# Design & Optimization of a Power Generation System based on Renewable Energy Technologies

**Devendra Kumar Doda, Amit Shrivastava, Mahesh Bundele**

***Abstract:*** ***The application of this study is to make an instrument that will consider wind, solar, and biomass assets on a location and decide how these three wellsprings of energy would be best consolidated into a hybrid structure to take care of the load demand. The apparatus will enable the user to enter the specifications for different models for each sort of framework, and after that meet the load based on user inputted parameters. The cost of energy will then be dissected, permitting the consumer to perceive what mix of components would bring about the minimum costly cost of energy, and additionally unique ways the load might be met. The software named as HOMER (Hybrid Optimization Model for Electric Renewables) will consider not just the logical principle of vast energy; it will likewise represent economic and required factors.***

***Keywords*****:** ***Decentralised Energy Generation; HOMER; Hybrid System; Renewable Energy; Optimization.***

## I. INTRODUCTION

The decentralized power generation system is basically designed for fulfill the electricity demand of rural and remote areas [1-3]. Off-grid generation is picking up significance in the developing nations where the entrance to power is generally limited [4-6]. The sustainable power sources can be viewed as the best contrasting option to decrease the energy neediness of the local regions where the structure expansion through a upsetting area and thick jungle isn't conceivable or financial. In many developing nations, the national power structure neglects to give rural groups a solid supply of power. Given the high financial cost of this approach failure, the researchers and policymakers have as of late turned out to be occupied with off-grid electrification programs.

The main objective is to utilize renewable resources to fulfill the energy demands at particular location in Jaipur, Rajasthan, India. A Grid connected system is designed as an experimental demonstration system. Hybrid system is designed and optimized using HOMER software.

**Revised Manuscript Received on September 03, 2019**

* Correspondence Author

***Devendra Kumar Doda**, Research Scholar, Dept. of Electrical Engineering, Poornima University, Jaipur, India.

Email id-devendra.doda@gmail.com

**Amit Shrivastava,** Professor, Dept. of Electrical Engineering, Poornima University, Jaipur, India

**Mahesh Bundele**, Professor, Dept. of Computer Engineering, Poornima College of Engineering, Jaipur, India

## II. METHODOLOGY

### A. Grid connected Hybrid Experimental System Description

The hybrid with Grid connection is simulated for an Institutional. The configuration of the simulated hybrid system is shown in Figure 1.

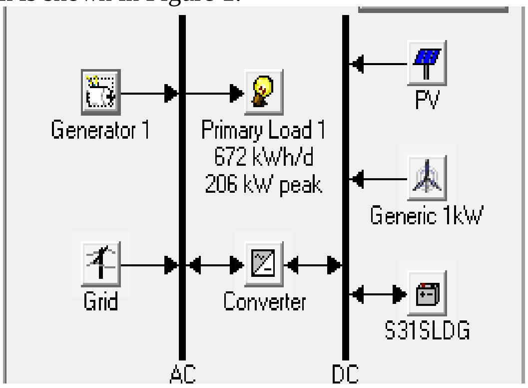


**Fig.1 370 kWp Solar -Wind hybrid system configuration**

### B. Photovoltaic specifications

Photovoltaic are well-known as a technique for generating electrical energy by means of solar cells to convert power from the sun into a surge of electrons. The photovoltaic outcome refers to photons of light stimulating electrons into a higher position of energy, allowing them to perform as charge carriers for an electric current.

The monthly average radiation varies from 3.740 kWh/m$^2$/d to 6.380 kWh/m$^2$/d and the annual average radiation is found to be 5.041 kWh/m$^2$/d at the site with average clearness index (Kt) of 0.562. The monthly average global horizontal solar radiation and clearness index is shown in Figure 2.

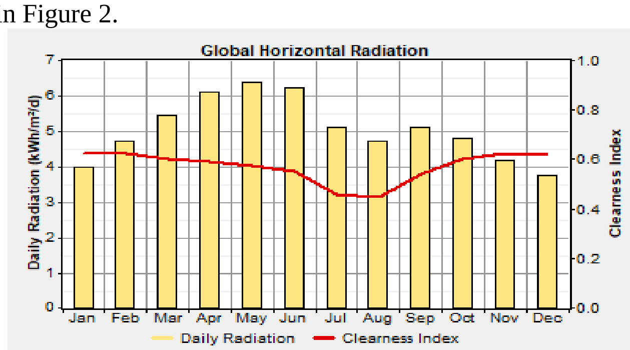


**Fig.2 Global solar radiation and clearness index**

### C. Grid Specifications

The rating of electricity grid taken & arrange from power grid and Institution.

TABLE 2 GRID SPECIFICATION

| Rate | Price ($/kWh) | Sellback ($/kWh) | Demand |
|---|---|---|---|
| Rate 1 | 0.122 | 0.00 | 0.00 |

Table 1 PV system specifications [7]

| Description | Specifications | | | | |
|---|---|---|---|---|---|
| Size (kW) | 1 | 10 | 20 | 25 | 40 |
| Capital Cost ($) | 900 | 8450 | 16000 | 20000 | 28000 |
| Replacement ($) | 400 | 7000 | 12500 | 16000 | 20000 |
| O & M ($) | 18 | 170 | 320 | 400 | 500 |
| Life Time (Yrs) | 18 | | | | |
| Derating Factor | 0.8 | | | | |
| Temp. Coefficient of Power (%/°C) | 0.41 | | | | |
| Efficiency at STC (%) | 15 | | | | |
| Reflectance (%) | 20 | | | | |

### D. BATTERY SPECIFICATIONS

Due to irregular character of both energy resources, energy storage is required to provide electrical power constantly. The battery specifications are presented in Table 3.

Table 3 Battery specifications [8]

| Quantity | Power (V/Ah) | Capital Cost ($) | Replacement Cost ($) | O & M Cost($/yr.) |
|---|---|---|---|---|
| 1 | 150 | 17 7 | 30 | 10 |

The electricity produced is supplied to faculty rooms and office. The rest of power is stored in the battery bank. The average daily load demand, energy demand, peak load, load factor are 672kWh/d, 28 kW, 206 kW and 0.136 respectively. The seasonal load profile system is shown in Fig. 3.

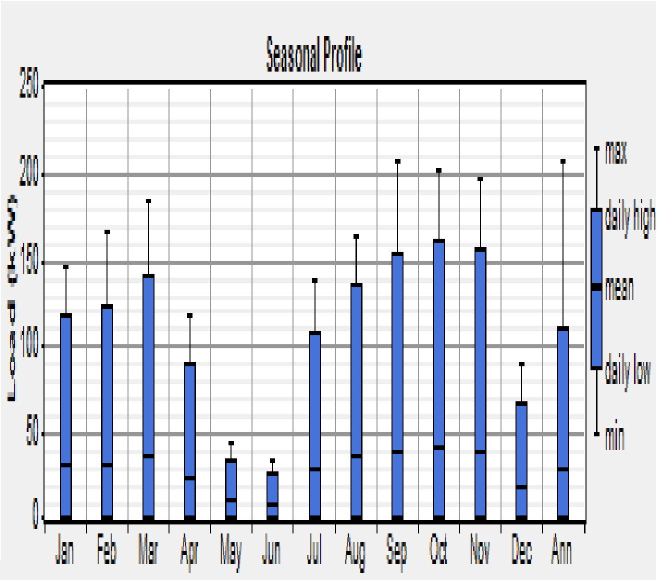


**Fig. 3 Annual hourly load profile**

An electric grid network is an interconnected system for conveying power from providers to consumers. It comprises of generating stations that deliver electric power from inaccessible sources to demand focuses, and conveyance lines that link individual clients.

Table 4 Different combination used for various components

| System | Combinations |
|---|---|
| PV Array | 1, 2, 3, 4, 5 |
| Wind Turbine | 1 |
| Battery | 1, 2, 3, 4 |
| Converter | 1, 2, 3, 4 |
| Grid | 1 |

The main objective functions of the study are shown in following equations

$$\text{Min} \sum \text{NPC} \quad (1)$$

$$\text{Min} \sum \text{COE} \quad (2)$$

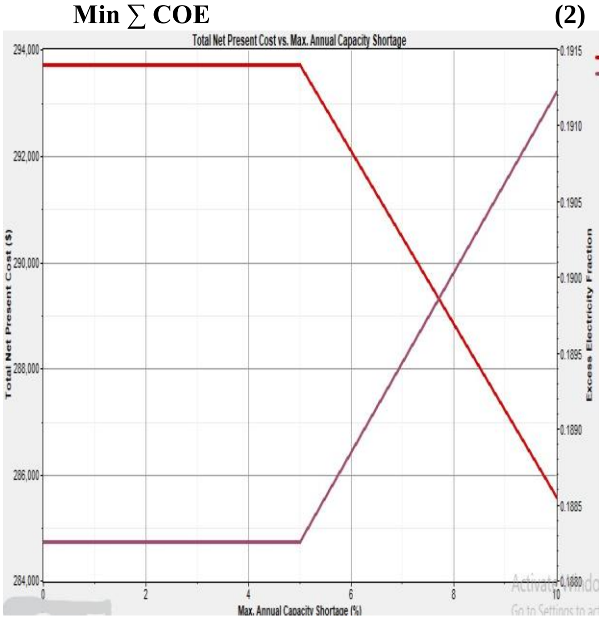


**Fig.4 Sensitivity analysis of maximum annual capacity shortage**

### III. SIMULATIONS RESULTS AND ANALYSIS

Simulation of the projected hybrid system is performed to get the optimized arrangement of resources from a number of potential combos. Study of the result is carried out in order to accomplish the ultimate objectives, which are given in the next section.

In this section, the techno-economic analysis and optimization results of Solar-Wind-DG hybrid system are obtainable and discussed.

The hybrid system described with Grid connection of 100kW is simulated for a particular geographic location of an institutional area.

The optimization results of the hybrid system according to variation with capacity shortage penalty are shown in figures 5, 6 & 7 respectively.

Sensitivity Results | Optimization Results

Sensitivity variables

Max. Annual Capacity Shortage (%) 0

Double click on a system below for simulation results.

Categorized

| PV (kW) | G1 | Label (kW) | S31SLDG | Conv. (kW) | Disp. Strgy | Grid (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Capacity Shortage | Diesel (L) | Label (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 160 | | | 40 | 120 | LF | 210 | $ 148,715 | 11,344 | $ 293,727 | 0.094 | 0.81 | 0.00 | | |
| 160 | | 40 | 40 | 120 | LF | 210 | $ 151,940 | 11,318 | $ 296,623 | 0.095 | 0.81 | 0.00 | 37 | 6 |
| 160 | 1 | | 40 | 120 | LF | 210 | $ 150,715 | 12,836 | $ 314,806 | 0.100 | 0.81 | 0.00 | | |
| 160 | 1 | 40 | 40 | 120 | LF | 210 | $ 153,940 | 12,811 | $ 317,702 | 0.101 | 0.81 | 0.00 | 37 | 6 |
| 190 | | | | 170 | CC | 210 | $ 172,085 | 13,003 | $ 338,310 | 0.108 | 0.81 | 0.00 | | |
| 190 | | 40 | | 170 | CC | 210 | $ 175,310 | 12,973 | $ 341,149 | 0.109 | 0.81 | 0.00 | 31 | 5 |
| 190 | 1 | | | 170 | CC | 210 | $ 174,085 | 14,493 | $ 359,358 | 0.115 | 0.81 | 0.00 | | |
| 190 | 1 | 40 | | 170 | CC | 210 | $ 177,310 | 14,463 | $ 362,196 | 0.116 | 0.81 | 0.00 | 31 | 5 |

**Fig.5 Optimization result for 0$/kWh capacity shortage penalty**

Sensitivity Results | Optimization Results

Sensitivity variables

Max. Annual Capacity Shortage (%) 5

Double click on a system below for simulation results.

Categorized

| PV (kW) | G1 | Label (kW) | S31SLDG | Conv. (kW) | Disp. Strgy | Grid (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Capacity Shortage | Diesel (L) | Label (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 160 | | | 40 | 120 | LF | 210 | $ 148,715 | 11,344 | $ 293,727 | 0.094 | 0.81 | 0.00 | | |
| 160 | | 40 | 40 | 120 | LF | 210 | $ 151,940 | 11,318 | $ 296,623 | 0.095 | 0.81 | 0.00 | 37 | 6 |
| 160 | 1 | | 40 | 120 | LF | 210 | $ 150,715 | 12,836 | $ 314,806 | 0.100 | 0.81 | 0.00 | | |
| 160 | 1 | 40 | 40 | 120 | LF | 210 | $ 153,940 | 12,811 | $ 317,702 | 0.101 | 0.81 | 0.00 | 37 | 6 |
| 190 | | | | 170 | CC | 210 | $ 172,085 | 13,003 | $ 338,310 | 0.108 | 0.81 | 0.00 | | |
| 190 | | 40 | | 170 | CC | 210 | $ 175,310 | 12,973 | $ 341,149 | 0.109 | 0.81 | 0.00 | 31 | 5 |
| 190 | 1 | | | 170 | CC | 210 | $ 174,085 | 14,493 | $ 359,358 | 0.115 | 0.81 | 0.00 | | |
| 190 | 1 | 40 | | 170 | CC | 210 | $ 177,310 | 14,463 | $ 362,196 | 0.116 | 0.81 | 0.00 | 31 | 5 |

**Fig.6 Optimization result for 5$/kWh capacity shortage penalty**

Sensitivity Results | Optimization Results

Sensitivity variables

Max. Annual Capacity Shortage (%) 10

Double click on a system below for simulation results.

Categorized

| | PV (kW) | G1 | Label (kW) | S31SLDG | Conv. (kW) | Disp. Strgy | Grid (kW) | Initial Capital | Operating Cost ($/yr) | Total NPC | COE ($/kWh) | Ren. Frac. | Capacity Shortage | Diesel (L) | Label (hrs) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 160 | | | 40 | 120 | LF | 100 | $ 148,715 | 10,707 | $ 285,589 | 0.093 | 0.82 | 0.08 | | |
| | 160 | | 40 | 40 | 120 | LF | 210 | $ 151,940 | 11,318 | $ 296,623 | 0.095 | 0.81 | 0.00 | 37 | 6 |
| | 160 | 1 | | 40 | 120 | LF | 100 | $ 150,715 | 12,201 | $ 306,681 | 0.100 | 0.82 | 0.08 | | |
| | 160 | 1 | 40 | 40 | 120 | LF | 210 | $ 153,940 | 12,811 | $ 317,702 | 0.101 | 0.81 | 0.00 | 37 | 6 |
| | 190 | | | | 170 | CC | 210 | $ 172,085 | 13,003 | $ 338,310 | 0.108 | 0.81 | 0.00 | | |
| | 190 | | 40 | | 170 | CC | 210 | $ 175,310 | 12,973 | $ 341,149 | 0.109 | 0.81 | 0.00 | 31 | 5 |
| | 190 | 1 | | | 170 | CC | 210 | $ 174,085 | 14,493 | $ 359,358 | 0.115 | 0.81 | 0.00 | | |
| | 190 | 1 | 40 | | 170 | CC | 210 | $ 177,310 | 14,463 | $ 362,196 | 0.116 | 0.81 | 0.00 | 31 | 5 |

**Fig.7 Optimization result for 10$/kWh capacity shortage penalty**

Table 5 Comparison of different results obtained

| S. No. | Capacity Shortage Penalty ($/kWh) | Total Net Present Cost ($) | Cost of Electricity ($/kWh) | Best Combination |
|---|---|---|---|---|
| **1** | **0** | **293,727 (Rs 1,87,98,528)** | **0.094 (Rs.6.016)** | **Grid- PV-battery** |
| **2** | **5** | **293, 727 (Rs 1,87,98,528)** | **0.094 (Rs.6.016)** | **Grid- PV-battery** |
| **3** | **10** | **285,589 (Rs 1,82,77,696)** | **0.093 (Rs.5.952)** | **Grid- PV-battery** |

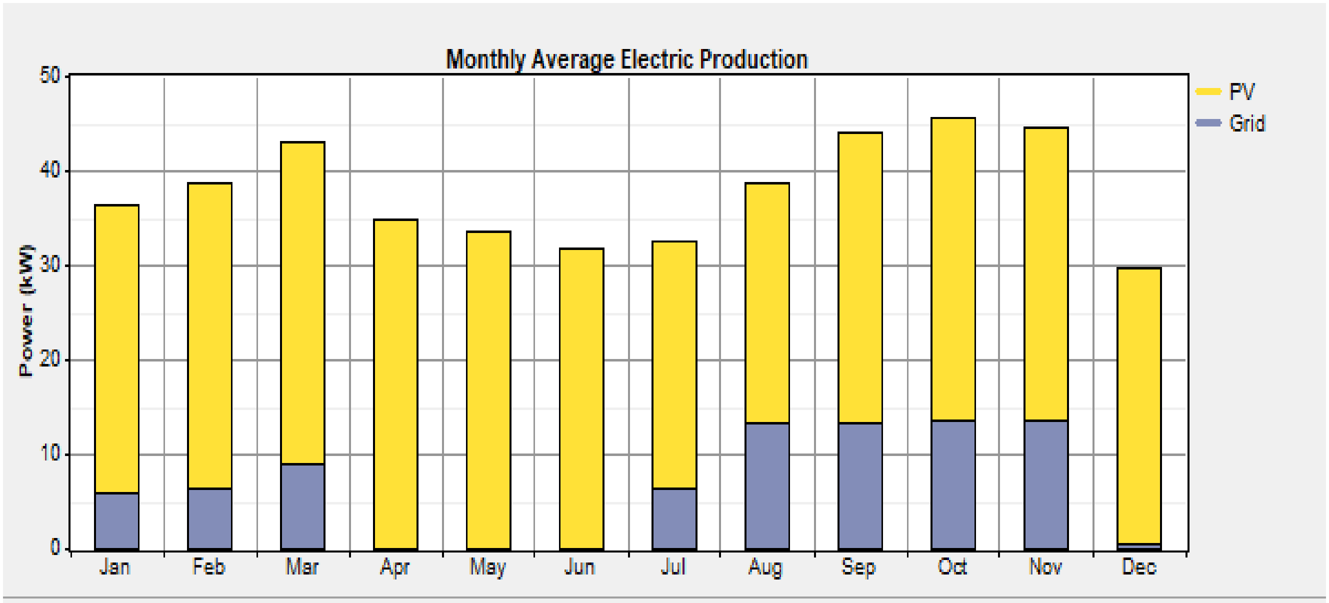


**Fig.8 Monthly average electricity production by best optimized Grid connected hybrid system**

## IV. CONCLUSIONS AND FUTURE SCOPE

The Grid connected system shows the meaningful and optimal result among all combinations in terms of NPC and COE generated by simulation model of Grid connected solar-wind-diesel System is the Grid connected PV system. NPC and COE of optimal combination are found to be $285,589 (Rs 1,82,77,696) & $0.093/kWh (Rs.5.952) respectively. The application of Grid connected solar-wind-diesel System saved average total electricity bill of $2255.549 / month (INR 152136.845/ month) and

$.0179/ month (INR1.211 / Unit).

The optimized results shows that on considering a grid connected system hybrid with SPV-Wind- DG, for 10 $/kWh capacity shortage penalty, the COE of system decreases from $0.094/kWh (Rs.6.016) to 0.093/kWh (Rs.5.592) also NPC decreases from $293,727 (Rs 1,87,98,528) to $285,589 (Rs 1,82,77,696) and operating cost also decreases from $11,344 to 10,707.

The option of diesel generator could also be studied with designed system for reliability improvement. In comparison with the existing system, the cost of optimum wind solar hybrid system is slightly lesser and system is more reliable.

From here in the upcoming endeavor this study can be extended by including the biomass / diesel generator as one more renewable source of power in the hybrid system. By doing this, reliability of the system will further increase for remote and inaccessible locations.

## REFERENCES

1. D. P. Kaundinya, P. Balachandra, and N. H. Ravindranath, "Grid-connected versus stand-alone energy systems for decentralized power-A review of literature," Renew. Sustain. Energy Rev., vol. 13, no. 8, pp. 2041–2050, 2009.
2. S. C. Bhattacharyya, "Review of alternative methodologies for analysing off-grid electricity supply," Renew. Sustain. Energy Rev., vol. 16, no. 1, pp. 677–694, 2012. Renew. Sustain. Energy Rev., vol. 16, no. 7, pp. 5379–5390, 2012.
3. Kanase-Patil AB, Saini RP, Sharma MP. Integrated renewable energy systems for off-grid rural electrification of remote area. Renewable Energy 2009; 35(6):1342–9.
4. Bhattacharyya S. Energy access problem of the poor in India: is rural electrification a remedy? Energy Policy 2006; 3418:3387–97.
5. Ashok S. Optimised model for community-based hybrid energy system. Renewable Energy 2007; 32(7):1155-64.
6. Ramakumar R, Shetty PS, Ashenayi K. A linear programming approach to the design of integrated renewable energy systems for developing countries. IEEE Transactions on Energy Conversion 1986; 194:18–24.
7. http://sukam-solar.com/wp-content/uploads/Su-Kam-Data-Sheet-for-Solar-Panels-Poly-Rev-02Nov2016.pdf
8. http://docs.exideindustries.com/pdf/industrial-batteries/NDP-Tubular-Range.pdf

## AUTHORS PROFILE

**Mr. Devendra Kumar Doda** has completed B.E. in Electrical Engineering from University of Rajasthan, Jaipur, Rajasthan in 2004 and M.Tech. in Power Engineering from Punjab Technical University, Jalandhar, Punjab in 2008. Now he is doing Ph. D. in Electrical Engineering from Poornima University, Jaipur, Rajasthan. His focus areas are Renewable Energy, Decentralized Power Generation and Power System Engineering. He has more than 14 years teaching experience in various engineering institutes and taught different courses such as Power System Engineering, Non-Conventional Energy Resources, Power System Planning, EHV AC/DC Transmission, FACTS Devices and Their Control, Control System Engineering and Modern Control System.

Dr. Amit Shrivastava is a Professor of Electrical Engineering. He received B.E., M.E. in Electrical Engineering from from Madhav Institute of Technology & Science Gwalior and Ph.D. in Electrical Engineering from Technical University of M.P. RGPV Bhopal. He has more than 18 year of teaching and administrative experience. He has published and presented many papers in international journals and conferences. He is life time member of institution of engineers india and iste. His research interests are in condition monitoring of electrical machines and photovoltaic system.

**Dr. Mahesh Bundele** is working as Director and Principal, School of Engineering and Technology, Poornima College of Engineering, Jaipur, Rajasthan, India. He has completed his Ph. D. degree in wearable computing in computer science stream from Sant Gadge Baba Amravati University, Maharashtra. He has more than 30 years experience of teaching of different courses (more than 45 courses) in various institutes across the India. He is associated with various technical committees such as IEEE, ISTE, Member of STDCOM Tech. & Prof. Activities. He is a Member Execom, IEEE Delhi Section and Former Secretary, IEEE Rajasthan Subsection. His focus areas are Renewable Energy, Decentralized Power Generation, and Smart Grid Technologies.