Computer Based Data Acquisition and Control in Agriculture

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ABSTRACT

It gains much attractive attention on the increasing oil price that derived from a energy shortage, decreasing earning power in agricultural field caused by price rising of oil, and environmental problems of using fossil fuel. In order to reduce oil dependency, the heat pump (HP) with greatly improving performance has aroused remarkable concern again in recent years; especially water heat pump was widely used in agricultural field. However, the problem remains in an initial investment such as the cost of digging in the groundwater well, which restricts the development of heat pump. Thereby, it deserves much more attention to use melting snow well largely in cold regions covered with snow so as to save investment of machinery equipment. The existing equipment can be used as heat supply and then to build compatible type heating systems without using oil. Coefficient of Performance (COP) is used to evaluate heat pump cropping system that can be obtained based on calculating temperature of groundwater, internal temperature in greenhouse, the temperature and flux at alleyway of groundwater drained by heat pump, and electric consumption.

Keywords: water heat pump, underground water, snow melting, snowy cold area, coefficient of performance

Introduction

Approximately 82% of original energy demand in Japan depends on being imported from foreign countries, thereinto, about 99.8% is oil. It is shown that a domestic productive capacity in energy is extremely low. Therefore, the primary task of research work is to establish the stable supply of energy by seeking other approaches and then to reduce the import dependency degree of energy.

The reserve-production of oil can provide only about 40 years’ sustainable production after being calculated provisionally while giving an optimistic view (the exploitable reserve is divided by production yield each year) as being the finite resources. For some reasons that it is necessary to increase other alternative energy and reduce the dependency degree of exhaustible resources, such as to limit the use of fossil fuel which exhaust much CO2, NOx, and Sox while being burnt and cause the global warming because of greenhouse effect and then to reducing environmental problems. In addition, the utilization of the clean energy that can suppress the consumption of the fossil fuel and reduce the environmental load is necessary and indispensable. In this current state, the use of the renewable energy that exists in the natural world as an alternative energy to oil is expected. The greatly improving performance of gain of the heat pump (HP) where natural energy can be effectively used is remarkable. Air heat
sourc HP use has extended by the miniaturization and lowering the cost. Although, the coefficient of performance (COP) was decreased by defrosting in the cold region where the outside temperature is too low, stable COP can be obtained no defrosting by making the heat source using underground water in hydrothermal source HP. The excessively high investments of digging in the wells become a large encumbrance and causes that it is not widespread. In the present study, the purpose of this paper is to reduce the amount of the consumption heating oil and the amount of the carbon dioxide emission by solving the problem of the excessively high expense by constructing the greenhouse heating system that uses snowmelt water as the heat source of HP, which are used for melting the snow in the snowfall cold region in general.

Materials abd Methods

The experiment was performed in Yuzawa-machi, Tsuchitaru, Minamiuonuma-gun, Niigata Prefecture, Japan. The test region is the heavy more-snow region in Japan, and the horticultural crops were cultivated using the greenhouse in winter which was covered by the bilayer acrylic with great snow endurance (NS-trending greenhouse with 9.2 m in width, 15.5 m in length, 5.5 m in height of the building, and 2.9 m in the eaves height) incidental the ventilating fan. Two water heat pumps (EC042, FHP) were set up in the house heated with the warm water boiler with Oil-fired Engine as an existing facility (SBG80s and Chofu Factory). The main cultivated crops were floriculture in greenhouse and the temperature of inside was controlled between 15-25 °C.

a. Measurement and analysis of the environmental data

In order to observe the environmental control situation of greenhouse, the data were recorded using the data logger by various sensors being installed on the inside and outside of the greenhouse. The thermocouples (T type and φ0.32 mm) were set from ground to the position of 2.0 m height locating on four different places in the greenhouse the thermocouples also were set from ground to the height of 0.5 m, 1.0 m, and 2.0 m in the center of the greenhouse, respectively. The temperature of seven points were measured and recorded. Thermohygrometer (RTR-53, T&D) was set at the center of the greenhouse and Oil meter (LM05ZAT-AR, HORIBASTEC) was set in the boiler to control greenhouse heating comparing to normal conditions. The amount of the oil consumption was measured (boiler heating investigation period: from Jan. 20th to Mar. 25th of 2010). In addition, temperature and flux (FD-50MY, KEYENCE) of the heat source groundwater at gateway were measured in HP, and both of them were recorded by the data logger.

b. Comparative analysis of heat production and its consumption of energy by measurement

This test was performed using two HPs during 25th-27th in Jan. (Period1) and using one HP during 17th-22th in Mar. of 2010 (Period2). The heat production was calculated according to temperature difference at gateway of the groundwater and the actual measurement value of water flux during the experiment period. In addition, the amount of power consumption in the heat pump was measured to evaluate the efficiency of thermal transformation
using Coefficient of Performance (COP) of the heat pump. The calorific value from the heat pump was converted into the amount of heating oil when it was supplied with the boiler (Alternative heating oil). The boiler efficiency (85\%) and the lower heating value of heating oil (9.47 kWh/L) were used for calculating the calorie value. In addition, the amount of the CO2 exhaust and its exhaust reduction rate of the heat pump were calculated from the electric energy consumed by the heat pump and the amount of alternative heating oil also were calculated respectively.

Results and Discussion

a. Groundwater of melting snow as heat source of heat pump

Figure 1 showed the temperature change of groundwater of melting snow and its variation range changed within the range of 7.8-9.2 °C after being continuously measured during the investigation period. It was lower temperature than the expectation as the heat source of the HP. It indicated that increasing the amount of groundwater was very important for improving the COP of the HP.

In general, the goal of the groundwater of the heat source was originally used for melting snow. The distribution of the volume of water should be adjusted when s melting now and the heat pump are operated simultaneously, as the outlet temperature of the groundwater reached a freezing temperature, the heat pump stopped to supply the heating by the safety device. As a result of the experiment, that the minimum requisite volume of water for supplying the heat pump was 20 L/min in one heat pump was operated by using 8.5 °C in the mean temperature of groundwater. In this experiment, it was controlled to supply for the minimum requisite volume of water for the melting snow priority to supply for HP.

b. Efficiency of HP

Figs. 2 and 3 show the running situations of the HP for supplying heat source in experiment periods 1, 2, responsibility. In Period 1, the mean outside temperature was -1.6 °C; both the snowfall and solar radiation were little. The temperature in the greenhouse was able to be maintained roughly within the range of the control target (Fig. 2). The temperature in the greenhouse was near to lower limit of the range of the control target when the outside temperature was very low from the morning of Jan. 27th. It was necessary to perform the heat insulation countermeasures for maintaining the preset temperature of greenhouse. In Period 2, the mean outside temperature was 3.3 °C; weather condition was fine weather with solar radiation in daytime and HP did not be operated because of a lot of solar radiation, but it was operated from about 5 pm to 7 am of next morning. The mean temperature from 5 pm to next 7 am was about 0 °C. It will be necessary to compare the efficiency of heating of two between HPs and a boiler in HP in the future because it often fell below the range of the control target in heating with one heat pump. The temperature change in the greenhouse under the oil boiler control (Jan. 22th) was compared with under HP control (Jan. 26th) at same weather condition of between 2 days. Results were shown in Table 1.

For both 2 control methods, the range of the target control temperature is maintained as shown in Fig. 4. It follows from this results that the regulating system by HP functions is
feasible to replace the habitual practice control as an alternative system.

It was observed that change of COP was inversely proportional to the air temperature change of the greenhouse after calculating the COP of the HP control during each period. The groundwater was 8.5 °C at inlet; and that the exhausted energy from the decreased temperature (3.6 °C from inlet to outlet) of groundwater was transferred for supplying heating source in the greenhouse. The difference between COP in HP1 and HP2 derived from the difference of the amount of the groundwater flux. The average COP of HP1 and HP2 was 3.4, and 4.4, respectively; moreover, the average COP of HP2 for period 2 was 3.8. The effectiveness of this system was considered as an available result derived that the value of water HP was kept in the range of practical level 3.0-4.0. COP is a ratio of the supply heat quantity to the greenhouse and the amount of power consumption of HP. It is necessary to calculate not only the amount of power consumption of HP but also to evaluate the effect of HP with a ratio of the supply heat quantity in the entire system and the amount of power consumption. When system COP is calculated, it should include the amount of power consumption of pump the drawing up the groundwater because it is a necessary amount of power consumption regardless of the operation of HP. when the melting snow and HP are operated at the same time, it is the advantage of this study that machine unit COP can be considered to be system COP in this system. When snow melting is not operating, system COP decreases greatly because of the calculation including the amount of power consumption necessary for the snow melting. Furthermore, the time of melting snow was investigated in this area and Fig. 5 showed the operating time of melting snow in February. The operating time for melting snow was 45.1% of the whole research period and the change of operating time was according to the weather condition. It is considered as a feasible method that uses the oil boiler instead of HP while it is non-time of melting snow.

c. Amount of alternative oil and reduction rate of CO2 emission using HP system

The calculated results showed that the amount of alternative oil using HP was 99.6 L (20.8 L/day) for period 1 and 92.7 L (51.7 L/day) for period 2. In addition, a remarkable reduction result was obtained as shown in Table 2 and the reduction rate of CO2 emission was 57.3% for period 1 and 56.2% for period 2, respectively.

Future Work

It is required to improve the HP system that a steady amount of the groundwater to HP is supplied when that is used to melt snow and to supply house heating at the same time. In addition, it is necessary to reduce the heating load depending on improving system COP. It is also necessary to do further research for using the auxiliary facility such as the heat insulation curtains to greenhouse and improving system COP of HP under a long-term running. In addition, the cooling experiment in summer by HP is scheduled to achieve the year-round culture in greenhouse.

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Promotion Foundation, and Sasaki Environment Technology Foundation for supporting this study.

References


Table 1 Weather Condition for Different Heating Systems

<table>
<thead>
<tr>
<th>Date</th>
<th>Mean air temperature (°C)</th>
<th>Maximum air temperature (°C)</th>
<th>Minimum air temperature (°C)</th>
<th>Sunshine hours (h)</th>
<th>Snowfall (cm)</th>
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<tbody>
<tr>
<td>Jan. 22th</td>
<td>-1.5</td>
<td>0.1</td>
<td>-3.2</td>
<td>0.7</td>
<td>17</td>
</tr>
<tr>
<td>(boiler</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>heating)</td>
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<tr>
<td>Jan. 26th</td>
<td>-1.1</td>
<td>-0.1</td>
<td>-2.0</td>
<td>0</td>
<td>15</td>
</tr>
<tr>
<td>(HP heating)</td>
<td></td>
<td></td>
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</table>

Table 2 Power Consumption, Amount of Alternative Heating Oil and CO\textsubscript{2} Emission During Each Experiment Period

<table>
<thead>
<tr>
<th>Investigation period</th>
<th>Power consumption (kWh)</th>
<th>HP Carbon dioxide emission (kg)</th>
<th>Boiler Alternative heating oil (L)</th>
<th>Carbon dioxide emission (kg)</th>
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</thead>
<tbody>
<tr>
<td>Period 1</td>
<td>225.2</td>
<td>99.3</td>
<td>92.7</td>
<td>232.8</td>
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<tr>
<td>Period 2</td>
<td>248.1</td>
<td>109.4</td>
<td>99.6</td>
<td>249.9</td>
</tr>
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</table>

Fig. 1. The Temperature Change of Underground Water

Fig. 2. The Temperature Change in Greenhouse, COP of the Heat Pump (Period 1)

Fig. 3. The Temperature Change in Greenhouse, COP of the Heat Pump (Period 2)

Fig. 4. The Temperature Change in the Greenhouse by the Oil Boiler Control (January 22th) and by HP Control (January 26th)
Fig. 5. The Operating Time of Snow Melting in February