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Optimal Design of PV-WTG Hybrid Energy System

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***Abstract*—Hybrid energy system generally consists of a primary energy source working in parallel with standby secondary energy storage units. Hybrid Renewable energy system (HRES) is a combination of one or several renewable resources such as wind, solar, biomass, small/micro hydro, with other technologies such as batteries and fossil fuel powered diesel generator (for backup) to provide electric power. HRES is an excellent solution for electrification of remote rural areas where the grid extension is difficult and not economical. A hybrid renewable energy system may be used to reduce dependency on either conventional energy or renewable system. This paper gives the design idea of optimized Hybrid Energy System for a certain technical college/remote rural area for a particular site in central India (Bhopal). For this hybrid system, the meteorological data of Solar Isolationis taken for Bhopal (Longitude 77˚42' E, Latitude 23˚25' N and Altitude 427 m) and the pattern of load consumption of load are studied and suitably modeled for optimization of the hybrid energy system using HOMER software. HOMER (Hybrid Optimization Model for Electric Renewable) is a design model that determines the optimal architecture and control strategy of the hybrid system. Validation of this result is through evolutionary computing such as GA (genetic algorithm). Our objective is selected as minimizing the total capital cost, subject to the constraint of the Loss of Power Supply Probability (LPSP). Studies have proved that the genetic algorithm converges very well and the methodology proposed is feasible for optimally sizing standalone hybrid power systems**

Keywords—GA, HOMER, HRES, LPSP, Optimization

I. INTRODUCTION

Hybrid Renewable energy systems (HRESs) using renewable and low carbon power sources are being increasingly preferred for power generation. As the world moves towards the end of its finite supply of fossil fuel resources, being able to use them sparingly, as well as refining ways of generating electricity without them, becomes increasingly important. At the same time the adverse effects of burning fossil fuels on the environment have been acknowledged and the move towards cleaner methods of energy generation is imperative. There are many advantages to renewable power generation especially within remote rural areas (or technical institute) where access to established grids is limited and large distances between the existing grid and the area cause the cost of extending the grid to be impractical. In this paper, hybrid renewable energy systems consisting of PV panel lead acid batteries and wind turbine generator are considered.

National Renewable Energy Laboratory's (NREL) Hybrid Optimization Model for Electric Renewable (HOMER) software has been employed to carry out the present study. HOMER performs comparative economic analysis on a distributed generation power systems. In this paper an optimal sizing method using the genetic algorithm (constraint is LPSP) is proposed.

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II. SYSTEM DESCRIPTION

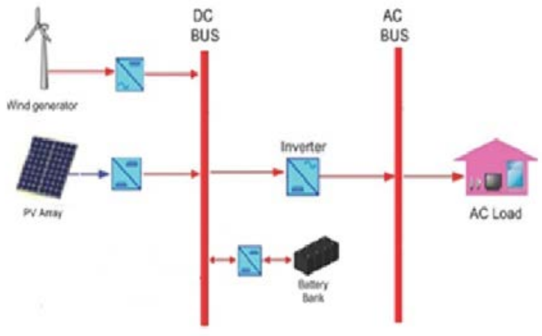

Fig. 2.1 – System Description

A. Solar Radiation

Table 2.1 shows the solar radiation of Bhopal, MP, India. Here Solar Energy resources data are taken from NASA. Fig. 2.2 shows the monthly average solar radiation.

Month	Daily Solar Radiation kWh/m^2/d	Month	Daily Solar Radiation kWh/m^2/d
Jan	4.50	July	4.11
Feb	5.27	Aug	3.70
Mar	6.07	Sep	4.77
Apr	6.59	Oct	5.15
May	6.52	Nov	4.64
June	5.46	Dec	4.20

Table 2.1 - Solar radiation of Bhopal

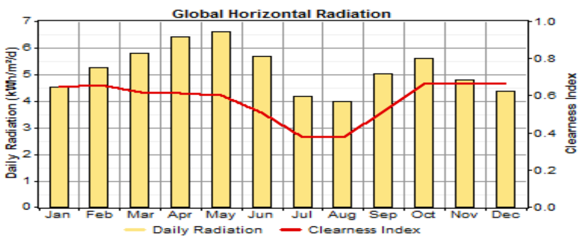

Fig. 2.2 Monthly average solar radiation

Month	Daily Solar Radiation kWh/m^2/d	Month	Daily Solar Radiation kWh/m^2/d
Jan	2.4	July	3.3
Feb	2.6	Aug	2.8
Mar	2.6	Sep	2.5
Apr	3.0	Oct	1.9
May	3.5	Nov	1.9
June	3.7	Dec	2.2

Table 2.2 - Wind Speed of Bhopal

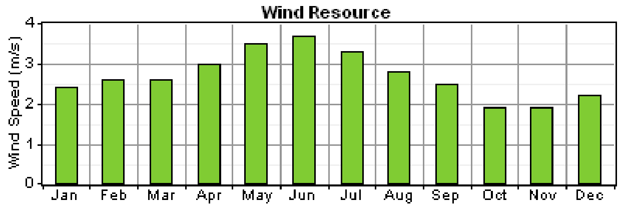

Fig. 2.3 - Monthly average wind speed

B. Load profile

Fig. 2.4 shows the daily load profile. Fig. 2.5 shows the Monthly load profile

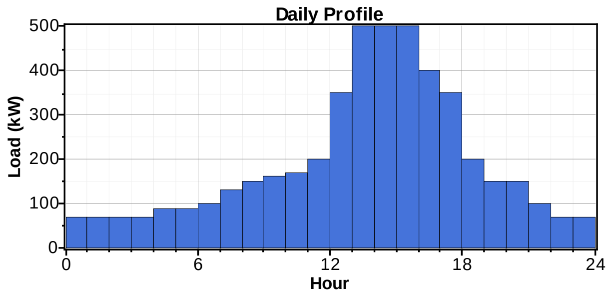

Fig. 2.4 Daily load profile

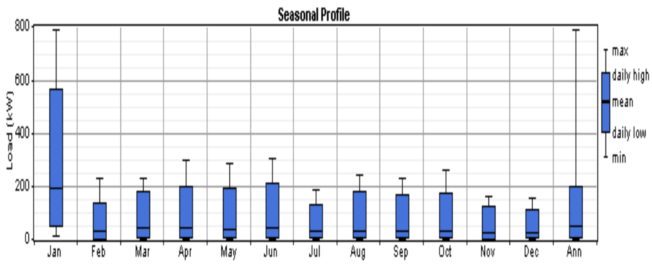

Fig. 2.5Monthly load profile

III. HOMER SIMULATION MODEL

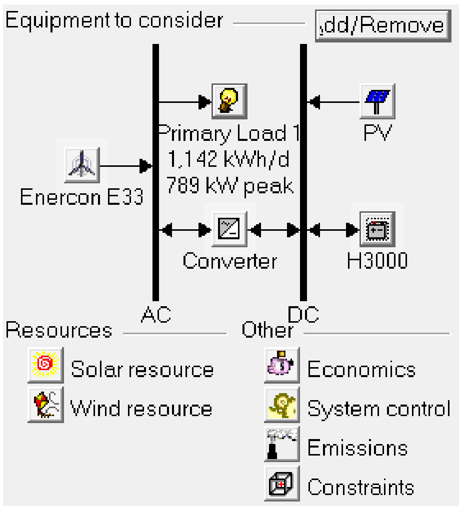

Fig. 3.6 Proposed systems Configuration in HOMER

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Table 3.1 shows Technical Data and Study of Assumptions Components

PV ARRAY(1kW Solar Panel)	
Installation Cost	42876 INR
O&M Cost	0 INR/Year
Replacement Cost	30000 INR
Life Time	25 Years
150kW Diesel Generator(Used as backup)	
Installation Cost	700000 INR
Q&M Cost	250 INR/Hr
Replacement Cost	500000 INR
Life Time	25 Years
Battery(Deep cycle battery)	
Range	2V,3000Ah
Installation Cost	54385 INR
Replacement Cost	34000 INR
Converter (1 kW)	
Installation Cost	44504 INR
O&M Cost	3000 INR
Life Time	15 Years with a efficiency of 90%
Enercon E33(Wind Turbine Generator)330kW AC	
Installation Cost	1000000INR
O&M Cost	10000INR

Table 3.1- Technical data and study of assumptions components

IV. SIMULATION RESULTS

The dollar symbol is taken as Indian rupees. Total net present cost (NPC), Initial Capital cost and cost of energy (COE) for such a system is INR 111535808, INR 87782400 and 22.393/kWh, respectively. The detailed optimization results are shown in Fig. 4.1.

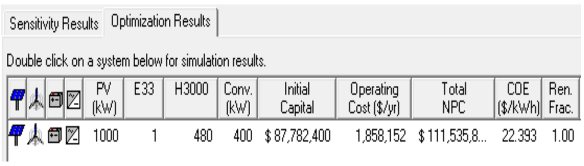

Fig. 4.1 Optimization results of hybrid energy system.

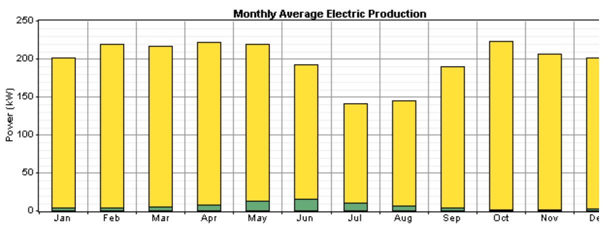

Fig. 4.2 Monthly average electricity production.

Component	Production(kWh/yr)	Fraction
PV Array	1680461	97
WTG	53875	3
Total	1734335	100

Table 4.1 - Annual Electric Energy Production

For validating this result we are using Genetic algorithm.

V. OPTIMAL SIZING USING THE GENETIC ALGORITHM

A Problem Description and Sizing Procedures

Optimization is a process that finds a best solution for a problem. The optimization problem is centered around objective function, a set of unknown variables and a set of constraints. An optimization problem is defined as finding values of variables that minimize or maximize the objective function while satisfying the constraints [4].

Here
Objective function: cost and
Constraints:
LPSP or
Equality Constraints
Sum of power of PV and WTG = Load Demand
Inequality Constraints
P_{max}< Solar Power <P_{min}

Let the total capital cost of PV panels WTG and batteries, C_{PB}

Min $C_{PB} = C_{PV}\ N_{PV} + C_{bat}N_{bat} + C_{WTG}\ N_{WTG}$

s.t.
LPSP d $LPSP_{set}$
N_{PV} = 0, 1, 2, …
N_{bat} = 0, 1, 2, …
Where:
C_{bat} = cost of the batteries,
C_{PV} = cost of the PV panel,
C_{WTG} = cost of the WTG,
$LPSP_{set}$ = LPSP set according to the load characteristics,
N_{bat} = number of the batteries,
N_{PV}= number of the PV,
N_{WTG} = number of the WTG,

The total capital cost is given as follows [5]

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$$C_{total} = C_{PB} + C_0 \quad (13)$$

Where C_0 is the total constant costs including the cost ofpower conditioning equipment, design and installation etc.

B. The Genetic Algorithm

The GA is a stochastic global search method that mimics themetaphor of natural biological evolution and does not requirederivative information or other auxiliary knowledge. It isimportant to note that GA provides a number of potentialsolutions to a given problem and the choice of final solution isleft to the user.MATLAB has an optimization toolbox which can be used for genetic algorithms; however itdoes not account for all situations and can therefore be adapted to the needs of the user.

After a lot of tests using various parameter values, the GA parameters used in this paper are:
1) Size of population: 100
2) Number of generations: 500
3) Fitness scaling: proportional
4) Probability of crossover: 0.8
5) Crossover function: Heuristic
6) Mutation function: Gaussian
7) Elitism: 2 chromosomes

Method	HOMER	GA
NPC	INR 111535808	INR 89948232
Initial Cost	INR 87782400	INR 70792258
CoE	INR 22.393/kWh	INR 18.75/kWh

Table 5.1 - Optimization Results using HOMER & GA

In tables VI, the optimal sizing results of the hybrid PV-WTGsystem, is presented.

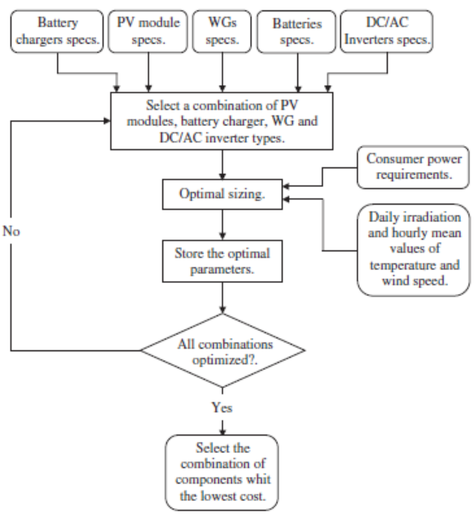

Fig. 9 Flowchart of the proposed optimization methodology (Koutroulis et al., 2006)

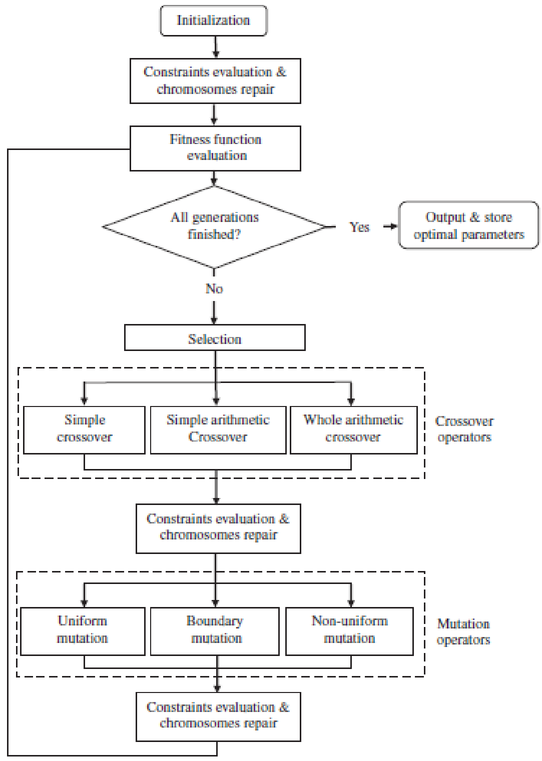

Fig. 10 GA used for optimization process (Koutroulis et al., 2006)

VI. CONCLUSIONS

On the basis of what we have seen so far, we can conclude that this technology is the need of the future to avoid energy crisis situation.

Load can be satisfied in the optimal way by using GA.In this approach all of economicalcosts include capital cost, replacement cost, operation andmaintenance cost and etc hasbeen considered. Because of variety of system's constraints,to solve the optimization problems, Genetic Algorithm hasbeen used.

VII. REFRENCES

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