Hybrid energy systems for off grid remote engineering essay

Engineering

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Abstract- Hybrid energy systems are increasingly being applied in areas where grid extension is considered uneconomical. Their costs can be minimised through proper equipment sizing and load matching. This paper reports the results of optimisation of solar-wind hybrid energy system for remote telecom site which is located at the coastal island (20. 330N latitude and 86. 730E longitude) in Kendrapara district of Odisha, India. The present power supply system has been optimized using HOMER (Hybrid Optimization Model for Electric Renewables) software (2. 68 version) package developed by National Renewable Energy Laboratory (NREL), Colorado, USA. From the load demand and different equipment sizing, the capital cost, costs of energy and operating costs were determined and compared with grid connected system.

Keywords: HOMER, PV, wind, hybrid.

I. INTRODUCTIONGrid power is not available in many remote rural areas of Odisha. Also in areas where grid electricity is available, it is always not reliable and hence, operation of telecom towers in these areas requires so-called " standby" generator sets, in fact running for several hours every day to supply power to telecom equipments. With the rapid rise of global energy prices, the fuel costs for running these diesel generators at tower sites are a major concern which results a higher operating expenditure (OPEX). The fuel cost (as a percentage of Total Cost of Operation) could be as high as 64% for a typical 12 kW diesel generator running for about eight hours per day. This cost is driving many telecom tower operators to consider alternative power system options, particularly renewable energy sources to reduce the operating expenditure. India is now in the second largest of the Global telecom markets and is projected to overcome China. Our country currently has about 4, 00, 000 telecom towers around the land and poised to increase to 450, 000 towards the end of 2013[1]. A large portion of these towers is not connected to the electricity grid or does not have access to reliable electricity implying they have to install back up power systems in order to run without interruptions. Diesel generators have been the choice of telecom operators despite their higher OPEX and carbon imprint. Telecom Towers are estimate to burn 2 Billion Liters of Diesel (around 500 million barrels) annually at a cost of $ 18, 232 million. On an average, about $ 4740 is being spent annually to fulfil the diesel requirements of a single telecom tower [2]. These high input costs also results in high pollution. While the government has been trying to convert these towers to renewable energy forms, most of the tower operators have been very slow to implement this change. The renewable energy ministry had asked telecom companies to reduce their dependency on conventional fuels and consider alternatives for partly powering telecom towers. While some tower creators are looking at compressed natural gas and piped natural gas to power their towers. Indus Towers, the largest with over 1 lakh towers in India, planned to set up 2, 500 solar towers by end of this year. Viom networks, which operates more than 38, 000 towers across India, plans to run more than one fourth of this number on alternative energy within the next two years. It plans to run 2, 000 towers on solar power alone by 2013 [2]. Each tower requires energy from 1000 W to 3000 W (older installation consumes more power as compare to new one because of technological advancement). Assuming average power consumption of each tower is 1200 W then total CO2 emission is 105. 6 lakh tonne per hour by all these towers if we assume that all are running on state electricity. In India about 70% telecom towers are in rural areas. Presently 40% power requirements are met by grid electricity and 60% by diesel generators [3]. The diesel generators are of 10-15 KVA capacity and consume about 3 litres of diesel per hour and produce 2. 63 kg of CO2 per litre. For every kWh of grid electricity consumed, 0. 84kg of CO2 is emitted. Total CO2 emission is about 5 million tones due to diesel consumption and 8 million tones due to grid power per annum. Extensive use of DG has very adverse effects on environment as it emits higher amount of CO2 and other GHG emission causing global warming. During 20th century, global surface temperature has increased by 0. 740 C [4],[7]. The move from diesel to solar and other alternative sources of energy will result in a reduction of 5 million tones of CO2 emissions as well as a savings of huge amount in operating expenses for telecom tower companies. Move to renewable energy sources can generate millions of carbon credits that could offset the opex on their towers. Thus by replacing diesel generators with solar –wind hybrid power systems in telecom towers, more than 5 million tons of carbon emissions could be prevented from entering the atmosphere. India, with its excellent irradiance (5 kWh/m2/day), has excellent opportunity to explore solar photovoltaic (SPV) power to meet this challenge of onsite power generation. Also wind speed in coastal region is almost above the cut-in speed of wind turbines through out the year. As most of the base stations are located in open spaces and exposed to sunlight and wind, solar-wind hybrid system make the most feasible solution for powering the telecom sites in coastal areas of our country. Coupled with a DG and battery backup for uninterrupted power supply, PV-wind hybrid systems are most viable and exciting alternative to reduce the power cost and total operating expenditure thereby providing a sustainable and reliable solution to the power problem in telecom sites. Nema et al [5] have made size optimization of Wind Turbine Generator (WTG), SPV arrays and other components for a SPV-Wind-battery-converter system along with generator based power supply for BTS sites by using HOMER. Bajpai et al [6] made the simulation of various types of renewable energy based power system models for powering stand-alone BTS sites using HOMER. Moury et al [8] compared the grid connected BTS with SPV model by using HOMER and found that SPV system is more economical with lower COE than traditional system. In all these papers, the focus is solely on feasibility study of renewable energy for powering BTS sites. II. PRESENT ARCHITECTURE OF SITEThe basic component of the SPV-wind-diesel system that is installed in the telecom site is shown in the Fig. 1. Fig. 1 Hybrid system used in telecom siteThe electrical energy generated from SPV-wind-diesel system is fed directly to BTS load through the charge controller and battery unit. The energy that is stored in the battery is used to supply the power during low power production or at night when only WT is functional. DG is used in the system as the secondary backup power supply as SPV arrays and wind turbine are not the 100% reliable energy sources. As in a cloudy or rainy day, output electrical power from SPV cells can be very low which might cause a significant problem and also incase of wind turbine, sometimes wind speed may come below cut-in speed. DG can supply power when both solar-wind- battery systems fail to supply power to the load. As the load of the BTS is dc, but the DG and WT produce ac, converter is used to convert ac to dc. It also regulates the power flow from each of the sources, acting as charge controller or boosting up the power. The details of the systems configuration used in the site are given in Table 1. Table 1. Equipment used in telecom siteEquipmentSpecificationsSolar PV array10 kWpModule type- ES-250M60BWind turbine5. 1 kWp, ac generatorRotor diameter 5. 24 mHub height 25 mCut-in speed 2. 7 m/sCut-out speed 35 m/sBattery1250 Ah, 2 V each48 no used in 2 stringsDG20 KVA, 0. 8 pfConverter12 kWIn this paper the simulation result of hybrid renewable energy system is analyzed and compared with on-grid telecom system to find out the most cost effective one. III. ENERGY RESOURCES FOR HYBRID POWER SYSTEMFor this hybrid system, the meteorological data of Solar Radiation, hourly wind speed were imported from NASA site and it is analysed by using HOMER. Fig. 2 shows the variation of solar radiation and clearness index of the site. The average solar radiation of the site is 4. 7 kWh/m2/day. Fig. 2 Solar radiation with clearness indexWind speed also varies seasonally. Average wind speed of the area is 4. 34 m/s. Fig. 3 shows the monthly wind speed variation of the site. Fig. 3 Wind speed in different months in the siteAverage energy consumption of the site is 23 kWh/d with a peak load demand of 2. 0 kW. Fig. 4 shows the daily load profile and Fig. 5 shows monthly load pattern of the telecom tower. Fig. 4 Daily load profile of telecom towerFig. 5 Load of telecom tower in different monthsIV. SYSTEM ANALYSISFor the simulation, salvage value of 10% (except battery), O&M as 10% were taken. Actual cost of solar system, wind turbine, battery unit, DG was collected from the Executive Engineer, BSNL maintenance division, Cuttack for analysis purpose. The simulations were performed using HOMER to get the optimized sizing, cost, electrical production and emissions. Price, O&M and lifetime of all the elements are presented in Table-2. Table 2. System equipment and costElementInitial cost($/kW)Replacement cost($/kW)O&M($/kW)Lifetime(years)SPV43633927025WT164114778220Battery268 (per unit)268(per unit)13(per unit)8Converter1000100010015DG4534080. 02(per hour)10

- For simulation purposes, DG sizes of 8, 12 and 16 kW were selected. Similarly battery of 1 and 2 strings having 24 and 48 batteries were taken. The present load of the tower having 1 BTS is 22. 7 kWh/d. Another two loads of 55 and 83 kWh/d were considered keeping in mind that in future, two more BTS will be commissioned at the site. Similarly, different values of other variables like global radiation, wind speed and diesel price were taken for sensitivity analysis. Simulation results of existing renewable system-I (PV-wind-DG) and the traditional system-II (Grid-DG) are discussed below

A. SPV-wind-diesel system (System-I)

Solar PV (SPV) array of 10 kW, wind turbine (WT) of 5. 1 kW, DG of 20 KVA capacity with 48 nos of tubular gel battery in two strings are installed at the telecom site. The system architecture is shown in Fig 6. Fig. 6 Architecture of system-IThe net present cost (NPC) of the system is shown in Fig. 7 while the simulation results at 22. 7 kWh/d load, 4. 7 kWh/m2/d of solar radiation, 4. 34 m/s wind speed with diesel price of 0. 9 USD per litre is shown in Fig. 8. Fig. 7 Cash flow of the system-IThe cost summary of the system is presented in Table 3. Optimized values of the components that were found out were 10 KW for SPV, 24 batteries in single strings, 8 KW for DG and 12 kW converter (6 kW inverter and 6 kW rectifier). Fig. 8 Optimised system with existing resourcesTable 3. Cost summary of the optimised systemsTotal net present cost$ 81, 556Levelized cost of energy$ 0. 770/kWhOperating cost$ 1, 711/yrDiesel consumption153 litresExcess electricity energyProduction, kWh/yr36. 9%The levelised cost of energy of pv-diesel system was found to be lowest ($ 0. 770/kWh) with 153 litres of annual diesel consumption and 36. 9% excess electric energy production as against $ 0. 778/kWh of COE with no diesel consumption and 46. 4% excess electric energy production in pv-wind-diesel system (Fig. 8). But the higher operating cost of $ 1, 711/yr in pv-diesel system was observed as compared to the pv-wind-diesel system ($ 1, 647/yr) and this may be due to higher diesel consumption in first case.

B. Grid-diesel system (System-II)

The system architecture and the cash flow summary of this system are shown in Fig. 9 & 10. The cost summary of this system is presented in Table-4. For simulation, grid power of 1, 3 and 4 kW was taken as input with 8 & 12 kW DG and 24 batteries for storage of energy for emergency backup. Fig. 9 System architectureFig. 10 Cash flow summaryThe optimised system is shown in Fig 11. Fig. 11 Optimised system in grid-diesel systemTable 4 Cost summary of the system-IITotal net present cost$ 115, 125Levelized cost of energy$ 1. 087/kWhOperating cost$ 7, 750/yrDiesel consumption4048 litresExcess electricityProduction, kWh/yr23. 4%The levelised cost of energy of this system was found to be $ 1. 087/kWh with operating expenses of $ 7, 750/yr and 4048 litres diesel consumption. Excess electric energy production of 23. 4% was obtained in this system. The GHG emissions of these two systems are shown in Table 5 which indicates that system-I discharge very negligible amount of pollutants as compared to system-II. Table 5 GHG emissions by two systemsPollutantEmission, kg/yrSystem-ISystem-IICarbon dioxide37013, 883Carbon monoxide0. 91426. 3Unburned hydrocarbons0. 1012. 91Particulate matter0. 06891. 98Sulphur dioxide0. 74335. 4Nitrogen oxides8. 15242When the results of NPC, COE, operating cost, excess electricity are compared between the two systems, it is seen that PV-wind-DG based system-I displays the better economy. Lower COE and operating cost were obtained in system-I. Also consumption of diesel fuel is reduced from 4048 litres to 153 litres in system-I which not only save cost but also has greater importance for the environment by reducing emission of 13, 513kg of CO2 to the atmosphere as compared to system-II. V. CONCLUSIONFrom the results obtained in two methods, it is clear that installing renewable elements like solar PV array coupled with wind turbine has lots of advantages in powering telecom sites. It reduces the operating expenses as well as cost of energy thereby making telecommunication sustainable and economically profitable.