COST EFFECTIVE POWER GENERATION USING RENEWABLE ENERGY BASED HYBRID SYSTEM FOR CHAKWAL, PAKISTAN

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ABSTRACT:-*Pakistan is an agricultural country so rural electrification is most important factor for its progress. Present generation system has proved to be expensive and unreliable. Varying prices of oil also have adverse effect on country's generation and economy. An effective solution of this power issue is to use renewable resources in electricity generation especially in those areas which are far from grid and expansion of grid becomes uneconomical. This paper shows the effect of adding renewable generation with present supply system. Case study of a village named as Dhab Khushal located in Chakwal is presented and the system is optimized using HOMER software.*

Key words: HOMER, Hybrid System, Renewable, Potential of Chakwal

1. INTRODUCTION:

Energy plays an important role for the economic and industrial growth of developing countries like Pakistan. Although there are a lot of natural renewable energy resources as like wind, solar and biogas which are present in Pakistan but still the country is facing worst energy crisis from past few years. There is a huge gap of almost 5000 MW between generation and demand [1] which becomes wider in summer season due to increment in load and we can expect that this gap will go on increasing in absence of proper energy utilization and generation policies. This situation has created an alarming condition. Country is facing worst load shedding of 10 to 18 hours per day [2]. People are disturbed, local business is destroyed and industry is shifting to other countries. According to 3rd annual report of Institute of Public Policy Beacon House National University Pakistan, in 2009 industrial sector in our country has faced a loss of worth 230 billion due to this worst load shedding. Further there is a decrease in employment opportunities as also almost 535,000 workers have lost their jobs in this duration [3]. This huge unemployment is the main cause of poverty, crime and economic disorder.

In past we were producing most of energy from water resources but at present this trend is decreasing. Now due to silting of dams and other issues, our main generation is shifting to thermal power plants. These plants operate on fossil fuel as like oil and gas and their per unit cost is much high. A huge amount is being wasted on the import of oil as there are not enough reserves present in Pakistan. Present reserves of oil and gas in country contribute only 5 and 48.8 percent in total energy generation and are expected to diminish by 16 years approximately [4]. Use of oil in thermal plants has two main disadvantages. Pollution of environment through hazardous gases as like CO_2, CO and N etc. and increment in financial burden of country. Overview of electricity generation from 2001 to 2011 in Pakistan is given in Table 1.

Table.1 Electricity Generation During 2001 to 2011
***Data Source:* [5]**

Generation Source	Use in total generation
Coal	0.09 %
Oil	35.06 %
Gas	27.34 %
Hydro-electric	33.61 %
Nuclear	3.61 %
Imported	0.28 %

The present energy scenario clearly indicates that there must be a reliable solution to fulfill the energy demands of this country which according to Zeeshan A N. *et al* [6] is to maximize the use of renewable energy resources in our generation. These resources are clean and always available. Hafiz Bilal and Syed Jawad [7] have also concluded in their research that renewable energy resources must be developed to overcome the present energy shortfall.

Solar and wind are two main renewable resources which are easily accessible but the main problem is that both of these resources are seasonal in nature. They can't produce energy throughout the year. For example a standalone solar system unable to provide energy in absent of sun. The standalone wind system is also unable to fulfill constant demand because wind speed fluctuates from hour to hour throughout the year. This problem can be reduced if we use some type of storage in our system. But this makes our system more expensive. Simple solution of this problem is to use a hybrid system containing both solar and wind resources with much less storage requirements.

Hybrids systems are gaining worldwide attention these days. Many researchers from different countries are working on these type of systems. Lanre Olatomia et al. [8] presented a complete economic evaluation of hybrid energy systems for rural electrification in six geo-political zones of Nigeria with the conclusion that hybrid system is an economical solution to provide electricity to remote locations. Saheb-Koussa et al. [9] has also concluded that PV (Photovoltaic) /wind/diesel hybrid systems are more feasible to generate electricity as compared to stand alone PV or Wind systems. Hanane Dagdougui et al. modeled a wind, solar and biogas based hybrid system for heating and energy requirements of their green building [10]. Yuehua Huang et al. gave the idea to use MPPT (Maximum Power Point Tracking) control to wind solar hybrid systems [11].Prasad GVT et al. used reflectors to the PV (Photo Voltaic) panel and sensors to detect the high wind direction in their wind solar hybrid system [12]. In this paper we presented a complete design and economic analysis of a hybrid system containing PV/Wind and Biogas as a case study for Chakwal, Pakistan. For this analysis we used

HOMER (Hybrid Optimization of Multiple Energy Resources) software.

HOMER is a hybrid system modeling tool developed by NREL (National Renewable Energy Laboratory. HOMER takes user data in form of different component prices, lifetime, grid extension cost, storage system cost, load profile of location and weather data of selected location. Using this data HOMER performs calculations and provided results. HOMER can perform mainly three types of calculations known as Simulation, Optimization and Sensitivity analysis. In simulation, HOMER compare the energy supply and demand for every hour of year and decides how to operate dispatch able sources (generators, battery and grid).In optimization, HOMER simulates each system configuration and sort by net present cost (NPC) and finally in sensitivity analysis, HOMER performs an optimization for each sensitivity variable. HOMER results show complete comparison of various given systems and their alternate configurations sorted with respect to their NPC and COE (Cost of energy).From these results we can easily see which system is most feasible for any given location.

This paper is divided into six parts. In second part availability of renewable energy resources in Pakistan is discussed, in third part methodology of economic analysis is discussed for proposed system, in fourth part background data of proposed system is provided, in fifth part system design is discussed, in sixth part results are given and finally conclusion is given in seventh part of this research paper.

2. Renewable Resources in Pakistan:

Pakistan is rich in renewable resources. These resources include Solar, Wind, Biogas and Micro-hydal resources. A brief detail of solar, wind and biomass energy resources is presented below.

2.1 Wind Energy:

Wind energy is getting attention now a day's all over the world. Our neighbor country China is currently at the top in Wind energy generation with a total Installed capacity of 62,634 MW.USA is on second position with 46,919 MW installed capacity while Germany is on third number with 29,060 installed capacity [13]. Wind speed varies from 5 m/s to 7m/s in coastal and North West areas of Pakistan [14].This speed is suitable to generate electricity. Unfortunately Pakistan has almost negligible installed capacity of wind energy at present and research is going on this topic. Figure.1 represents the planning of Pakistani government for promotion of wind energy [15].

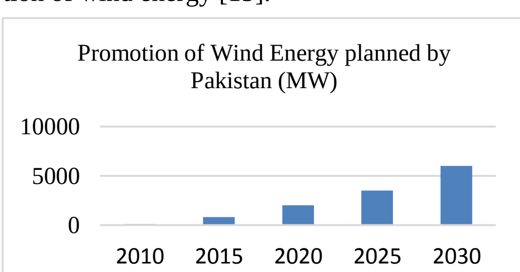

Figure.1 Wind Energy Promotion Plan [15]

2.2 Solar Energy:

Solar energy is the energy gained from solar radiations. This energy can be utilized mainly by using two techniques. One is the use of PV panels and other is Concentrating Solar Power System. A detailed flow chart given in Fig.2 shows the different type of solar energy utilization techniques.

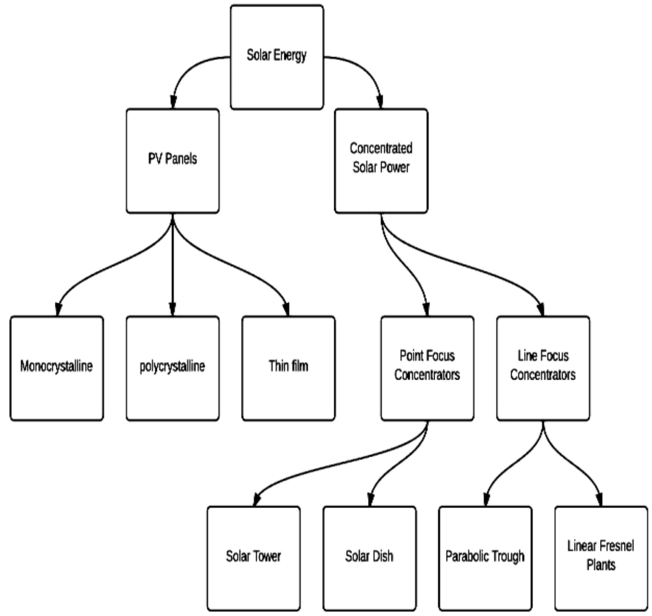

Figure.2 Types of Solar Power Utilization Techniques

Trend of solar generation is growing in Pakistan. T Muneer and M Asif discovered that energy from sun is the most optimum choice from all other available renewable energy resources [16].According to NASA, Pakistan is in the region where the solar insolation is almost 1800-2200 KWh/m^2 which makes it second highest insolation region is the world [17].Currently more than 800 companies are working on sale and installation of solar panels. Pakistan's first 365 kW solar power grids were installed in 2012 in Islamabad [18]. Our Prime minister has recently laid the foundation stone of the country's first 1000 MW solar power project in Bahawalpur. Government is planning to invest more for the expansion of solar generation in future.

2.3 Biogas Energy:

Pakistan is an agricultural country so biomass is abundantly available. Mirza UK et al. have studied the biomass energy availability and usage in Pakistan [19].Crops residue as like cotton, silk, rice husk, bagasse and animal waste can produce biogas for the generation purpose. More than 57 million animals are present in country which can produce 21 million m^3 biogas [17].More developed techniques are required in order to efficiently utilize the available biomass in country.

3. Methodology of economic analysis:

To perform economic analysis of a proposed hybrid system following basic steps are required.

I. Analyze load profile of selected location.
II. Collect weather data.
III. Check which renewable energy resources are easily available in selected area?

IV. Model the proposed system by providing the data about load, renewable energy sources share and price of components associated with the complete system.

Sometimes, storage facility can also be added into the system. Economic feasibility of each configuration is based on net present cost (NPC).Environmental impacts of a system can also be checked.

4. Background Data of Proposed System:

4.1 Load Profile

For this research, a village area of Chakwal is selected as case study and the load profile is obtained. It is a village area name as Dhab Khushal and coordinates of selected location are 32°59N and 72°52E. Load of 25 houses is considered with 2 kW / day / house hold. Peak demand of the selected area is 52.4 kW with a load factor of 0.704.Load profile of selected area is given in Figure 3.

As it is a rural area so people mostly spend their time in farms. In morning people usually go outside and load becomes much less. Then load increases till 7:00 PM while peak occurs between 6:00 PM to 7:00 PM because at this time people comes back to their houses. This load demand also varies day by day or season to season. So, during HOMER calculations we can add random variability factor of 1.97 % for day to day and 1.94 % for time step to time step. These factors compensate the variation in peak demand.

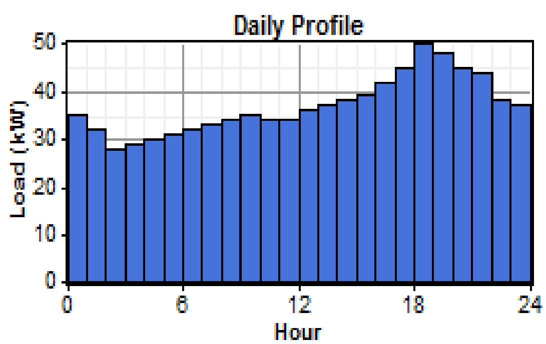

Figure.3 Load profile of Dhab Khushal

4.2 Solar, Wind and Biomass inputs:

Solar:

HOMER has the ability to acquire the data of solar radiations automatically using given coordinates. Solar radiation graph is given in Figure 4.This graph shows that scaled annual average solar radiations for selected location is 5.07 $kWh/m^2/d$ which is sufficient to generate enough amount of electricity.

Wind Data of selected location is given in Figure 5 [20].This figure shows an average wind speed of 7.2 m/sec and this wind speed in good enough to generate electric power and meet the load demand of selected area.

Biomass:

There are almost 34 villages located in Chakwal and Dhab Khushal is one of these villages [21].Different type of biomass is excessively available in selected area. An approximate availability of biomass is assumed for the hybrid system and is provided in Figure 6.This figure shows that an annual average of 129 t/d of biomass is available in selected location. Price to purchase this biomass is taken as 20 $/t.

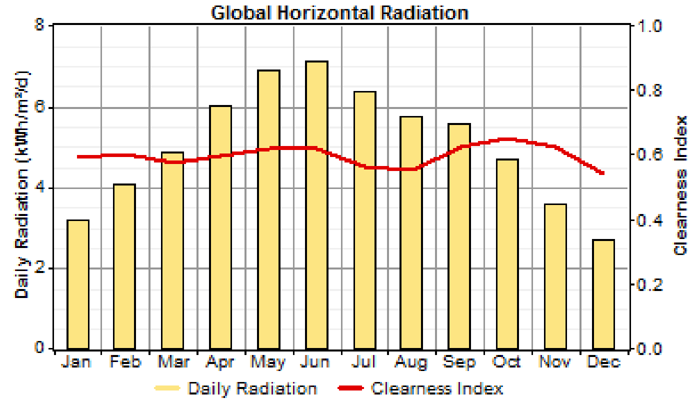

Figure.4 Daily Solar Radiations with clearness Index

Wind:

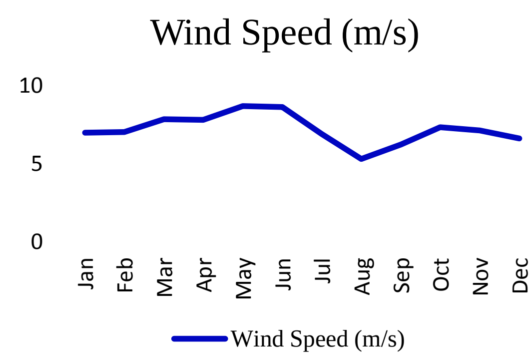

Figure.5 Wind Speed data of Dhab Khushal (Chakwal)[20]

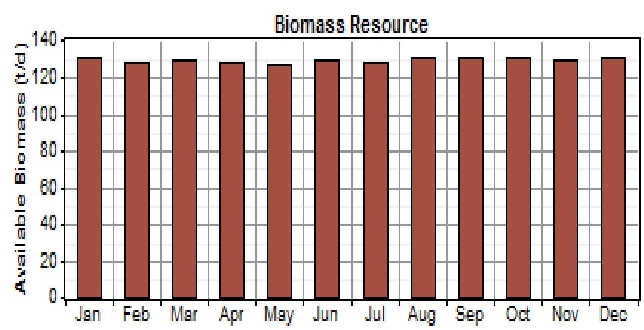

Figure.6 Available Biomass for hybrid system

4.3 Current Tariff Plan:

IESCO (Islamabad Electric Supply Company) provides electricity to the selected location [22].Upfront tariff is given by NEPRA (National Electrical Power Regulatory Authority) for solar, wind and biomass [23].An average price of 0.099 $/kWh for IESCO tariff and 0.130 $/kWh is selected for upfront tariff.

5. Equipment Specifications and Price

Specifications of different components is given as

1) 40kW from PV (Photovoltaic Panels).The capital cost of these panels was provided as 48586 $ and a life time is taken as 25 years which is equal to the life time of

designed system so there will be no replacement charges. Derating factor for PV panels is taken as 80 %.

2) 50kW from Two wind turbines, model PGE 20/25 (each of 25kW capacity) .Capital cost of these two turbines is taken as 200,000 $ with a replacement cost of 100,000 $ and O&M cost of 100 $/yr.
3) 10kW from biogas generator with a capital of 1232 $ and replacement of 700 $.It is estimated that 10kg/hr fuel consumption is required to produce an output of 10kW.
4) A 40kW converter is used to convert power from PV panels into AC. Capital Cost of converter is provided as 7376 $.It is assumed that converter has efficiency of 96% and a lifetime of 25 year.
5) Surrette 6CS25P battery with nominal voltage of 6V and nominal capacity of 1156Ah is also connected in this system to analyze the cost optimization of system with and without storage. Capital cost of connecting 24 batteries into the system is taken as 28800 $ with replacement cost of 24000$ and 10 $/yr operation and maintenance cost.

6. System Design

A HOMER based system design is shown in Figure 7.PV panels and battery are connected to DC link. This link is connected to an AC link with the help of a bidirectional AC to DC and DC to AC converter. Load, Wind Turbine, Biogas generator and grid supply is connected to the AC link. Lifetime of this system is assumed to be 25 years. This system is optimized using different percentage share of all the equipment.

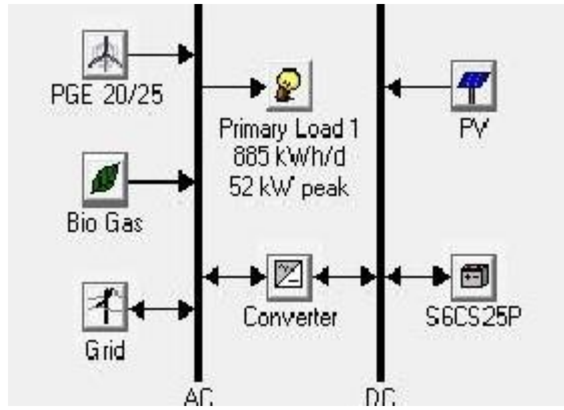

Figure.7 Design of proposed hybrid system

7. RESULTS AND DISCUSSIONS

System is analyzed and results are given on the basis of NPC (Net Present Cost) and COE (Cost of Energy) of different configurations. Results are divided into three main categories.

a) When only grid supplies to the load.
b) When Hybrid system is supplying to load with maximum share.
c) When storage capacity is also added to the system.

a) When Only Grid is Supplying to the Load

Optimization results in Figure 8 shows that when only grid supplies to the load initial capital required is zero but still this system configuration requires expensive fossil fuel to operate so operating cost of system per year is 32,076 $/yr which is second highest cost among all other configurations.

PV (kW)	PGE25	Bio (kW)	S6CS25P	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Bio (hrs)
40	2	10		40	CC	500	$ 257,194	6,400	$ 385,121	0.060	0.74	125	8,760
40	2	10	24	40	CC	500	$ 285,994	7,458	$ 435,080	0.067	0.74	125	8,760
40		10		40	CC	500	$ 57,194	19,931	$ 455,603	0.071	0.47	125	8,760
	2	10			CC	500	$ 201,232	13,038	$ 461,867	0.072	0.62	125	8,760
40		10	24	40	CC	500	$ 85,994	20,989	$ 505,563	0.078	0.47	125	8,760
40	2			40	CC	500	$ 255,962	12,517	$ 506,169	0.078	0.56		
	2	10	24	40	CC	500	$ 237,408	14,097	$ 519,207	0.080	0.62	125	8,760
		10			CC	500	$ 1,232	26,264	$ 526,249	0.081	0.27	125	8,760
40	2		24	40	CC	500	$ 284,762	13,575	$ 556,130	0.086	0.56		
40				40	CC	500	$ 55,962	25,743	$ 570,551	0.088	0.20		
	2				CC	500	$ 200,000	18,850	$ 576,816	0.089	0.41		
		10	24	40	CC	500	$ 37,408	27,321	$ 583,556	0.090	0.27	125	8,760
40			24	40	LF	500	$ 84,762	26,791	$ 620,313	0.096	0.20		
	2		24	40	CC	500	$ 236,176	19,909	$ 634,155	0.098	0.41		
					CC	500	$ 0	32,076	$ 641,197	0.099	0.00		
			24	40	CC	500	$ 36,176	33,133	$ 698,505	0.108	0.00		

Figure.8 Load is supplied by grid only

PV (kW)	PGE25	Bio (kW)	S6CS25P	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Bio (hrs)
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			24	40	CC	500	$ 36,176	33,133	$ 698,505	0.108	0.00		

Figure.9 When Renewable Energy has Max Share

PV (kW)	PGE25	Bio (kW)	S6CS25P	Conv. (kW)	Disp. Strgy	Grid (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.	Biomass (t)	Bio (hrs)
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Figure.10 System Optimization with Battery Backup

b) When Hybrid system is supplying to load with maximum share

Optimization results in Figure 9 shows that when the renewable generation is also supplying load then both NPC and COE decreases with every increase in share of renewable energy and system has lowest NPC 385,121$ and COE 0.060 $/kWh with a maximum renewable generation share of 74 %.Although system has second highest values of initial capital 257,194 $ but this is one time investment and lowest operating cost/yr will easily compensate this high initial capital. This makes the given system ideal to supply electric power at lowest per unit cost to the selected area.

c) When storage capacity is also added to the system

Figure 10 shows the effect of connecting a battery in the system. This storage system is designed to provide backup of solar system for almost four hours. Results shows that there is a slight increase in initial capital, operating cost, NPC and COE but still this configuration has the second favorable values so we may also include a battery backup in the proposed hybrid system and it will increase per unit cost from 0.060 $ to 0.067 $.

8. Conclusion: Electricity in Pakistan is costly and unpredictable because of maximum share of thermal generation. Results show that when we add up renewable energy generation with conventional system then overall cost and hence per unit cost of energy consumption becomes less. Another advantage of using renewable energy is that generation from these sources is pollution free and ever available. Case study of a village located in Chakwal shows that system will have minimum per unit cost (0.067 $/unit) when renewable energy has maximum (74%)share in overall generation.

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