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Decentralized/stand-alone hybrid Wind–Diesel power systems to meet residential loads of hot coastal regions

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Abstract

In view of rising costs, pollution and fears of exhaustion of oil and coal, governments around the world are encouraging to seek energy from renewable/sustainable energy sources such as wind. The utilization of energy from wind (since the oil embargo of the 1970s) is being widely disseminated for displacement of fossil fuel produced energy and to reduce atmospheric degradation. A system that consists of a wind turbine and Diesel genset is called a Wind–Diesel power system.The literature indicates that the commercial/residential buildings in Saudi Arabia consume an estimated 10–40% of the total electric energy generated. In the present study, the hourly mean wind-speed data of the period 1986–1997 recorded at the solar radiation and meteorological station, Dhahran (26°32′N, 50°13′E in the Eastern Coastal Region of Saudi Arabia), has been analyzed to investigate the potential of utilizing hybrid (Wind–Diesel) energy conversion systems to meet the load requirements of a hundred typical two bedroom residential buildings (with annual electrical energy demand of 3512 MWh). The long term monthly average wind speeds for Dhahran range from 4.2 to 6.4 m/s. The hybrid systems considered in the present case study consist of different combinations/clusters of 150 kW commercial wind machines supplemented with battery storage and Diesel back-up. The deficit energy generated by the Diesel generator (for different battery capacities) and the number of operational hours of the Diesel system to meet a specific annual electrical energy demand of 3512 MWh have also been presented. The evaluation of the hybrid system shows that with seven 150 kW wind energy conversion system (WECS) and one day of battery storage, the Diesel back-up system has to provide 21.6% of the load demand. Furthermore, with three days of battery storage, the Diesel back-up system has to

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provide 17.5% of the load demand. However, in the absence of battery storage, about 37% of the load needs to be provided by the Diesel system. The study also places emphasis on the monthly average daily energy generation from different sizes (150 kW, 250 kW, 600 kW) of wind machines to identify the optimum wind machine size from the energy production point of view. It has been noted that for a given 6 MW wind farm size (for 50 m hub height), a cluster of forty 150 kW wind machines yields about 48% more energy as compared to a cluster of ten 600 kW wind machines.

Keywords: Wind machines; Battery; Hub height; Wind farm; Wind–Diesel system; Residential loads

1. Introduction

In the wake of the ever increasing cost of oil and the uncertainty in supply of oil experienced since the mid-1970s, utilisation of energy from renewables such as wind has gained sizeable momentum and is being widely deployed for displacement of fossil fuel produced energy and, consequently, to reduce atmospheric degradation. Modern thinking believes wind is a permanent shield against ever increasing power prices.The literature indicates that wind energy (being freely accessible, inexhaustible, site dependent, environmentally friendly, promising, non-polluting/benign) is being vigorously pursued/deployed by a number of developed and developing countries with average wind speeds in the range of 5 m/s–10 m/s in an effort to reduce their dependence on fossil based non-renewable fuels [1–8]. The cumulative global wind energy installed capacity topped 31 000 MW in 2002. The price of generating energy using wind machines has dropped dramatically over the last decade and currently is in the range of 4–5 cents per kWh. The technology of the wind machines has improved remarkably over the last five years. Wind energy conversion systems (WECS) in the range of 3.2 MW are commercially available. The rate of increase in installed capacity during the last ten years is in the range of 30% per annum [9]. By and large, typical wind power applications include lighting, electrical appliances, military installations, communications/gas stations, electricity for remote settlements (that are far from an existing utility grid), water pumping for irrigation/desalination, cathodic protection of pipe lines etc.

Stand alone WECS (in spite of remarkable technological advancements/milestones) do not produce usable energy for considerable portions of the time during the year. This is basically due to the relatively high cut-in wind speeds (speed at which the WECS starts producing usable energy), which range from 3.5 to 4.5 m/s. In order to overcome this downtime/offset, the use of hybrid (Wind–Diesel) systems has been recommended in the literature. Stand alone Diesel generator sets, while being relatively inexpensive to purchase, are generally expensive to operate and maintain, especially at low/partial load levels (because, even at zero load, small Diesel engines use about 30% of the full load fuel consumption). In other words, when a Diesel generator is operated at less than about 30–40% of full load, its life span will be shortened and the frequency of maintenance will be increased [10]. In general, the variations/fluctuations of wind energy generation (wind does not blow all the time) do not match the time distribution of the load demand on a continuous basis. One possible solution for this is the association/incorporation/employment of a short term battery storage facility to smooth/shrink the time distribution mismatch between the load and the wind energy generation and to account for the maintenance/outages of the