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Design and Evaluation of Small Wind Turbine Driven Earth to Air Heat Exchanger System for Heating Greenhouses

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ABSTRACT

For the first time, the simple EAHE and SWTS are analyzed from the thermodynamics viewpoint. The main goal of this study is to investigate the use of wind energy in greenhouse heating, which is modeled as hybrid earth to air heat exchanger (EAHE) and a small wind turbine system (SWTS) fixed at the Solar Energy Institute at Ege University, Izmir, Turkey. The study shows that 100 percent of the overall annual electricity usage of the model system (1970 kWh) can theoretically be achieved using SWTS. Under this result, developed passive solar preheating techniques combined with EAHE and SWTS might become economically better than conventional space heating / cooling systems used in agricultural and residential heating applications if such buildings are built in a location with a heavy winds resource.

1. INTRODUCTION

The study presented was inspired by the publication of Ozgener (2010), in which the SWTS drive GSHP system for greenhouse heating was investigated intensively for the first time.

Applications for greenhouse heating have an significant influence on product production, efficiency and time of cultivation. Thus, architects and engineers build many passive methods of heating and cooling renewable energy. Based on the energetic features of urban and farm construction air conditioning systems in the open literature. EAHE systems are not only used to install air conditioning but also to increase the performance of energy systems. EAHE systems have a higher output in thermodynamics than the solar-assisted geothermal heat pump technique used to test a solar greenhouse.

Moreover, numerous research has been carried out on geothermal and solar residential and farm building heating systems, from fundamental studies to energy and exergy studies (Ozgener and Ozgener, 2010a-d, Ozgener, 2011, Ozgener and Ozgener, 2011, Ozgener et al, 2011, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020)

Given the difficulty of connecting wind energy to conventional space heating and cooling equipment, wind power seems to be an exciting alternative. This paper argues an improved model for the heating and energy market by the use of wind power from agricultural buildings. This new model is used to research two distinct interconnection schemes for the major users of thermal energy: (i) examine the rate of energy gain from geothermal and passively heated solar greenhouses and (ii) investigate the use of wind energy in greenhouse heating with model hybrid EAHEs and SWTSs installed separately at the Solar Energy Institute of the University of Ege, Izmir, Turkey.

2. DEFINITION AND DESIGN OF METHOD

The system conceived in principle is as shown in Figure1. The framework has similar application Ozgener(2010). In this analysis, a 1.5 kW small wind turbine driving an Earth to air heat exchanger (EAHE), a hybrid system, is assumed to meet the thermal loads of a 12.54 m^2 solar greenhouse. This research looks at the solar greenhouse heating system which includes the following subsystems- see Figure 1: (a) earth linking loop, and (b) SWTS; a vertical axis wind turbine device. Together with EAHE and SWTS, figure 1 presents a model system diagram. In Figure 1. Displays a schematic diagram of the planned and investigated device, which is earth to the air heat exchanger system mainly of a powered electric motor driving 0.7 kW blower (fan) and 1.5 kW of small wind turbine. The principal characteristics of the built and investigated device components, in the accompanying papers of the author (Ozgener, 2006, Ozgener and Ozgener, 2007, Ozgener, 2010, Ozgener and Ozgener, 2010a-d, Ozgener, 2011, Ozgener et al, 2011, Ozgener and Ozgener, 2011, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020) all the relevant experimental instruments used in the studies have been clearly defined, e.g. the form, model, precision, etc. Past studies (Ozgener and Ozgener, 2010a-d, Ozgener and Ozgener, 2011, Ozgener et al, 2011, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020) imply that daily energy use for greenhouse heating is dependent on seasons and evolving climatic conditions. Usage of the modeled system is as follows:

This paper does not explain the thermodynamic study of SWTS and EAHE, more data can also be found in a series of articles (Ozgener and Ozgener, 2010a-d, Ozgener and Ozgener, 2011, Ozgener et al, 2011, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020). Models are therefore provided for all sub-systems. The sub-systems of the studied model (SWTS, greenhouse, and EAHE) were introduced at the Solar Energy Institute of Ege University (Izmir, Turkey). The active EAHE heating system provides heat greater than the electricity supplied by the passive solar heating system.

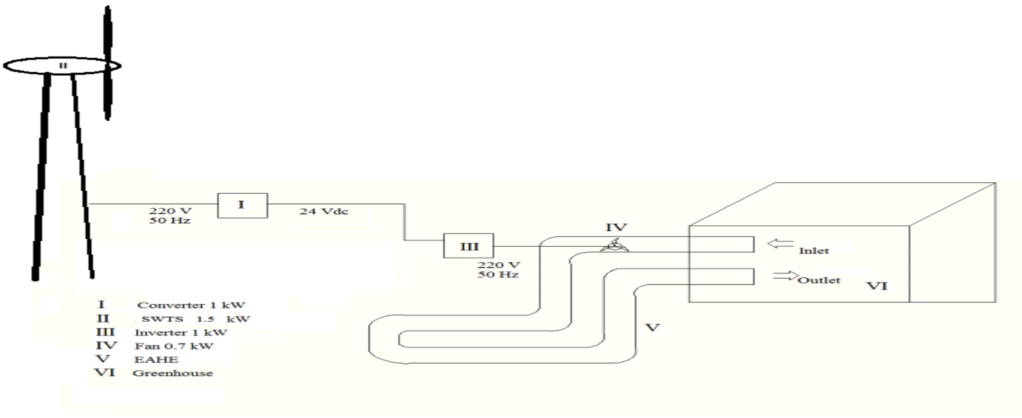

Figure 1: Schematic description of the system theoretically conceived and examined

3. PERFORMANCE AND DISCUSSION

The study indicates that using improved passive heating methods annually is more efficient, and EAHE drives SWTS drives for residential and agricultural buildings. In this study the findings obtained from SWTS performance experiments during the heating cycles of 16 December 2003-31 March 2004, September-August 2003 and 30 October-5 November 2003. For comparative purposes, performance is measured to determine the efficiency characteristics of the unit being designed and investigated (Ozgener and Ozgener, 2010a-d, Ozgener and Ozgener, 2011, Ozgener et al, 2011, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020).

3.1.1 Passive solar preheating efficiency

Passive heating system evaluation was carried out on the basis of experimental and theoretical analyzes during the 2016 heating season, and meteorological data such as variance of monthly average ambient temperature values, relative humidity was obtained for the outside greenhouse, whereas greenhouse air temperatures and humidity were measured using multi-channel cable free thermo-hygrometer. Measurement of greenhouse surface temperatures of glass reinforced plastics (GRPs) was done with an infrared thermometer. The experiments on the passive heated greenhouse were carried out under steady state conditions during the heating season 2016. Average standard values of 21600 measurements were begun at 0.00 A.M. within 23.59 hours. A multi-channel cable free thermo-hygrometer was used to measure the average minimum and maximum temperatures and humidities. During the night, energy consumption levels were found to be low, as planned. The average uncertainties associated with greenhouse air temperatures and thermal load were respectively 5.03% and ~6.42%. A measurement of the heat loss is the first step in evaluating the potential of the heating system before choosing the system and its different parts. Under severe weather conditions, the heating system should be appropriately designed to suit the greenhouse needs. At design conditions, the average heating load of the prototype solar greenhouse is obtained to be 7.4 kW (Ozgener and Ozgener, 2010a-d, Ozgener and Ozgener, 2011, Ozgener, 2011, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener and Ozgener, 2020, Ozgener et al, 2011,2013) show the difference in the average monthly outdoor air levels, passive heated greenhouse inside average temperatures and relative humidity for 2016. The average monthly ambient air temperatures ranged from 6.69 to 29.11 ^{o}C while the minimum and maximum greenhouse temperatures ranged from 16 to 36.9^{o}C. The annual average temperature values for ambient air and greenhouse are 18.76 ^{o}C, respectively, and 22.1^{o}C.

3.1.2 EAHE Efficient Heating

An experimental device for investigating an EAHE's thermal efficiency in greenhouse heating was installed. It was run satisfactorily in the 2016 heating season, without any significant defects. The results obtained during the 2016 heating cycle were discussed and debated. EAHE heating efficiency is provided through (Ozgener and Ozgener, 2010a-d, Ozgener and Ozgener, 2011, Ozgener et al, 2011, Yildiz, et. al, 2012, Ozgener et al, 2013, Ozgener and Ozgener, 2013a-b, Ozgener et, al, 2017, Ozgener and Ozgener, 2020). The volumetric efficiency of the fan was taken to be 85 percent, according to these experimental tests. EAHE 's output coefficient (COP) values were found to be within a range of 2-4.5, respectively, whereas the average uncertainties associated with COP were found to be around 4 percent. The main parameter for the EAHE, i.e. the heat extraction rate in Watt per meter of pipe length, is heat extraction rate. The rate at which heat is extracted from the ground (EAHE load) was found to be averaging 2,5 kW during the heating season. The required heating capacity of the borehole lengths in meter per kW was found to be 53.20.

3.1.3 SWTS Power Generation Output

A test facility was built during night conditions to research the electricity required for the Solar Energy Institute 's environmental lighting. Energy used for environmental lighting purposes is dependent on seasons and climatic conditions that change daily. A horizontal axis wind turbine with three plastic bladed rigid hub supported by epoxy carbon fiber was installed and included full SWTS units at Solar Energy Center, Ege University, Izmir (Ozgener, 2006, Ozgener and Ozgener, 2007, Ozgener, 2010).

3.1.4 General Outcomes of an Audit of the Program Studied

In this section, the total energy consumption and the results of the modeled hybrid EAHE and SWTS are given. For different reference state values, the total heat demand values are obtained for a range from 0 kW to 7.4 kW, essentially from 0^{o}C to 20^{o}C for better coverage and presentation of how the varying reference state temperature affects device output in terms of energy demands. While the total thermal energy consumption of the studied system is estimated to be 7600 kWh / year, the total consumption of electricity is found to be 1970 kWh by taking the COP value as 3.85.

4. CONCLUSIONS

A system was developed to investigate efficiency by using wind power to ensure the power supply for greenhouse heating. Also the impact of environment conditions and operating parameters on the output parameters of the model system were investigated. The key conclusions to be drawn from this review can be summed up as follows: We could decrease power consumption until 50W, and COP value reached over 4.

a) The mean monthly ambient air temperatures ranged from 6.69 to 18.96°C in the 2016 heating season, the average monthly greenhouse temperatures ranging from 12.1 to 23.6°C for this heating season the average temperature values for the ambient air and greenhouse are obtained as 12.56°C and 20.1°C.
b) It is estimated that 100 per cent of the modelled system's overall annual electricity demand can be achieved by potentially using SWTS.

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