Potential of Different Grid Connected Hybrid System based on Cost

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***Abstract*–Renewable electric energy resources have been considered one of the most promising energy alternatives. This paper proposes economic cost analysis and comparison of hybrid distributed power system consist of various combination of photovoltaic, wind turbine, grid and battery for deterministic criteria in probabilistic approach for provides system operating information related to health, margin and risk state of the system. Simulation result based on energy economic optimized system and their comparison for cost and probabilistic criteria are PV-grid type, Wind-grid type, PV-Wind hybrid system and PV-Wind-battery-grid hybrid system. By using HOMER optimization model all grid connected system are studied. The hybrid system is connected to grid and simulate with or without battery. The grid plays the important role of backup power component in the hybrid system, when the renewable energy resources are not enough to meet the load. The complexity due to random variables inherent in renewable sources so here grid is acts as a back up for the system and makes it healthier.**

Keywords*–*Renewable electric energy resources; hybrid distributed power system;* optimized system; cost analysis; *HOMER.

I. INTRODUCTION

This paper explores the importance of minimizing the cost of energy for renewable hybrid energy system. The comparative economic analysis on a distributed generated power systems for maximize output and perform an hourly simulation of every possible combination of components entered and rank the systems according to user specified criteria, such as cost of energy (COE) or capital costs, Initial capital(IC), Net present cost (NPC) and Operating cost(OC).For the proposed hybrid system, the meteorological data of Solar radiation and wind speed is taken for Mumbai located in Maharashtra with longitude of 19˚17 N and latitude of 72˚8 E and the pattern of load consumption are studied and modeled for optimization of the hybrid energy system. The wind and solar energy are ever present, freely available and eco-friendly[17]. The wind energy may not be technically viable at all sites because of low wind speeds and being more unpredictable than solar energy[18], but wind energy technology is rapidly growing and has lowest cost per KW among other renewable sources[3,14]. The design of a wind/PV/Battery/Grid hybrid power generation system is complex because of the randomness of renewable energy sources (RES), load demand, uncertainty and non-linear characteristics[2]. With new technologies like smart grid this will allows distribution generation of renewable energies more feasible than before[12].

II. DISTRIBUTED POWER SYSTEM

Hybrid distributed generation play an active role of minimum losses, maximum efficiency, improve the system stability, reliability and economically feasibility [15]. To maximize these benefits, reliable hybrid Distributed generation units have to be connected at proper locations with proper size. Distributed generation is defined as a integrated or standalone utilization of small, modular electric generation near end user terminal[10].Distributed generation can be defined as the concept of connecting generating units of small sizes, between several KW to a few MW [9]. Renewable energy can be used in two ways: first for specific areas far from grid (standalone), second for areas connected to grid to provide part of total energy [8].The greatest challenge in realizing a sustainable future is to develop technology for integration and control on RES [12].

A. Micro hybrid distributed system

The electrical system of a micro hybrid plants is composed by three elements: the hybrid power plant, the loads, and the low voltage grid converter.

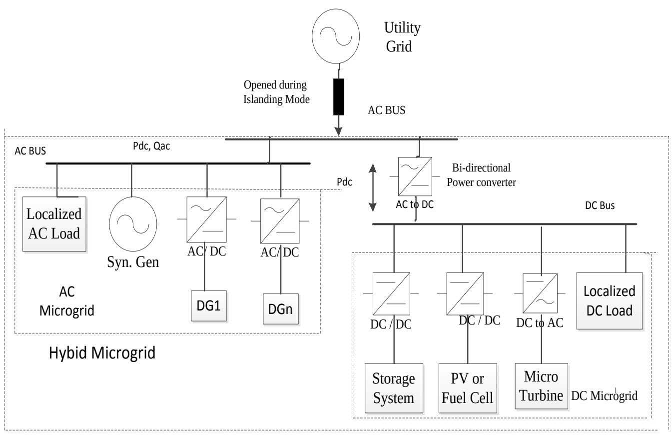


Figure. 1. Hybrid ac/dc microgrid

Usually the loads are concentrated in a small area, not bigger than a medium rural village, and the hybrid power plant is located as near as possible to the loads, so the low voltage grid has usually a reduced extension and presents a very simple radial structure. The renewable energy sources are one of the most suitable solution to provide electricity in the rural areas[11]. In general, hybrid power system can be categorized into AC hybrid power system (ACHPS) & DC hybrid power system (DCHPS). For mobile application typical DCHPS are used as isolated power solution with no grid connection[16]. A hybrid ac/dc microgrid is regarded as a small scale power generation , distribution & consumption system with the presence of ac/dc buses, distributed generation unit,energy storage system, and ac /dc load [6] as shown in figure. 1.

III. HYBRID SYSTEM COMPONENT

A. Potntial Of solar and wind energy

With the chosen longitude & lattitude, the data for solar & wind are collected. PV solar monthly clearness index, daily radiation data(kwh/m^2/day) and wind average speed m/s is shown in table I.

TableI.

	Solar Energy Radiation Data		Wind Speed Data
Month	Clearness Index	Daily Radiation (kwh/m^2/day)	Average(m/s)
Jan	0.700	5.320	3.840
Feb	0.730	6.250	4.660
Mar	0.727	7.050	5.100
Apr	0.701	7.380	5.620
May	0.673	7.330	5.670
June	0.516	5.640	5.640
Jul	0.460	5.000	6.460
Aug	0.483	5.120	5.840
Sept	0.569	5.650	4.050
Oct	0.645	5.720	3.480
Nov	0.691	5.380	3.410
Dec	0.688	5.000	3.450

The resources indicates the amount of global solar radiation that strikes earth's surface. Solar radiation for this study area is obtained from the NASA surface meterology and solar energy website[4]. An average solar radiation of 5.9kwh/m^2/d and clearness index of 0.631is obtained. The clearness index is expressed by the fraction of the solar radiation that is transmitted through atmosphere to strike the surfaceof earth[5].

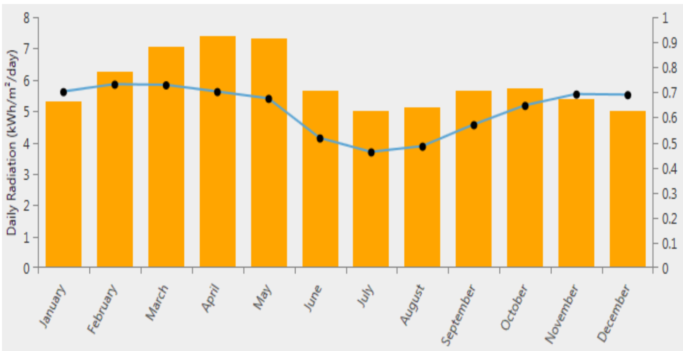


Figure. 2. Monthly Solar radiation

Wind also varies seasonally the average wind speed of the respective area is 4.77 m/s and the monthly wind speed variation shown in fig. 2.

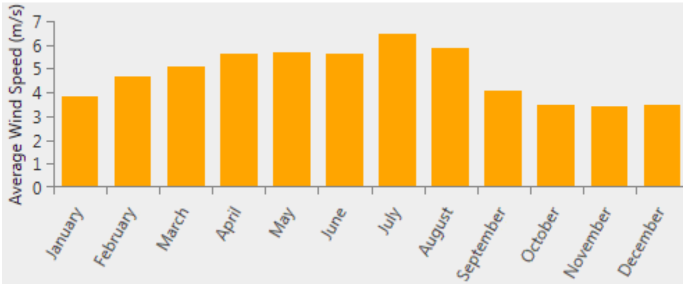


Figure. 3. Monthly wind speed data

B. Battery

The Lead Acid battery used for this system having 25 numbers in each string of 12V, so bus voltage is 300V. The strings are in parallel is 50, so the capacity of battery is 1250 kwh

C. Grid

The grid of 40 MW is an auxillairy source whereby it act as a backup to the renewable energy system. The grid also acts like a storage system when renewable energy system produces excess energy. There is a grid power price which is the price of electricity bought from the grid and the price of electricity sold to grid is known as feed-in-tariff (FiT) [7].

D. Load

Load is varied with seasonal and monthly consumption depending on climate. The AC load taken as 400 kwh/day and DC load is 100 kwh/day. Monthly AC and DC load profile shown in fig. 4 and 5.

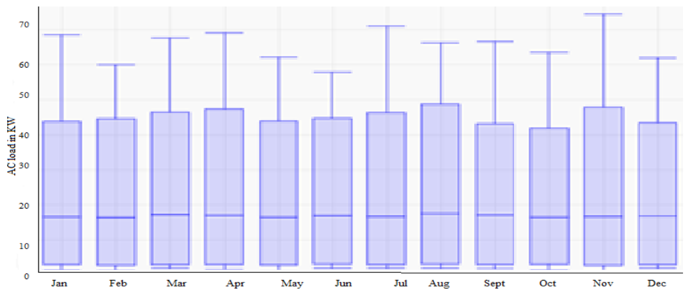


Figure. 4. Monthly AC load profile

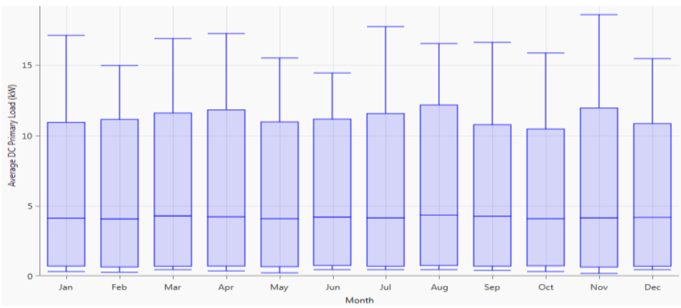


Figure. 5. Monthly DC load profile

IV. Optimal System Configuration

A. PV-Grid system

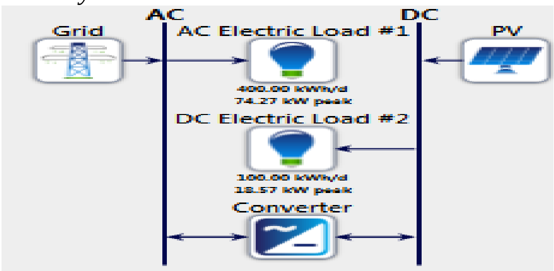


Figure. 6. Layout of PV-Grid hybrid system

B. WT-Grid system

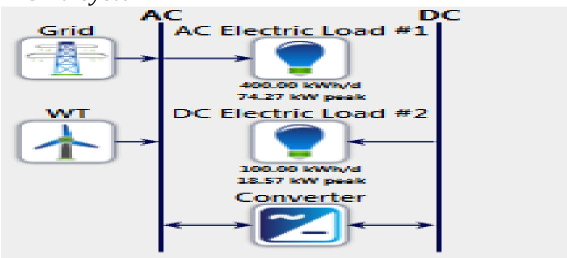


Figure. 7. Layout of WT-Grid hybrid system

C. PV-WT-Grid system

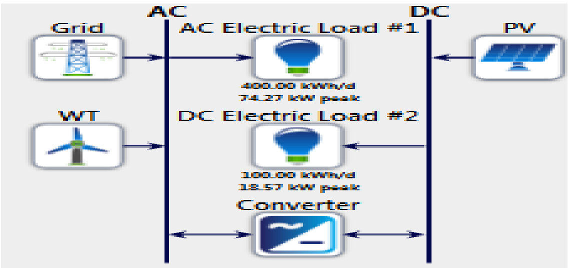


Figure. 8. Layout of PV-WT-Grid hybrid system

D. PV-WT-Battery-Grid System

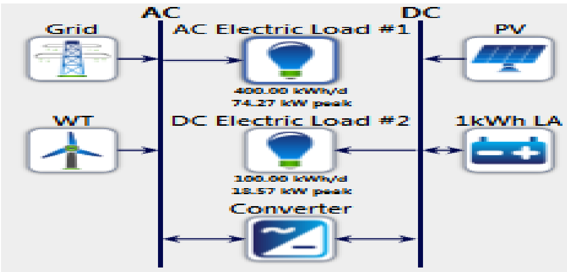


Figure. 9. Layout of PV-WT-Grid- Battery hybrid system

The different layout of hybrid power system shown in fig. 6,7, 8 and 9 uses the component of following ratings are shown in table II.

Table II.
Configuration of different hybrid system

Case	System Configuration
Case A	PV(120KW)+Grid(40MW)
Case B	WT(140*3)+Grid(40 MW)
Case C	PV(120KW)+WT(140*3+Grid(40 MW)
Case D	PV+WT+Battery(1250KWH)+Grid(40 MW)

E. Optimal dispatch strategy

Optimal dispatch strategy of hybrid energy system is to find the most economical schedule for different combination of renewable generators with grid, satisfying load balance, resource availability and equipment costrant.

$$\Delta P = [(P_s \times N_s) + (P_W \times N_W)] - Load\ demand \quad (1)$$

Where ΔP is the total power generated by hybrid system, N_s and N_w are the total number of solar PV panel and wind turbine respectively, and P_s and P_w are corresponding power generated. If the renewable energy excess after meeting the demand then no grid connection is required, if load exceed the renewable energy output then grid connection required for fulfill demand [2].

if ΔP > 0, No grid connecttion required.
if ΔP < 0, Grid Connection required.

Operational impact of high penetrations of solar and wind power needed to be considered, the model of PV and wind having variation in their outputs with the help of proper selected storage device the mismatch between supply and demand can be managed[1].The renewable fraction is the portion of the system's total energy production originating from renewable power sources. This can be calculated by dividing the total annual renewable power production by the total energy production. As its value increases the system become more and more renewable energy dependent.

V. Probability Concepts

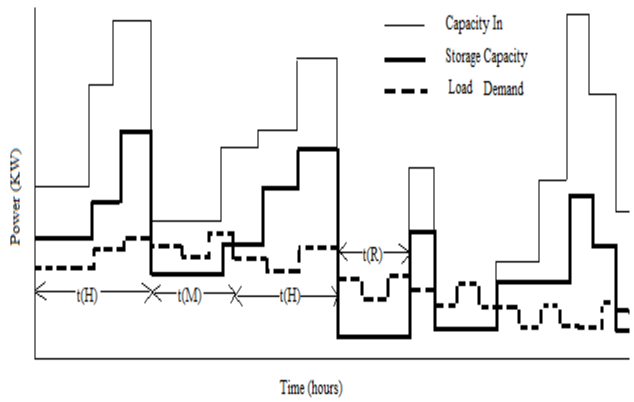
For maintaining the system health and economy up to the mark, the following criteria of probability must be satisfy. The probabilistic concepts can be created through the definition of the system operating states in terms of Healthy, Marginal and at Risk states. A system operates in the healthy state when it has enough storage capacity to meet a criterion such as the loss of the largest unit. The system is not in any difficulty but does not have sufficient margin or storage capacity to meet the specified load criterion then it is marginal state and when the system load exceeds the available source capacity then system is at risk state. The probabilities for finding the system in the healthy, marginal and at risk states respectively.

$$\text{Probability of health } P(H) = \frac{\sum_{i=1}^{n(H)} t(H)_i}{N \times Years\ in\ hours} \quad (2)$$

$$\text{Probability of Marginal } P(M) = \frac{\sum_{i=1}^{n(M)} t(M)_i}{N \times Years\ in\ hours} \quad (3)$$

$$\text{Probability of risk} = \frac{\sum_{i=1}^{n(R)} t(R)_i}{N \times Years\ in\ hours} \quad (4)$$

Where n(H), n(M) and n(R) is total number of healthy, marginal and risk state and their duration t(H), t(M) and t(R) respectively. N is the total numbers of years [19, 20]. Here an example of generation and load model for indicating how many time the system is in health, marginal and risk state.



The PV- Grid (case A) system can be a cost-effective option but the PV has supplied 62% energy to the load and grid supply 38%. During night whole system is supplied and depend on grid. So this is not reliable and feasible, if grid has any discontinuty then probability of risk state always there.

The WT- Grid system (case B), WT has supplied 70% energyand grid supply 30% energy to load, but this system highly depend on atmospheric condition so all the time grid is require as a back up. So maintenance cost, operating cost is increases and this system always have probabity of risk state.

The PV-WT-Grid combination (case C) has supplied 87% energy by PV and WT combinationand grid supply only 13% to the load with increased reliability, feasibility and decreased cost of O&M, COE and OC as compared to other system. If grid has lost its connection or grid power failure then this system comes in the category of probability of marginal state otherwise this system always have probability of healthy state.

The PV-WT-Grid and battery (case D) has supplid 87% energyby PV and WT combination and storage supply only 13% to the load to the load and due to the presence of battery and grid backup make this system more reliable and costlier amongst all type of system. This system always has the probability of healthy state.

VI. COST ANALYSIS

A detail of the cost analysis of each system is presented in table III.

Table III.
Cost Analysis

Case	COE ($)	NPC ($)	OC ($)	IC ($)	O&M ($)	Ren. Fraction
Case A	0.09	369683.9	749.1	360000	749.1	62%
Case B	0.74	3502774	54362.6	2800000	24226	70%
Case C	0.57	3757009	46181.2	3160000	16044	87%
Case D	0.69	4579975	80833.3	4579975	28544	87%

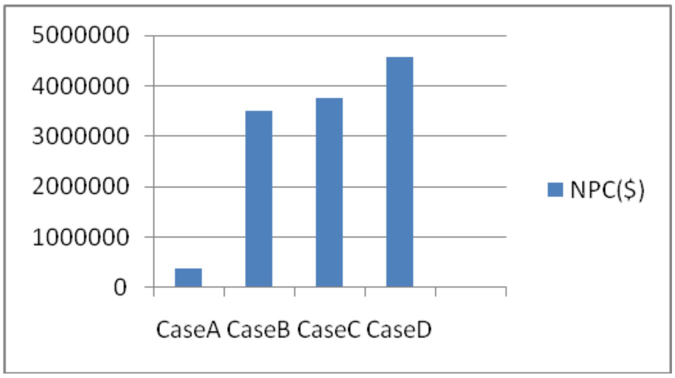


Figure 12. Comparision of net present cost for various system

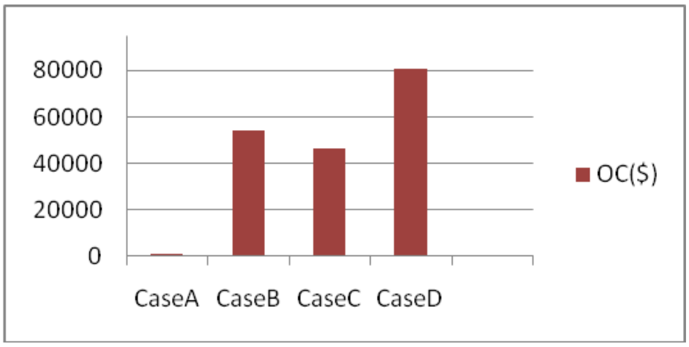


Figure. 13. Comparision of operating cost for various system

In all five cases oerating cost of case c is lower and good choice for operation as shown in figure. 13 & 14.

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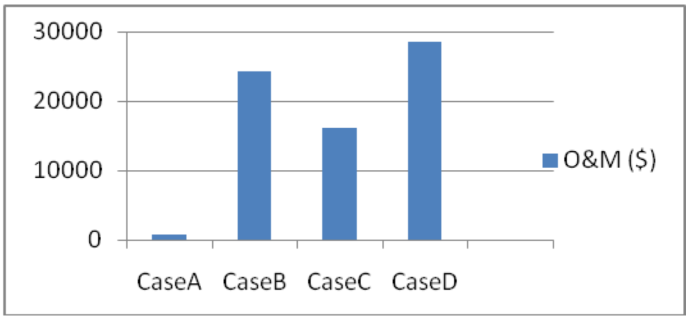

Figure. 14. Comparision of operating& maintenance cost for various system

This is the operating & maintenance cost and cost of electricity for case c, which is again least among all type of system shown in figure. 14

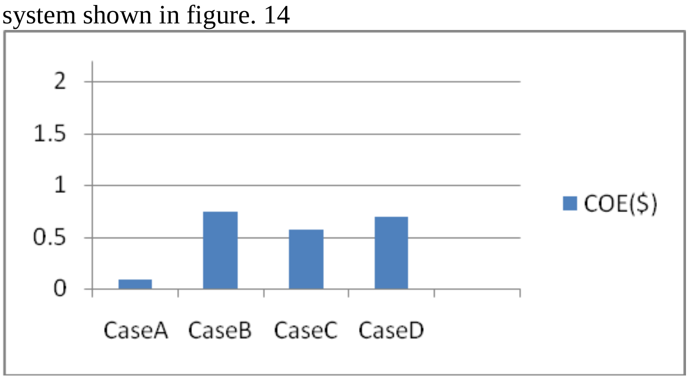

Figure 12. Comparision of cost of electricity for various system

Fig.15 illustrates the increase in system health with increase in renewable energy penetration. Addition of Renewable fraction makes system costlier in all way.

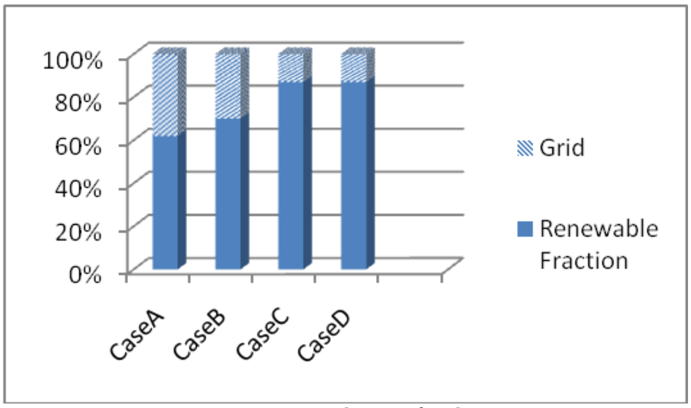

Figure. 15. Percentage contibution of each component

VII. CONCLUSION

The conventional energy sources are much superior to renewable energy sources in terms of system reliability. As the load increase, size of RES is also increases, grid side demand is reduces and cost of the system is increase. The increase in fuel savings with increasing renewable energy penetration is not the stable solution. Maximum benefit in utilizing renewable energy can be achieved by injecting an appropriate mix of energy sources in order to generate a power output profile that closely matches the load profile. The study suggests that adding only renewable energy to meet load growth may not be able to provide the desired reliability and system health. It is very important to obtain reliable atmospheric data for a system location since realistic reliability and cost analysis strongly depend on the validity of the available data. The probabilistic states criteria of the system useful in designing practical hybrid power system. The simulation and optimization result give the best optimized system runs economically. The economically best hybrid system solution have discussed that satisfies the electrical power requirement for considered location.

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