Paper

Comparison of Operating Methods of Battery in a Stand-Alone Photovoltaic/Wind/Diesel/Battery Power System

Student Member Yusuf Ismail (Toyohashi University of Technology)
Member Yoshishige Kemmoku (Toyohashi University of Technology)
Member Hirofumi Takikawa (Toyohashi University of Technology)
Member Tateki Sakakibara (Toyohashi University of Technology)

A new method for operating a stand-alone photovoltaic/wind/diesel/battery hybrid power system is presented. The system, especially its diesel generator, is controlled so that the battery charge is kept at a specified level. The battery is charged when its present charge level is lower than the specified level and discharged when higher. A simulation is carried out over one year using the hourly data of electric load, insolation, temperature, and wind speed at Kamishima Island, Japan in 1996. This method is compared with other methods: a conventional operating method and a dynamic programming operating method. The results show that in regards to the fuel consumption of diesel generator, the proposed operating method is superior to the conventional method although not than the DP method, and the fuel consumption has a minimum if the PV energy is same as the wind energy.

Keywords : photovoltaic/wind/diesel/battery system, simulation, operating method, battery charge-level, fuel consumption

1. Introduction

Stand-alone diesel generator units, while being relatively reasonable in cost, are generally expensive to operate and maintain especially at low load levels. However, integrating them to a wind turbine generator, a photovoltaic generator and a battery storage becomes cost-effective. Besides being emission-free, the energy coming from the wind and sunrays are available at no cost. In addition, they offer a solution for power supply to remote areas that are not accessible by the utility company, and to developing countries that are poor in fossil-based resources. The interest in renewable energy forms is indeed growing worldwide [1]. From the view point of reducing CO_2 emission, utilization of wind and photovoltaic energies have been positively in advanced [2].

Because of the variation of regions, seasons and weather conditions, power outputs from these two kinds of energy sources are very unstable and power densities are also low relatively [3]. Thus it is limited when they are applied exclusively. In fact, the supply of renewable energies may not coincide with electricity demand. So, the battery must be provided for this missing link [4].

The main purpose of introducing the battery storage is to import/export energy depending upon the situation. The following basic operating strategy is employed [5]:

- The use of electric power generated by the wind turbine generator and photovoltaic generator has priority in satisfying electricity demand over that provided by the batteries or by the diesel generator.
- If the total electric power generated by the wind turbine generators and photovoltaic generator is higher than the demand, the additional electric power will be charged into the battery.
- After charging the battery, the electric power that remains is disposed of.
- If the total electric power generated by the wind turbine generator and the photovoltaic generator is less than the demand, electric power will be discharged from the batteries to supply the demand because once the battery is bought, their major cost would have been committed and their use is given to priority.
- If the battery cannot supply the demand, then electric power has to be drawn from the diesel generator.

A new operating method has been proposed in our previous paper [6]. The diesel generator is so controlled that the battery charge is kept at a specified level: the battery is charged when its level is lower than the specified level and discharged when higher. A minimum specified charge level has been investigated at which the annual fuel consumption of the diesel generator has a minimum.

In the present paper, the new operating method is applied to a photovoltaic/wind/diesel/battery system and the fuel consumption is discussed, where the system parameters are the natural energy supply ratio, the energy ratio of photovoltaic generator to the wind turbine generator, the diesel generator size and the battery size.

2. System Configuration

The system consists of a photovoltaic generator, a wind turbine generator, a diesel generator and a battery.

Energy flows in the stand-alone photovoltaic/wind/diesel/battery hybrid system are shown in Fig. 1, in which $Ps(t)$ is the output of the photovoltaic generator, $Pw(t)$ is the output of the wind turbine generator, $Pd(t)$ is the output of the battery, $Pl(t)$ is the energy consumed in an electric load and t is the hourly time over one year. These flows must satisfy the equation (1). $Pb(t)$ is positive when the battery is discharged and negative when charged.

$$Ps(t) + Pw(t) + Pd(t) + Pb(t) = Pl(t) \quad \cdots\cdots (1)$$