European Journal of Emerging Technology and Discoveries
ISSN (E): 2938-3617
Volume 2, Issue 4, April - 2024

GREENHOUSE HEATING SYSTEMS BASED ON GEOTHERMAL ENERGY

Alijonov Xabibullo Avazbek o’g’li
Andijan Machine Building Institute, "Machine-building production
Assistant of the Department of Automation"
Email: habibulloalijono39@gmail.com
Tel:+998937037710

Fayzullayev Zafarbek Farxod o’g’li
Andijan Machine Building Institute, "IB and KT" faculuty student
Email: zafarbekfayzullayev524@gmail.com
Tel:+998907681315

Jo’raboyev Mashhurbek Yaqubbek o’g’li
Andijan Machine Building Institute, "IB and KT" faculuty student
Email: mashxurjoraev56@gmail.com
Tel:+998912956401

Muxammad Aminov Abrorbek Dilshodbek o‘g‘li
Andijan Machine Building Institute “IB and KT" faculuty student
Tel:+998934160528
Email: abrorbekmuhammadaminov412@gmail.com

Abstract
Geothermal energy is one of the most important energy resources for electricity generation and is also used directly in heating, food and agriculture, aquaculture and some industrial processes. This paper presents a design of a greenhouse using a renewable energy resource for the thermal heating and electrical requirements for its operation. Photovoltaic , wind and geothermal energy are used for improve efficiency of crop production. In Egypt, the Suez Gulf is rich of geothermal springs. Ras Sedr is the site under consideration for chilli production, the required temperature is between 25-35 oC. There are several methods for greenhouse heating systems using geothermal energy which are finned pipe, standard unit heaters, low temperature unit heaters, fan coil units, soil heating, and bare tube. The economic analysis of thermal and electrical is done. The PV-wind hybrid system is proposed for greenhouse heating system which contains of (0.5 kW) photovoltaic arrays, (6 kW) wind turbines, one battery storage, inverter and charge regulator subsystems with levelized cost of energy of 0.114 $/kWh.[1]

Keywords: Agriculture, geothermal energy, heating system photovoltaic, renewable energy.

Introduction

Geothermal energy has the potential to provide long-term, secure base-load energy and greenhouse gas (GHG) emissions reductions [1, 2]. Accessible geothermal energy from the Earth's interior supplies heat for direct use and to generate electric energy. Direct use provides heating and cooling for buildings including district heating, fish ponds, greenhouses, bathing, wellness and swimming pools, water purification/desalination, and industrial and process heat for agricultural products and mineral extraction and drying [3-5]. Agriculture applications are particularly attractive because they necessitate heating at the lower end of the temperature range where there is a plenty of geothermal resources. Using geothermal energy for greenhouse heating reduces operating costs and permits operation in colder weathers where commercial greenhouses would not normally be economical [2].

The technology of producing crops in greenhouses has been around for decades. Greenhouse agriculture is a growing trend around the world, and crops grown under these conditions are in high demand. Greenhouse has several advantages such as providing cultivators with the ability to accomplish significantly higher yields than open field production, using less land area compared to open field production and using water resources efficiently [8]. Also it declines the using of chemicals to control pests and diseases. Moreover, greenhouses enable a higher quality of products suitable for international markets, it needs less labors than open field production and allows extending period of the crop production [3-5].

This paper presents a design of electrical and thermal subsystems of a greenhouse using solar, wind, and geothermal energy respectively. The analysis of the electrical energy requirements of the greenhouse has been done using HOMER software. The peak heating requirements are calculated to select the appropriate heating system for a greenhouse. Comparison between the geothermal heating systems using analytical and software methods are introduced. Finally, a techno-economic analysis of the sustainable energy supply of the heat and electricity for the greenhouse has been done.

GREENHOUSE SPECIFICATION

Chilli is selected as the plant under consideration. Chilies are excellent source of vitamin, A, B, C and E with minerals like molybdenum, manganese, folate, potassium, thiamin, and copper. Also chilli is used as a spice, flavour pungent, preserving material. In addition, chilli is used as tonic to ward off many diseases as it activates stomach, eliminates colic and abdominal cramps and pain stopping from the teeth and gums, postate cancer treatment.

For the suggested greenhouse, a combination of fiberglass and plastic film material is used, the greenhouse is arched roof type and the roof is constructed with double poly and the walls are made of fiberglass. The frames of the greenhouse are constructed from aluminum which is relatively light in weight and at the same time very strong. It is malleable, adaptable, water proof and nonpoisonous. It does not rust or erode and conducts heat and electricity [6]. The proposed greenhouse

ISSN (E): 2938-3617
Volume 2, Issue 4, April - 2024

specifications and dimensions are indicated in Table 1.

Table 1. Proposed greenhouse specification and dimension.

Length	**45 m**
Width	9 m
Height	4 m
Roof area	418 m2
Wall area	420 m2
Volume	1620 m3
Shape	Arched roof
Side and end wall material	Fiberglass
Frame material	Aluminum
Roof material	Double poly

GREENHOUSE SYSTEM DESIGN

Greenhouse system is divided into two subsystems which are electrical and heating subsystem. The two subsystems are designed and discussed in details in the following sections.

ELECTRICAL SUBSYSTEM DESIGN

The Hybrid Optimization Model for Electric Renewable (HOMER) software has been used to perform random selection of sizing and operational strategy of generating system in order to obtain the finest solution of hybrid renewable energy with lowest total net present cost. [7]

Thus, the information required for this analysis was collected based on the load profile, average monthly wind speed and solar radiation. Ras Sedr is an Egyptian town located on the Gulf of Suez and the Red Sea coast. It is a part of the South Sinai governorate. Ras Sedr is 200 km from Cairo. Ras sedr is located at the latitude and longitude of 29o 25' N, and 32o 47' E respectively. The daily average radiation and wind speed data are given by Fig. 1 and Fig. 2 respectively [17]. The solar radiation in Ras Sedr (latitude 32o 47' East and longitude 29o 25' North) is between 3.58 kWh/(m2 day) and 8.15 kWh/(m2 day). The wind speed is between 5.6 m/s and 9.2 m/s. For the greenhouse system, it is required for the designer to stay near the system so a small house is designed for the labors of greenhouse. The electrical load consists of circulating pump, valves, controller, energy saving lamps, fans, refrigerator, washing machine, and television. The monthly load profile is shown in Fig. 3. From the load profile, the peak load is about 1.83 kWh with average energy consumption of 29.1 kWh/day.[8]

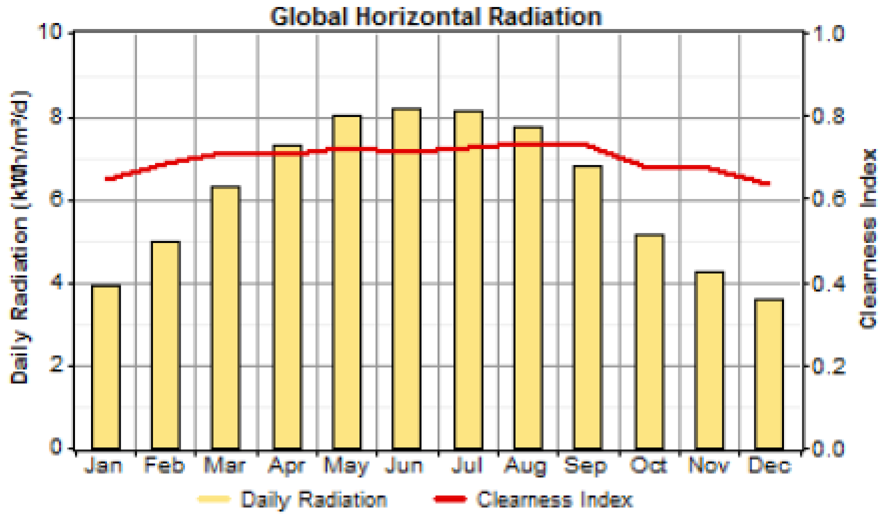

Fig. 1. Monthly average solar irradiance variation over the year.

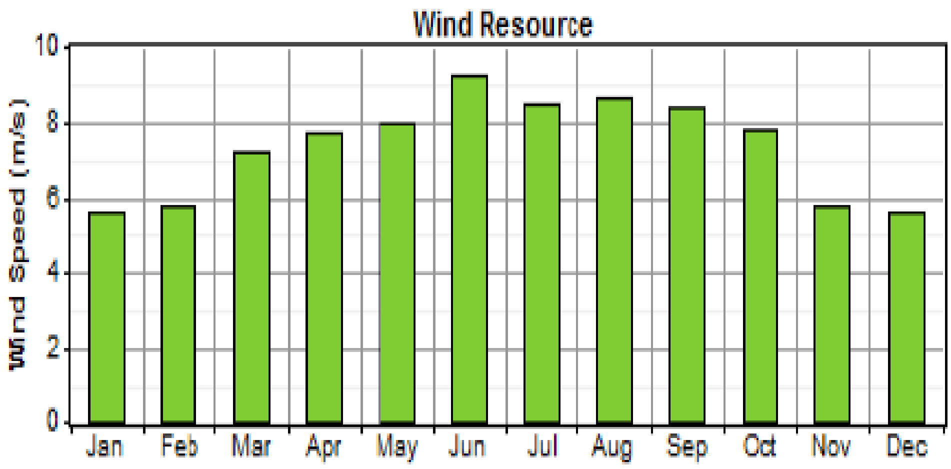

Fig. 2. Monthly average wind speed variation over the year.

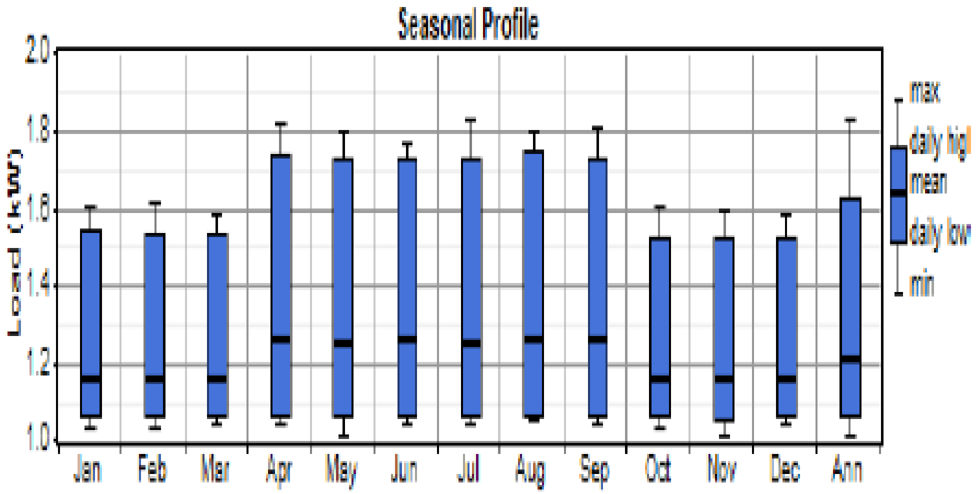

Fig. 3. Monthly average variation of electrical load over the year.

ISSN (E): 2938-3617
Volume 2, Issue 4, April - 2024

HEATING SUBSYSTEM DESIGN

The proposed greenhouse heating system is shown in Fig. 4. The heat exchanger is required to separate actual heating equipment from the geothermal fluid. The heating system is used to compensate the heat loss in the greenhouse. The greenhouse heat loss is composed of two components which are transmission heat losses (through the walls and roof), and infiltration heat losses caused by outside cold air as shown in Fig. 5. The total transmission heat losses can be estimated as follows [18- 21]:

The air change method is the general method for the calculation of infiltration heat losses. The method is based upon the number of times per hour (ACH) that the air in the greenhouse is replaced by cold air leaking from outside. The infiltration heat losses are calculated as [20, 21]:

The greenhouse heating load variation during the year is given by Fig. 6. In winter season, the heating load is higher than that of summer due to the difference between inside and outside design temperature.

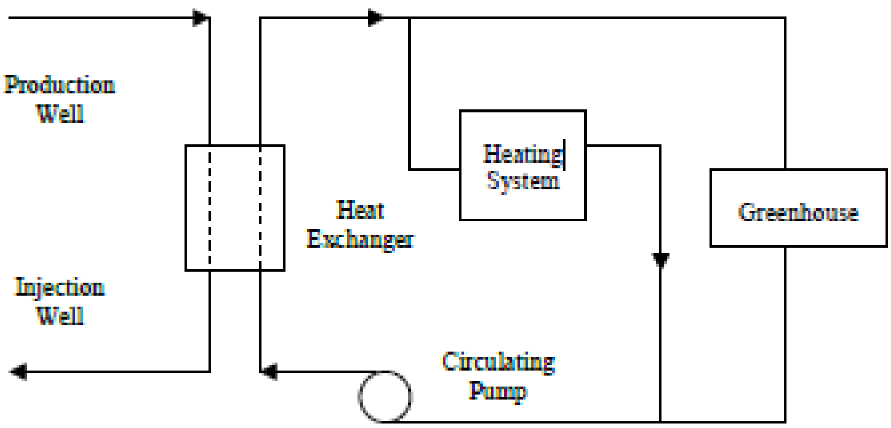

Fig. 4. Proposed greenhouse heating system.

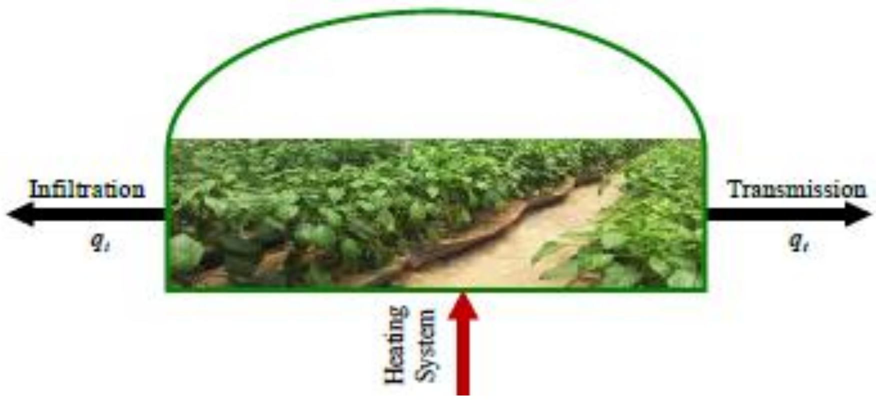

Fig. 5. Energy transfer through the proposed greenhouse.

F. Low temperature unit heate. Low temperature unit heaters are similar to standard unit heaters but their design is optimized for low-water temperature operation. These units incorporate a more effective water coil and a higher capacity fan. Low temperature unit heaters are larger and heavier than standard unit heaters. These units are horizontal in configuration and use a propeller fan type [20].

RESULTS DISCUSSION

Ras Sedr -2 well is used as a heating source for the suggested greenhouse. Ras Sedr -2 well has a moderate water temperature of 70 oC [22]. The analytical method results are given by Table 2. For the finned pipe heating system, the required heating element length is calculated using Eq. 7. To meet the heating load requirements, the UH and FC heating system is chosen from standard unit specification. According to soil heating system, the floor surface temperature is calculated firstly using Eq. 8. The total pipe length required to heat the soil of the greenhouse is determined using Eq. 11. For bar tube heating, the pipe length is determined using Eq. 16. Two types of GLW unit heater are considered which are one fan and two fans. The capacity and number of unit used is determined according to the standard unit specifications.[9-10]

Conclusion

Maximum required heating capacity can be calculated based on location and greenhouse construction characteristics. Different heating system options (hot air or water) are available (carefully evaluate pros and cons). When selecting a fuel source, consider unit price, energy content and conversion efficiency.

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