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Brief Note

On the addition of heat to solar pond from external sources

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ABSTRACT

This brief note addresses the method of adding heat to a solar pond from an external source which is used to enhance the performance of a solar pond. Heat energy collected by Evacuated Tube Solar Collectors (ETSC) is transferred by circulating fluid from the Lower Convective Zone (LCZ) of a solar pond. While adding the heat, a strange phenomenon is observed here which is against the intuition that higher the amount of heat added to the pond higher will be the temperature of the pond always. It is noticed that in the case of no or low heat extraction from the pond the heat is actually lost from the pond to the circulating heat adding fluid in specific periods of time which causes a drastic downfall of solar pond temperature. Moreover, it is observed that larger the capture area of the ETSC, larger is the heat loss from the pond. A strategy to control the heat loss from the solar pond by installing temperature sensors and flow controller in LCZ and the circulating fluid exiting ETSC is discussed here.

1. Introduction

Solar ponds are solar thermal collectors with inbuilt thermal storage. Solar ponds have not been widely used in the industry due to their low thermal efficiency as compared to other types of solar thermal collectors. A solar pond is a body of water with increasing density gradient with depth. The higher density of the fluid at the bottom helps suppress convective heat loss and traps the solar energy that reaches the bottom of the pond. Heat loss from a solar pond can occur in multiple modes. Heat is lost by conduction to the ground from the walls and the floor. Heat is lost by convection and evaporation to the atmospheric air from the top surface of the upper convective zone (UCZ). Some extremely small amount of heat is also lost by radiation. Solar ponds have been researched for over 5 decades and researchers around the world have tried to improve the efficiency of the solar ponds (Yaakob et al., 2011; Andrews and Akbarzadeh, 2005; Leblanc et al., 2011; Bozkurt and Karakilcik, 2012; Rubin and Bemporad, 1989). One of the methods proposed to improve the efficiency of the solar pond is by simultaneously extracting heat from LCZ and Non-Convective Zone (NCZ) of the solar pond (Yaakob et al., 2011; Andrews and Akbarzadeh, 2005; Leblanc et al., 2011; Date et al., 2013). This method was proposed to extract the solar energy absorbed in the upper layers of the solar pond and by doing so improve the efficiency of the solar pond. Studies show that the main limit to the solar pond energy collection efficiency is the rapid attenuation of sunlight in water and this presents a practical limit to the sunlight that reaches the storage zone. The main advantage of the solar ponds is their long term thermal energy storage capability. The idea of using solar ponds as thermal energy storage device has been proposed in recent years by some researchers (Singh et al., 2014, 2012, 2013). ETSC have high efficiency as compared to solar pond collectors to capture solar thermal energy, but they need a separate thermal energy storage device (i.e. insulated tank). Commercially available non pressurised insulated tanks can store hot water at around 90 °C for a very limited period of time (a couple of days) with over 8 °C of temperature drop in 2 days (Cynthia and Stephen, 2010; Hasnain, 1998). While solar ponds as storage device can store heat for much longer periods (weeks) without a significant drop in temperature (Cynthia and Stephen, 2010). Combining ETSC with solar ponds can help improve their performance as a hybrid system. The present note numerically investigates the coupling of ETSC with solar pond, discusses some problems of this hybrid system and finds out practical solutions to that.

2. Heat addition to the solar pond

Here the total energy added by the ETSC to the solar pond is calculated using Eq. (1), where η_{et} is the thermal efficiency of the ETSC and is a function of incident solar radiation and the temperature difference between average hot water temperature and ambient temperature as discussed by Budihardjo and Morrison (2009). The heat added to the solar pond q_a is proportional to the ratio (R) of aperture area of ETSC to the solar pond floor/surface.

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$$q_a = R \times \frac{\eta_{et}}{100} \times H_{et} \quad (1)$$

$$\eta_{et} = \left\{0.536 - 0.8240\frac{(T_{lcz} - T_{atm})}{H_{et}} - 0.0069\frac{(T_{lcz} - T_{atm})^2}{H_{et}}\right\} \times 100 \quad (2)$$

$$R = \frac{A_{et}}{A_{sp}} \quad (3)$$

where H_{et} is the global solar radiation flux incident on the ETSC (W/m^2), A_{et} is the ETSC aperture area (m^2), A_{sp} is the surface/floor area of solar pond (m^2), T_{lcz} and T_{atm} are the temperature of LCZ and atmosphere respectively (°C). Numerical model similar to that discussed by Date et al. (2013) has further been developed with heat addition component and used to study the thermal performance of the ETSC coupled solar pond hybrid system.

Increase in the ratio of aperture area R means increased evacuated tube collector area (i.e. increased number of components). The efficiency of adding more number of components to a system influences the overall system efficiency. Each component of a system contributes its own efficiency to the entire system. Increase in the value of R also indicates increase in the rate of heat addition to the solar pond from ETSC. To have improved thermal efficiency of a solar pond with a certain rate of external heat addition, the rate of heat extraction must be equal to heat addition. Instantaneous efficiency of solar pond as defined in literature (Date et al., 2013) will increase with increase in the value of R, if the rate of heat extraction is increased in proportion to rate of heat addition. If the rate of heat extraction is smaller than the rate of heat addition, then the solar pond temperature will rise and increase the heat loss to the ground and the atmosphere. Similarly if the rate of heat extraction larger than rate of heat addition the solar

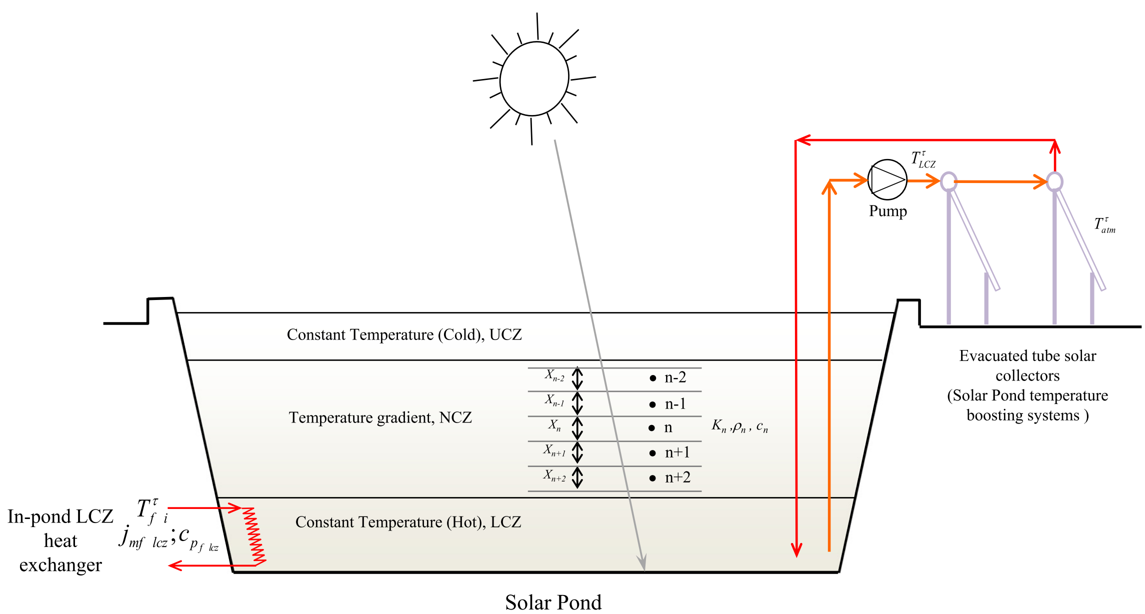

Fig. 1. Schematic diagram of salinity gradient solar pond with heat addition ETSC.

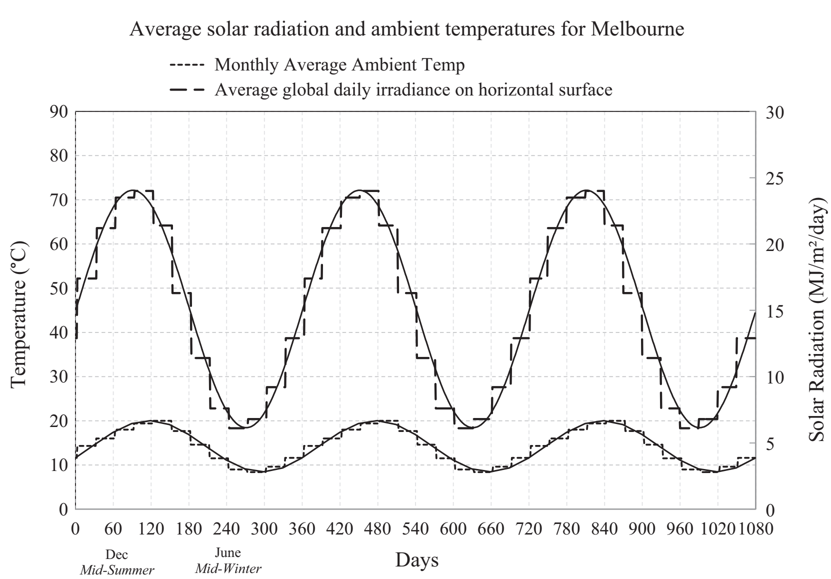

Fig. 2. Monthly average of daily solar radiation on a horizontal surface and monthly average temperature in Melbourne.