shortage system

The model of battery which is selected from HOMER library is Idealized battery model (Generic 1Kwh Li-Ion) the efficiency is 90%. The initial cost is taken as 12,500 RS/per battery with same replacement cost and O&M is taken as zero; initial cost also includes the cost of installation and power electronics. The battery is selected only in off-grid renewable system for the backup power.

Grid System

Grid system is only used in on-grid system for the backup power system. The grid supplies power to the system only when there is no enough renewable energy resource to meet the load demand and support the system. In grid window the price of kWh is taken 10 RS.

Results of Analysis

On-grid cost analysis of Renewable Energy system

In on-grid connect system the system is linked with the grid for the backup power, the cost analysis of grid connected system is shown in the figure: 5 where in architecture of components section for PV (kW) the capacity optimization for selection on feasible solution for PV system the upper and lower limit was given between 20 to 30 kW according to the peak load, from which the HOMER selected 24 kW from the limits and the converter was selected of 10 kW. In cost section the

cost of the whole system for 25 years is calculated, where COE (cost of energy) is 0.525 RS, NPC (Net Present Cost) 429,346 RS and the initial cost for the system is 1.92 M.

Architecture						Cost		
PV (kW)	Grid (kW)	Converter (kW)	Dispatch	COE (Rs)	NPC (Rs)	Initial capital (Rs)		
24.0	1,000	21.0	CC	$0.525	$429,346	$1.92M		

Figure 5. Screenshot of simulation result of on-grid power system

Figure 6. Screenshot of production and consumption of electricity

In figure 6 the production of electricity is shown by PV system is 72,909 kWh/year and the consumption is 35,653 kWh/year and the rest of the energy is if in case any variability occurs in the load then the system can manage it or other hand we can sell the electricity to the grid.

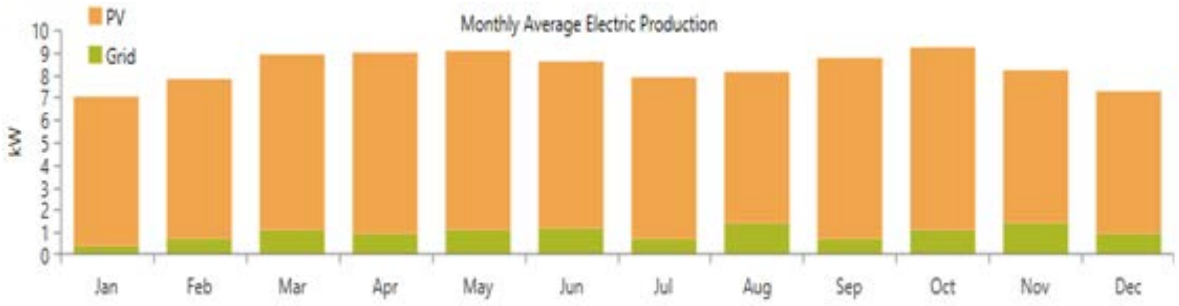

Figure 7. Monthly average electric production chart

Off-grid cost analysis of Renewable Energy system

In off-grid where the system is not connecting with the grid batteries are used for back power. In this system, the cost analysis of off-grid system is shown in the figure: 8 where in architecture of components section for PV (kW) the capacity optimization of upper and lower limit was given between 30 to 20 kW according to the peak load, from which the HOMER selected 24 kW from the limits and the battery was chosen of nominal capacity of 110 kWh and converter was selected of 10 kW. In cost section the cost of the whole system for 25 years is calculated therefore COE (cost of energy) is 242.98 RS, NPC (Net Present Cost) 64.4 M and the initial cost for the system is 2.99 M.

In figure 10 as shown below the production of electricity is shown by PV system is 64,403 kWh/year and the consumption is 24,840 kWh/year and the rest of the energy is if in case any variability occurs in the load then the system can manage.

Architecture						Cost		
			PV (kW)	1kWh LI	Ideal30kW (kW)	Dispatch	COE (Rs)	NPC (Rs)	Initial capital (Rs)
			20.0		10.0	CC	$10.42	$2.14M	$1.48M
			24.0	100	10.0	CC	$242.98	$64.4M	$2.99M

Figure 9. Screenshot of simulation result of off-grid power system.

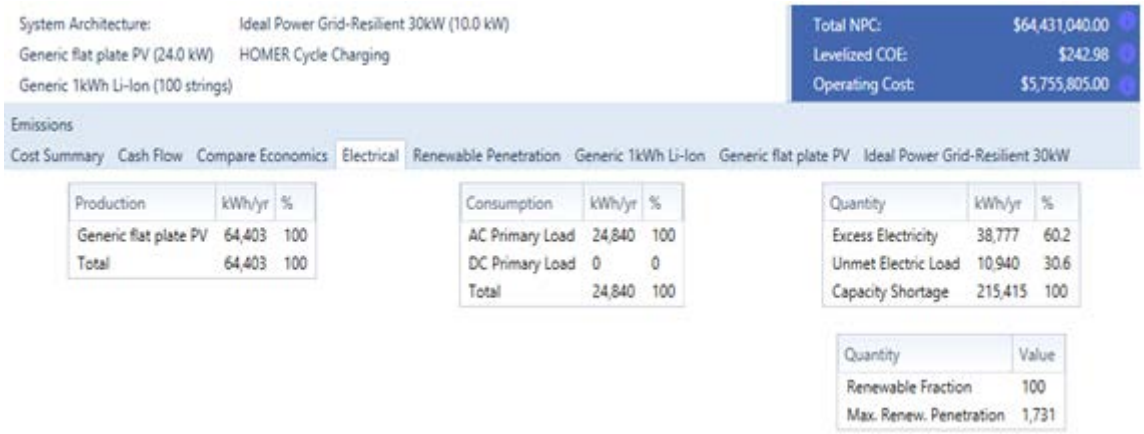

Figure 10. Screenshot of production and consumption of electricity

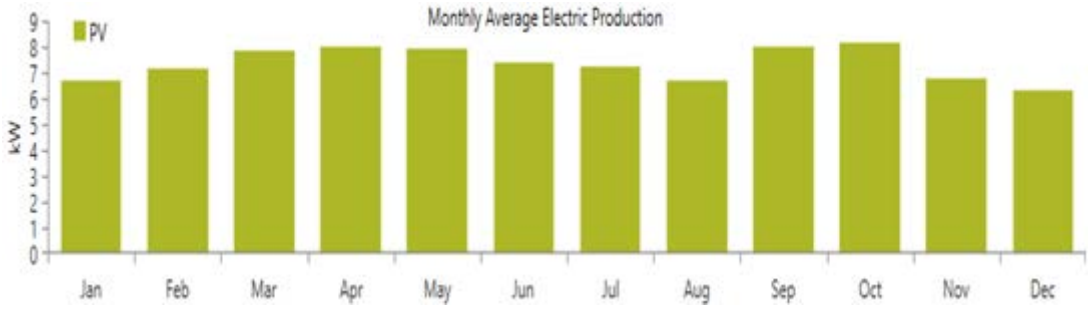

Figure 11. Monthly average electric production chart of off-grid system

Conclusion

This paper presents the cost analysis of on-grid and off-grid solar PV system for the Institute of Environmental Engineering & Management, MUET Jamshoro Pakistan. The optimization results shows that the grid connected system is more economically if we compare it with the off-grid solar PV system for the same load with that from the simulation results it is investigated that the NPC (net present cost) of on-grid system is less than off-grid system and the reason is the extra-large battery bank is required for the backup system although the off-grid system is 100% renewable system for (IEEM). Therefore it is proposed that economically grid connect system is better for IEEM but environmentally off-grid connected is preferred.

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