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Stand Alone Hybrid Energy Generation for Remote Telecom Towers

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Abstract
Renewable energy has emerged tremendously as a vital alternative over the conventional energy. The conventional energy methods pose hazardous effects on environment resulting a paradigm shift towards the renewable energy sources having negligible GHG emissions. In Pakistan, the telecom sector faces problem of power generation for smooth operation of remote BTS where grid supply is unavailable. In the work, a hybrid PV-wind energy generation system is proposed for remote BTS located at Gwadar, Karachi, and Balochistan regions. The different systems are analyzed considering solar and wind resources for remote BTS. The optimal system is selected on the basis of COE, operating cost and NPC. Further, the renewable sources in proposed system contribute 99% in annual production of electricity. It is good for those sites where average wind speed is greater than or equal to 4m/s and solar energy is 5 KWh/m^2/ day. Moreover, the payback period is 4 years which makes it cost effective.

Keywords: hybrid energy system; solar; wind; homer energy.

1. INTRODUCTION

Pakistan has an emerging telecom industry. In the last few years the mobile companies have invested a huge amount, this amount increased to $3.3 billion between 2014 and 2016 [1]. The telecom sector contributes greatly in Pakistan's revenue. It has generated 126 billion for the year 2014-2015, which is the 3rd portion of revenue [1]. According to GSMA estimations mobile user of off-grid areas in Pakistan are approximately 16% [1].

Pakistan has 33,160 BTS sites of which 5,636 sites are using a hybrid power system of diesel generator and battery and 1,706 are off gird sites. From 1,706 off grid sites 1,156 sites are using 24/7 diesel generator and only 550 sites are using green energy [2].

"NokKundi", selected site of study, is in district Chaghi of Balochistan, Pakistan. Chaghi has great potential for wind power. In the Nok-Kundi area wind speed is often 12.5% higher than average required for energy generation [3]. In Balochistan due to poor security and terrorist attacks, telecom facilities were distant for more than two decades. In most of the districts 2G, 3G network coverage and other mobile phone services are being launched for the first time. Companies are looking ahead for business prospects because of the improved security situation and further development schemes under the CPEC. Two companies are being financed by USF for providing network in seven districts of Balochistan. In the districts of Chaghi, Awaran, Khuzdar, Lasbela, Kalat and Sibi, telecom companies Telenor and Ufone are going to launch their service and also extend already present network. USF's supportive plans ensure improved cellular network in remote areas of Pakistan. Initially, 383 BTSs are being installed in above mentioned districts [4].

Telecom sector have an increasing amount of energy demand. The power generated in Pakistan relies heavily on conventional fuels. Burning of fossil fuel contribute to emission of GHG that result in global warming. Reduction of GHG emissions from the telecom sector is called the greening of telecom sector. Among different companies' competition and increased advertisement cost are big concern for telecom sector. Main purpose to "go green" is the need

Table 1. Hybrid system designs for the telecom sector using homer

Author name	Work	Proposed Hybrid System	Country
M. T. Chaichan et al. [5]	Optimization of a Solar/DG system for telecommunication tower	PV/Battery/DG	Al-Buraimi, Oman
K. Kumar et al. [8]	A novel optimization technique for a standalone renewable hybrid energy model for telecom station	PV/Wind/Battery/DG	Chhattisgarh, India.
S. A. Chowdhury. [9]	Solar/DG system for telecom station	PV/Battery/DG	Dhaka, Bangladesh
P. Bajpai at al. [10]	Analysis and modeling of independent system for telecom tower	PV/Battery, PV/Fuel Cell and PV/FC/Battery system	Kolkata, India
S. Moury et al. [11]	Study of feasibility for photovoltaic arrays in grid connected telecom sites	Grid/PV/Battery/DG	Mymensingh, Bangladesh
A Ullah et al. [12]	Study of hybrid energy system for telecom tower in Bangladesh	PV/Wind/Battery/DG	Chittagong, Bangladesh
L. J. Olatomiwa at al. [13]	Optimization of hybrid renewable energy system for remote telecom site of Nigeria	PV/Wind/Battery/DG	Doka-Sharia, Nigeria
A. Iqbal at al. [14]	Study of hybrid Solar/DG/Battery system for telecom site	PV/Battery/DG	Doha, Qatar
S. Goel. [15]	Standalone hybrid system for telecom site of Odisha	PV/Wind/Battery/DG	Odisha, India

to reduce high operating cost, increase revenues and to expand the network into rural areas where conventional utility power supply is unavailable [5]. This study will help to fulfill power demand of telecom sector in mobile areas which will also be cost effective.

A remarkable effort has been made to develop the micro grid energy modeling and solution software for detailed analysis [6]. Our study is particularly useful in mobile area of Pakistan abundant in renewable sources which can be harnessed to give clean and free energy. Table 1 summarizes the work, technology choices, and country of application of BTS based studies on HOMER software.

HOMER is able to simulate all possible systems depending on real time problems and load, making it more reliable and usable all over the world as it gives enhanced view of technical analysis. This software simulates the designed hybrid system for a full year, the simulation for any minute can also be checked [7].

HOMER executes three major tasks of optimization, simulation and sensitivity analysis. In simulation process different models are studied to find the model that is best technically and economically. In optimization this software evaluates different models and arrange them on the basis of NPC. In sensitivity analysis simulations are performed for different inputs to check the effect if the values of the inputs changes in future. [8].

2. SYSTEM MODELING

2.1 Selected Site Pakistan is blessed with the natural resources like solar energy along with abundant wind speeds. A village, named Nok-Kundi, is selected for study because it has high wind speed and solar radiation. It is located in Baluchistan province of Pakistan

Fig.1. Selected site (Nok-Kundi, Balochistan, Pakistan)

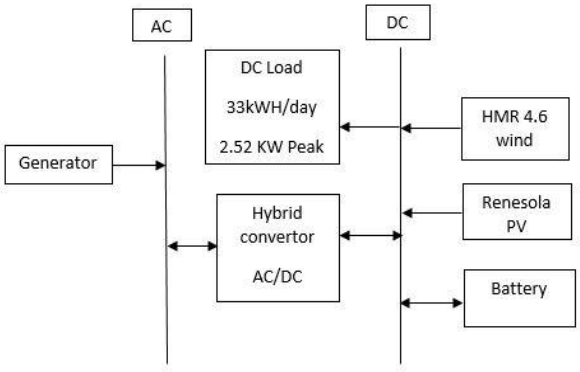

Fig.2. Proposed hybrid system model

which lies between the longitude and latitude of (28° 58'N, 62°27'E). It has hot climate with temperature reaching to 43°C in summer and the wind speed reaches to 7.1 m/s [16]. The selected site is taken as the case study because it has high solar radiation level and high wind speed. The proposed energy generation system can also be applied to the other sites with good solar radiation and wind speeds in Baluchistan. The site selected for study is shown in Fig. 1.

2.2 Proposed Hybrid System HOMER proposes different systems selecting from one or more energy sources. Hybrid system is combination of two or more than two energy sources supplying energy to the load [12]. Selected system contains Solar PV arrays, batteries, Wind energy and generator as energy sources. Solar system depends on the daily energy from the sun and wind turbine depends upon the wind speed in particular area. Batteries are used to provide energy backup overnight. A diesel generator (DG) is used as a backup in case the renewable sources are not able to meet the energy demand. The schematic of system is shown in Fig. 2.

2.3 Load Parameters Load demand for BTS station which has to be feed all the time is taken as the base demand. BTS system is a telecommunication base system of remote area between customer appliance and telecom administrator base station. Remote area's BTSs consists of diesel generators for providing power and to ensure system accessibility. Remote area's BTS equipment is placed outdoor and it lies under 2KW system [8]. For BTS station power is derived from Solar PV or Wind turbines, specifically for small BTS stations (less than 2KW) for low operating cost. DG or natural gas-based generators are preferred in bigger sites for getting better results [17]. Selected system is considered with constant load of 1.3KWh as remote area BTS load and an average daily load of 33KWh/day with peak load of 2.5KWh.

2.4 Solar Energy PV panels convert solar energy into electrical energy. The selected site has abundant solar energy over the year with annual solar radiation of 5.45KWh/m^2/d [18]. PV arrays of 5.5KW is selected for the system which is producing 9,642KWh/year. Solar panels of Renesola are taken with price of $800 is selected for per KW. Solar radiation over the year monthly wise is shown in Fig. 3. Technical specifications are shown in Table 2.

2.5 Wind Energy In win d turbine kinetic energy of the wind is converted into electrical energy. The amount of electricity generated is directly proportional to wind speed. The annual wind speed of the selected site is 5.9m/s [18]. Single Hummer 3KW wind turbine is selected for the system whose cost is $6000 per piece. Monthly wind data is shown in Fig.4. Technical specification is shown in Table 2.

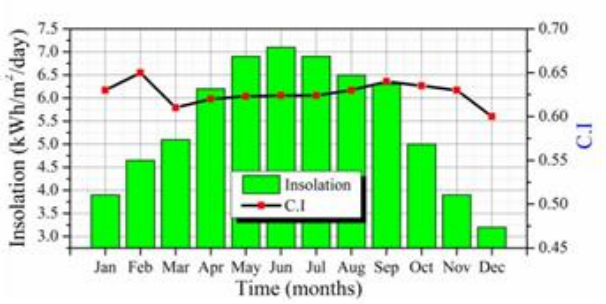

Fig.3. Monthly solar radiation and Clearness Index

Table 2. Technical specification of PV and wind

Parameters	Solar	Wind
Total rated capacity (KW)	5.50	3.00
Mean output (KW)	1.10	0.91
Capacity factor (%)	20.01	30.35

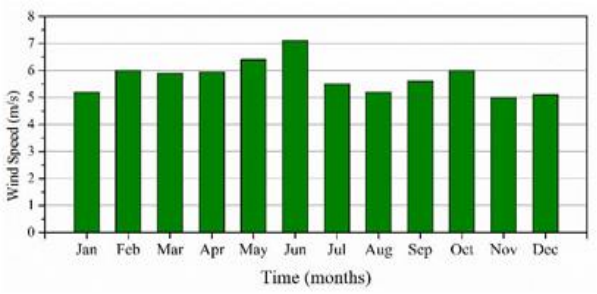

Fig.4. Monthly average wind speed data

2.6 Battery Trojan L16RE-2V flooded acid battery is used in this system. The battery used is a 12V, 1100Ah and 2.2KWh. 24 battery cells are used as a string in the system The price of single battery is taken as $450.

2.7 Diesel Generator Apart from the abundant solar and wind resources on the selected site, the system cannot design to fully rely on the natural resources. There is a probability that someday neither wind nor solar resource is available. For this purpose, a diesel generator is also installed in the system to increase the reliability of system which has capacity of 3.1 kVA and its cost is $1,240. The generator consumes 0.462 L/KWh and used only 15 liter yearly as shown in Table 3.

Table 3. The diesel generator

Parameters (Units)	Value
Fuel Consumption (L)	15
Fuel Consumption Yearly (L/KWh)	0.462
Fuel Energy Input (KWh/Yr)	148

2.8 Converter Converters converts AC-DC and DC-AC as per the requirement of the load. By using this converter both AC and DC loads can be served at the same time. In the proposed system 3KW converter is installed costing is $300 per KW. The efficiency of the converter is 90%

3. SIMULATIONS AND RESULTS

3.1 Optimization Results HOMER proposes different systems for the chosen load demand and ranks them based on NPC. NPC is the cost of the system during the lifetime of project (25 years). It is clear for the Table 4 that the proposed system 1 is the optimal one. However, it fails to produce maximum power if both solar and wind is not available. **To** overcome this scenario, it is better to add DG and optimally select the values of PV and wind. HOMER proposed the best combination as tabulated in Table 4. The proposed system 2 has a lower value COE, NPC and initial cost. However, the operating cost is comparable to proposed system 1.

3.2 Summary of Possible Hybrid System Summary of economics of the proposed system for life time of 25 years is shown in the Table 5

3.3 Cost analysis of the proposed hybrid system The proposed system has NPC of $29,843, COE is $0.194/KWh and Operating Cost of $696/year as shown from Table 4.

3.4 Comparing Economics The system is designed for the lifetime of 25 years. It will complete its cost in first 4.12 years as shown in Table 6.

Table 4. Comparison of the viable system by software

Hybrid No System	Generation (KW)		No of Batteries	No of Convertors	Cost ($)			
	PV	DG			COE($/KW/h)	NPC($)	Operating cost ($)	Initial Capital ($)
1	6.5		24	1	0.184	29154	700	20200
2	5.5	3.1	24		0.193	29843	696	20940
3	8	3.1	24	1	0.205	31259	1120	16940
4	12		24		0.205	31406	1001	18600
5		3.1	24	1	0.237	36216	1069	22540
6			24		0.240	36521	744	27000

Table 5. Cost summary of proposed hybrid system no. 1 by software

Element	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
Generator	1,240	0	43.99	134	271.10	1,147.48
Wind Turbine	6,000	1,870.83	1,022.65	0	1,084.49	7,844.99
Converter	300	125.18	0	0	23.30	401.88
PV	4,400	0	703.09	0	0	5,103.09
Batteries	9,000	5,818.69	1,534.09	0	1,006.67	15,346.04
System	20,940	7,8184.70	3,303.75	134	2,349.56	29,843.38

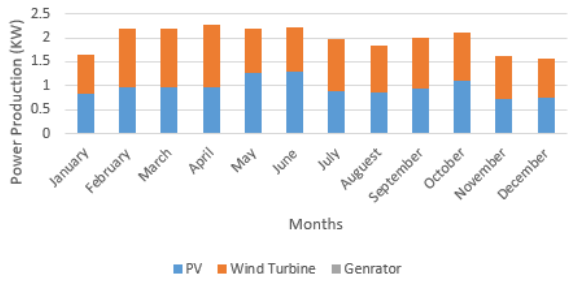

Fig.5. Monthly electricity production for each source

Table 6. Economics of the Proposed System

Parameters	Values
Present worth ($)	36,005
Annual Worth ($)	2,817
Return on Investment (%)	22.6
Pay back (Year)	4.12

3.5 Electrical analysis In electrical analysis, it has shown that how much electricity is produced annually from each energy source Analysis shows, excess energy of 26.1% is produced by the system. PV produces 9,643KWh and the wind turbine produces 7,975KWh with contribution of 54.64% and 45.18% respectively as shown in Table 7. The DG produces only 33KWh and will operate only when there is no supply from PV and Wind having contribution of 0.18% shown in Fig. 5

Table 7. Annual Production of Electricity

Source	**PV**	**DG**	**Wind**
Energy (KWh/Year)	9,643	33	7,975
Percentage	54.63	0.18	45.15

3.6 Emissions The proposed system heavily relies on the renewable energy generation which in turn has reduced the GHG emissions to a very low amount, proving the system is environmental friendly. The environment pollution is increasing day by day. By using the proposed system, the system not only produces low cost energy as compared with the conventional power generation but also effectively reduces the hazardous gasses and chemicals which pollute the environment. Table 8 shows the in-detail comparison of the two energy generation systems. The Table 7 shows that the system reduces the 13009 kg/year CO_2 emission. Apart from CO_2, the other harmful chemicals/gasses like carbon monoxide, Sulphur dioxide and nitrogen oxides are also reduced.

3.7 Sensitivity Analysis Sensitivity analysis explain the fact what will happen if there is changing in the set variables. In this study sensitivity analysis is done for inflation rate and fuel price. For inflation rate the values selected are 0 to 5%. For diesel fuel price, the values selected are 0.7, 0.8, 1, and \$1.2/L. According to trading economics online website, the inflation rate of Pakistan is 5.84% [19]. Fig. 6 shows that with low fuel price and low inflation rate our proposed system is best suited even with \$1.2/L and 2% inflation rate but above 2% inflation rate, NPC go higher (\$32,000\$ to \$35,000) with low operating cost. Due to this reason software chooses second most optimal system which is Wind/PV system with no DG. Fig. 7 shows COE reduces by skipping generator because of its high fuel and maintenance cost with reduced operating cost and increased NPC.

Table 8. Emission comparison

Pollutant (Kg/year)	**Proposed**	**DG based**
Carbon dioxide	39.37	13,049
Carbon monoxide	0.25	82.26
Unburned hydrocarbons	0.01	3.59
Particulate matter	0.00	0.50
Sulphur dioxide	0.10	31.96
Nitrogen oxides	0.23	77.27

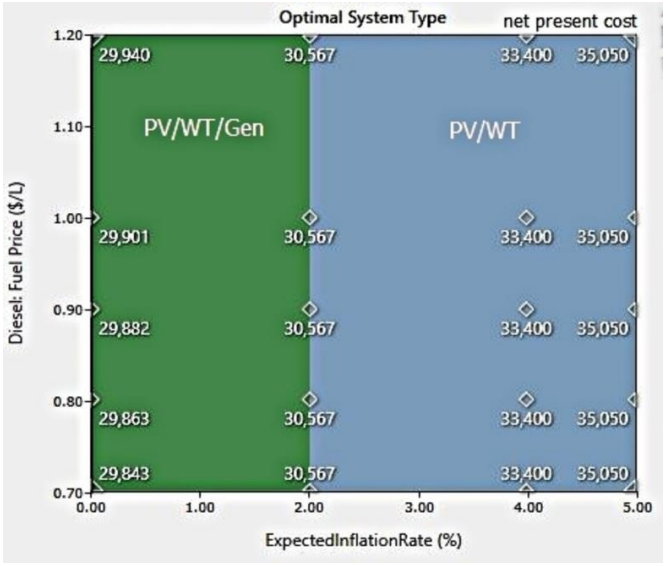

Fig.6. Optimal system type graph of inflation rate and fuel price

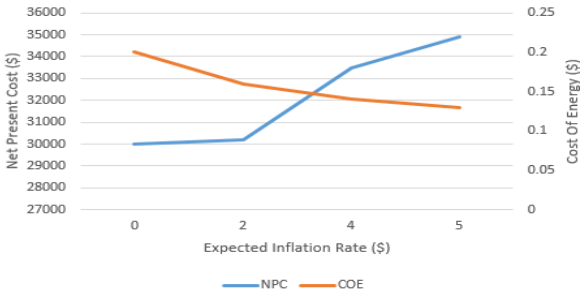

Fig.7. Plot of net present cost and inflation rate

4. CONCLUSION

This paper shows that in southern coastal areas of Pakistan, Wind-PV-DG hybrid system is the most economical of standalone wind or PV system and can generate revenue for telecom sector by reducing Operating Cost and COE. System's COE is $0.194 /KWh. Selected site of study is part of USF development program which is being considered for tele-density enhancement. Due to short fall of electricity in Pakistan load shedding is much higher in remote areas. BTSs require more and reliable power. Generator backup for BTSs sites makes the system more reliable. But these generators have high capital and operating cost resulting in consumption of revenues as shown in results. Fluctuation in the prices of fuel and GHG emission make generator not only system expensive but also hazardous to environment. Due to the above mentioned factors, a hybrid system is proposed which uses renewable sources with addition of generator backup. Renewable energy system is contributing more than 99%, and DG is only contributing 0.2% in annual production of electricity. Results show that proposed system is environmental friendly and cost saving because of low operating cost. Project has payback period of 4 years. Study concludes, selected system will be good for sites above average wind speed of 4m/s and solar insolation of 5 KWh/m^2/day making it cost effective and environmental friendly.

NOMENCLATURE

Abbreviations

GHG	Green House Gas
BTS	Base Transceiver Stations
COE	Cost of Energy
NPC	Net Present Cost
GSMA	Global System for Mobile Communication Association
USF	Universal Services Fund
PV	Photovoltaics
DG	Diesel Generator
KWh	Kilo Watt hours Power consumption

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