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Design and Optimization of Hybrid Micro-Grid System

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Abstract

Hybrid microgrid systems (HMGS) comprise of several parallel connected distributed resources with electronically controlled strategies, which are capable to operate in both islanded and grid connected mode. HMGS based on renewable energy sources (RES) is the cost-effective option for solving the power supply problem in remote areas, which are located far from grids. In this paper, the wind and solar meteorological data for Sundarban (India) station are used to design Islanded HMGS for providing necessary electricity. Cost effectiveness and system reliability are major factors considered for designing HMGS to achieve better power management scheme. Particle Swarm Optimization (PSO) scheme is applied to identify the sizing of wind turbines (WT), photovoltaic (PV) module, battery energy storage system (BESS) and diesel generator, and find the optimal configuration of HMGS system. The design and optimal operation of HMGS system has been developed and validated through MATLAB software.

Keywords: HMGS; PSO algorithm; Power Management Scheme.

1. Introduction

In India, over three hundred million people still don't have electricity. There are twenty-eight thousand villages not accessing electricity [1]. Sufficient stand-alone systems for regionally accessible Wind and PV renewable energy sources have become recommended option for remote areas [2]. BESS and diesel generators are used for backup system to overwhelmed the stochasticity of wind and irregular nature of solar energy [3]. ON/OFF and continuous control strategies are involving the operation of the diesel generator within HMGS [4,5]. PSO algorithm is used to

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minimize the annual cost of the HMGS and it is directly depending on its reliability [6]. PSO will be recognized as a simple concept and shorter computation time when compared to GA [7,8]. PSO is the most promising and powerful strategies to find the best configuration in HMGS [9].

The main goal of this paper, is to choose a cost effective and reliable HMGS by using PSO method, owing to find high Renewable Factor (RF), the lowest Price of Electricity (POE) and Loss of Power Supply Probability (LPSP). Meteorological data for Sundarban station is used to design HMGS which is situated in North east of India and lies on geographical coordinates of latitude 21.95° N and longitude 89.1833° E.

The paper is structured as follows. Section 1 provides an introduction of Islanded HMGS. Section 2 describes the mathematical model of hybrid microgrid system. Section 3 and 4 briefly introduces power management scheme and particle swarm optimization algorithm respectively. Design considerations of islanded HMGS explain in Section 5. Section 6 and 7 presents economic analysis and simulation results.

2. Hybrid microgrid system

HMGS is designed as low voltage distribution network to supply 220V, 50 Hz, 1Φ AC system and detailed model depicted in Fig.1 (a). Load profile determination is the primary step for designing HMGS. In India, most of the loads are lights, fans, Television, Mixer, Laptop, Mobile phone and others [10]. The average power requirement to meet the load demand is approximately 6kWh per day and peak load is approximately 1.5kW per house as tabulated in Table. 1. The load profile of 15 houses in Sundarban site as shown in Fig.1 (b) with a peak load of 8.75 kW and the hourly load profile as depicted in Fig. 2 (a).

2.1. Mathematical model for HMGS

Fig. 2(b) shows the hourly solar incident of the horizontal for Sundarban site. It is clear from the figure that the average horizontal solar radiation is 239 W/m^2 and the peak solar irradiance exceeds 1000 W/m^2 [11]. The input data of PV generator could be the hourly solar radiation on the horizontal surface. The solar irradiation of PV can be calculated by [12],

$$P_{pv\_out} = \frac{G}{G_{ref}}\left[1 + K_T\left(T_c - T_{ref}\right)\right]P_{N-PV} \quad (1)$$

$$P_{N-PV} = P_{r_{pv}} * \eta_{pv} \quad (2)$$

$$T_c = T_{amb} + (0.026 \times G) \quad (3)$$

Where, G and G_{ref} are solar radiation (W/m^2) and solar irradiation at reference conditions ($G_{ref} = 1000\ (W/m^2)$) respectively. K_T is the temperature coefficient of maximum power ($K_T = -3.7 \times 10^{-3}$ (1/°C)) for mono and polycrystalline silicon. T_{ref}, is the PV cell temperature at reference condition (T_{ref} = 25°C). T_c, is cell temperature and T_{amb} is the ambient temperature as shown in Fig. 2(c). P_{N-PV} is the rated power of the PV panel at reference conditions and P_{PV-out} is hourly output power of PV cell as shown in Fig. 2(d).

The bi-directional inverter offers a path from the DC bus to the AC load and acts like a rectifier, which converts AC supply to DC voltage to charge the battery banks. The inverter has been selected 20% more than the rated power of AC loads.

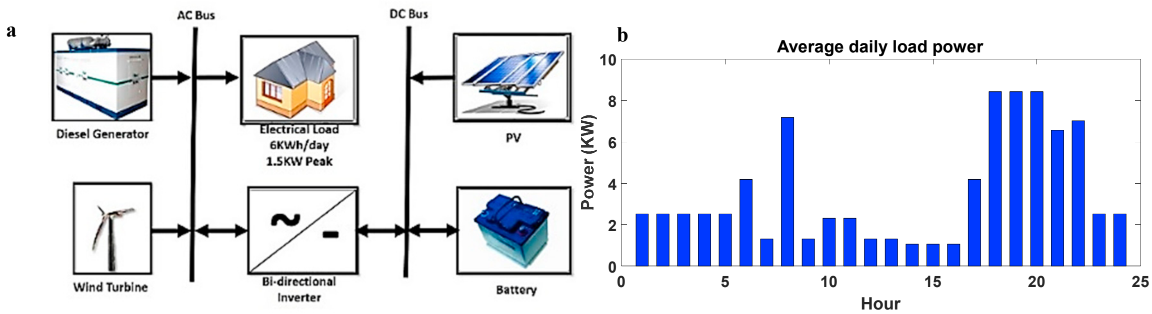

Fig. 1. (a) Hybrid Microgrid system; (b) Load profile consumption per day for 15 houses