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Energy Harvesting from Ammonia Gas Treatment Tank in Organic Fertilizer Powder Plant

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Abstract

This paper proposes an ammonia monitoring system that harvests energy to operate in a chicken manure fertilizer plant. The harvesting is done via thermoelectric generators (TEGs) and photovoltaic (PV) cells. The TEGs convert heat energy on the surface of an air treatment tank into electrical energy by using the Seebeck effect. Since the temperature on the surface of the tank is not high, the TEGs can supply low-power loads. The other loads in the proposed system are powered by the PV cells. Energies obtained from TEGs and PV cells are stored in a supercapacitor (SC) and two lithium batteries, respectively. According to our experiment, the maximum power consumption used by the system was 644mW, while the maximum harvested energy was 4.4W on a sunny day. Together with our developed power management mechanism, our experiment showed that the harvested energies could supply enough energy for a device to run continuously while being able to detect abnormal level of ammonia correctly.

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Keywords: Energy Harvesting, Thermoelectric Generator, Energy Management, Hybrid Energy, Supercapacitor, Photovoltaic Cells.

1. Introduction

This paper is a collaborative work with a fertilizer powder factory in Chonburi province of CPF (Thailand) Public Company Limited. The organic fertilizer powder plant in Fig. 1 (a) has a cylinder tank for feeding chicken manure in. After a complete biodegradation, it creates hot intense ammonia gas (NH_3). The gas is an air pollution that must be treated by an air treatment tank. Temperature on the surface of the tank is approximately 45-50°C while air around the tank is 30°C. The tank has to be maintained when it lets out more ammonia gas. The factory needs an autonomous maintenance system with ammonia gas monitoring capability. This work is aimed to develop a system to harvest energy from an air treatment tank then to supply the energy to a monitoring system used for detection and notification of ammonia gas in the air which is released from the

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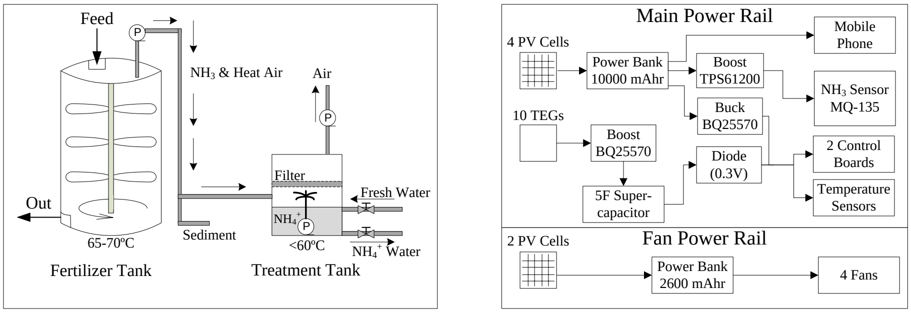
air treatment tank. Since the air treatment tank is hot and placed outdoor, the proposed embedded system in this work can harvest energy from the heat on the surface of the tank and the sunlight using TEGs and PV Cells as illustrated in Fig. 1 (b). The harvested energy from TEGs and PV cells are stored in a 5F supercapacitor and two lithium batteries. The harvested energies are used to operate major devices in the embedded system such as ammonia sensor, temperature sensors and control devices.

This paper focus on energy of the system and proposes two separate energy storages. That is the energy from TEGs is stored in a supercapacitor and the energy from PV cells is stored in two lithium batteries. The design in Fig.1 (b) has two power subsystems which are the main power subsystem and the fan power subsystem. The control boards are two microcontroller units (MCUs) used to read values from sensors and to enable sensors. The mobile phone controls the whole system via the control boards. It is also an energy manager and can send data to a server in the Internet via a GSM/GPRS gateway. Because of its tasks, it must be turned on all the time. The ammonia sensor is “MQ-135” sensor [1] which has a resistance value (R_s) that is inversely proportional to an ammonia level. The ammonia level can be estimated by $1/R_s$ which indicates when the air treatment tank has to be maintained.



(a) (b)

Fig. 1. (a) Organic fertilizer powder plant; (b) Energy harvesting diagram

2. Laboratory Test

The system cannot function properly if the maximum energy input is less than the maximum energy output. The laboratory test aims to solve this problem. Since the temperature on the surface of the tank is 45-50°C while the air around the tank is 30°C, the temperature difference will be more than 10°C. In our laboratory test, the temperature difference is simulated by a candle and heat sinks. A thermoelectric generator (TEG) model “TEC1-12706” [2] that can convert difference in temperature into electricity with the Seebeck effect [3] was tested. The results are showed in Table 1. The test used only one TEG on a number of temperature difference (ΔT) except the case A in the fifth column of Table 1 that used 10 TEGs. The maximum power was approximated by Eq. 1 [4]. According to Table 1, the maximum power of 10 TEGs is close to 5mW for 10^oC of difference temperature.

$$P_m = \frac{1}{2} I_{SC} \times \frac{1}{2} V_{OC} \tag{1}$$

The 6V 380mA photovoltaic cells is also tested in the laboratory. The results are showed in Table 2. Four parallel cells were used to supply the main power subsystem and two cells for the fan power subsystem. The maximum power is found by variation of load resistor from the lowest to the highest values. According to Table 2, the highest power for the main power subsystem are 4435.20mW. The maximum energy input on the main energy subsystem is more than 4440mW.