Sensitivity Analysis of PV-Diesel Hybrid System using HOMER

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Abstract -- The energy needs of humanity are enlarging at an exponential level and it is advisable to use renewable sources of energy more. Distributed generation using hybrid systems is one of the new trends in power generation. These distributed generating units are integrated to form a micro grid to serve the loads among the locality. Hybrid Renewable Systems with Diesel generator and Solar panels are capable for providing sufficient amount of electricity. The major challenge in designing hybrid system is the optimization of the various sources involved in hybrid systems. This project gives a model of a micro grid with sensitivity analysis of Solar Panel, Diesel Generator, Converter, Load and Battery using HOMER software. This model gives the design idea of various Sensitivity parameters such as lifetime of different components, state of a battery charging, etc. of a proposed system for a residential load.

Index Terms – Sensitivity Analysis, HOMER (Hybrid Optimization Model for Electric Renewables), Solar PV, Hybrid System, Micro grid.

I. INTRODUCTION

Microgrids are mostly low-voltage (LV) distribution networks that may use any combination of generation, load and storage technologies and can operate in grid connected mode or autonomous mode [1]. The distributed generation (DGs) or the storage systems in the microgrid can be of different technologies, depending on the system characteristics and expectations. Some examples are solar panels (PV), wind turbines (WG), small hydro, biomass power generation, fuel cells, batteries or supercapacitors. These technologies have lower emission and potential to have lower cost [5]. The analysis and the design of the microgrid do not only take under consideration the system requirements but also some uncertain factors such as the load variation, the fuel price or fuel sufficiency [1].

This paper gives the analysis of a various parameters such as Lifetime of PV Module, Minimum State of Charge of a Battery, Lifetime of PV MPPT, Battery Annual Throughput in kWh, Lifetime of Battery, Maximum State of Charge of a Battery, etc. By comparing various results, it is easy to find the most optimum and cost effective parameters for proposed system.

II. INTRODUCTION TO HOMER OPTIMIZER

HOMER (Hybrid Optimization Models for Energy Resources) is a power optimization software developed by NREL (National Renewable Energy Laboratory) in the United States. This software is used to design and evaluate technically and financially the options for off-grid and on-grid power systems. It allows consideration of a large number of technology options to account for energy resource availability and other variables.

HOMER performs three principal tasks:

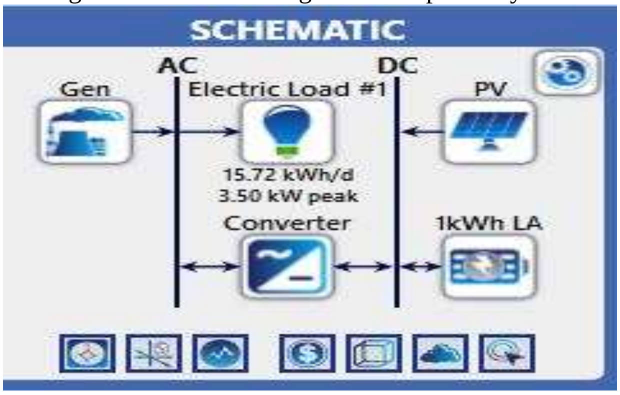
- Simulation,
- Optimization, and
- Sensitivity analysis [15].

In the simulation process, HOMER models the performance of a particular micro power system configuration each hour of the year to determine its technical feasibility and life cycle cost. In the optimization process, HOMER simulates many different system configurations in search of the one that satisfies the technical constraints at the lowest life-cycle cost. In the sensitivity analysis process, HOMER performs multiple optimizations under a range of input assumptions to gauge the effects of uncertainty or changes in the model inputs.

Optimization determines the optimal value of the variables over which the system designer has control such as the mix of components that make up the system and the size or quantity of each. Sensitivity analysis helps assess the effects of uncertainty or changes in the variables over which the designer has no control, such as the average wind speed or the future fuel price [16]. HOMER calculates the following four costs for every simulation result; COE (Cost of Energy), NPC (Net Present Cost), O&M (Operations and Maintenance Cost), Initial Capital Cost.

III. SYSTEM UNDER CONSIDERATION

Figure 1 Schematic Diagram of Proposed System



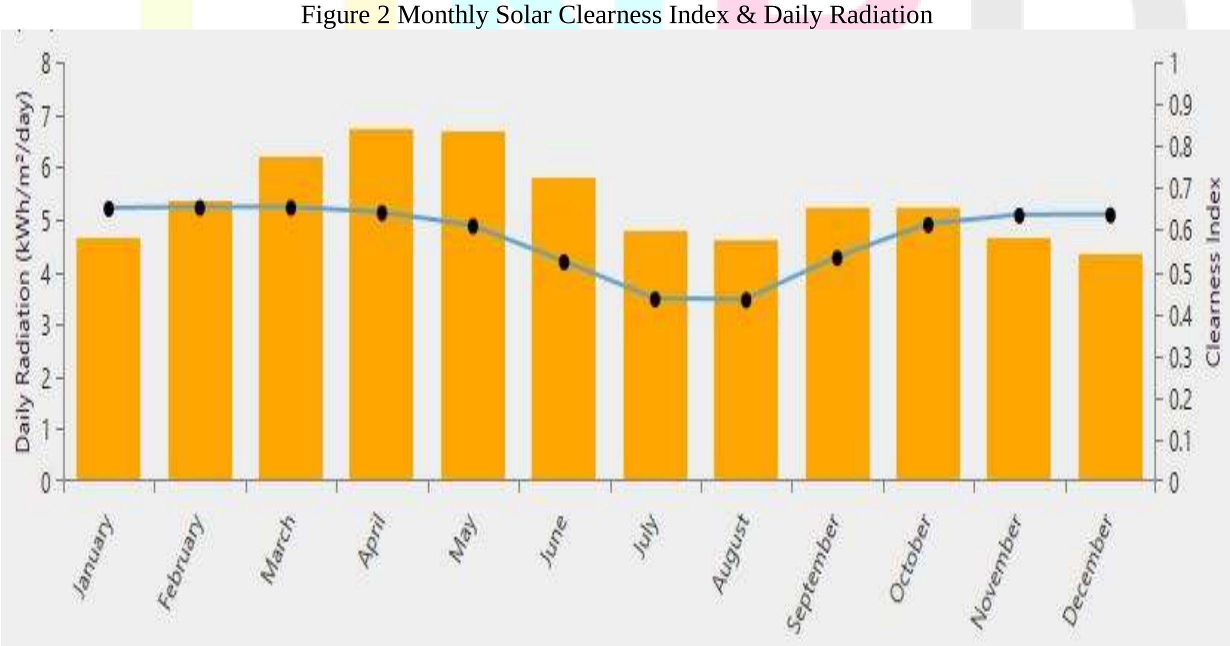
In the Figure 1, Schematic diagram of a proposed system is shown. The Hybrid system consisting of Solar PV Panel, Diesel Generator, Lead Acid Battery, System Converter and an Electric Load is taken under consideration. The system parameters of a proposed system is shown in following Table 1.

Table 1 System Parameters of a proposed system

Input Parameter	**PV Module**	**PV-MPPT**	**Converter**	**Li-Ion Battery**	**Diesel Generator**
Size(kW)	1	1	1	-	1
Capital Cost (Rs)	40,000	10,000	24,000	2,400	60,000
Replacement Cost (Rs)	2,400	8,000	20,000	2,000	52,000
O & M Cost (Rs/yr)	5,000	1,000	1,000	500	2,400
Lifetime(year)	25	15	15	4	20
Initial SOC (%)	-	-	-	80	-
Minimum SOC (%)	-	-	-	20	-
Operating Voltage (V)	144 V DC (36 V *4 in series)	144 V DC	230 V single phase output for inverter	12 V	230 V single Phase
Maximum Capacity(Ah)	-	-	-	150 Ah	-
Maximum Charge Current(A)	-	-	-	16.7	-
Maximum Discharge Current(A)	-	-	-	24.3	-

For the proposed system, the Solar GHI (Global Horizontal Irradiance) data is required and is obtained from NASA (National Aero Space Agency) Solar Energy Database. Monthly Solar Clearness Index & Daily Radiation is shown in the following Figure 2.

Figure 2 Monthly Solar Clearness Index & Daily Radiation



IV. RESULT ANALYSIS

In this system, we considered residential load and lifetime of whole project is assumed 25 years. Optimization process are carried out through every possible selection of variables in this hybrid power system considering different sensitivity variables which are as follow:

- Lifetime of – PV Module, PV MPPT, Battery,
- Minimum State of Charge of a Battery,
- Maximum State of Charge of a Battery,
- Battery Annual Throughput in kWh etc.

Figure 3 Screenshot of Electricity Production and Consumption. According to Figure 4, total yearly production of our proposed model is 13,686 kWh/yr and consumption for residential load 5,734 kWh/yr. The minimum COE obtained from the result is Rs. 2.99/kWh. The NPC for the system is Rs. 2, 21,873. Emissions of a proposed system are shown in Figure 5.

Figure 3 Screenshot of Electricity Production and Consumption

Production	kWh/yr	%
Generic flat plate PV	13,686	100
Total	13,686	100

Consumption	kWh/yr	%
AC Primary Load	5,734	100
DC Primary Load	0	0
Total	5,734	100

Table 2 gives the result analysis of various sensitivity cases. The Optimum result can be obtained from the bold highlighted parameters in Table 2.

Table 2: Sensitivity Analysis result of a various cases taken under consideration

Sr. No	PV Life-time (Yr)	MPPT Life-time (Yr)	1 kWh LA Life-time (Yr)	1 kWh Throughput (kWh)	Min. SOC (%)	Max. SOC (%)	COE (Rs)	NPC (Rs)	Initial Capital (Rs)	O & M (Rs)	Elect. Prod. (kWh/yr)
1	**25**,30	**15**,20	4, **3**	800	40	100	3.26	2,41,933	1,77,482	1,693	6,807
2	**25**,30	**15**,20	4, **3**	800, **1000**	40,**30**	100	3.25	2,40,779	1,77,609	1,674	6,879
3	**25**,30	**15**,20	4, **3**	1000	30	80	3.25	2,40,780	1,77,609	1,674	6,880
4	**25**,30	**15**,20	4, **3**	**1000**, 1200	30	90	3.25	2,40,779	1,77,609	1,674	6,879
5	25	15	3	900, **1000**	**25**,30	**85**,90	3.21	2,38,203	1,70,556	3,728	14,789
6	25	15	3	**1000**,1100	25	85	3.21	2,38,203	1,70,556	3,728	14,789
7	25	15	3	800,900,**1000**	25	85,**80**	3.21	2,38,203	1,70,556	3,728	14,789
8	25	15	3	**1000**, 1200	**20**,25	**80**,85	3.13	2,32,246	1,70,125	3,448	14,935
9	25	15	**2.5**, 3	1000	**30**,35	**80**,85	3.25	2,41,065	1,67,544	1,752	7,003
10	25	15	2, **2.5**, 3	1000	**20**,25	**75**,80	3.19	2,36,381	1,70,321	3,447	14,958
11	25	15	2, **2.5**, 3	1000	20,**15**	80,**75**	3.11	2,30,327	1,64,589	3,422	14,677
12	25	15,**10**	**2.5**, 2	1000	20,**15**	75,**70**	3.11	2,30,537	1,64,589	3,422	14,677
13	25	15,**10**	**2.5**, 2	1000	15,**10**	**65**,70	**2.99**	**2,21,873**	1,50,801	3,635	13,686
14	**20**,25	**10**,15	**2.5**, 3	1000	15,**10**	65,**60**	3.00	2,22,085	1,50,801	3,635	13,686
15	**20**,25	**10**,15	2,**2.5**,3	1000	**10**,15,20	**60**,70, 80	3.00	2,22,085	1,50,801	3,635	13,686

Figure 4 Screenshot of Optimized Result of a proposed system

Export...

Optimization Results

Left Double Click on a particular system to see its detailed Simulation Results.

Architecture					Cost				System			
PV (kW)	PV-MPPT (kW)	Gen (kW)	1kWh LA	Converter (kW)	COE (₹)	NPC (₹)	Initial capital (₹)	O&M (₹)	Elec Prod (kWh/yr)	Elec Cons (kWh/yr)	Excess Elec (%)	Excess Elec (kWh/yr)
10.2	5.00		40	4.08	₹2.99	₹2,21,873	₹1,50,801	₹3,635	13,686	5,734	51.0	6,982
		3.90	8	1.73	₹3.26	₹2,41,653	₹1,67,467	₹1,769	7,011	5,738	0.218	15.3
0.193	5.00	3.90	8	1.76	₹3.29	₹2,44,060	₹1,70,444	₹1,796	6,979	5,738	0.539	37.6
		3.90			₹4.23	₹3,13,441	₹1,56,000	₹3,416	9,798	5,738	41.4	4,060

Figure 5 Screenshot of Emissions of a proposed system

Quantity	Value	Units
Carbon Dioxide	0	kg/yr
Carbon Monoxide	0	kg/yr
Unburned Hydrocarbons	0	kg/yr
Particulate Matter	0	kg/yr
Sulfur Dioxide	0	kg/yr
Nitrogen Oxides	0	kg/yr

Table 3 Optimized Parameters for proposed system

PV Life-time (Yr)	25
MPPT Life-time (Yr)	10
1 kWh LA Battery Life-time (Yr)	2.5
1 kWh Battery Throughput (kWh)	1000
Min. SOC of LA Battery (%)	10
Max. SOC of LA Battery (%)	65

V. CONCLUSION

This paper represents the analysis of a Hybrid proposed system with consideration of the various sensitivity parameters. Optimization of these sensitivity parameters is carried out in the proposed hybrid model. The basic optimization parameters are NPC and COE. The simulation results show that the lowest Net Present Cost (NPC) and the lowest Cost Of Energy (COE) is for Solar PV alone with MPPT implemented which are 2,21,873 Rs./kWh and 2.99 Rs./kWh. The emissions in the optimized system is Zero. Here grid cost is not taken into account as our proposed system is stand-alone system. Table 3 Shows the Optimized Parameters for proposed system.

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VII. REFERENCES

[1] D. I. Papaioannou, C. N. Papadimitriou, A. L. Dimeas, E. I. Zountouridou, G. C. Kiokes and N. D. Hatziargyriou, "Optimization & Sensitivity Analysis of Microgrids using HOMER software- A Case Study", IEEE-2014

[2] Satya Prakash Makhija, Dr. S P Dubey, "Analysis of effects on hybrid power system's costs and pollutant emissions due to replacement of petroleum diesel with natural gas, fuel oil and biodiesel", 2016 3rd International Conference on Electrical Energy Systems,978 -1-4673-8262-5/16/$31.00 @ 2016 IEEE

[3] Temitope Adefarati, Ramesh C. Bansal, Jackson John Justo, "Techno-economic analysis of a PV-Wind-battery-diesel standalone power system in a remote area", The 6th International Conference on Renewable Power Generation (RPG), J. Eng., 2017, doi:10.1049/joe.2017.0429, Vol. 2017, Iss. 13, pp. 740–744.

[4] Jatrifa Jiwa Gandhi, Suyanto, Ni Ketut, Ontoseno Penangsang, Adi Soeprijanto, "Life-Cycle Cost Analysis of Laboratory Scale Micro-grid Operation in Power System Simulation Laboratory Using HOMER Simulation", 2016 International Seminar on Intelligent Technology and Its Application, 978-1-5090-1709-6/16/$31.00 ©2016 IEEE

[5] Bindu U Kansara and B.R. Parekh, "Modelling and Simulation of Distributed Generation System Using HOMER Software", 2011 International Conference on Recent Advancements in Electrical, Electronics and Control Engineering, 978-1-4577-2149-6/11/$26.00 © 2011 IEEE

[6] A. A. Hossam-Eldin, Karim H. Youssef, Hossam Kotb, "Technical and Economic Optimization of Reverse Osmosis Desalination Systems Integrated with PV/Wind Energy Resources: A Case Study", 2017 Nineteenth International Middle East Power Systems Conference (MEPCON), Menoufia University, Egypt, 978-1-5386-0990-3/17/$31.00 ©2017 IEEE

[7] Solar Irradiance data from NASA surface meteorology and Solar Energy Database, https://eosweb.larc.nasa.gov/sse/.

[8] Shantu Ghose, Adel El Shahat, Rami J. Haddad, "Wind-Solar Hybrid Power System Cost Analysis using HOMER for Statesboro, Georgia", 978-1-5386-1539-3/17/$3l.00 ©2017 IEEE

[9] HOMER Pro Help

[10] A. Jamalaiah, Dr. C.H. Padmanabhu raju, Dr. R. Srinivasarao, "Optimization and operation of a renewable energy based pv-fc micro grid using HOMER", International Conference on Inventive Communication and Computational Technologies (ICCICT 2017), 978-1-5090-5297-4/17/$31.00 @ 2017 IEEE

[11] Getting started guide for HOMER

[12] Y. V. Pavan Kumar and Ravikumar Bhimasingu," Optimal Sizing of Microgrid for an Urban Community Building in South India using HOMER", 2014 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), 978-1-4799-6373-7/14/$31.00 ©2014 IEEE

[13] S. K. Saraswat, K.V.S. Rao, "Comparison of Various Off-Grid Power System Models for a 10 kW Load at Jaipur in Rajasthan", Innovative Applications of Computational Intelligence on Power, Energy and Controls with their Impact on Humidity (CIPECH-16), 978-1-4673-9080-4/17/$31.00 @ 2016 IEEE

[14] Fahad Iqbal and Anwar Shahzad Siddiqui, “Optimal Configuration Analysis for a Campus Microgrid - A Case Study”, Protection and Control of Modern Power Systems (2017), DOI 10.1186/s41601-017-0055-z
[15] Prema V. and Uma Rao K., “Sizing of Microgrids for Indian Systems using HOMER”, 1st IEEE International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES-2016)
[16] Koutroulis, E., Kolokotsa, D., Potirakis A. & Kalaitzakis, K., "Methodology for optimal sizing of stand-alone photovoltaic/wind generator systems using genetic algorithms", Solar Energy, Vol. SO, No. 9, 2006, pp.I072-IOSS.