Operation Plan of a Photovoltaic and Diesel Engine Combined System with the Power Prediction Method

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Abstract: A prediction algorithm based on neural network is proposed in this paper to predict the output power from a Photovoltaic system. This research discusses the operation plan of a combined photovoltaic system and a diesel engine generator using the prediction algorithm. The prediction error of the prediction algorithm is determined with the numerical simulation exerting a significant influence on the system's operation. Additionally, the extended length of the engine generator operation time caused by this error is clarified. This is paper illustrates, that when the neural network prediction algorithm is introduced, the engine generator operating time is reduced.
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Index Terms – Photovoltaic system, Diesel engine generators, Neural network, Numerical weather information.

1. Introduction

Recently, the neural network (NN) has been proposed as a suitable for statistical approaches for classifications and prediction problems[1]. The objective of this study involves developing an algorithm based on NN to predict the output power from a Photovoltaic system (PV) and the energy supply characteristic of a PV and a diesel engine combined system is proposed. Two methods are examined in this paper, in Method 1, the actual calculations of the PV power are used. In Method 2, the system operation is determined based on the predicted output characteristic of the PV power. In the two methods, the battery supplies the power load when the PV power is insufficient compared to the power demand and the operation of the engine generator according to charge or discharge of the battery. In this study, the operation plans in the two methods are described. A layered NN is made to learn and teach based on the weather data of amount of solar radiation and outside air temperature. The energy supply characteristic of the PV and diesel engine generator combined system is studied. This paper illustrated that, The operating period of the engine generator is shortened by introducing the NN prediction algorithm.

2. System Model

The block diagram of the PV and diesel engine combined system is shown in Fig. 1. As shown in this figure, the proposal system consists of a PV, a diesel engine generator, heat storage tank and a battery. The output PV power can be supplied to the power demand through a DC-DC converter and inverter, also charges the battery. Energy is supplied to a demand side. Table 1 shows the specifications of the PV, battery, engine and generator[2]. Figure 2 shows the output characteristic of a test diesel engine generator, the maximum power generation from the diesel engine generator is 3kW output, the heat power of the engine generator is the cooling water heat and exhaust heat[3,4].

3. Analysis Method

3.1 Amount of slope–face solar radiation and electricity production of the solar cell

Direct solar radiation intensity (H_D) and sky solar radiation intensity (H_S) are used to calculate the amount of slope-face solar radiation and the electricity production from the solar cell[5-7]. The formulas for direct solar radiation and the sky solar radiation are calculated by using the following equations[6]:

$$H_D = I_D \cdot \cos\theta \quad (1)$$

$$\sin\theta = \cos\alpha \cdot \sin\delta - \sin\alpha \cdot \cos\varphi \cdot \cos\delta \quad (2)$$

$$H_s = 0.5 \cdot I_S \cdot (1+\cos\beta) + 0.5 \cdot \lambda \cdot I_H \cdot (1-\cos\beta) \quad (3)$$

$$\cos\beta = \cos\alpha \cdot \cot\varphi + \sin\alpha \cdot \operatorname{cosec}\varphi \cdot \tan\delta \quad (4)$$

Where I_D is the direct solar radiation intensity, I_H is the global solar radiation intensity, I_S is the horizontal sky solar radiation, λ is the reflection factor, θ is an incident angle to the acceptance surface of the sunlight, α is the latitude of the setting point, δ is the solar celestial declination, φ is the hour angle and β is the angle of the gradient of the acceptance surface. The following equation is used to calculate the PV output power[7].

$$P_s = S_S \cdot \eta_S \cdot (H_D + H_S) \cdot \{1-(T_C - T_O)\cdot(R_T/100)\} \quad (5)$$

where P_S is the output power from the PV, T_c is the temperature of the PV, S_s is the area of the PV(72 m^2), ηs is the generation efficiency (14%), R_T is the temperature coefficient (0.4%/K) and T_o is the reference temperature (298 K).

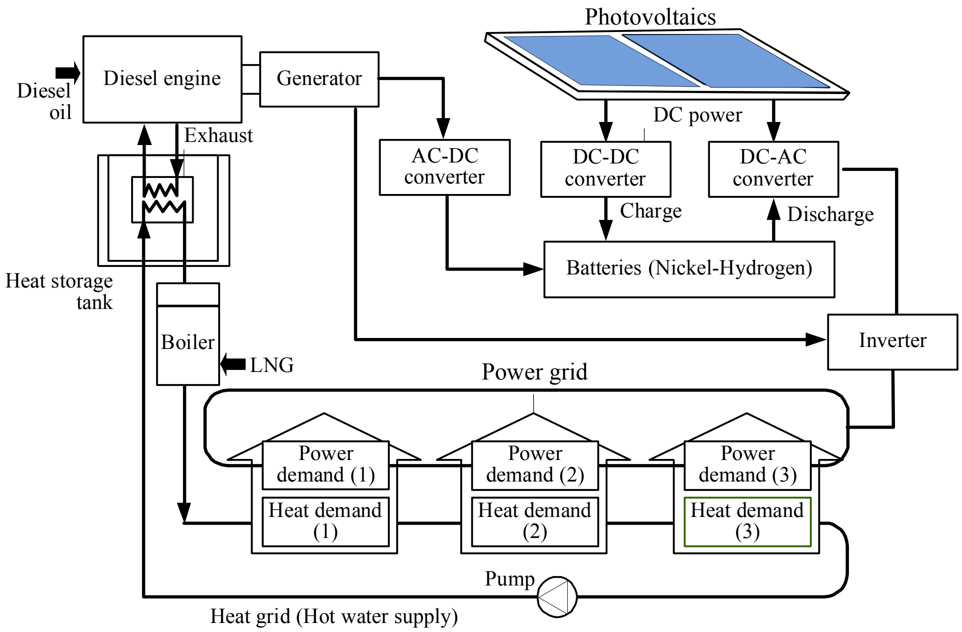


Figure 1 System scheme

Table 1 System apparatus specifications

Apparatus	Specifications
Solar cell type Area and generation efficiency Temperature coefficient of a solar cell	Multi crystalline silicon 72 m^2, 14% 0.4%/K
Battery type Battery efficiency, Battery capacity	Nickel – Hydrogen 95%, 4 kWh
Engine type Number of cylinders Total stroke volume, Rated shaft output Combustion type Compression ratio, Fuel Size, Dry weight	Vertical straight 4 cycle diesel, 2 cylinders 451 cc, 8.6 kW Special swirl chamber 24.5, Kerosene 369 X 385 X 485 mm, 60 kgf
Generator type Rated out, Rated voltage Frequency, Number of revolution Size	Single phase synchronized 5kVA, 100 V 50 Hz, 300 rpm 200 X 221 X 359 mm

3.2 Examination methods and Energy demand patterns

Two methods are examined in this paper. In Method 1, the operation plan of the system depends on the actual calculations of the PV power. On the other hand in Method 2, the NN prediction algorithm is introduced, and the operation plan of the system based on the predicted PV power.

The power demand patterns of a typical household is shown in Fig. 3 [4-8]. In this figure, the power demand pattern does not change significantly each month, this is because there is no cooling load in the summer. The power demand includes household appliances and electric lighting. The operating methods are introduced into three apartments with the load patterns shown in Fig. 3, multiplied by three.

3.3 Proposal Neural Network

The prediction algorithm of the PV power uses a layered NN as shown in the block diagram of Fig. 4. The structure of the layered NN is shown in Fig. 5, it consists of three layers: the input, the hidden layer and the output layer.

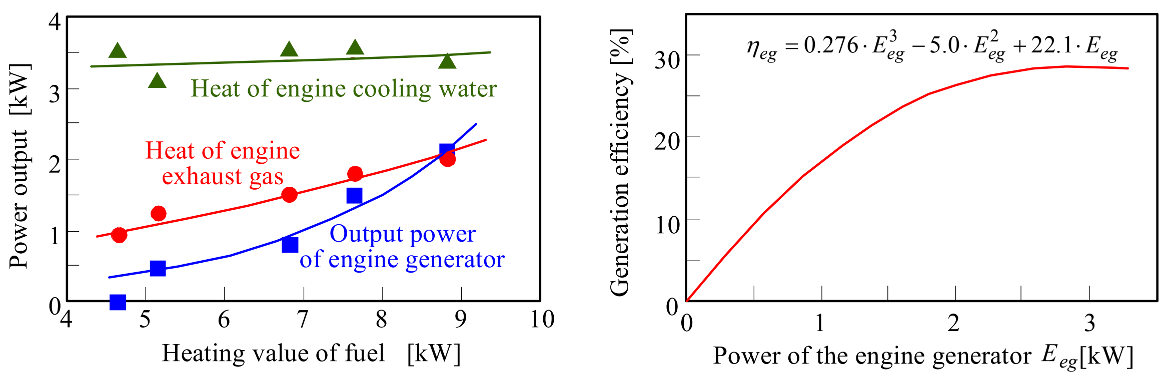
In learning process, first all weights are chosen in random and the past weather pattern of a slope-face solar radiation and outside air temperature are used as input signals to the NN and the teaching data are input into the output layer. The teaching data is the calculation of output power by using Eq. (5). The error of the training signal and data of the output layer is calculated.

The learning process is stop when the error is approached 0.0055%. Second step is the analysis process. In this process, the meteorology data of actual values of the solar radiation and the outside air temperature of a past day is inputted into the learned NN and the output is the prediction values of the PV power.

4. Results and Discussion

The PV output power by using Eq.(5) is shown in Fig. 6. On the other hand, the prediction values of the PV power by using NN prediction algorithm is shown in Fig. 7, these results is an average values per months. When comparing Fig. 6 with Fig. 7, the average values of the percentage of error are 25%, 29%, 19% and 26% for months December, March, June and September respectively as shown in Fig. 8. on the actual calculations of the PV power.

On the other hand in Method 2, the NN prediction algorithm is introduced, and the operation plan of the system based on the predicted PV power.



(a) Output characteristics of the engine generator

(b) Power generation efficiency of the diesel engine generator

Fig. 2 Output characteristics of the diesel engine generator at 1600 rpm

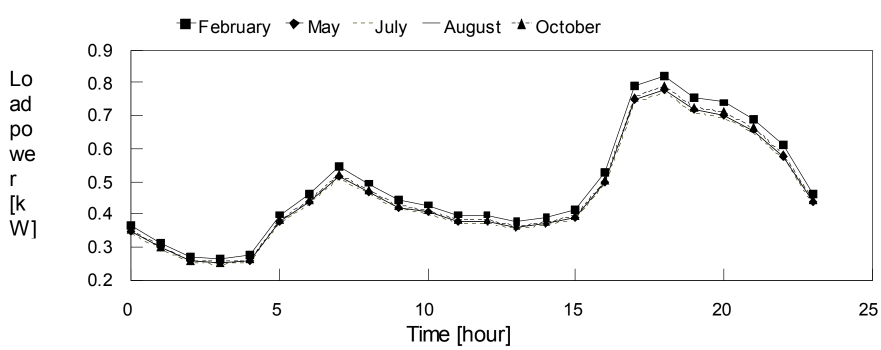


Figure 3. Average power demand of one household

4.1 Operating Methods Results

A battery is used to supply the demand side when the output power from the PV is insufficient compared to the power demand, as shown in Fig. 9. The surplus power from the PV is used to charge the battery. The diesel engine generator operates according to the charge or discharge of the battery, as shown in Fig. 10. The engine generator operates an average of 8, 6, 4, and 6 hours in Method 1 and 7, 5, 4, and 5 hours in Method 2 for each month, respectively. During these engine generator operating hours, the heat is supplied to the demand side.

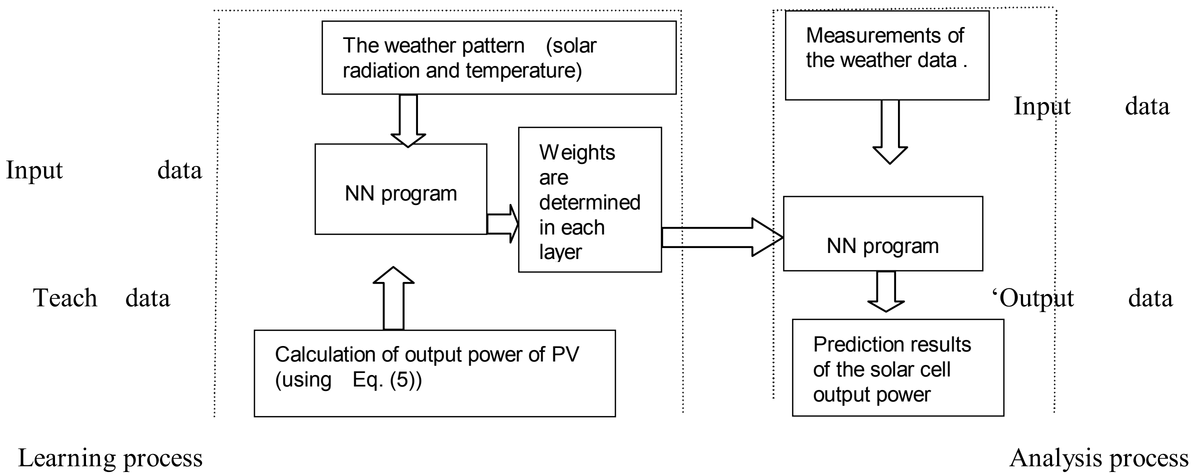


Figure 4 Prediction algorithm of electricity production from the solar cell

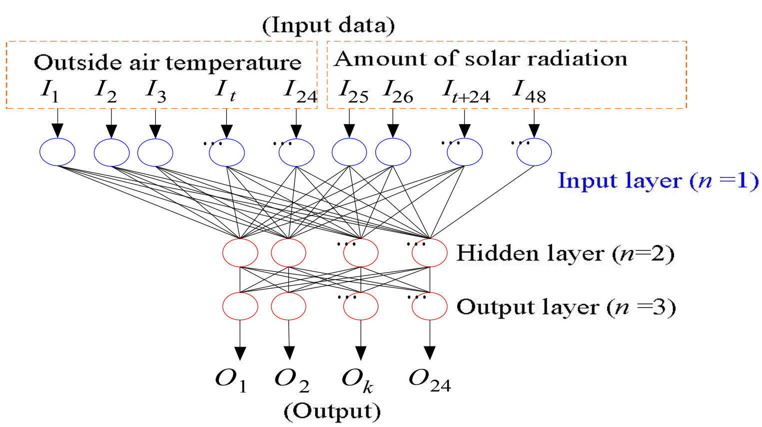


Figure 5 The layered neural network of the prediction algorithm

When comparing Fig. 10 (a) with Fig. 10 (b), the operating period of the engine generator is shortened by introducing the NN prediction algorithm. The engine operating time is reduced by 12.5% in December and 16.7% for March and September.

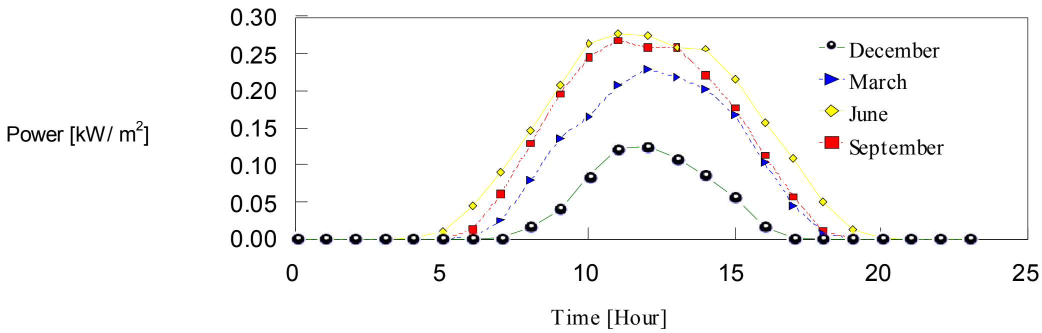


Figure 6 Average values of the output power from the PV

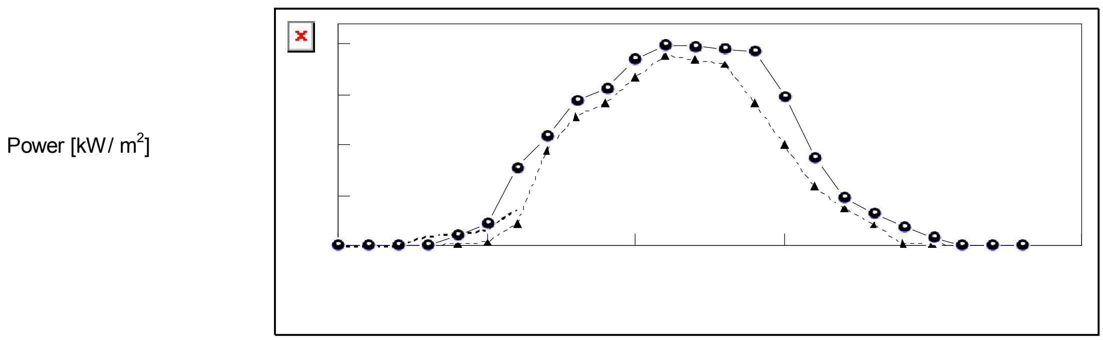


Figure 7 Predictive average values of the output power from the PV.

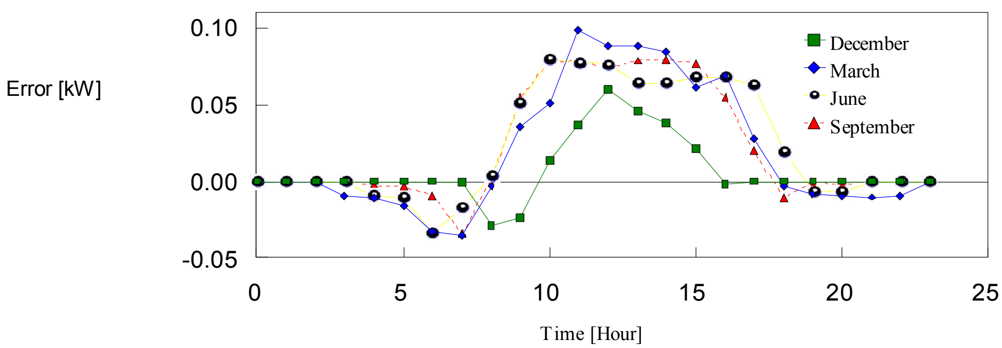


Figure 8 Error of power generation prediction of the power output from the PV

4. Conclusion

The prediction algorithm using neural network for the output power from the PV is developed. The energy supply characteristic of the PV and diesel engine generator combined system is proposed in case of two methods. In method 1, the operation plan of the system depends on the calculated results of the output power from the PV. Method 2 introduces the operation plan of the system according to the output power results from the NN prediction algorithm. The average values for the prediction error of the output power from the PV are 25%, 29%, 19% and 26% for December, March, June and September, respectively. The operating period of the engine generator is shortened by introducing the NN prediction algorithm for the power supplied to the demand side. The engine operating time is reduced by 12.5% in December and 16.7% for March and September.

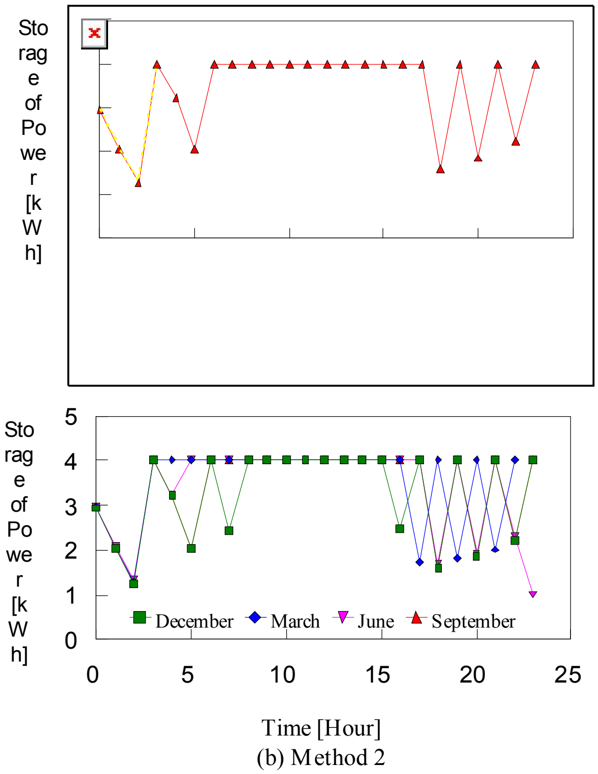


Figure 10 Operation plan of the engine generator

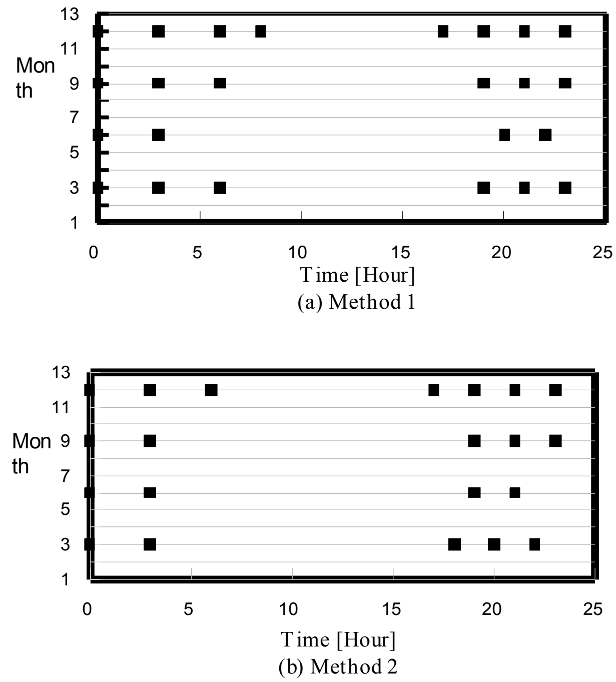


Figure 9 Operation plan of the battery

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