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Feasibility Study of Solar-Wind Hybrid Power System

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***Abstract*—This paper presents feasibility study of hybrid power system. Rapid depletion of fossil fuel resources necessitated research on alternative energy sources. A wind-solar hybrid system is a reliable alternative energy source because it uses solar energy combined with wind energy to create a stand-alone energy source that is both dependable and consistent. Solar power or wind power alone can fluctuate, when used together they provide a reliable source of energy. The perfect solution is to combine these two forms of energy sources to create a constant energy flow. Main objective of this paper is to study feasibility of stand-alone solar-wind hybrid power system and to maximize use of renewable energy generation system while minimizing the total system cost.**

***Index Terms*—HOMER, Hybrid System, Optimization, Solar, Wind**

I. INTRODUCTION

Solar energy and wind energy have been deemed clean, inexhaustible, unlimited, and environmental friendly. Such characteristics have attracted the energy sector to use renewable energy sources on a larger scale. However, all renewable energy sources have drawbacks. Wind and solar sources is dependent on unpredictable factors such as weather and climatic conditions. Due to both sources' complementary nature, some of these problems can be overcome the weaknesses of one with the strengths of the other. This brings us to the hybrid solar-wind power plant concept. Hybrid energy stations have proven to be advantageous for decreasing the depletion rate of fossil fuels, as well as supplying energy to remote rural areas, without harming the environment.

Distributed Generation (DG) refers to small power plants (a few watts up to 1MW) at or near the loads, operating in a stand-alone mode or connected to a grid at the distribution or sub-transmission level, and geographically scattered throughout the service area. Distributed Generation includes small, modular technologies for electricity generation, located close to the load. DG technologies are used both in stand-alone mode as well as in grid parallel mode. Conventional electricity generating stations are typically located close to the fuel source and away from the loads, and electricity generated is conveyed through the transmission system to the load centre, which often requires large investment.

Transmission and distribution costs account for about 30 per cent of the cost of delivered electricity. DG technologies obviate the need for an expensive transmission system and minimize transmission and distribution losses.

The Hybrid Optimization Model for Electric Renewables (HOMER) software is used as a tool to carry out the research. The main objective of this paper is to assess the feasibility and economic viability of utilizing hybrid Solar–Wind–battery based standalone power supply systems to meet the load requirements.

The hybrid of picohydro, PV, wind turbine, generator and battery as back-up is the basis of assessment. The results from the simulation of renewable hybrid system shows that in order to reduce the COE, it is important to look into the amount of excess energy the system produced. COE is defined as the ratio of total annualized cost and annual load served, reducing the annualized or/and increasing the annual load served should be one of the objective of optimization [1].

[2] Discusses on the optimization of the renewable energy hybrid system based on the sizing and operational strategy of generating system. In this case study, PV array system, wind turbine, diesel generator with battery and converter are the components chosen for the analysis. HOMER simulates the system based on the estimation of installing cost, replacement cost, operation and maintenance cost, fuel and interest.

[3] will discuss cost benefit analysis of solar-wind hybrid power system at Nigeria done using HOMER software and comparison was also made with the cost per kilowatt of central grid or utility supply. The hybrid system have a payback period of about 33 years and at current costs, central grid power is the least expensive option but may not be available to most rural households far from the grid. Simulation is done using Homer software and found that wind-solar cell hybrid energy system would be cost effective if there is reduction in component cost by installation of many of this hybrid system in a farm thereby lowering the investment cost per kilowatts.

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II .WIND POWER

Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Seasonal variations in the energy received from the sun affect the strength and direction of the wind.

The wind turbine captures the winds kinetic energy in a rotor consisting of two or more blades mechanically coupled to an electrical generator. The turbine is mounted on a tall tower to enhance the energy capture [7].

III. SOLAR POWER

The solar modules (photovoltaic cell) generate DC electricity whenever sunlight falls in solar cells. The solar modules should be tilted at an optimum angle for that particular location, face due south, and should not be shaded at any time of the day.

IV. HYBRID SOLAR-WIND SYSTEM

A stand-alone wind system with solar photovoltaic system is the best hybrid combination of all renewable energy systems and is suitable for most of the applications, taking care of seasonal changes. They also complement each other during lean periods, for example, additional energy production through wind during monsoon months compensate the less output generated by solar through wind during monsoon months compensate the less output generated by solar. Similarly, during winter when the wind is dull, solar photovoltaic takes over. The hybrid solar wind power system is as shown in figure 1.

Applications of Solar-Wind Hybrid Power System are listed below [4].

- Remote and rural village electrification
- Ideal for cell phone recipient stations,
- Residential colonies and apartments for general lighting
- Street lighting

With the use of renewable energy based system the emission of carbon and other harmful gases are reduced to approximately 80% to 90% in environments.

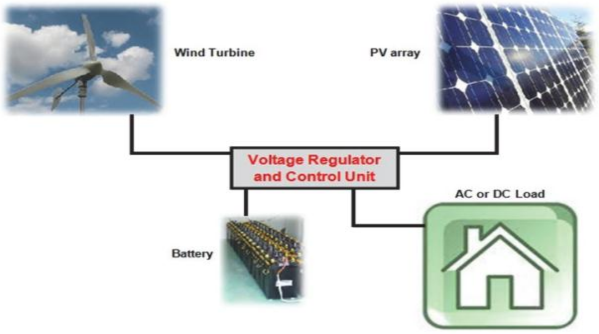

Fig:1 Solar-wind hybrid power system

V. ANALYSIS METHOD

The HOMER is a micro power optimization software developed by Mistaya Engineering, Canada for the National Renewable Energy Laboratory (NREL) USA, which can useful for evaluating designs by simplifying the given task for both off-grid and grid-connected power systems for plenty of applications . It also provides the cost benefit analysis for hybrid energy system. In designing any power system, the decisions about the configuration of this system needs to be analysed, like components and its specification for the system design, size of that all components, the availability of energy resources and technological options, and the cost of each available technology, all these information are difficult to achieve [5].

HOMER simulations are performed by analyzing energy balance calculations and show the all possible configurations. This all possible configuration arranged by net present cost which can be useful for comparison of system design. HOMER's optimization and sensitivity analysis make this task easier. Also it finds all possible system configurations related to it

Six different locations are selected for analyses i.e. are Vadodara, Ahmedabad, Surat, Mundra Khambhat, Junagadh. Solar radiation data for tilted panel and average wind speed data at 50 m above the surface of the earth is taken from NASA website[6]. HOMER consider all cost in dollars, so conversion we take for this simulation is 1$= 50 INR.

VI. SIMULATION

We consider six different locations i.e. Surat, Vadodara, Ahmedabad, Khambhat, Mundra, Junagadh and two load condition i.e. 5KWh/day and 10 KWh/day for simulation.

Components to be considered for standalone solar-wind hybrid power system.

Wind turbine :

Type: Air Stream 1 KW
Rated power: 1 KW DC
Life time: 15years
Hub Height: 25m

PV panel:

Rated power : 1KW DC
Slope: 30
Lifetime: 20years

Battery:

Type: Vision 6FM 200D
Nominal Capacity: 200Ah
Nominal Voltage: 12V

Primary load

Type: AC
Rating: 5 KWh/day and 10 KWh/day

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TABLE. I: COST TABLE

Component	Rating	Cost (INR)
PV panel	1 KW	175000
Wind Turbine	1 KW	113500
Converter	2 KW	55500
Battery	12V, 200Ah	10000

VI ANALYSIS OF RESULTS

The below table shows the summary of result for 5 KWh/day and 10KWh/day for six location.

TABLE II: RESULT FOR 5 KWH/DAY

5 KWh/day				
Location	Initial capital	Operating cost	Total NPC	COE
Vadodara	664000	36250	1127200	48
Ahemadabad	664000	36250	1127200	48
Surat	839000	38600	133255	57
khambhat	664000	36250	1127200	48
Mundra	664000	36250	1127200	48
Junagadh	839000	38600	133255	57

TABLE III: RESULT FOR 10 KWH/DAY

10 KWh/day				
Location	Initial capital	Operating cost	Total NPC	COE
Vadodara	1041750	41950	1578300	33
Ahemadabad	980250	47600	1588900	34
Surat	1041750	41950	1578300	33
khambhat	1041750	41950	1578300	33
Mundra	1041750	41950	1578300	33
Junagadh	1041750	41950	1578300	33

The above mentioned results declair that the proposed stand-alone hybrid system will be able to feed the power to the ac load of rating 5 KWh/day and 10 KWh/day, constantly throughout the year.The proposed system is best suitable for ac load. The sensitivity variables considered for the proposed system analysis of stand-alone hybrid system are wind speed, solar insolation and loading condition. The simulation results are evaluated for each one of this sensitivity. An hourly time series simulation for every possible configuration system is achieved for the 1-year period. From all suggested configuration, the best optimal system is kept, which fulfils the condition of meeting the load demand.

VII. OPTIMIZATION RESULT

After analyzing the simulation, one can suggest that the for higher loading stand-alone solar-wind hybrid system is most suitable, for supplying the power to the ac load. The simulation result suggests that this hybrid system is most suitable for all location. Result suggests that from the different possible configuration, one can choose the better optimal solution. From the optimization results the most suited optimal configuration of energy system components are Airstream 1 KW wind turbine, 1 KW PV-Array. From the result, the total net present cost (NPC), Initial cost, operating cost and cost of energy (COE) for such a system is 1578300 INR, 1041750 INR, 41950 INR and 33 INR/kWh, respectively for one year as shown in table III. This is optimized result for 10 KWh/day.

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VIII. SIMULATION RESULTS

The simulation result allows only feasible solution with their increasing in number of cost and eliminates all other infeasible possible solutions. Also simulation performs the number of parameters displayed against sensitivity variables to identify optimal solution for energy system. According to the optimal solution the total energy required to satisfy the laod demand by the hybrid combination of 36% PV, 64%wind as shown in figure 2.1 with excess electricity of 35%.

Figure 2.2 shows monthly average electric production from wind energy and solar energy in graph format. Yellow colour indicates electric energy production from solar energy and green colour indicates electric energy production from wind energy.

Production	kWh/yr	%
PV array	2,526	36
Wind turbines	4,536	64
Total	7,063	100

Consumption	kWh/yr	%
AC primary load	3,650	100
Total	3,650	100

Quantity	kWh/yr	%
Excess electricity	2,473	35.0
Unmet electric load	0.0000124	0.0
Capacity shortage	0.00	0.0

Quantity	Value
Renewable fraction	1.00

Fig. 2.1 Optimized result for hybrid solar-wind power system

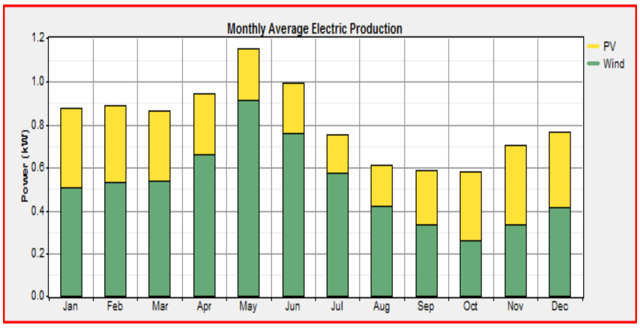

Fig. 2.2 Graphical representation of result for hybrid solar-wind power system

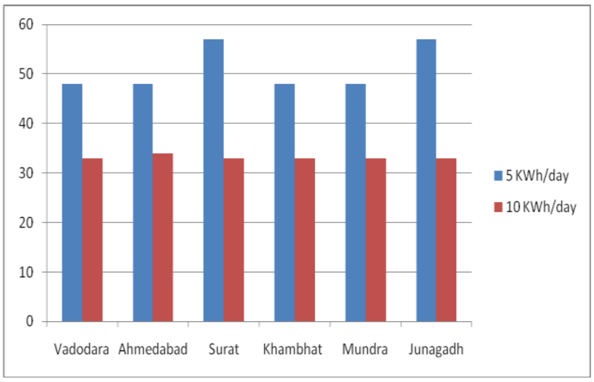

Fig. 3 Graph of location versus cost of energy.

IX. CONCLUSION

With the help of simulation, the cost of energy production is calculated for Ahmedabad, Vadodara, Surat, Mundra, Khambhat, Junagadh. It can be concluded that for loading condition of 5 units per day the cost of energy production is 48 INR per unit, where for the load of 10 unit per day, the cost of energy production reduces to 33 INR per unit. So it is proved that as loading condition increases per day, the cost per unit will reduce as show in figure 3.

As shown in above figure for 5 KWh/day cost of energy for six selected location is vary in large range but for 10 KWh/day cost of energy is almost constant i.e. 33 rupees per KWh.

Although initial cost for solar-wind hybrid power system is high, but it produces electricity at least cost. Due to distributed generation it eliminates installation cost transmission lines. It has many advantages that it produces no pollution and requires less maintenance. HOMER software is used for the optimization of hybrid combination and gives best combination according to least price. It is feasible to use solar wind hybrid power system for higher loading.

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