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Life Cycle CO_2 Emissions of a Photovoltaic/Wind/Diesel Generating System

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SUMMARY

A photovoltaic/wind/diesel generating system with a battery (PWD system) is discussed from the viewpoint of total CO_2 gas emissions during system lifetime. The total emissions are the sum of the emissions occurring at manufacturing and operating. First, the manufacturing CO_2 emissions of the photovoltaic generator and the wind turbine generator are calculated by "the process analysis method." This method considers the material used in each generator, its weight and its CO_2 emission rate. On the other hand, the manufacturing CO_2 emissions of the diesel generator and the battery are calculated using "the interindustry (input-output) table." Second, the PWD system is operated on a computer so that the fuel consumption of the diesel generator is a minimum assuming that hourly series data of electric load, insolation intensity, wind speed, and air temperature are known during the year. And CO_2 emissions occurring at system operation are obtained from the annual fuel consumption of the diesel generator.

The results show that CO_2 total emissions of the PWD system are lower than those of the conventional diesel generator system. The CO_2 total emissions reach a minimum when the photovoltaic/wind generating ratio is 50/50. The CO_2 emissions of manufacturing decrease with increasing of the wind generating ratio from 100/0 to 0/100. The CO_2 total emissions decrease as the natural energy ratio increases. It is, however, saturated to about 60% when the ratio is more than 60%. And the CO_2 total emissions increase with increasing of the battery capacity. It is concluded that the PWD system plays an important role in decreasing considerably the CO_2 total emissions while the total system cost is high under the present price circumstances. © 2001 Scripta Technica, Electr Eng Jpn, 138(2): 14–23, 2002

Key words: Photovoltaic/wind/diesel generating system; battery; total CO_2 emissions; life cycle; input energy; cost.

1. Introduction

Conventionally, electric power is supplied by a diesel power generating system in an isolated island which is not connected to the power grid. In recent years, for the purpose of reducing CO_2 emissions, the introduction of photovoltaic/wind power generation into this kind of region has been positively advanced.

When a photovoltaic/wind power generating system is introduced, fuel consumption is generally reduced accompanying the operation of the diesel generator. However, although the photovoltaic/wind power generating facilities will not consume fossil energy during their operation, fossil energy will be consumed during equipment manufacture. In particular, the photovoltaic power generating equipment consumes more fossil energy during manufacturing than other system equipment.

For that reason, the effect of introduction of a photovoltaic/wind power generating system must be evaluated over the life cycle, including the effects during manufacture of system equipment and during operation of the system.

In this research, we will calculate the total CO_2 emissions, input energy, and total cost throughout the life cycle of the photovoltaic/wind/diesel power generating system. The CO_2 emissions during equipment manufacture are calculated using the "process analysis method" and "interindustry method" [3]. The CO_2 emissions during system operation are calculated using dynamic programming such that the fuel consumption will reach a minimum, assuming that the hourly series data of the electric load, insolation intensity, wind velocity, and air temperature are known during one year.

Moreover, with the size of photovoltaic/wind power generation introduced and the battery capacity as parameters, we will also study the system configuration at which the total CO_2 emissions reach a minimum.

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