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Cost Optimization of Grid-Connected and Off-Grid Hybrid System for a Community in Rural Area of Pakistan

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Abstract— Remote and far off communities are usually not connected to grid owing to their location and are not economically feasible. Rural areas possess great abundance of renewable energy resources, utilizing these resources for energy production are environmentally friendly compared to thermal energy systems for power generation. Thermal power plants are costly and releases poisonous gases which causes many environmental menaces. Where the grid-connected rural communities also faces the issues like load shedding and power outages due to which rural community peoples suffered a lot. These aspects are the core driving forces to motivate the scientists, academics, technologists and investors to discover and finance in the field of renewable energy systems. But renewable energy sources are weather dependent and site specific. The main obstacle towards the deployment and investment in these systems is the intermittent and dynamic characteristic of renewable energy sources. The most appropriate option is hybrid renewable energy system to overcome the intermittent nature of the renewable energy sources. In our design model the hybrid renewable energy systems are based on photovoltaic, micro-hydro and biomass to provide reliable and cheaper electricity to remote areas of the Pakistan in case of off-grid and grid-connected mode. The one and only tenacity and purpose of this study is to design reliable and optimized hybrid energy system by using HOMER software with lowest possible Levelized Cost of Energy (LCOE) and Net Present Cost (NPC). The hybrid energy system comprised of solar PV, micro-hydro and biomass for grid-connected and off-grid models. HOMER software analyze different configurations of hybrid renewable energy system and according to the NPC and LCOE most optimized hybrid energy system is selected among the possible configurations. In our hybrid energy system models micro-hydro and solar PV has been used as a primary sources for delivering the base load demand while for meeting the peak demand and for backup biomass gasifier is used. This optimization tactics overpowers the uncontrolled behavior of the renewable energy sources. By well-organized and effective planning we can lessen use of biomass gasifier fuel for power generation along with the system Net Present Cost, LCOE and environmental dangers are abridged.

Keywords— Biomass Gasifier, Net Present Cost (NPC), Cost of Energy (COE), HRES, Microhydro.

I. INTRODUCTION

The major drive behind any country's economic development, industrialization and prosperity is reliable and continuous supply of electricity. Pakistan is developing country and population of Pakistan is increasing drastically, due to increase in population energy demand is going up day by day. To meet the demand of energy with growing demand rate the world is seeking for some alternative source of energy instead of conventional energy sources because conventional energy sources are limited and lessen with the passage of time [1]. According to [2] almost 70-75% population of Pakistan's is living in the far off scattered areas, where they have either very poor access to grid electricity or don't have grid electricity access. The only way they have to get energy is the traditional way of using wood, crops and animal waste for domestic purpose. These traditional ways of getting energy is very old and have very poor efficiency, which leads to wastage of most of the biomass potential.

According to [3], the economic survey held in 2017-2018 the transmission and distribution losses are 18.9% in 2013. With the improved infrastructure these losses decreased by 1% and fall down to 17.9% in 2018. The transmission losses can be reduced by two ways, either by further improving the transmission infrastructure or by adding renewable energy sources near to load centers. By adding renewable energy near to load center can reduce burden on the transmission lines along with reduced carbon footprints and providing energy to those areas where grid electricity is not available.

The renewable energies has proven to be a reliable, clean and green technology to overcome the energy crisis in Pakistan [4].

Cost-effective and reliable generation of energy can be made possible through proper use of renewable resources. In addition, stability and reliability of the renewable energy systems can be further enhanced through efficient management, optimization and proper scheduling of different generation units. Pakistan is entirely relying on fossil fuels for the generation of electrical energy. Escalating prices of fossil fuel in global market has a direct impact on local market, due to which per unit cost of energy is increasing day by day. Moreover, too much exploitation of the conventional power plants has destroyed the wildlife, greenery and polluted the environment to a great extent, which is alarming for the whole world. The generation of electrical energy from the renewable resources is too much cheaper and environmentally friendly compared to conventional power plants. As, conventional energy resources such as oil and gas are limited and their fear of depletion motivated and encouraged the world towards some alternative sources of energy for energy security. Alternative Energy Development Board (AEDB) was evolved in 2003 to motivate, support and encourage the researcher to find out feasible renewable energies technologies. The objective of AEDB is to attain 5% share of energy from renewable resources by the end of 2030 [5][6].

In [7][8] the role of different renewable technologies have been discussed specially stresses on the promotion and development of renewable projects in Pakistan. This paper enlighten the total energy usage along with the electricity related issues in the country. Each and every perspective of Pakistan power sector is analyzed such as demand and supply, generation capacity, installed capacity, energy risks and increasing electricity costs. This paper clearly proclaim that renewable energy resources are sustainable and economical then convention al energy resources. Geographical location of Pakistan is very indispensable in term of potential of renewable energy resources such as solar PV, wind, biomass and wind. The estimated renewable potential is around 168GW, which is extremely mammoth amount of energy.

In [9][10][11], the significance of the electrical energy in the economic and industrial development and the overview of renewable energy resources in Pakistan have been discussed. Pakistan is among those countries which are facing worst energy crises and contingent solely on imported fossil fuels to compensate for growing energy demand. As discussed, Pakistan has enormous amount of renewable energy resources which can be utilized to meet the growing demand of industrial, commercial and domestic sectors. The PV potential is around 2900GW, hydro is 60GW and biomass is 10GW, which is plenty amount of energy. Pakistan energy deficiency can be easily cover up by proper management and utilization of these resources.

Pakistan generation capacity is 25.2GW in 2017, 30GW in 2018 and in 2019 it is around 34.3GW. The increase in demand is 8% per year along with that the mean energy is 22GWand the energy shortfall is 5,000 to 6,000 MW. According to [12], the present generation installed capacity from different sources is shown in the diagram below. It shows that the share of hydro generation in term of installed capacity is 29%, thermal share is 61%, nuclear share is 4% and share from renewable sources is 6%.To properly solve the energy issues in different areas of Pakistan, specifically rural areas, either load shedding, power outages or unavailability of grid electricity, we will design a power system comprised of renewable energy sources. But renewable energy resources are site specific and intermittent in nature[13]. So, a micro grid relying on just single renewable source is very unreliable. To cater out intermittency and unreliability issues we will devised a hybrid system which will be composed of multiple renewable resources. This hybrid system or micro grid could be either in grid-connected or off-grid form and its range vary from few kilowatt to 100kW. The suggested Hybrid Renewable Energy System (HRES) is very advantageous in term of reducing transmission lines stresses and losses and it is also helpful in avoiding installing extra transmission line to the far off rural areas[14]. Rural areas are usually too far from the grid station so, extension of transmission lines to these areas are either too expensive or not feasible. So micro grid is the best solution for these rural areas to meet their energy demand. In this research work an integrated approached is used to design an optimize hybrid system comprised of solar PV, biomass and micro hydro as renewable resources to meet the load demand of a rural community cost-effectively, either in grid-connected or off-grid situation[15].

In all the above work the authors has employed HOMER for simulation of the hybrid model after inserting all the required data. The optimization results of the HOMER can be easily interpreted and the optimized system among different system can be obtained. In this system integration of these sources is done intelligently and effectively to minimize the greenhouse gases emission and cost of the system. The primary sources which feed the base load in both grid-connected and off-grid mode are solar PV and MHP. In order to enhance the stability and reliability in case of peak demand and low generation from primary sources, the biomass and grid electricity will be utilized. Generation from MHP is almost constant throughout the year except in the month of December and January, in which water flow is reduced almost to zero, so, in this case biomass is integrated with solar to meet the demand in off-grid situation. Also, during night times, generation from solar PV become zero and MHP cannot fulfill the load demand independently, so biomass will provide the required energy to serve the load, where, in case of grid-connected mode, grid will provide the required energy. This is the first system in this region of KPK to be exploited. On the other side, the intermittent nature of the renewable sources get diminished through idea if hybrid system. Optimization is done through HOMER software to lessen the NPC and COE of the system.

II. RESEARCH METHODOLOGY

The methodology of this research work comprised of several most important steps for the design of optimal and economically viable hybrid stand-alone system for the selected off-grid and on-grid site. The steps carried out for the completion of this research work are the following

i. Collection of load data site description

ii. Meteorological data collection i.e. solar/ Resource assessment or estimation

iii. Component assessment

iv. Making the objective and cost function for different equipment's and operations

v. Hybrid energy system design

vi. System optimization through HOMER

vii. Optimization results

As we know, the designing of hybrid system, for a community, includes the load data collection, so, it is important to collect the load data of the community properly. For this purpose, a survey has been conducted for the selected site. The survey include, a school, two mosques, minor industry and twenty five residential users. In this survey, questions were asked from the customers about number of lights, fans, television, Air condition, fridge, PCs and printers and water pump. Customers were asked about the usage pattern of different electrical appliances. Seasonal load profile is estimated for different seasons according to data gathered. In the second step, diverse resources potential was acknowledged to proposed and design an electrical hybrid system to accomplish load demand. A survey was conducted to discover the micro hydro potential at the selected site. The information about the discharge rate is being gotten from the viability report of Mardan irrigation department. Average solar Global Horizontal Insolation (GHI) and clearness index figures is taken from (NASA), which is available online. Biomass resource potential data for the community is gained from the World Bank site and due to an agriculture area waste of diverse crops is noted for simulation use. The renewables sources available at the selected site are micro hydro, biomass and solar PV, which were selected for the designing and modeling of hybrid energy system. Cost of each equipment is necessary for the designing and planning of optimal system. After getting different quotations from various dealers and discussion with specialists in the relevant field helped us to know the actual cost of each equipment. HOMER software is exploited for the designing of hybrid energy system. HOMER do simulations and modeling based on several inputs like resources potentials, cost of each equipment's, and load data. After simulation HOMER deliver the top optimized model and relates it with other possible systems.

III. SITE ELUCIDATION AND LOAD ESTIMATION

A. Site Elucidation

The selected site is located in Skardu one of the districts of Mardan, Pakistan. The selected area has both on-grid and off-grid sites but this research focuses on the prototype of a hybrid system for both the off-grid and on-grid sites. The geographical location of is 35oN 74oE with time zone (UTC + 05:00) Islamabad, Karachi.

B. Load Estimation

As the nominated site for the project installation is a small town in Mardan, where the load is divided into four different categories i.e. a School, two mosques, one small industry and residential load. The load requirement of each consumers is different and their load profiles are presented in detail in the subsequent section.

1. Residential Load

The The load data for thirty five house hold users is gathered by counting number of fans, lights, lights for security purposes, fridges, televisions, water pumps, AC and PCs. The collected data shows that, the peak demand of residential load occurs in months of June, July and august, on the other hand in winter off-peak occurs from November to December. The daily peak load demand in summer is from 18:00 to 23:00, while in winter season the peak load occurs from 16:00 to 21:00. The figure below depicts daily load profile for the summer season.

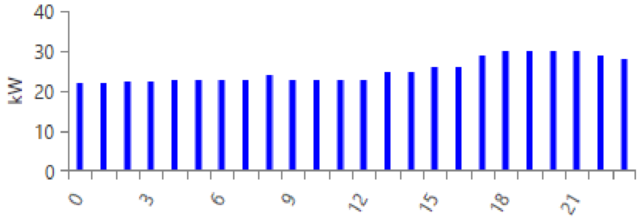

Figure 1. Daily Load Profile of Residential Load

2. School Load

The daily load profile of the school shows that the peak load of the school is around 2 kW. The load comprises of lighting load, fans, water pump heater etc. In winter season the school timing is from 08:00 am to 01:00 pm, while in summer school starts at 07:00 am and closes at 12:00 pm. There are four security lights which are ON during the night time. The diagram below depicts daily load profile of the school during summer.

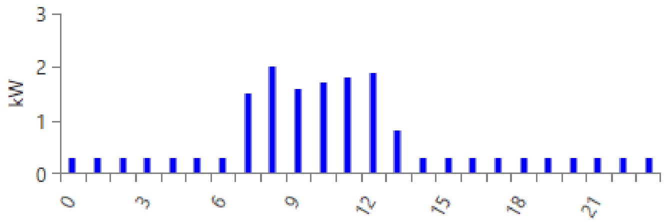

Figure 2. Daily Load Profile of School

3. Mosque Load

The load requirement of a mosques changes with the season conditions and occurs during prayer timings. In mosque, five times prayers are offered and their timing changes from on weather on another, for Fajar prayer the timing is 04:00 am to 07:00 am, time for Zuhar prayers is from 12:45 pm to 02:00 pm. Prayers timing for the other three prayers i.e. Asr, Maghrib and Isha is from 03:45 pm to 08:00 pm in winter season and from 05:00 pm to 10:30 pm in summer season. Water pump in mosque is usually operated during Fajar and Maghrib time. The figure below shows the variation in load demand of mosque.

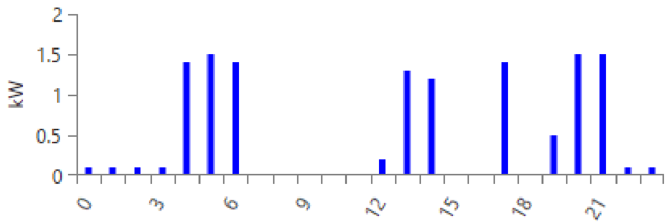

Figure 3. Daily Load Profile for Mosque Load

4. *Industrial Load*

There is a small industry in the community which has a peak load of 17kW. The operating time of the industry is from 9:00 am to 5:00 pm daily. The industry load is almost constant and appears for the whole year. There is only two fans and ten lights for security purpose when the industry working hours is off.

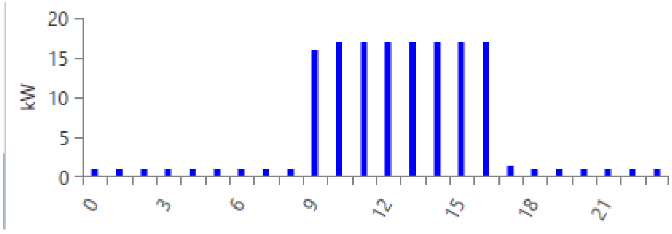

Figure 4. Daily Load Profile for Industrial Load

5. Combine Load Demand

The connected load of the community is 50kW and the peak demand is almost 46kW, as we know which are composed of industrial, school, residential and mosque load. The load demand change with the weather conditions. In summer the load demand is highest, while in winter the load demand is at their lowest value. The diagram below shows the daily average load profile for the combine load over 24 hours.

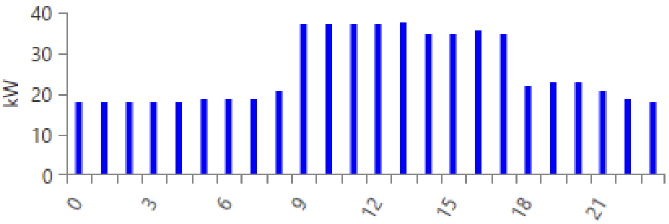

Figure 5. Combine Average Load Profile

IV. RESOURCES POTENTIAL

Detailed study and analysis of resource potential is compulsory before going to design and install the project. The available potential of various sources is studied and are nominated to integrate to supply uninterrupted power to the clients. Three renewables sources are selected for the optimization of the suggested system, the sources are micro hydro, photovoltaic and biomass which are discoursed in detail below.

A. *Biomass Potential*

Pakistan is a country having large fertile property and great portion of the population belongs to the agriculture sector. Pakistan has a huge biomass potential e.g. only sugar industry could contribute more than 10,000 MW potential. There is huge requirement for advance research and technology to transform waste into useful biomass fuel for power generation. The site chosen for the hybrid energy system is a rural area of KPK province, Pakistan, where main source of revenue of the individuals is agriculture crops. The World Bank report demonstrate that, biomass data for Mardan of KPK province of Pakistan is given in table below.

TABLE I. BIOMASS POTENTIAL OF MARDAN

Residue Name	Theoretical Potential 1000 ton/year	Current Technical Potential 1000 ton/year	Available Potential and Readiness to participate in supply Chain 1000 ton/year
Wheat, Straw	125	1	1
Cotton, Stalks	36	6	5
Rice, Straw	6	0	0
Rice, Husks	1	0	0
Maize, Stalks	110	3	3
Maize, Cobs	29	1	1
Maize, Husks	19	1	0
Sugarcane, Trash	33	1	1
Sugarcane, Bagasse	82	2	2

B. *Solar PV Potential*

Monthly average solar Global Horizontal Irradiance (GHI) data for the selected site has been collected from National Renewable Energy Laboratory (NREL) database. The table below shows the monthly average irradiance

TABLE II. MONTHLY AVERAGE IRRADIANCE

Month	Clearness Index	Daily Radiation ($kWh/m^2/day$)
January	0.581	3.031
February	0.580	3.804
March	0.561	4.697
April	0.572	5.748
May	0.610	6.787
June	0.612	7.056
July	0.575	6.475
August	0.541	5.598
September	0.616	5.429
October	0.643	4.490
November	0.612	3.343
December	0.517	2.485

C. *Micro-Hydro Potential*

Jalala canal of district Mardan, KPK has a microhydro potential, in Cusec is exposed in table. The available head is 10 meter and the two years e.g. 2013-14 discharge and the data about the average discharge each month is estimated based on on-site calculations.

TABLE III. MICRO-HYDRO POTENTIAL

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2013	50.5	61.1	76.2	118.1	132.25	130.1	119.1	92.3	103.4	98.1	80.2	78.3
2014	52.3	58.2	70.3	99.4	133.35	134.3	138.2	105.2	97.3	80.2	70.5	68.6
Mean Monthly Discharge	102.8	119.3	146.5	217.5	265.6	264.4	257.3	197.5	200.7	178.3	150.7	146.9

The power generated by the water potential is calculated through the formula below

$$Power = (Q)(g)(\rho)(h) \quad (1)$$

Where, Water density is denoted by ρ = 103 kg/m3, Q is flow rate of water, Qminimum =0.1275m3/s and Qmaximum =0.382m3/s, Earth gravity is denoted by g=10m/sec2 & head is denoted by h =15m

$$P_{minimum} = (\rho)(Q_{min})(g)(h) \quad (2)$$

P_{min}=19 KW

We have taken system efficiency of 80% for micro hydro. For simulation we have taken it 80% too. For maximum power generation from MHP at Qmax is

$$P_{Max} = (\rho)(Q_{max})(g)(h) \quad (3)$$

Considering 80% efficiency, so, the maximum power from MHP is,

P_{Max}= 57.3 KW

V. SYSTEM DESIGNING

A. Hybrid System Design for Off-Grid Community

The hybrid energy system is designed for the rural community where, there is no access of grid electricity. The sources utilized while designing of the hybrid system are solar PV, hydro and biomass. These resources are available in abundance at the selected site. The disgram is given below

The hybrid system shown above comprised of 30kW hydro, generator size of 10kW and PV size of 30kW. Generator and hydro power is AC in nature so, it is connected to the AC bus, whereas, PV output power is DC in nature so it is connected to the DC bus and converter transform this DC power into AC. The inverter size is 20kW. During night time when the solar PV output is zero than the biomass generator meet the remaining demand of electricity. Electronic Load Controller (ELC) is interfaced with micro hydro to make the system more stable by attaching or detaching ballistic load with rise or reduction of load/generation. The governor is installed to control the output of biomass generator according to the received data from the controller. In peak hours' biomass generator operate and generate electricity to meet the peak load demand.

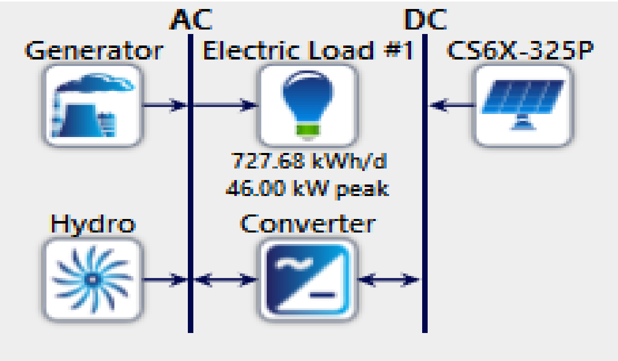

Figure 6. Hybrid system layout for off-grid community

B. Hybrid System Design for Grid-Connected Community

In this section, hybrid system is designed for a rural community, in Mardan district of KPK, connected to the grid. The system comprised of solar PV, biomass, micro hydro and having grid access too. The diagram below shows the whole schematic diagram of the grid-connected hybrid system for the rural community.

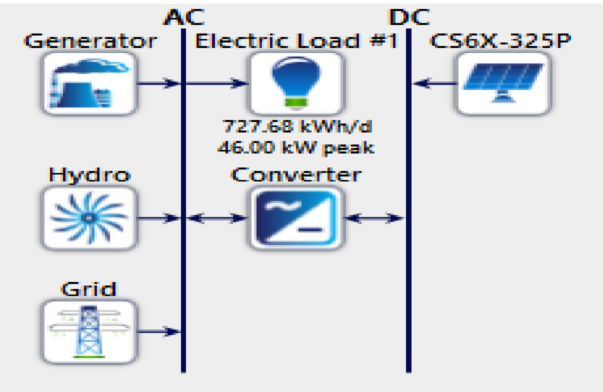

Figure 7. Hybrid system layout for grid-connected community

Here the hybrid system comprised of the sources as was there for off-grid site, but here this hybrid system is connected to the grid. The grid electricity price is taken 15Rs/kWh.

VI. OBJECTIVE FUNCTIONS

Cost of each and every element is very imperative for the economic analysis, optimization and modelling of the hybrid system. HOMER exploit these cost functions to determine the Net Present Cost and LCOE of the system. In the following segment cost functions of each system elements are discoursed.

A. *Micro-hydro Cost Function*

The economic analysis and optimization of the hydro power plant is done using equation below

$$NPC_{MH} = CC_{MH} + INS_{MH} + \sum_{1}^{K} O\&M_{MH} * T_{life\ time} + REP_{MH} * REP_{K} \quad (4)$$

Where NPCMH, CCMH, INSMH, O&MMH, REPMH designates Net Present Cost, Capital Investment, Installation and Commissioning Cost, System Operation and Maintenance Cost and Replacement expenditures. Initial capital comprised of synchronous alternator, protection devices, crossflow turbine, cables and other various costs. Installation cost consist of shipment, civil work, labor and installation cost. Power house life time in years is depicted by Tlifetime and the annual operating and maintenance cost of the micro hydro power plant is indicated by O&M. Replacement expenditures include the cost of any security or protective equipment's which needs replacement in case of failure. REPN indicates the total amount of components required to be replaced in project running time.

B. *Solar PV Cost Function*

Solar PV plant economic analysis and optimization is done using equation below

$$NPC_{PV} = CC_{PV} + INS_{PV} + \sum_{1}^{K} O\&M_{PV} * T_{life\ time} + REP_{PV} + REP_{K} \quad (5)$$

Initial capital investment cost comprises of solar panel and mounting structure cost, Cables and protective equipment's and other essential material cost. Installation cost consist of modules consignment cost, labor and installation cost. O&M is the cost of all necessary operation and maintenance cost.

C. *Objective Function of Biomass Power Plant*

Biomass power plant cost function is shown below

$$NPC_{BM} = CC_{BM} + INS_{BM} \sum_{1}^{K} O\&M_{BM} * T_{life\ time} + REP_{BM} * REP_{K} + \sum_{1}^{8760} Fuel * T_{life\ time} \quad (6)$$

Here the Initial investment consist of biomass generator and equipment's cost, and other essential material cost obligatory for the operation of biomass power plant. For the proper operation of biomass generator biomass fuel cost is prerequisite, which is contingent on the operation hours of the whole project life.

D. *Inverter and Sync Panel Cost Function*

Equation 7 is used for the economic analysis and optimization of invertor.

$$NPC_{inv\,\&\,sync} = CC_{inv\,\&\,sync} + INS_{inv\,\&\,sync} + \sum_{1}^{K} O\&M_{inv\,\&\,sync} * T_{life\ time} + REP_{inv\,\&\,sync} * T_{life\ time} \quad (7)$$

Where, all the terminologies are same as above. These all cost values are essential for calculating net present cost of the inverter.

VII. RESULTS AND DISCUSSION

For getting optimized results a well-known software HOMER is used. HOMER needs several input parameters for the designing, modelling and optimization of the system. Figure 5.1 put down a simple and lucid view of the general structure of the input and output.

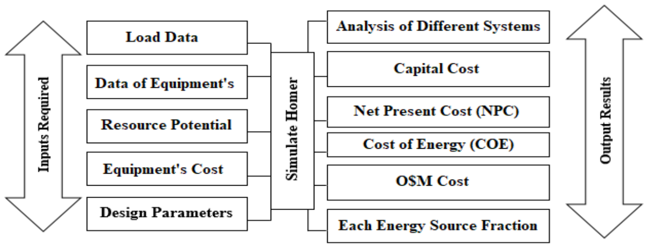

Figure 8. HOMER Modeling with Several Input Parameters

A. *Optimization Results for Off-Grid Community*

As we know peak load for the off-grid community is almost 45kW and the hybrid system consist of hydro, PV, biomass generator and converter. Hydro and PV act as a primary sources of electricity whereas the biomass gasifier acts when the demand reached to their peak value and when PV output is negligible, during the night time. The diagram below shows the simulation results for the off-grid community using HOMER. HOMER simulates all the possible configuration from the available sources.

Architecture					Cost				System	
CS6X-325P (kW)	Generator (kW)	Hydro (kW)	Converter (kW)	Dispatch	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	Ren Frac (%)	Total Fuel (tons/yr)
30.0	10.0	30.0	20.0	CC	Rs33.1M	Rs9.63	Rs2.00M	Rs7.26M	100	3.21
	20.0	30.0		CC	Rs67.2M	Rs19.57	Rs4.72M	Rs6.20M	100	9.02
	50.0			CC	Rs403M	Rs117.47	Rs30.7M	Rs7.00M	100	147
20.0	50.0		20.0	CC	Rs405M	Rs118.05	Rs30.7M	Rs8.76M	100	128

Figure 9. Simulation Results for Off-Grid Community

There are two possible configurations: the first one is composed of PV, hydro, biomass generator and converter and; the second configuration is composed of biomass generator and hydro. The first configuration is the most optimized one due to low Cost of Energy (COE) and Net Present Cost (NPC), which are 9.63Rs/kWh and 33.1M respectively. The first configuration consist of 30kW PV, 10kW biomass generator, 30kW hydro and 20kW converter. The initial capital cost of the system is 7.62M and operating cost is 2.00M. Now, the second configuration is comprised of 20kW biomass generator and 30kW hydro having COE and NPC of 19.57Rs/kWh and 67.2M, which is too much higher than the above case. So, the HOMER chosen the first configuration as the most optimized one on the basis of COE and NPC.

The monthly electric production from all the three sources is shown in the diagram below. Different color represents the production of electricity from the different sources. The hydro production is greater than from the PV and biomass. Production from the biomass generator is very less because is operates only in peak hours and when PV is not available.

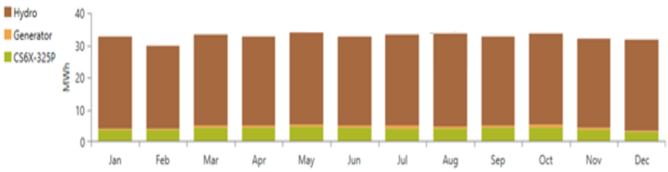

Figure 10. Monthly Electric Production

In the month of December and January production from the PV system get reduces due to reduction in day hours and irradiance. The diagram below shows the various cash flows, including capital cost, O&M cost, replacement cost and salvage value, for the hybrid system over a period of 25 years.

The table below shows different sources along with their generations for the first configuration means the most optimized one. Major portion of the electricity is generated from micro-hydro and then from solar PV. Almost 85.5% is contributed from hydro and 12.8% from solar PV. The amount of excess electricity is generated nearly 125,954, which is almost 32.1%.

TABLE IV. ELECTRICITY PRODUCTION AND CONSUMPTION SUMMARY

Production	kWh/yr	%	Consumption	kWh/yr	%
Canadian Solar Dymond (CS6K-285M-FG)	50,069	12.8	AC Primary Load	265,603	100
Generic 10kW Biomass genset	6,686	1.71	DC Primary Load	0	0
Micro-Hydro	335,064	85.5			
Total	391,819	100	Total	265,603	100

B. *Optimization Results for ON-Grid Community*

The peak load for the grid community is same as in the above case of off-grid community. The system comprised of PV, biomass gasifier, micro hydro and converter which is connected to the grid. This hybrid system is net-metering enabled, so, per kWh tariff of buying and selling are Rs17 and Rs8 respectively. The hybrid system consist of 30kW hydro, 10kW generator and 10kW of solar PV. The optimization results below shows different configuration along with their COE, NPC, capital and operating cost and other parameters.

Architecture						Cost				System	
CS6X-325P (kW)	Generator (kW)	Grid (kW)	Hydro (kW)	Converter (kW)	Dispatch	NPC (Rs)	COE (Rs)	Operating cost (Rs/yr)	Initial capital (Rs)	Ren Frac (%)	Total Fuel (tons/yr)
10.0	10.0	999,999	30.0	10.0	CC	-Rs10.9M	-Rs1.93	-Rs1.25M	Rs5.28M	100	13.1
	10.0	999,999	30.0		CC	-Rs10.3M	-Rs1.88	-Rs1.14M	Rs4.40M	100	13.1
10.0		999,999	30.0	10.0	CC	-Rs2.59M	-Rs0.566	-Rs531,074	Rs4.28M	99.3	0
		999,999	30.0		CC	-Rs1.13M	-Rs0.253	-Rs350,275	Rs3.40M	97.2	0

Figure 11. Optimization Results for Grid-Connected Community

As this hybrid system is net-metering enabled, so, the extra electricity from the renewable sources will be sold out to the grid. The NPC and COE for the first configuration is, which is comprised of PV, biomass, micro-hydro, converter and grid, -Rs10.9M and -Rs1.25. The negative sign is show that the revenues is greater than the expenses. The initial capital cost for the first configuration is 5.28M, which is higher than other but HOMER compare system on the basis of NPC and COE. In the first configuration the renewable fraction is 100%, its mean the community don't need to buy electricity from the grid. Other configurations are shown along with their NPC and COE. The system having less NPC and COE are the most optimized one among the configurations. So, the first one is the most optimized configuration having less COE and NPC. Different other important parameters are shown subsequently. The diagram below shows the monthly electric production from the different sources.

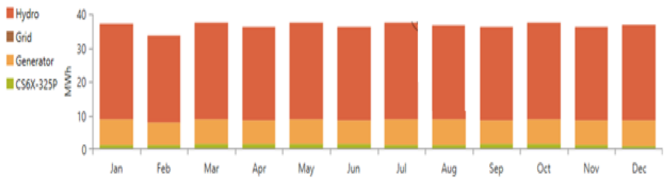

Figure 12. Monthly Electric Production

In the diagram 12, percentage of electricity generation from each source is shown by different colors. Maximum generation is done by hydro and minimum from the PV. The table following is shown energy generation and consumption scenario along with grid sales.

TABLE V. ELECTRICITY PRODUCTION CONSUMPTION AND GRID SLAES

Production	kWh/yr	%	Consumption	kWh/yr	%
Canadian Solar Dymond (CS6K-285M-FG)	16,690	3.80	AC Primary Load	265,603	60.6

Generic 10kW Biomass Genset	87,600	19.9	Grid Sales	172,916	39.4
Micro-Hydro	335,064	76.3			
Total	391,819	100	Total	438,519	100

The table depicts, almost 172,916 kWh/yr is sold out to the grid for getting revenues, and it is almost 39.4 percent of the total energy production.

CONCLUSION

To reduce the problem of power outages and load shedding in rural areas of Pakistan and to diminish the environmental hazards of the greenhouse gases, distributed generations and micro-grids are the most feasible solution both technically and economically. As we know, there is a huge potential of renewable energy resources in Pakistan, but the intermittent nature of the renewable sources and climate conditions make hurdles in the implementation of RES. This project is carried out to diminish the intermittent nature of the renewable sources through a hybrid system approach; combining several renewable sources. This project further explore the optimization approaches for getting the optimization of the hybrid system out of several different configurations. With this approach rural community in Mardan district got retrieve from the power outages and load shedding issues. The hybrid system for the community comprised of micro-hydro, solar PV and biomass; first in stand-alone mode and then in grid-connected mode.

HOMER Pro tool established by National Renewable Energy Laboratory (NREL), was used for designing, developing and optimization of hybrid renewable energy system for stand-alone and grid-connected mode. It is concluded from the simulation results that the first configuration for off-grid system, comprising of 30kW PV, 10kW biomass generator and 30kW hydro is the most optimized system among the different available configurations due to their less NPC and COE, which are 33.1M and 9.63RS/kWh. In this configuration the solar PV and micro-hydro are the main and primary sources for the generation of electricity, where biomass is employed during peak load hours and usually in night hours. In the other configuration such as biomass and hydro, biomass, PV and biomass the COE and NPC is got higher, so, these configuration are not the optimized one.

The second case is the grid-connected, where the community is connected is connected is to the grid too, so, a hybrid system has been designed to completely diminish the problem of load shedding and power failure and net-metering allowed the system to sell extra energy to the grid, which has further increased the revenues and reduced the NPC and COE. The simulation results has shown that the first configuration, comprising of 10kW PV, 10kw Biomass generator, 30kW hydro and having grid access, has the NPC and COE of –Rs10.9M and –Rs1.93 respectively, which are much less than the other configuration. So, HOMER software helped us for the designing and getting a most optimized hybrid system. By proper strategies and designing we have reduced the intermittent nature of the renewable sources.

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