222. Economic and Technical study of Hybrid system (Wind-Photovoltaic) Electrification for rural area of Tharparkar district, Sindh using HOMER software

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Abstract

A massive proportion of the world populace lives in far off rural areas which might be geographically remote and in moderation populated. Such areas have very low power demand and are not connected to the grid. In a development country like Pakistan, the maximum of the populace lives in faraway rural areas with no utility grid and this appears to be the primary impediment to normal development. Power is one of the cleanest electricity switch choice and is therefore the basis for the improvement of a place no matter the supply of electricity. In recent years, from an environmental factor of view, the renewable strength assets are being looked at as unlimited, inexhaustible, environment pleasant and sustainable assets. Direct and indirect advantages of the electricity technology through renewable sources in rural areas include irrigation, food protection, crop processing, cooling and small-scale industries which assist in improving the dwelling preferred of the people. The provision of renewable electricity assets is exceptionally variable and placement particular. The different regions have unique forms of energy assets available for electrification. The trouble of variability of the output from these assets will be in part conquer by installing individual big renewable strength plant or adding electricity garage and reconversion facilities or growing integrated renewable power gadget (IRES). The latter options had been adopted everywhere in the world as the quality options for energizing far flung rural regions by way of electricity in decentralized mode. The study region beneath consideration is positioned in Nangarparkar reserve woodland and wasteland range of the Tharparkar district of maximum populated. The one un-electrified village is chosen from this deserted location. The desolate tract terrain and dense wooded area and the large distance from the generating station are the limitations within the extension of grid and could handiest be energized in decentralized mode the use of renewable power sources. This paper affords feasible renewable electricity eventualities and shows the best scenario on basis of better reliability and minimal value of energy (COE) criteria and Net Present Cost (NPC) the usage of Hybrid Optimization and Multiple Energy Resources (HOMER) software.

This work is an improvement of an indigenous technology hybrid Solar -Wind power device that harnesses the renewable energies in sun and Wind to generate energy. Here, electric powered DC energies produced from photovoltaic and wind turbine systems are transported to a DC join power controller. The controller is bidirectional related to a DC-AC go with the flow charging-inverter machine that provides charging cutting-edge to a heavy obligation storage bank of Battery and on the identical time produces inverted AC energy to AC hundreds. Load estimates of a regular rural network and for rural infrastructures had been estimated. Simulation of wind electricity ability in W/m2 in Tharparkar District, Sindh will do based totally at the acquired wind information from National

Aeronautics and Space Administration (NASA). The outcomes confirmed that the average exploitable wind power density among 4W/m2 and 5.6kW/m2/day is realizable and that improvement of hybrid wind-sun machine for off- grid groups will move a protracted way to improve socio-economy lives of human beings.

Keywords: Hybrid, IRES, COE, NPC, AC, DC, HOMER

1. Introduction

Unfortunately, Pakistan is facing acute energy crisis of the last decade to increase in population and the heavy reliance on imported fossil fuels. The Power blackout 8-10 hours in urban areas and 14-18 hours in rural areas. This situation has drastically affected the country, residential, industrial and commercial sectors. Currently the government to keep the country's future energy supply, it is a big challenge. In these circumstances, researchers have been able to rise to the search for renewable energy sources in order to meet the country's deficit scenario. Fortunately, Pakistan is lying where often the potential exists for all renewable energy sources, such as geographic location. Solar, Wind, Bio-gas, biomass and feedstock's, mini and micro hydel to bio-energy.

Pakistan is blessed with 5.5 Whm^2/day solar insolation with average annual sunshine duration of 8-10 hours/day throughout the country. Wind speeds of more than 20,000 economically feasible wind power capacity of 5-7 m/s MW persists in coastal areas of Sindh and Baluchistan provinces. However, the use of renewable energy around the world, Pakistan is still lacking in these blessed [1] of the adaptation technologies, is already on a fast track.

This paper presents a combination of solar photovoltaic and wind energy systems. Only production system with solar or wind generation, but there are problems associated with both of them. Solar energy is not available for 24 hours and the time is not constant. If using a hybrid solar system and is designed to overcome these shortcomings. A system that uses both solar and wind power generation system is designed in this paper. To show that you can work with the latest research results from solar and wind hybrid power generation system enhancements and increased practicality in the field of renewable resources [2].

1.1. Objectives

Although several studies are conducted for hybrid renewable energy system, no research is reported for this system for Sindh Pakistan. In this work, the techno-economic feasibility study of wind/ solar hybrid system is analyzed for Resham-Jo-Tar near Nangarpakar, Tharparkar (Latitude: 24.968 N, Longitude: 70.815 E). Resham-Jo-Tar is located on the coastal area and has great wind potential and good level of solar irradiation [3]. Technical and economic analyses are performed for a wind/solar system with battery storages. HOMER is used as tool that facilitates optimum design of the wind/ solar hybrid systems. The analyses of the hybrid power system are performed by simulating system operation for the project lifetime.

2. Literature Review

2.1 Review of Solar Power Technologies

This technology such as refrigeration, lighting, has been used in autonomous systems to meet the load requirements of the applications of electrical pumping or other low power. It PV modules, storage batteries, inverters and control components [4]. Photovoltaic durable [5] to achieve development is one of the most promising green technologies. Almost zero production of greenhouse gases, using the PV system; thus, they are an environmentally friendly option for each region. The modules are stationary and without any noise. Less than the maintenance cost, wind turbines, PV systems is an advantage. However, their relatively high initial cost is depressing morale. It is interesting to know that the power consumption peak season usually takes place in the summer time, ie, when the PV power generation peak.

2.1.1 The Solar Energy Resources

The sun is the main energy source which is responsible for supporting all life activity around the world, such as the Earth's thermal comfort, photosynthesis in plants and the whole biogeochemical system. The sun emits its energy in form of electromagnetic radiation and after reaching the earth surface it is converted to other types of energy sources and used for many purposes [6].

The human beings are using the energy from the Sun in two main ways, i.e. for photo-electric generation and thermal conversion. These applications represent one big leap for the solution of the world energy shortage

2.1.2 General calculations

In this section and also in section 2.2.2 we give main equations that are relevant for calculating power production from PV panels and wind turbines, respectively. The formulas, which are described in this section and section 2.2.2, give background information to reader and support theories regarding energy production evaluation of the modelling tools that we have worked with. The total solar radiation incident on a surface depends on the position of sun in the sky, which differs from month to month. The total solar radiation [7] incident on the array as the input of a solar cell is

$$I_T = I_b R_b + I_d R_d + (I_d + I_b)\, R_r, \tag{1}$$

where I_b and I_d are direct and diffuse solar radiations, respectively. Variables R_b, R_d and R_r are beam, diffuse and reflected tilt factors of solar radiation, respectively. The voltage current equation in an ideal solar cell, with a current source in parallel with a diode, is provided by [7]:

$$I_{pv} = I_{ph} - I\,\left(\frac{q.V_{pv}}{e^{kT}} - 1\right), \tag{2}$$

where I_{ph} is the photo current (A), I the diode reverse saturation current (A), q the charge of electron 1.6 $\times 10^{-19}$ C, k the Boltzmann constant 1.38 $\times 10^{-23}$ J/K and T is the cell temperature (K).

The output power of a cell [7] is given by:

$$P_{pv} = V_{pv} I_{pv} \tag{3}$$

where I_{PV} is the output current of solar cell (A), V_{PV} is the operating voltage (V) and P_{PV} is the output power of solar cell (W).

The efficiency of a PV system [7] is:

$$\eta = \eta_m\, \eta_{pc}\, P_f \tag{4}$$

and η_m the modular efficiency[7] is given by:

$$\eta_m = \eta_r\, [1 - \beta(T_c - T_r)] \tag{5}$$

where η_{pc} is the power conditioning efficiency, η_r is the module reference efficiency, P_f is the packing factor (the fraction of absorber plate area covered by the solar cells), β is the array efficiency temperature coefficient, T_r is the reference temperature for the cell efficiency, and T_c is the monthly average cell temperature. From [7], hourly power output of PV system with an area A_{PV} (m^2) on an average day of j^{th} month, with incident total solar radiation of I_T (kWh/m^2) on PV surface is given by:

$$P_{sj} = I_{Tj}\, \eta\, A_{pv}. \tag{6}$$

2.2 Review of Wind Power Technologies

Wind turbines capture the kinetic energy of the wind by means of a multiple bladed rotor coupled with an electrical generator on a tall tower. The taller the tower, the higher the wind speed hitting rotor blades can become [4]. A stand-alone wind energy conversion system is a complete off-grid system composed of the wind turbine, the turbine tower, the battery bank and an inverter.

Selection of a wind turbine is difficult and a wrong choice may have negative consequences. Moreover, picking the right alternative has advantage above the lowest price. It is worth economically to wait little longer to find a quality system than having one which imposes extra costs to the projects.

2.2.1. The Wind Energy Resources

The wind is an abundant, free, clean, sustainable and environmentally-friendly renewable energy source. It has served the human civilization for many centuries by propelling ships and driving windmills to grind grain and pump water, and nowadays also for electrical power production [8].

2.2.2 General Calculation

The following expression gives the power output of a wind turbine [9]:

$$P = ½\, C_p\, A\, \rho\, U^3 \quad (7)$$

where C_p is the power coefficient of the rotor and A is the swept area perpendicular to the direction of wind in square meter. Also, ρ is the air density (around 1,225 kg/m^3) and U is the wind speed (m/s).

The wind speeds at any height [10] can be estimated from:

$$U\,(z) = \frac{U}{k} \ln\left(\frac{Z - Z_d}{Zo}\right) \quad (8)$$

where κ is von Karman's constant, Z is hub height, Z_o is the roughness length and Z_d is the displacement height. The friction velocity (U^*) depends on the shearing stress and shows the wind speed near the Earth's surface.

2.3 Review of Hybrid Power Technologies

Many experts maintain that it is not possible for a single renewable energy source to replace all conventional energy sources (fossil fuels), whereas with a combination of different clean energy sources this becomes more viable. Such a system is called hybrid energy system [11]. Hybrid systems are usually a combination of renewable electricity generation units, such as wind, PV, hydro, biomass integrated with conventional ones, such as gas turbines, diesel generators and fuel cells. As conventional power plants need continuous supply of fuels, which is expensive to transport to isolated places, use of a hybrid renewable energy system can be a good solution for overcoming this economic limitation. The main benefit of a hybrid system is that the weakness of one source is rectified by the other source. Solar radiation and wind energy both are not available continuously and thus, by using both wind and solar technologies the periodical gap between demand and supply of each technology can be filled and the disadvantage of each one can be minimized. It is recommended that accurate meteorological data should be available in order to avoid designing of an inappropriate system and to minimize operation and maintenance costs, especially in large scale projects. For instance, they can support areas with small agricultural loads, with special needs like telecommunication facilities, hospitals or everywhere that the exploitation of hybrid systems is efficient. Hybrid renewable energy systems usually have storage units in order to operate in duration of low power production. [4]

An optimal combination of a wind/PV system depends on the sizes of the PV array and wind turbine, which should provide high availability with low cost. Having 100 % availability means that it is always possible to cover load demand [12].

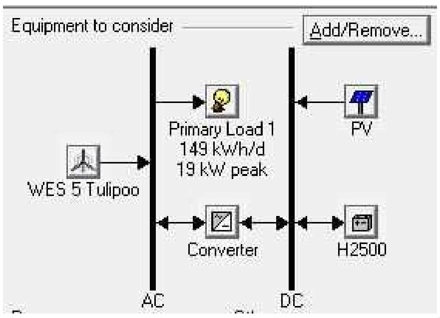


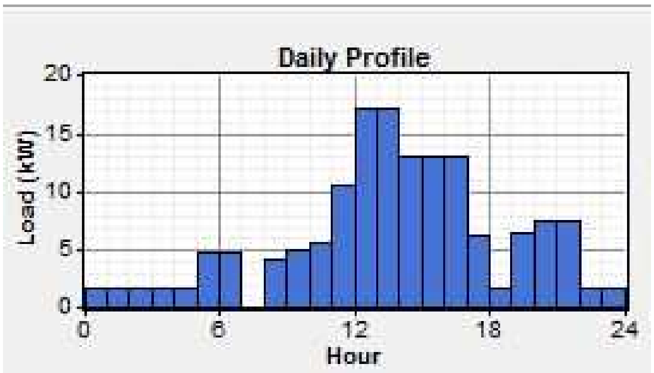
Fig. 1. Design of the selected Renewable Energy Technology (RET's) for the hybrid system.

3. Methodology

This study uses the HOMER software package developed by National Renewable Energy Laboratory (NREL) for designing micro-power systems but complements it by undertaking pre HOMER analyses. In the HOMER analysis the hybrid Renewable Energy Technology system is designed, followed by a techno-economic analysis. It compares a wide range of equipment with different constraints and sensitivities to optimize the system design. HOMER performs simulations to satisfy the given demand using alternative technology options and resource availability. We have considered a combination of the following technologies, namely wind turbines, solar Photovoltaic (SPV) systems and batteries (see Fig. 01 for a schematic system configuration diagram). In the hybrid system the demand from the village is AC-coupled and the SPV, wind turbine and the batteries are connected to its DC side.

3.1 Village Load Assessment

In a remote rural village, the demand for electricity is not high compared to urban areas. Electricity is demanded for domestic use (for appliances like radio, compact fluorescent lamps, ceiling fans), agricultural activities (such as water pumping) and community activities (such as in community halls, schools).



In this study, the demand has been estimated separately for two distinct seasons prevailing in this area, namely summer (April to October) and winter (November to March) considering the appliance holding and use patterns for households, potential commercial activities, and energy use in productive applications.

Primary Load 1 – This includes the domestic load, medical centre and school demand. The load demand is approximately 149.09kWh/day and 18.6 kW peak. It has a load factor of 0.334.

3.2 Resources Assessment

We have considered solar and wind resources in this simulation. The resource assessment is presented below. The solar resource used for Resham-Jo-tar village at a location of 24.968 N latitude and 70.815 E longitudes was taken from NASA Surface Meteorology and Solar Energy website. The annual average solar radiation was scaled to be 5.2kWh/m^2/Day and the average clearness index was found to be 0.567. The solar radiation is available throughout the year; therefore, a considerable amount of PV power output can be obtained.

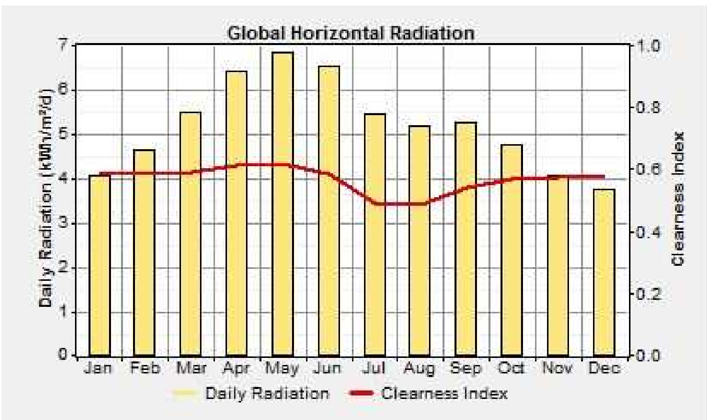


Fig. 3. Solar energy profile at the selected village

The monthly average wind resource data from an average of ten years was taken from the above NASA resource website based on the longitude and latitude of the village location. The annual average wind speed for the location is 4.8 m/sec with the anemometer height at 50 meters. The wind speed probability and average monthly speed throughout the year is also observed. It shows that there are 15 hours of peak wind speed. The wind speed variation over a day (diurnal pattern strength) is 0.25 and the randomness in wind speed (autocorrelation factor) is 0.85.

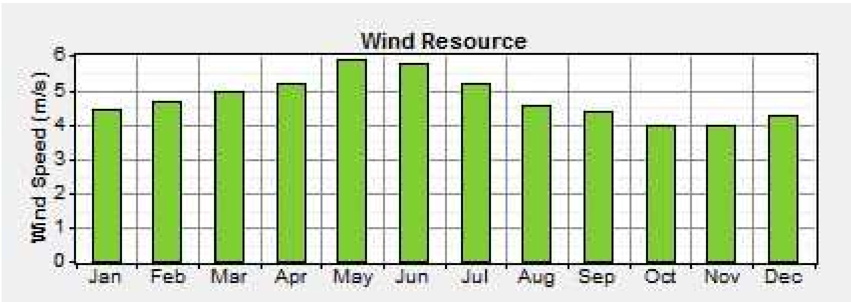


Fig. 4. Wind energy resource at the selected village

4. Results and Discussion

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 Solar (Photovoltaic) used for Power generation
b) When only Wind used for Power generation
c) When Hybrid System (photovoltaic and wind) used for Power generation

Double click on a system below for simulation results.

PV (kW)	WES5	H2500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
80	4	20	20	$ 56,800	657	$ 65,203	0.094	1.00
	20	30	20	$ 64,000	1,686	$ 85,552	0.123	1.00
120		40	20	$ 88,000	1,267	$ 104,195	0.150	1.00

Fig. 5. Simulation for only solar system

a) When Only Solar Is supplying the power to the load the optimization results in figure 05 Shows that Both NPC and COE increase as NPC 104,195$ and COE 0.150$ and initial cost is 88,000$. In only solar generation there is a large numbers of batteries are used that's why initial cost is increased as well as cost of energy COE.

Double click on a system below for simulation results.

PV (kW)	WES5	H2500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
80	4	20	20	$ 56,800	657	$ 65,203	0.094	1.00
	20	30	20	$ 64,000	1,686	$ 85,552	0.123	1.00
120		40	20	$ 88,000	1,267	$ 104,195	0.150	1.00

Fig. 6. Simulation for only wind system

b) When using only wind resources to power generation for the same load the COE and NPC is more than the Hybrid System (photovoltaic, wind) but less than the only solar generation for the same load shown in figure 06. The NPC is 85,552$ and COE is 0.123$ and initial cost is 64,000$.

Double click on a system below for simulation results.

PV (kW)	WES5	H2500	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kWh)	Ren. Frac.
80	4	20	20	$ 56,800	657	$ 65,203	0.094	1.00
	20	30	20	$ 64,000	1,686	$ 85,552	0.123	1.00
120		40	20	$ 88,000	1,267	$ 104,195	0.150	1.00

Fig.07. Simulation for Hybrid system

c) When Hybrid system is supplying to load with maximum share Optimization results in Figure 07 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 65,203$ and COE 0.094 $/kWh with a maximum Solar generation share of 74 %.Although system has second highest values of initial capital 56,800$ 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**.**

5. Conclusion

In this paper HOMER is used to analyze the hybrid power generation system at Resham-Jo-Tar. The meteorological data of Resham-Jo-Tar shows that the area has good solar irradiance and wind speed throughout the year. The feasibility report shows that the site is most suitable for designing hybrid power generation system. Since Pakistan has not yet designed a hybrid power generation system, this paper contributes a lot to the power generation in the country. In this paper the importance of diesel generation is also discussed. 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 Resham-Jo-Tar district Tharparkar shows that system will have minimum per unit cost (0.094 $/unit) when Solar energy has maximum (74%) and Wind has (26%) share in overall generation.

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