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Techno-Economic Sizing and Optimization of Microgrid; A Case Study of A Higher Education Institution

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***Abstract* — Renewable energy is the need for today's world being a cleaner and readily available source of energy. The supply side management is required for efficient provision of best suitable for alternative energy option. This paper is focused on life cycle cost, optimal design and sensitivity analysis of the microgrid. For the modeling HOMER software is used for microgrid optimization. the model has NPC of $15.40, Operation cost of $216.167 per year, Initial cost is $$3.06, the COE is $0.055 per unit. This is achieved by the sizing of 1.826 MW of PV and 6 MW of wind turbines. The model has tendency to generate 4.25% excess electrical energy. The renewable fraction is 63% of the microgrid which is at least but it also surges to 64% when favorable condition of solar radiation and wind speed is available.**

***Index Terms*— HOMER, Microgrid, Optimization, Sensitivity analysis**

I. INTRODUCTION

Energy demand is increasing globally so to meet it conventional energy resources are used which are depleting at very alarming rate but also the main cause of global warming. Pakistan is currently seeking to meet the country's energy demand. The capacity of Pakistan is 37402 MW in 2020 while the demand remain 25 thousands MW but the country's capacity of transmission and distribution is 22000 MW.

The energy resources are distributed in nature. The combing all the resources which could be in the form of wind turbines, solar panels, diesel generators or other energy sources can form a concept of Microgrid (MG).[1]

These combination of supply energies are varied in nature. There is need to optimize each among the different sources of energy or the different combination of configuration. The HOMER software use different configuration strategies for loading. For the comparison the benchmark used is life cycle cost based upon it the optimization is considered. Following are the possible variables upon which the decision is taken:[2, 3]

PV Arrays.
Wind turbines.
Batteries (if considered)
Grid Supply (if considered)
AC-DC converters.

II. METHODLOGY

The model is created by NREL (National Renewable Energy Laboratory) in the country of US. It simulates the optimized model of different configurations from the data of load and system constraints[4].[5]

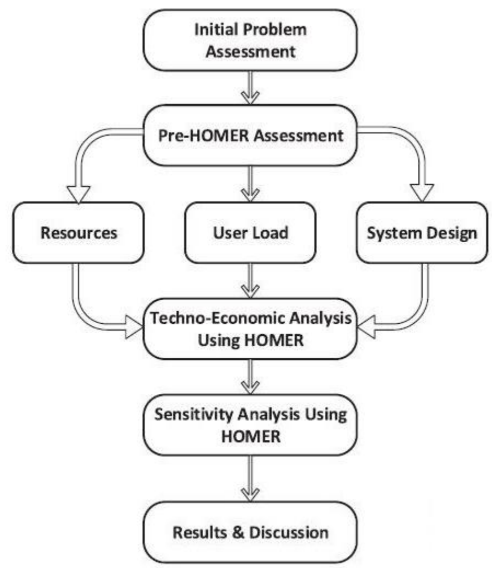

Fig. 1. A Schematic diagram indicating methodology

HOMER is used for designing on-grid and off-grid systems, and it also facilitates in comparing different distributed generation technologies[6]. HOMER software can be used to compare different hybrid systems based on their economic and technical advantages. HOMER performed three major tasks simulation, optimization, and sensitivity analysis[7]. In the simulation process, energy balance calculations are performed by HOMER software for each system configuration. HOMER then finds the optimal and feasible system configuration. In the optimization process, HOMER simulates all possible system configurations and sorts them out based on NPC[8].

III. MODELING AND SIMULATION

A. Load Profile

The case study area is an education institution which operates in only day time when sunlight is present. The load of the case study area was calculated with 4.7 MW as peak load and energy consumer per day is 17.529 MWh.

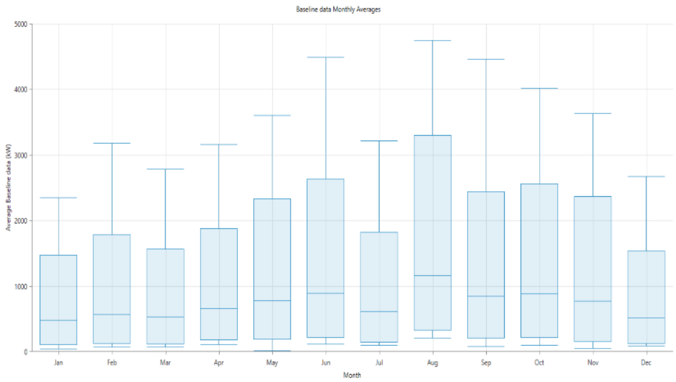

Fig. 2. Seasonal Load Profile of MUET, Jamshoro

The figure represent the load of institution with monthly values. It can be seen that in hotter months the consumption is increased but it remain lowered in winter months.

B. Solar Irradiance

The case study area is located at 68 15.6′E longitudes and 25 24.5′N latitudes which is obtained by NREL (National Renewable Laboratory Database). The unit of measurement for solar irradiance is m2/day with a value of 5.54kWh energy. The annual representation of solar irradiance is depicted in figure below.

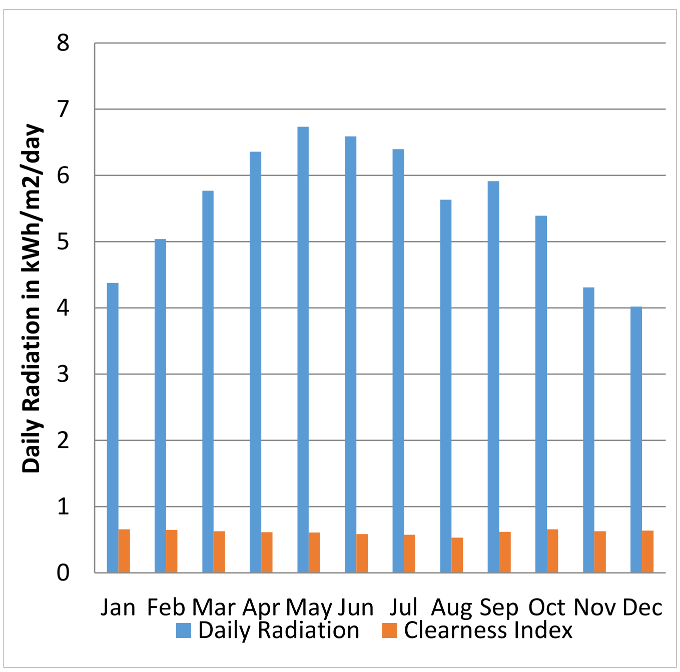

Fig. 3. Solar Irradiance Data of Jamshoro

The area has good clearness index except in August month due to very dusty winds.

C. Wind Speed

Pakistan meteorological department has evaluated the wind speed for the area as 8.5 m/s maximum value and the average value is 7.28m,/s.[9]

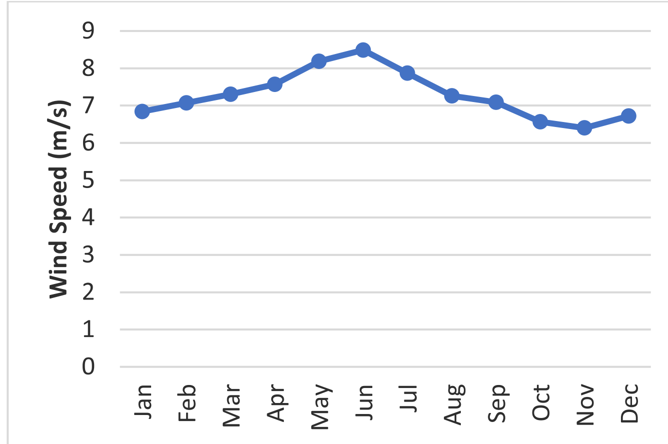

Fig. 4. Wind Profile of MUET Jamshoro

In the month of June the wind speed is higher in comparison to the other months and it remains almost constant in the other months.

IV. Results and Discussion

A. Optimization

This optimization is done by HOMER software. In this model multiple possible outputs is generated from possible optimized values based on NPC. It has generated four possible outcomes with different energy generation or supply equipment[10]. In this first scenario there is usage of PV, Wind turbine, Converters and grid connection with their optimized output values for best overcoming the NPC. It is calculated that PV used will approximately 1.8MW and 6MW from wind turbines while the rest of energy if demanded will be supplied by the national grid.

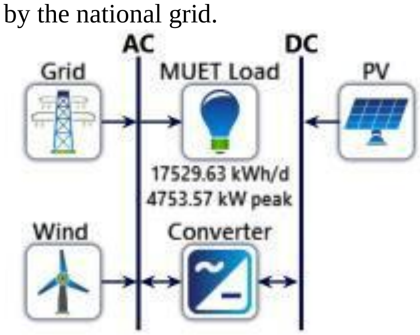

Fig. 5. HOMER Model.

Since the model is designed for renewable based so the renewable fraction used is 63% the other 37% energy will be consumed from national grid. However, since the institution is closed in night time so the energy produced from the wind turbine will be consumed by the national grid.

PV (kW)	Wind	Grid (kW)	Convertor (kW)	Dispatch	NPC ($)	COE ($)	Operating cost ($/yr)	Initial capital ($)	Ren Frac (%)	Elec Prod (kWh/yr)	Elec Cons (kWh/yr)	Excess Elec (%)	Energy Purchased (kWh)	Energy Sold (kWh)
1,826	6	999,999	966	LF	$5.40M	$0.0628	$216,167	$3.06M	63.0	8,511,795	7,946,918	4.25	2,944,042	1,548,603
	6	999,999		LF	$6.22M	$0.0818	$472,667	$1.11M	32.8	7,032,174	7,032,174	0	4,727,424	633,858
3,438		999,999	1,760	LF	$6.31M	$0.0734	$248,024	$3.63M	62.9	9,090,261	7,943,994	8.47	2,946,789	1,545,679
		999,999		LF	$7.89M	$0.114	$729,408	$0.00	0	6,398,315	6,398,315	0	6,398,315	0

Fig. 6. Optimization Results of Hybrid System

The total NPC for the project is $15.42 with operational cost of $216,167 annually. The electrical energy consumed will 7946918 kWh/yr.

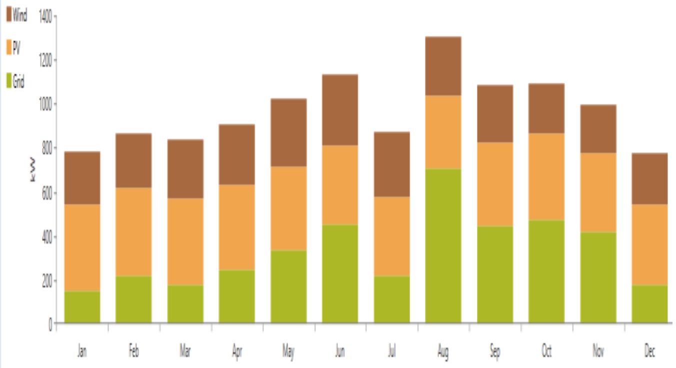

Fig. 7. Monthly Electricity Generated from PV-grid System

This figure shows the energy produced from each source i.e. PV, wind, and National Grid. The peak amount of energy is consumed in the month of August since the mostly load is Air conditioners because of summer season. The least energy supplied is observed in the months of January and December due to winter season.

B. *Sensitivity Analysis*

According to the optimization models, the optimized model contains the four sources i.e. PV, Wind, National grid, and converters. The intensity of wind and solar radiation changed throughout the year and also in every hour value of the whole year. Each resource has its own COE. The total COE is depended upon the COE of each source. When the wind or solar radiation changes with respect to time the COE also changed[11].

Sensitivity		Architecture						Cost	System
Solar Scaled Average (kWh/m²/day)	Wind Scaled Average (m/s)		PV (kW)	Wind	Grid (kW)	Convertor (kW)	Dispatch	COE ($)	Ren Frac (%)
5.54	7.28		1,826	6	999,999	966	LF	$0.0628	63.0
5.54	8.50		1,461	6	999,999	743	LF	$0.0579	61.4
5.54	8.00		1,653	6	999,999	851	LF	$0.0594	62.8
6.74	7.28		1,680	6	999,999	932	LF	$0.0601	63.6
6.74	8.50		1,461	6	999,999	817	LF	$0.0550	64.3

Fig. 8. Sensitivity Analysis

1. *Cost of Energy:*

The sensitivity analysis is simulated when wind speed or solar radiation changed to extreme ends. The solar radiation value when changes from 5 units to 6 units the COE becomes $0.055. in the same scenario when the wind speed changes from 7 units to 8.50 units the COE also decreases to $0.055.

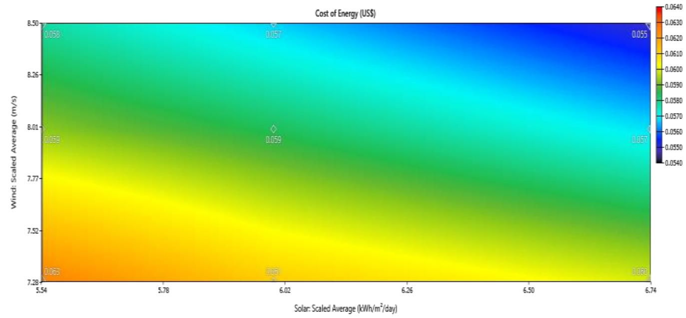

Fig. 9. Sensitivity Analysis Cost of Energy

2. *Renewable Fraction:*

As illustrated in the fig. AA the sensitivity analysis of the wind and solar magnitude's effect upon the cost of energy. Since these two sources are the renewable so there is increase or decrease in the magnitude has the directly effect upon the renewable fraction in the microgrid [12].

TABLE I: Renewable fraction sensitivity analysis

S.No	Solar Scale Average (kW/m2/day)	Wind scaled Average (m/s)	Ren. Fraction (%)
1	5.54	7.28	63
2	5.54	8.5	61.4
3	5.54	8.6	62.8
4	6.74	7.28	63.6
5	6.74	8.5	64.3

When the solar radiation is changed from 5.54 to 6.74 units the renewable fraction is increased from 63% to 64.3%. also, in the case of wind speed when it is changed from 7.28 to 8.5 units the renewable fraction is changed from 63% to 64.3.

V. CONCLUSION

This paper performs techno-economic evaluation of microgrid for an higher education institution with sizing and optimization of renewable energy sources. The system analyzed was through HOMER with optimization based upon NPC. The COE calculated is $0.055 and NPC is $5.40M. The renewable fraction used by the microgrid is 63% to 64.3%.

VI. ACKNOWLEDGMENT

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