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Numerical Investigation On Sensitivity Analysis Of Single Slope Solar Still With Series Connected N Compound Parabolic Collector

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Abstract

This research article deals with the numerical investigation for the sensitivity analysis of four different parameters (1) mass flow rate (2) number of collectors (3) water depth and (4) packing factor on single slope solar still connected in series with partially covered photo voltic thermal integrated with N compound parabolic collector. The weather data has been collected for the Dehradun region for the month of April from Indian metrological department Pune. The sensitivity analysis was performed in MATLAB 2015 software by varying one parameter at a time and other parameters are kept constant. The result shows the productivity and electrical power output is most sensitive for no. of collectors. The average value of sensitivity for productivity of water of system by varying mass flow rate, no. of collectors, water depth and packing factor was found to be 0.298,0.331,0.143 and 0.078 respectively while the average value of sensitivity for electric power of the system by varying mass flow rate, no. of collectors, water depth and packing factor was found to be 0.011,0.78,0.008 and 0.920 respectively.

Keywords: Single Slope Solar Still, Photo Voltic Thermal, Compound Parabolic Collector, Sensitivity.

Introduction

The analysis of single slope solar still integrated with N similar compound parabolic collector is referred to as active type of solar still[1]. The working principle of the active type solar still is similar to passive type of solar still both works on evaporation and condensation of water and vapors by the use of solar energy. While purifying impure water by the help of

Conventional sources of energy it creates polluting elements which adversely affect the environment by polluting ecosystem, so sun as the main source of energy possess many advantages as clean source of energy, abundant in nature and non-polluting in nature etc.[2] over conventional sources of energy. This makes solar still shown in Fig.1 as the one of the best promising sources of water treatment. Now a days with rapid increase in population and poor water management system[3] every developed as well as developing nations are suffering from water scarcity problem and in future this can led to brutal situations like war.

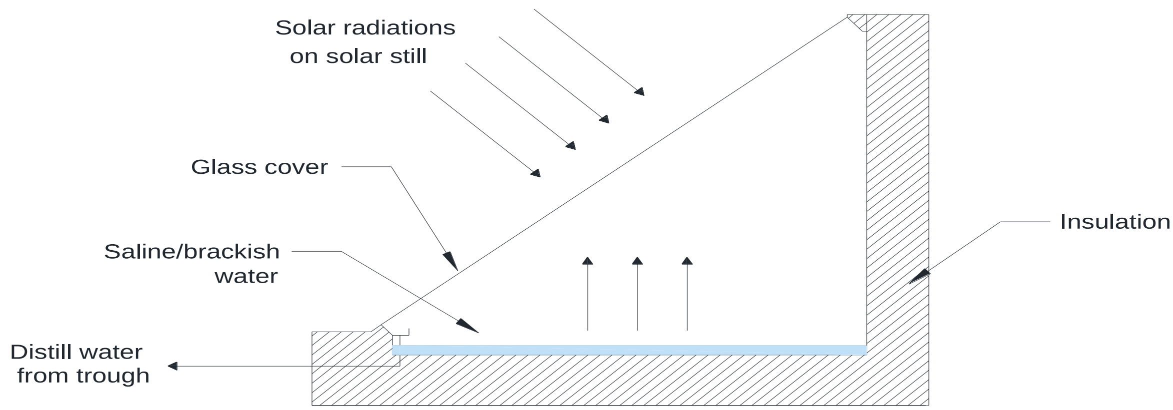

Fig.1 Schematic diagram of Single Slope Solar Still

In 1882, Charles Wilson invented conventional solar still[4] but due to low productivity it was limited in applications later many authors contributed in the field of solar distillation to enhance day as well as night productivity by modifications in design[5], integrating collectors[6], introducing nano particles/fluids[7], different coating on absorber plate[8] and glazing surface, using sensible[4] and latent heat storage etc. Some recent experimental and theoretical work carried on solar stills in order to enhance the distillate output of the still is discussed below:

Negi et al.[9] performed an experimental investigation on CSS by modifying CSS with tilted wick and FPC for the water depth of 3cm. The day and cumulative efficiency of MSS was found to be 16.3% and 22.1% high compared to CSS. Fayaz et al.[10] performed an experimental investigation by modifying CSS with tilted wick inside the basin at different angles. The maximum distillate output of 3.60kg/m^2.day was found at 30° inclination of wick at 0.2g/m^2 flow rate. D.B. Singh [11] investigated N PVT-FPC-SS and concluded exergy payback time of N PVT-FPC-SS is lower by 44.45% while energy payback time of N PVT-FPC-SS higher by 24.75% compared to CSS. Singh et al.[12] performed an analytical study over N PVT-CPC- BTSS. The optimum mass flow rate of 0.04m/s and 7 collectors in series were found to be ideal for study. Singh et al.[13] performed analytical study over N PVT-CPC- BTSS the parameters like exergoeconomic, enviroeconomic and productivity was found to be higher in case of N PVT-CPC DSSS compared to N PVT-CPC SSSS by 16.22%,21.48% and

8.56% respectively. Singh et al.[14] performed a comparative theoretical study on NETC-BTSS for the climatic condition of Delhi, India. The results show lowering of productivity cost by 15.19% for NETC-DSSS compared to NETC-SBSS. Badran et al.[15] performed an experimental study on SSSS with FPC, study shows increase in productivity by 231% for normal water and 51% in case of saline water.

From reviewing the above literature several researchers have contributed to enhance productivity of the solar still by introducing wicks, FPC, ETC, CPC but from the best knowledge of the author no work has been reported on sensitivity analysis of SSSS with series connected NCPC with partially covered PVT. So, in order to fill this gap a numerical investigation has been done in Graphic Era to be Deemed, Dehradun, Uttarakhand, India.

Description of System

The detailed description of the partially covered PVT NCPC-SSSS is shown in Fig.2. All the dimensions regarding the system are shown in Table 1. The average wind velocity data for the day was taken to be 3.5m/s from the Indian Metrological Department, Pune, India. The N CPC are connected in series in such a way that outlet of the collector was connected to the SSSS. Water was taken to be working medium for CPC. CPC were partially covered with PVT which simultaneously generate electricity to operate the pump used to circulate water. The CPC increases temperature of the water and the temperature inlet for the next CPC is the outlet temperature of the previous and so on that water was poured into the SSSS which cause increase in productivity of the system simultaneously.

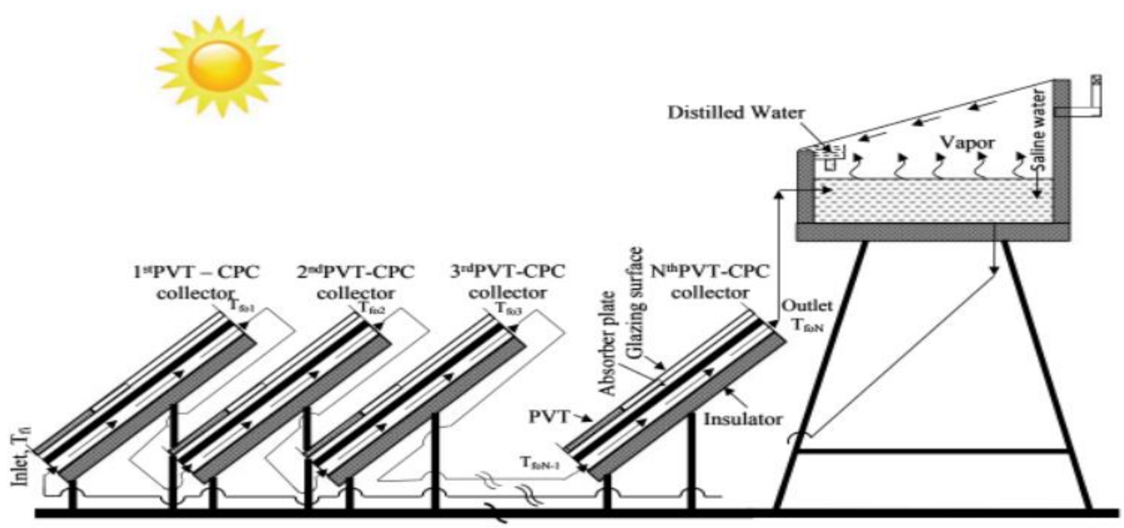

Fig.2 Schematic Diagram of Series Connected NCPC with SSSS with partially covered PVT

Table 1 Dimensions of SSSS [1], [11], [12]

Length (cm)	200

Width (cm)	100
Glass inclination (°)	15°
Thickness of Glass (cm)	0.4
Thickness of insulation (cm)	10
Material for Stand	Galvanized Iron
Material for body	Glass Reinforced Plastics

Mathematical Model Equations

Various equations were used to build a mathematical model for partially covered PVT with NCPC SSSS.

The outlet temperature of water from the N^{th} CPC is given by eqn. 1

$$T_{fo}N = [\frac{(PF)2\ K(\theta)(\alpha\tau)meff}{Ulm} I_u(t)+T_a]\ [1\text{-}exp\ \{\frac{-NFUlm.Am}{\dot{m}fCf}\}] + T_{fi}\ exp\ \{\frac{-NFUlm.Am}{\dot{m}fCf}\} \quad 1$$

Where $T_{fo}N$ denotes outlet temperature from N^{th} CPC and T_{fi} denotes inlet temperature of water.

Useful heat gain by the system is calculated by using eqn. 2

$$\dot{Q}uN = \dot{m}fCf(T_{fo}N - Tfi\ ) \quad 2$$

Where $\dot{m}_f$ = mass flow rate of water, C_f = specific Heat of fluid

Electrical power available by sun for the 10hours per day due to availability of the solar flux, and it can be calculated by eqn. 3 where, Ex_{elec} denotes power developed by the system

$$\dot{E}x_{elec} = A_m\ I_u(t)\sum_1^N \beta c\ \tau g\ \eta cN \quad 3$$

The various equations for the components of the single slope solar still[12][14] is discussed below

$$Tw = \frac{\dot{F}(t)}{a}(1 - e^{-at}) + Twoe^{-at} \quad 4$$

Where Tw denotes temperature of water, $\dot{F}(t)$ is average value of F(t) and T_{wo} denotes temperature of basin water at T=0. The value of a can be calculated by eqn. 5.

$$a = \frac{U_l}{(MC)w} \quad 5$$

The inlet glass temperature of the SSSS is calculated by using eqn. 6

$$Tgi = \frac{\acute{\alpha}gIg(t)Ag + h1wTwAb + UcgTaAg}{UcgaAg + h1wAb} \quad 6$$

The hourly yield $\dot{m}_{ew}$ can be from eqn.7

$$\dot{m}ew = \frac{hew(Tw - Tg)}{L} 3600 \text{ kg/m}^2\text{h} \quad 7$$

Where h_{ew} calculated by using eqn.8.

$$hew = 16.273 \times (10\hat{} - 3)hcwg \frac{Pw - Pgi}{Tw - Tgi} \quad 8$$

P_w and P_{gi} can be calculated using eqn.9&10

$$Pw = \exp\left(25.317 - \frac{5144}{Tw + 273}\right) \quad 9$$

$$Pgi = \exp\left(25.317 - \frac{5144}{Tgi + 273}\right) \quad 10$$

Sensitivity Analysis of the Model

Sensitivity analysis can be defined as change in output parameter w.r.t input parameters. Sensitivity helps to achieve insight about the critical parameters that will affect the model. In this study the effect of inputs parameters such as mass flow rate, no. of collectors, water depth and packing efficiency factor on the productivity and electrical power is calculated.

Methodology

The weather data was for the study was taken from IMD, Pune for the month of April as shown in Fig.3 for the climatic condition of Dehradun. These data and mathematical eqn. were fed into MATLAB-2015. At each run a single parameter was varied and others are kept constant. Results of the study were obtained for the productivity and electrical power obtained. Change in output of the study w.r.t input were calculated and sensitivity of the system calculated.

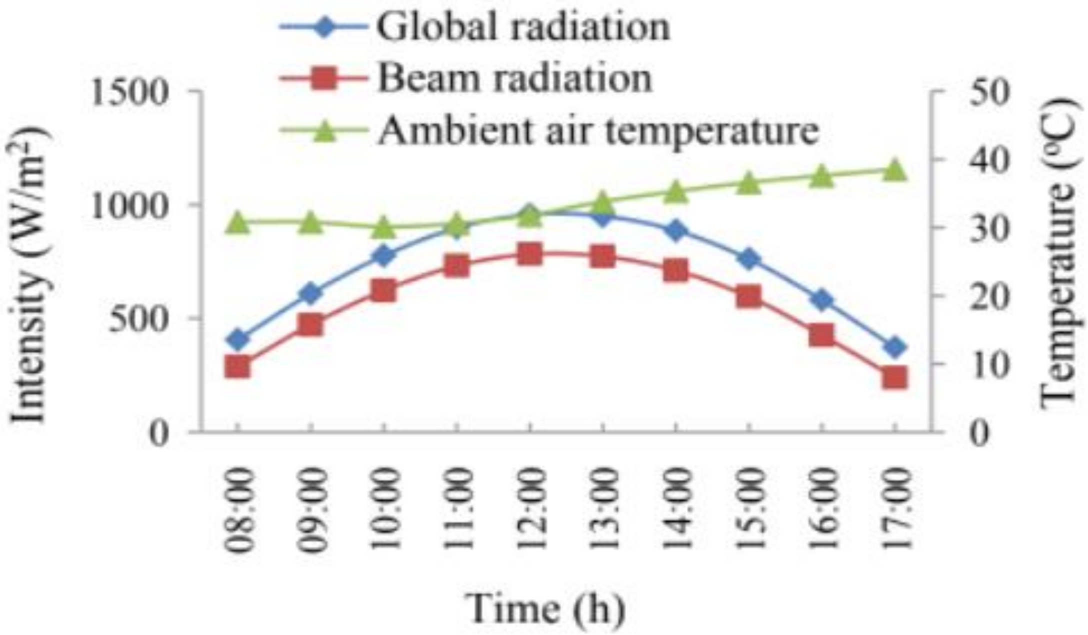

Fig.3 Weather data of the Study

Results & Discussions

After fed of all the data related to study into the computer in MATLAB for investigation of sensitive parameters value of the system and Table 2 shows the different values of sensitivity

Variation in Productivity Output by % Change in Input Parameters

Fig.4 shows the % change in productivity of SSSS by variation of % change in mass flow rate and partially covered PVT with NCPC. From the graph it can be clearly seen that the productivity of the still is more sensitive to no. of CPC when compared to mass flow rate. Lowering the values of mass flow rate and no. of CPC the system is more sensitive. Also, from Fig.5 The sensitivity analysis of the SSSS system w.r.t water depth and packing factor can be seen. The graph indicates the maximum change in productivity by changing water depth but the packing factor shows little deviation and remains around constant for less than 33.33%. Also, water depth variation less than 25% shows minimum output of potable water and reaches to 0% for variation in water depth below 11.11% but for more than 25% variation of water depth shows the maximum variation in distillate output up to 100%.

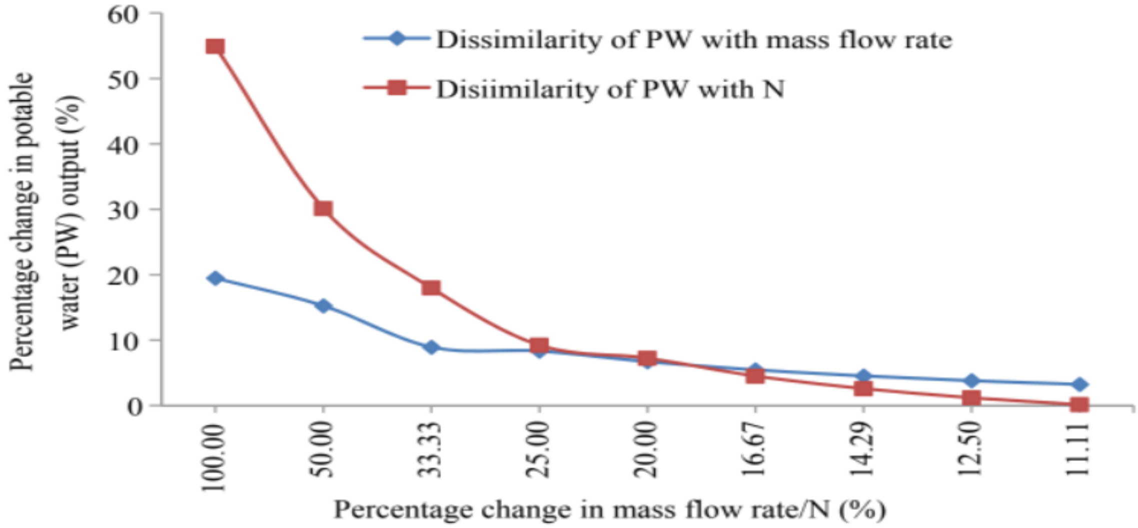

Fig.4 Variation in Potable Water productivity of SSSS by % Change in Mass flow rate and Partially Covered PVT with NCPC

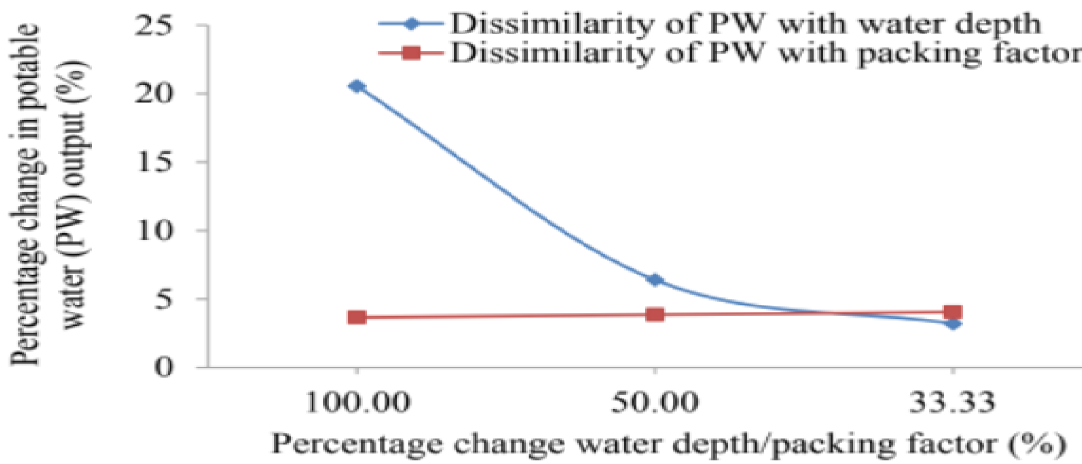

Fig.5 Variation in Potable Water productivity of SSSS by % Change in Water Depth and Packing Factor

Variation in Electric Power Output by Varying Input Parameters

Fig 6&7 shows variation in generation of electric power by varying input parameters mass flow rate, no. of collectors, water depth and packing factor. From both the graph it can be seen that the maximum variation in electric power is shown in variation of no. of CPC compared to others.

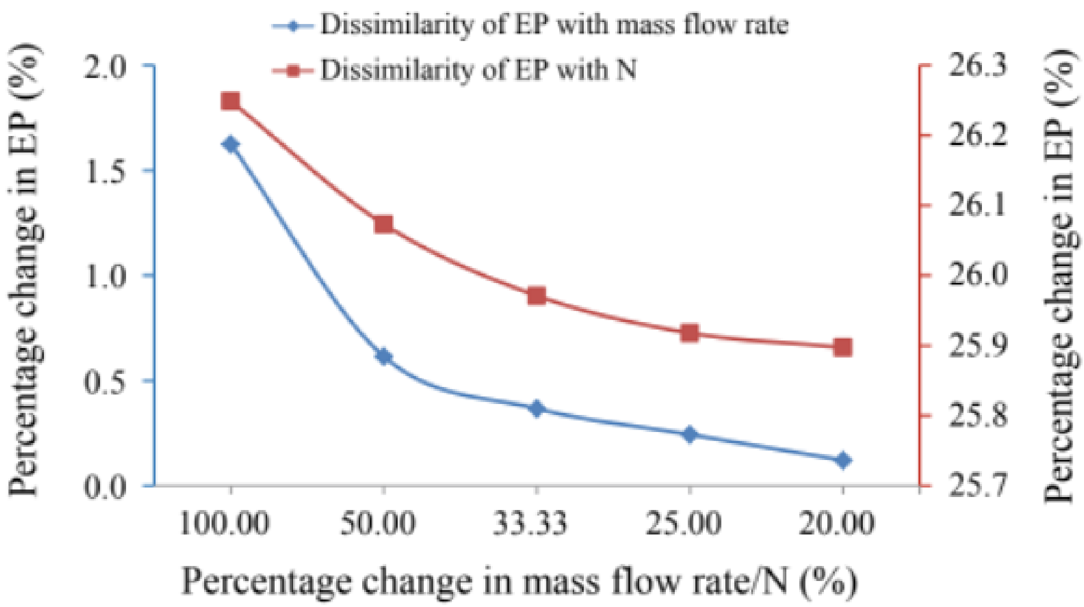

Fig.6 Variation in Electric Power by % Change in Mass flow rate and Partially Covered PVT with NCPC

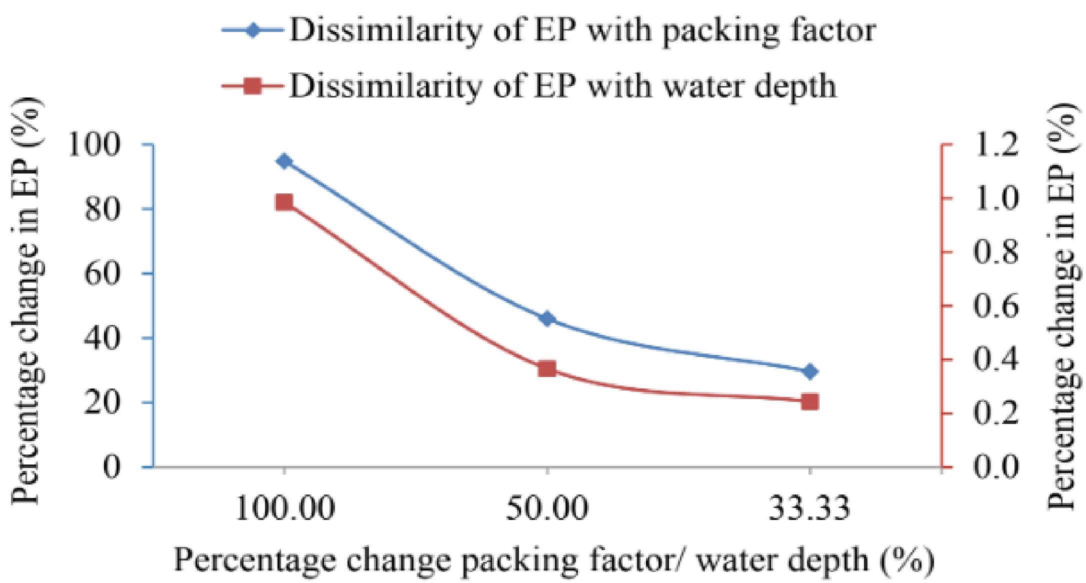

Fig.7 Variation in Electric Power by % Change in Water Depth and Packing Factor

Table 2. Different values of sensitivity for SSSS with partially cover PVT with NCPC

Average Value of Sensitivity for Input Parameters	Value
Productivity of water w.r.t mass flow rate	0.298

Productivity of water w.r.t N partially covered PVT with CPC	0.331
Productivity of water w.r.t water depth	0.143
Productivity of water w.r.t packing Factor	0.078
Electric power output w.r.t mass flow rate	0.011
Electric power output w.r.t N partially covered PVT with CPC	0.780
Electric power output w.r.t water depth	0.008
Electric power output w.r.t packing Factor	0.920

Conclusions

On the basis of analytical study of the system for the sensitivity some conclusions were made:

1. The average value of sensitivity for productivity of water of SSSS with partially covered PVT with NCPC by varying mass flow rate, no. of collectors, water depth and packing factor was found to be 0.298,0.331,0.143 and 0.078 respectively.
2. Productivity of water is maximum sensitive to the no. of collectors compared to other parameters.
3. The average value of sensitivity for electric power SSSS with partially covered PVT with NCPC by varying mass flow rate, no. of collectors, water depth and packing factor was found to be 0.011,0.78,0.008 and 0.920 respectively.
4. Electric power output is maximum sensitive to the no. of collectors compared to other parameters.
5. The no. of collectors should be choosed in such a way that the output water temperature should be less than its boiling point.

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