RESEARCH ARTICLE OPEN ACCESS

PV-solar / Wind Hybrid Energy System for GSM/CDMA Type Mobile Telephony Base Station

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Abstract
This paper presents the design of optimized PV-Solar and Wind Hybrid Energy System for GSM/CDMA type mobile base station over conventional diesel generator for a particular site in south India (Chennai). For this hybrid system ,the meteorological data of Solar Insolation, hourly wind speed, are taken for Chennai (Longitude 80^{o}.16'and Latitude 13^{o}.5') and the pattern of load consumption of mobile base station are studied and suitably modeled for optimization of the hybrid energy system using HOMER software. The simulation and optimization result gives the best optimized sizing of wind turbine and solar array with diesel generator for particular GSM/CDMA type mobile telephony base station. This system is more cost effective and environmental friendly over the conventional diesel generator. The presented system reduce approximate 70%-80% fuel cost over conventional diesel generator and also reduced the emission of CO_2 and other harmful gasses in environments. It is expected that the proposed developed and installed system will provide very good opportunities for telecom sector in near future.
KEYWORDS: Hybrid Energy Systems, Mobile Telephony base station, Optimization, PV-solar, Wind Turbine

I. INTRODUCTION

Obtaining reliable and cost effective power solutions for the worldwide expansion of telecommunications into rural and remote areas presents a very challenging problem. Grids are either not available or their extensions can be extremely costly in remote area. Although initial costs are low, powering these sites with generators require significant maintenance, high fuel consumption and delivery costs due to hike in fuel prices.

A sustainable alternative to power remote base station sites is to use renewable energy sources. Recent research and development of Renewable energy sources [1] have shown excellent potential as a form of contribution to conventional power generation systems. In order to meet sustained load demands of mobile base station during varying natural conditions, different energy sources and converters need to be integrated with each other for extended usage of alternative energy For Indian remote location, one of the most alternative solution [2] of renewable energy sources such as wind-solar Hybrid Energy System for mobile base station. The use of the stand-alone solar-wind with diesel backup system for the power supply of remote areas may give an economically attractive alternative [3] for mobile telecom sector over the use of conventional diesel generators in near future. This paper illustrate the design of wind, solar photovoltaic hybrid energy system. Based on the energy consumption of mobile base station and the availability of renewable energy sources, it was decided to implement an innovative standalone Hybrid Energy System [4] combining small wind turbine-generator, solar photo-voltaic panels, battery storage, advance power electronic equipment and existing diesel generators. The system architecture employed in the hybrid system is AC coupled where the renewable energy sources [5] and the conventional diesel generators [6] all feed into the AC side of the network as shown in Figure1.

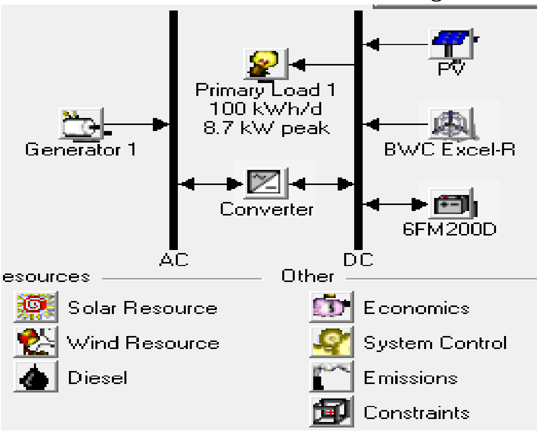

Fig. 1. Proposed Hybrid renewable energy

National Renewable Energy Laboratory (NREL)'s, Hybrid Optimization Model for Electric Renewable (HOMER version 2.19) [14] has been used as the sizing and optimization software tool [10]. It contains a number of energy component models and evaluates suitable technology options based on cost and availability of resources. In this paper, the system sizing [7-9] is carried out using HOMER-optimization and simulation software tool. Analysis with HOMER requires information on resources, economic constraints, and control methods. It also requires inputs on component types, their numbers, costs, efficiency, longevity, etc. Sensitivity analysis could be done with variables having a range of values instead of a specific number.

II. RENEWABLE ENERGY RESOURCES FOR HYBRID SYSTEM

The availability of renewable energy resources at mobile base station sites is an important factor to develop the hybrid system. Many parts of the India wind and solar energy is abundantly available [11]. These energy sources are intermittent and naturally available, due to these factor our first choice to power the mobile base station will be renewable energy sources such as wind and solar. Weather data are important factor for pre- feasibility study [12-13] of renewable hybrid energy system for any particular site. Here the Wind and Solar energy resources data are taken from NASA [15] for Chennai-Central India (Longitude 80°.16'and Latitude 13°.5') and shown in Table 1. In south India wind speed is an average and sun brightness is good.

Month	Insolation (kWh/m2)	Wind Velocity m/s
January	4.309	4.870
February	5.558	4.460
March	5.773	4.450
April	6.192	4.490
May	5.673	4.860
June	4.878	5.520
July	4.882	5.300
August	4.794	5.240
September	4.998	3.830
October	4.564	3.560
November	4.061	4.560
December	3.892	5.280
Average	4.958	4.507
Maximum	6.192	5.520
Minimum	3.892	3.560

Table 1: Solar and Wind Resources

IIA Solar Energy Resources

Hourly solar irradiation data for the year was collected from Environment Chennai. Scaling was done on these data to consider the long-term average annual resource (4.958kWh/m^2/d). The clearness index for the latitude and Average daily radiation in a year is shown in Figure 2 (i). According to solar radiation, PV-power output are available throughout the year is shown in Figure 2 (ii). In summer, solar power is higher than winter season. In rainy season clearness index and solar power availability is lower than summer and winter season.

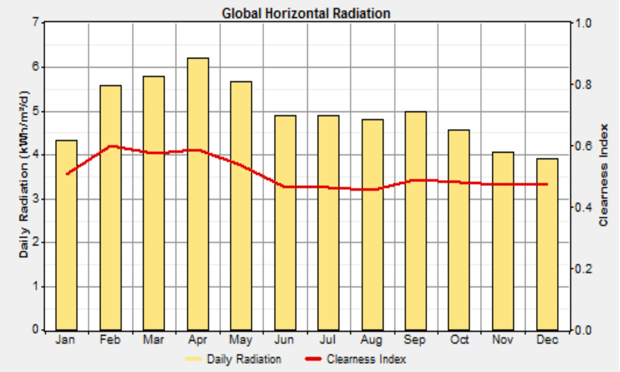

Fig.2 (i) Average monthly radiation

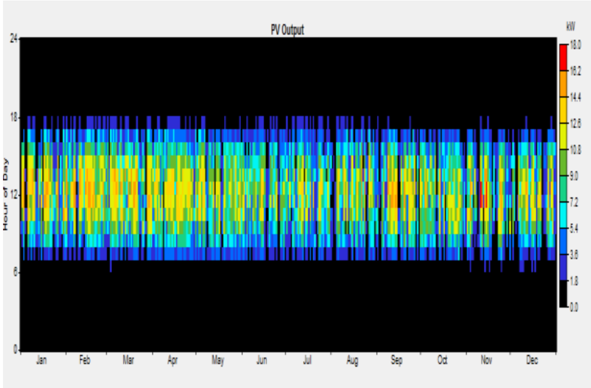

Fig.2 (ii) PV Power output available throughout the year

IIB Wind energy resource

A monthly average wind dataset for Chennai were collected from Environment Chennai climate. This is an average of last ten year and indicates that annual average wind speed as shown in Figure 3. From the above given data, wind speed probability function and average hourly wind speed throughout the year is shown in Figure 3. The autocorrelation factor (randomness in wind speed) is found to be 0.85. The diurnal pattern strength (wind speed variation over a day) is 0.25 and the hours of peak wind speed is 15. Average wind speed in the summer season is slightly higher than the winter season as shown in Figure 3. The power output throughout the year according to wind speed is shown in Figure 3.

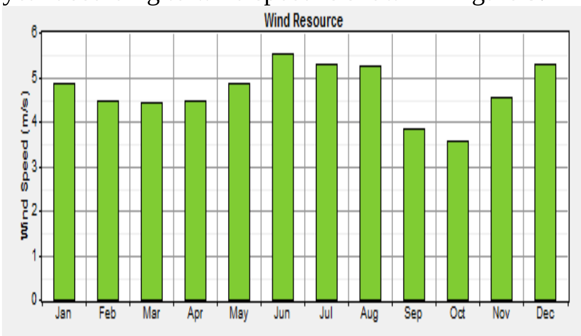

Fig.3 Average monthly wind speed

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III. LOAD PATTERN FOR MOBILE TELEPHONY BASE STATION

Cellular telephone service is a rapidly expanding and very competitive business world over including developed and developing countries like India, America, European countries etc. Right now there are 55,000 different type base stations for telecom sector in India and most of them running on diesel generators. But diesel generators are often expensive to run and more than one diesel generator are installed for uninterrupted service. The different types of telecom base station are used according to the technological advancement in telecommunication sector. Recently the GSM 2/2/2 (2nd Generation Global System Mobile telephony base station) are used in all over the world. For pre-feasibility study of designing the solar wind hybrid system considered the 2nd Generation GSM base station. In this present study consider the power requirements for GSM telephony base station site are about 4.16 kW continuous. The load demand is approximate 100kWh/d and 8.7 kW peak.

IV. HYBRID SYSTEM COMPONENTS

The proposed hybrid system consists of the following:

IVA 7.5 kW Wind turbine

Three 7.5kW horizontal-axes, BWC-EXCEL-R/48 type [14] wind electric generators are taken for this system. It converts wind energy into electrical energy. Availability of energy from the wind turbine depends greatly on wind variations. Therefore, wind turbine rating is generally much higher compared to the average electrical load. In this analysis, Wind Power's BWCExcel-R/48 model is considered. It has a rated capacity of 7.5 kW and provides 48 V DC. As outputs Cost of two unit is considered to be $17000 while replacement and maintenance costs are taken as $13000 and $80/year. The cost analysis is shown in Figure 4 (ii). The power curves of wind turbine are shown in Figure 4 (i). To allow the simulation program find an optimum solution, lifetime of a turbine is taken to be 20 years.

IVB A 5 kW Photovoltaic array

Solar PV modules are connected in series parallel. When the sunrays strike the Solar PV panels, it produces electricity. The Solar PV power at the site is higher than the wind power. The installation cost of PV arrays may vary from $5.00 to $8.00/W considering a more optimistic case [1]. A 1 kW solar energy system's installation, and replacement costs are taken approximate as $5000 and $3000, respectively (Figure 5). The lifetime of the PV arrays are taken as 20 years and no tracking system is included in the PV.

IVC Battery bank

A battery bank is used as a backup system and it also maintains constant voltage across the load. The battery pack consists of 8(6), 48V, 305Ah, 1.83kWh batteries connected in series / parallel configuration, two parallel sets of 8 batteries in series. Cost of one battery is $520 with a replacement cost of $370 (Figure 6). The battery stack may contain a number of batteries are 8, and 16.

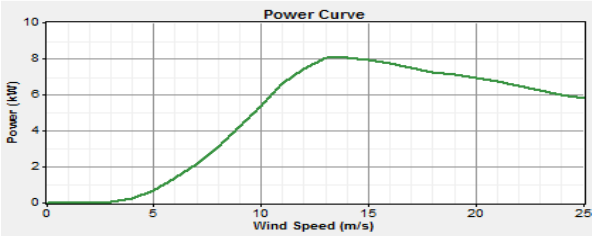

Fig. 4(i): Variation of power with wind speed

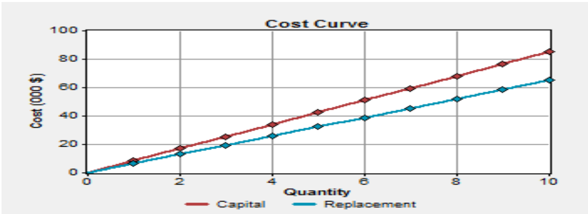

Fig. 4(ii): Capital and replacement cost of 7.5BWC-Excel R/48 wind turbine

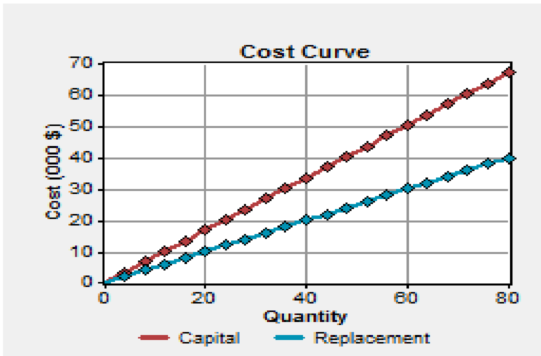

Figure 5. Cost curve of PV.

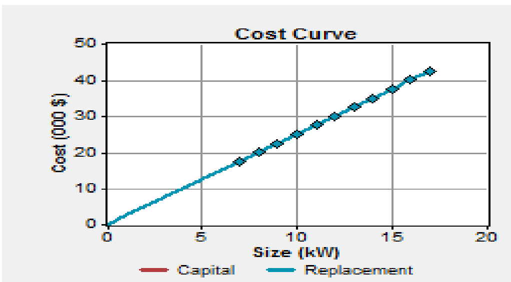

Figure 6 .Cost curve of battery

IVD Converter

A power electronic converter is needed to maintain flow of energy between the ac and dc components. For a 1 kW system the installation and replacement costs are taken as $720 and $460, respectively. Cost analysis shown in Figure 7. Lifetime of a unit is considered to be 15 years with an efficiency of 90%. Consider for this hybrid system 6kW converter.

IVE Diesel generator

The fuel consumption per year is approximate 1300 Litter for 1kW Diesel Generator. The 1 kW diesel generator capital cost, replacement cost, operation-maintenance cost are 400$, 300$, 0.75$. The Diesel price is used for sensitivity analysis and three discrete values (0.8, 0.85, and 0.9 $/L) were introduced. At present, diesel price is around 0.85$/L and for a very remote location this could increase up to 0.9$/L. Sizes to be consider for obtaining optimal hybrid system are 2kW and 5kW .This analysis shown in Figure 8.

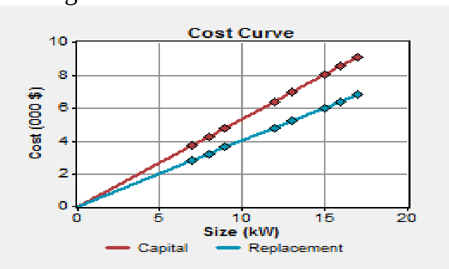

Figure 7. Cost curve of diesel generator.

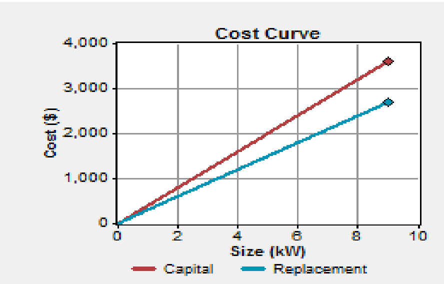

Figure 8. Cost curve of converter

V. RESULTS AND DISCUSSION

The above proposed hybrid system supply the power to the mobile telephony base station continuously throughout the year. For the analysis of this hybrid system four sensitivity variables are considered (wind speed, solar irradiation, fuel cost and Battery cost). An hourly time series simulation for every possible system type and configuration is done for a 1-year period. An optimal system is defined as a solution for hybrid system configuration that is capable of meeting the load demand of telephony base station.

VA. Optimization results

From the simulation result the installation of wind solar hybrid system configuration for various locations are most suitable power solutions for telecom base station network in Indian sites. Considering present cost analysis of a PV/Wind hybrid system is suitable for stand-alone loads around Chennai. From the optimization results the best optimal combination of energy system components are two 7.5kW BWC-Excel-R/48, 2 kW PV-Array and 2 kW diesel Generator. Total net present cost (NPC), Capital cost and cost of energy (COE) for such a system is $207,538, $53,440 and 0.942$/kWh, respectively for one year. The detailed optimization results are shown in fig. 9

Sensitivity Results | Optimization Results

Double click on a system below for simulation results.

PV (kW)	XLR	dg (kW)	6FM20...	Conv. (kW)	Initial Capital	Operating Cost ($/yr)	Total NPC	COE ($/kW...	Ren. Frac.	Capacity Shorta..	Diesel (L)	dg (hrs)
17	3		68		$ 125,052	9,089	$ 352,279	0.418	1.00	0.10		
17	4		48		$ 116,772	9,531	$ 355,042	0.419	1.00	0.09		
17	3		72		$ 128,408	9,095	$ 355,791	0.421	1.00	0.09		
16	4		52		$ 117,628	9,547	$ 356,309	0.421	1.00	0.09		
15	4		56		$ 118,484	9,524	$ 356,575	0.422	1.00	0.10		
17	5		40		$ 118,560	9,549	$ 357,287	0.423	1.00	0.10		
17	3		76		$ 131,764	9,096	$ 359,155	0.423	1.00	0.09		
15	5		44		$ 116,916	9,698	$ 359,364	0.426	1.00	0.10		
14	4		64		$ 122,696	9,486	$ 359,840	0.427	1.00	0.10		
17	4		52		$ 120,128	9,607	$ 360,296	0.422	1.00	0.08		
15	4		60		$ 121,840	9,559	$ 360,815	0.425	1.00	0.09		
16	4		56		$ 120,984	9,598	$ 360,946	0.423	1.00	0.08		
17	3		80		$ 135,120	9,093	$ 362,442	0.425	1.00	0.08		
16	5		44		$ 119,416	9,731	$ 362,690	0.426	1.00	0.09		
14	5		48		$ 117,772	9,801	$ 362,787	0.429	1.00	0.09		
14	4		68		$ 126,052	9,503	$ 363,621	0.429	1.00	0.09		
15	6		40		$ 122,060	9,695	$ 364,435	0.433	1.00	0.10		
13	4		76		$ 130,264	9,374	$ 364,604	0.433	1.00	0.10		
15	4		64		$ 125,196	9,581	$ 364,712	0.428	1.00	0.08		
13	5		52		$ 118,628	9,846	$ 364,770	0.432	1.00	0.10		
17	4		56		$ 123,484	9,655	$ 364,853	0.424	1.00	0.07		
16	4		60		$ 124,340	9,629	$ 365,077	0.426	1.00	0.08		
17	5		44		$ 121,916	9,754	$ 365,773	0.427	1.00	0.08		
15	5		48		$ 120,272	9,835	$ 366,150	0.429	1.00	0.08		
14	4		72		$ 129,408	9,508	$ 367,107	0.432	1.00	0.09		

Table 2: Detailed optimization result

VB Simulation results

In this simulation results eliminates all infeasible combinations and ranks the feasible systems according to increasing net present cost. It also allows a number of parameters to be displayed against the sensitivity variables for identifying an optimal system type. The Monthly Average Electricity Production of Hybrid Energy System for mobile telephony base station is shown in Figure 10. In this system the total production of electrical energy is fulfil the load demand by the combination of 13% PV, 56%wind and rest of 31% by generators.

Production	kWh/yr	%
PV array	25,067	39
Wind turbines	38,868	60
Generator 1	1,016	2
Total	64,950	100

Consumption	kWh/yr	%
DC primary load	36,464	100
Total	36,464	100

Quantity	kWh/yr	%
Excess electricity	23,666	36.4
Unmet electric load	0.000000477	0.0
Capacity shortage	0.129	0.0

Quantity	Value
Renewable fraction	0.972
Max. renew. penetration	8,664 %

Table 3: Electrical output for most feasible solution

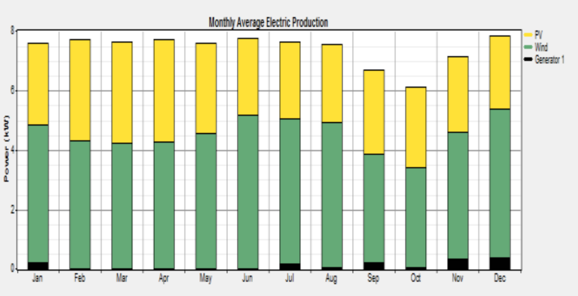

Fig. 9. Monthly average electric production

VI. CONCLUSION

In India more than 1 billion peoples are mobile user. To provide better network services mobile operator installed new mobile base stations. Power is main issue for remote or isolated areas base station, because grid extension is not feasible. In these sites the above proposed renewable base hybrid system is most viable solution. These solutions of power supply to the telecom base station are cost effective and available throughout the year. The circumstance of each sites are studied in order to decide the feasible combination of alternative energy resources. Alternate power solutions are not commonly used in mobile telecommunication system today but are actively evaluated for remote and isolated areas over worldwide. With the help of above pre-feasibility study the solar and wind hybrid energy system are most viable power solution for mobile base station in Indian sites over conventional diesel generator**.** Although the net present cost is high but the running and maintenance cost are low as compared to the diesel generator power solution. Its payback time is around 15 years. The fuel consumption is also reduced to approximate 80%.with increasing oil prices, payback times on the investment to hybrid solar-wind powered base station sites are continuously decreasing. Considering operating cost and maintenance cost, an autonomous site powered by wind solar hybrid system pay-off after 2-4 years in a good sunny and windy location. The Base stations powered by the solar wind hybrid energy system with diesel backup – are proving to be the most environmentally friendly and cost-effective solutions for many challenging sites. Operating and maintenance costs are extremely low, making it economical to extend cellular coverage in far-flung regions. Solar- and wind-powered sites benefit the environment as well as the operator business case, whether they are located in highly populated or remote areas. Due to powering the base station by hybrid renewable energy system, it will reduce the carbon and other harmful gases emission is about 90% in environments. Due to powering the base station by hybrid renewable energy system, it will reduce the carbon and other harmful gases emission is about 90% in environments.

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