Experimental investigation of an active inclined solar panel absorber solar still - Energy and Exergy analysis

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Abstract

The objective of the current study is to investigate the performance of the Inclined Solar Panel Basin Still (ISPBS) incorporated with a Spiral Tube Collector (STC) for various mass flow rates of water (m_f). The maximum potable water yield of 8.1, 6.9 and 6.1 kg is obtained for different mass flow rates of 1.8, 3.2 and 4.7 kg/hr in each instance. Also, for m_f values of 1.8, 3.2 and 4.7 kg per hour, the daily average energy and exergy efficiency of the ISPBS is recorded to be 47.9, 39.3 and 31.02 % and 9.8, 7.9 and 5.6 % in each instance. The average electrical, energy and exergy efficiency of the PV panel is noted to be 6.5, 7.1 and 7.5 %, 15.67, 17.1 and 18.04 % and 20.03, 22.21 and 23.36 % for m_f values of 1.8, 3.2 and 4.7 kg/hr in each instance. The rise in m_f causes a drop in the fresh water production yield, thermal, exergy and overall thermal effectiveness and an enhancement in the power production of the panel, electrical, thermal, exergy and overall exergy efficiency of the system.

1. Introduction

Our planet is globally marching towards ultimate progression in all aspects. This causes increasing demands for necessities in the human life. (El-Agouz et al. 2018, Manokar et al. 2018, Manokar et al. 2018a) Greater desires and demands are causing the depletion of our natural resources. The needs of the industrial enterprises are fulfilled by the resources which would disappear in few years. This leads to the need for switching our concentration towards inexhaustible energy sources to meet our needs and protecting our conventional sources of energy. (Manokar et al. 2019, Kabeel et al. 2019, **Manokar et al. 2017**) Water can be desalinated using the solar still and the power requirements can be met with Photovoltaic (PV) panel. These methods provide great hope to safeguard our future resource requirements. Commercially, PV panel is coupled with solar still to produce electricity and also fresh water at the same time. Scarcity of potable water and absence of electrical facilities can be tackled by this technique (**Raj et al. 2019, Manokar et al. 2017a**, Manokar et al. 2018b, El-Agouz et al. 2018a).

(**Al-Nimr et al. 2018**) introduced a distillation unit model with photovoltaic/thermoelectric cooler (PV/TEC). The TEC is incorporated to enhance the condensation of water and prevent excessive heating in this model. The daily highest distillate yield of 4.2 kg was obtained at air temperature of 25⁰C, wind rate of 5.5 m/s and solar intensity of 1000 W/m². 73 W of power output was reported to be achieved with photovoltaic cell efficiency of 12.32 %. (**Al-Nimr et al. 2015**) introduced a novel PV/T distillation unit with SSB still within which the photovoltaic cells were submerged inside the basin. Potable water yield of 6.8 L/m²/day was achieved. (**Al-Nimr and Dahdolan 2016**) then designed a novel PV/T unit which uses the eliminated heat energy for the purpose of distillation. The model is incorporated with an evaporator and a condenser to augment its performance.

(**Layek et al. 2018**) investigated the yield and efficiency of basin type solar stills by making use of black toner, black ink and black dye as absorptive substances. It was noted that the stills with black ink, dye and toner showed highest energy efficiency of 41.3 %, 43.42 % and 45.79 % and exergy efficiency of 5.91 %, 6.34 % and 7.10 % in each instance. (Panchal et al. 2018) did a relative study between a triangular pyramid still under active and passive mode to analyze the exergy and economic factors. The energy efficiency was reported to increase at the time of sunset while the values fell during the day. (Madhu et al. 2018) published the exergy of Conventional Solar Still (CSS) integrated with sand heat energy storage arrangement. The distillate yield from the still with energy storing substance was reported to be 3.3 kg/m² and it showed 30 % greater exergy efficiency in relation to the olden type of still. (Kumar et al. 2017) used a triangular pyramid solar still incorporated with Inclined Solar Still (ISS) to enhance the distilled water production. The percentage rise in yield was recorded to be 79.05 % for the modified still at water depth of 0.02 m compared to the CSS. (Kabeel et al. 2018) researched about the potable water production by the CSS combined with an ISS. The productivity of the modified still was reported to be 6.2 kg and it showed 46.23 % greater yield production compared to the CSS at a water depth of 0.02 m.

(Tiwari et al. 2015) studied the developed still integrated with PVT-FPC to determine its yield production, exergy and thermal efficiency. (Singh and Tiwari 2016) examined the cost analysis by combining the energy payback period effect to the PVT-CPC combined solar still in active mode. The percentage rise in yearly yield was reported to be around 5 % for the double slope compared to that of the single slope still at a water depth of 0.14 m. The cost of fresh water production was also noted to be lesser for the double slope still. (Singh and Tiwari 2017) analyzed the PVT-CPC integrated solar still for various economic and production factors. The double slope still showed a percentage rise in distillate yield of 8.56 % in relation to the still with single slope structure at 0.14 m depth of water. (Singh and Tiwari 2017a) experimented the double slope solar still combined with PVT flat plate collector. The energy producing factor and the life cycle conversion effectiveness were observed to be enhanced while the time of energy payback and the potable

water price were decreased for the modified still compared to the conventional stills. (Singh and Tiwari 2017b) investigated the energy, exergy and cost of producing distilled water in basin type solar still integrated with tubular collectors. The percentage rise in energy and exergy values in the modified double still slope was recorded to be 6.85 % and 12.30 % in each instance compared to single slope setup. Also the cost of obtaining the distillate yield from the developed still was 15.19 % lower compared to the olden type of stills. (Ahmed and Shinichi 2020) studied the stepped solar still model incorporated with reflectors and copper fins. It was noted that this model showed 129 % enhancement in yield when compared to the conventional model. The daily water production reached up to 8.28 L/day. From the referred theses, it is observed that only a few researches were conducted using ISS in active mode. Here, this research is primarily aimed at the investigation of ISPBS integrated with STC at varied mass flow rate of water.

2. Diagram And Fabrication Of The Suggested Model

The illustrative diagram and the experimental organization of the ISPBS combined with STC (AISS) are depicted in Figs. 1 and 2. The STC is incorporated along with the ISPBS and various parameters are analyzed for different input mass flow rates of water (m_f). 181 cm (Length) x 92 cm (Width) x 15 cm (Height) are the measurements of the still covered by 0.4 cm wide glass. The saline water at constant m_f reaches the solar heater from the storage tank. The absorber tube in the heater heats up the water flowing through it and delivers it to the still. The construction of the STC solar water heater was done with a flat solar collector (spiral), regulation valve and a tank for storage. The solar collector has dimensions of 90 cm (L) x 60 cm (W) x 0.4 cm (H) and its construction was done using a wooden container (2 cm thick) along with a 0.4 cm wide cover glass. The heater includes a copper tube (0.1 cm thick) having three windings each of diameter 1 cm and separated from each other by 5 cm. A 5000 ml plastic columnar reservoir tank is used to store water.

3. Outcomes And Analyses

3.1 Hourly changes in various parameters of the AISS

The alterations in the solar radiation and air temperature of the STC incorporated still are depicted in Fig. 3(a) and (b). The solar radiation rose to attain its highest value until 1 P.M after which it started to fall. The highest values of solar radiation were recorded to be 880, 870 and 900 W/m² on 1.8.2017, 4.8.2017 and 6.8.2017 in each instance. The average solar radiation of 699 W/m² was observed on 1.8.2017 while on 4.8.2017, it was noted to be 696 W/m² and 719 W/m² on 6.8.2017. 33, 32 and 35°C were the highest air temperatures recorded on 1.8.2017, 4.8.2017 and 6.8.2017 in each instance. The average air temperature per day was noted to be about 30 to 33°C.

The alterations in the wind speed and the temperature of the cover glass of the collector of the AISS are depicted in Fig. 4 (a) and (b). The average velocity of wind was recorded to be 1.1, 1.8 and 2 m/s on 1.8.2017, 4.8.2017 and 6.8.2017 on each instance. The highest temperature of the cover glass of the collector of 53°C was observed on 1.8.2017 while on 4.8.2017, it was noted to be 52°C and 47°C on 6.8.2017. The average temperature of the collector cover per day was recorded to be 47.1, 45 and 43.2°C on 1.8.2017, 4.8.2017 and 6.8.2017 on each instance.

3.2 Influence on glass, basin and brackish water temperature due to the mass flow rates

The alterations in the basin temperature of the AISS with respect to the m_f of water are depicted in Fig. 5 (a). The temperature of the basin rose with rise in solar irradiation to attain its highest value until 2 P.M after which it started to fall. For water m_f values of 1.8, 3.2 and 4.7 Kg/hr, the highest temperature of the basin was observed to be 72, 69 and 65°C in each instance. The average temperature of the basin per day was noted to be 62.1, 59.1 and 55.2°C for m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. The basin temperature fell by 4.8 % when m_f rose from 1.8 Kg/hr to 3.2 Kg/hr and by 11.1 % when m_f rose to 4.7 Kg/hr from 1.8 Kg/hr. So, from the noted values, it is seen that the basin temperature falls when the m_f of water is raised as a large quantity of water tends to absorb the temperature from the basin.

The alterations in the temperature of brackish water of the AISS with respect to the m_f of water are depicted in Fig. 5 (b). Similar to the basin temperature, the brackish water temperature also rose up to attain its highest value until 2 P.M after which it started to fall. For

water m_f values of 1.8, 3.2 and 4.7 Kg/hr, the highest temperature of saline water was observed to be 76, 73 and 70°C in each instance. The average temperature of saline water per day was noted to be 65.7, 63 and 60.7°C for m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. The average water temperature per day fell by 4.1 % when m_f rose from 1.8 Kg/hr to 3.2 Kg/hr and by 7.6 % when m_f rose to 4.7 Kg/hr from 1.8 Kg/hr. So, from the noted values, it is seen that the increased m_f leads to the flow of increased quantity of water which in turn causes inefficient heating and ultimately reduces the productivity of the still. Least m_f rises the time of contact between the brackish water and absorber plate which leads to efficient heating and enhanced productivity.

3.3 Influence on the distillate yield, thermal and energy efficiency due to the mass flow rates

The alterations in the distillate yield of the AISS with respect to the m_f of water are depicted in Fig. 6. Highest daily productivity is achieved only when the water m_f is the lowest as water temperature in the AISS can be enhanced only in this condition. The potable water yield was recorded to be 8.1, 6.9 and 6.1 Kg for m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. The daily productivity fell by 14.68 % when m_f rose from 1.8 Kg/hr to 3.2 Kg/hr and by 25.3 % when m_f rose to 4.7 Kg/hr from 1.8 Kg/hr.

The alterations in the thermal efficiency of the AISS with respect to the m_f of water are depicted in Fig. 7 (a). The highest thermal efficiency was recorded to be 68.3, 61 and 54.3 % for m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. Also, the average thermal efficiency was observed to be 47.9, 39.3 and 31.02 % for the m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. The thermal efficiency on average fell by 17.9 % when m_f rose from 1.8 Kg/hr to 3.2 Kg/hr and by 35.2 % when m_f rose to 4.7 Kg/hr from 1.8 Kg/hr.

Thermal effectiveness of the AISS is calculated by,

$$\eta_{A.th} = \frac{m_{ew} h_{fg}}{[A_c \times I_c(t) + A_s \times I_s(t)] \times 3600} \times 100$$

The alterations in the exergy efficiency of the AISS with respect to the m_f of water are depicted in Fig. 7(b). The highest exergy efficiency per hour was recorded to be 15.5, 12.5 and 10.2 % for m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. The average exergy efficiency was observed to be 9.8, 7.9 and 5.6 % for the m_f values of 1.8, 3.2 and 4.7 Kg/hr in each instance. Rise in m_f led to the fall in exergy efficiency due to the above cited reason. The exergy efficiency fell by 19.3 % when m_f rose from 1.8 Kg/hr to 3.2 Kg/hr and by 43.7 % when m_f rose to 4.7 Kg/hr from 1.8 Kg/hr.

The exergy efficiency of the AISS is calculated using,

$$\eta_{a.e} = \frac{e_{a.out}}{e_{p.in} + e_{fpc.in}}$$

Active exergy output of an ISPBS is determined using],

$$e_{a.out} = (m_d x h_{fg}) \left(1 - \left[\frac{T_a + 273}{T_w + 273} \right] \right)$$

Active exergy input of an ISPBS is calculated using,

$$e_{a.in} = e_{p.in} + e_{fpc.in}$$

Exergy input to STC is determined using,

$$e_{fpc.in} = Q_u \left[1 - \frac{T_a + 273}{T_w + 273} \right]$$

Useful heat gained by STC is calculated using,

$$Q_u = (I \times A_p) - q$$

Heat lost from STC is determined using,

$$q = UA(T_b - T_a)$$

3.4 Influence on power production, electrical, thermal and exergy effectiveness of the PV panel due to mass flow rates

Figure 8 (a, b, c) depicts the alterations in the panel temperature, PV panel electrical, energy and exergy effectiveness for an AISS at various m_f . From the Fig. 8 (a, b, c) it is recorded that when the m_f increases, the panel temperature falls.

The PV panel reached the highest temperatures of 66, 62 and 59 ° C for the m_f of 1.8, 3.2 and 4.7 Kg/hr in each instance. The average temperature of the panel per day at m_f of 1.8, 3.2 and 4.7 Kg/hr is 57, 53 and 48.8 ° C in each instance. Increasing the m_f of an ISPB still integrated with STC results in reduction in panel temperature. The average temperature of the panel per day reduces up to 7.02 and 14.42 % when the m_f of water rises from 1.8 to 3.2 Kg/hr and 1.8 to 4.7 Kg/hr in each instance. The highest hourly PV panel power generation and efficiency from an AISS at 1.8, 3.2 and 4.7 Kg/hr is recorded to be 68.4, 71.4, 74.1 W and 8.5, 8.7, 9.2 % in each instance. The average power generation and efficiency in a day are 41.64, 46.14, 50.44 W and 6.5, 7.1, 7.5 % for the m_f of 1.8, 3.2 and 4.7 Kg/hr in each instance. Power generation from an AISS is increase with an increase of an m_f of water. The percentage increase in PV panel power production and efficiency are noted to be 9.78 and 9.1 % when the daily average PV panel temperature decreases up to 7.02 %. Similarly, 17.47 and 14 % rise in PV panel power production and efficiency are recorded when the daily average PV panel temperature decreases up to 14.42 %.

The electrical efficiency of the solar panel is calculated using,

$$\eta_{pvelectrical} = \frac{FF * V * I}{I_s(t) * A_s} \times 100\%$$

PV thermal effectiveness has the similar characteristics as the electrical efficiency of the solar panel and it reaches its peak value of 20.45, 20.67 and 21.67 % at m_f of 1.8, 3.2 and 4.7 Kg/hr, in each instance at 1 P.M. The average daily thermal efficiency of the solar panel is 15.67, 17.10 and 18.04% at m_f at 1.8, 3.2 and 4.7 kg/hr in each instance. The constant 0.38 is electric power production effectiveness for a conventional power plant model. It is used to convert the electrical energy produced from PV panel to its equivalent thermal energy.

The thermal efficiency of the PV panel is determined using,

$$\eta_{pvthermal} = \frac{FF * V_{oc} * I_{sc}}{0.38 I_s(t) * A_s} \times 100\%$$

From Fig. 8 (a, b, c) it can be seen that the solar panel has higher exergy efficiency at least solar panel temperature. The average PV panel exergy efficiency in a day is 20.03, 22.21, and 23.36 % at m_f at 1.8, 3.2 and 4.7 Kg/hr in each instance. When the m_f of water increased from 1.8 to 3.2 Kg/hr and from 1.8 to 4.7 Kg/hr the exergy efficiency of a PV panel enhanced up to 9.8 and 14.3 % in each instance.

The exergy efficiency of the solar panel is calculated using,

$$\eta_{pvexergy} = \frac{FF * V_{oc} * I_{sc} - VI}{0.933 I_s(t) * A_s} \times 100\%$$

3.5 Hourly variations in the overall thermal and exergy efficiency of an AISS

The alterations in the overall thermal efficiency of an AISS (thermal efficiencies of an ISPB still and a PV panel) at various m_f are depicted in Fig. 9 (a). The overall thermal efficiency of the AISS is the highest when the m_f is the least. When the m_f rises, the thermal efficiency of the ISPB still decreases, whereas there is an increase in thermal efficiency of the PV panel. The highest overall thermal

efficiency of the system per hour is 88.72, 76.76 and 76.01 % at m_f at 1.8, 3.2 and 4.7 Kg/hr in each instance. The average overall thermal efficiency of the system in a day is 64.91, 58.75 and 52.95 % at m_f at 1.8, 3.2 and 4.7 Kg/hr in each instance. It is noted that there is a 9.5% and 18.4 % reduction in the overall thermal efficiency of the system when the m_f increases from 1.8 to 3.2 Kg/hr and from 1.8 Kg/hr to 4.7 Kg/hr in each instance.

The overall thermal effectiveness of an AISS is calculated by,

$$\eta_{overallA.thermal} = \frac{m_{ew} h_{fg}}{[A_c \times I_c(t) + A_s \times I_s(t)] \times 3600} \times 100 + \frac{FF * V_{oc} * I_{sc} - VI}{0.933 I_s(t) * A_s} \times 100\%$$

Figure 9 (b) depicts the overall exergy efficiencies of an AISS at various m_f . The average exergy efficiency of the AISS in a day are recorded to be 9.8, 7.9 and 5.6 % and average PV panel exergy efficiency of the model per day is about 20.03, 22.21 and 23.36 % and the overall average exergy efficiency of the AISS is 29.97, 30.25 and 29.07 % at m_f at 1.8, 3.2 and 4.7 Kg/hr in each instance. The daily average exergy efficiency of the AISS tends to reduce when the m_f increases whereas the daily average exergy efficiency of the PV panel is enhanced. The decrease in exergy efficiency of the AISS and increases in panel exergy efficiency will result in nearly equal overall exergy efficiency for all the m_f .

The overall exergy effectiveness of an AISS is determined using,

$$\eta_{overallAexergy} = \frac{(m_d * h_{fg}) \left(1 - \left[\frac{T_a + 273}{T_w + 273} \right] \right)}{\left(A_s * I_t \right) \left[1 + \left(\frac{1}{3} \left[\frac{T_a + 273}{6000} \right]^4 - \frac{4}{3} \left[\frac{T_a + 273}{6000} \right] \right) \right] + Q_u \left[1 - \frac{T_a + 273}{T_w + 273} \right]} + \frac{FF * V_{oc} * I_{sc} - VI}{0.933 I_s(t) * A_s} \times 100\%$$

3.6 Relative study between the productivity of various PV/T solar stills

A relative study on the amount of distillate yield from various hybrid PV/T solar still was done and noted in Table 1. (Dev & Tiwari 2010) analyzed the performance of the solar still integrated with FPC and PV module and obtained a yield of 7.223 kg/m². (Kumar & Tiwari 2009, Kumar & Tiwari <2010) recorded productivity in the range of 6–10 kg/m² from their hybrid active solar still. A yield of 7.9 kg/m² was noted in (Gaurr & Tiwari 2009 study involving hybrid solar still incorporated with collectors. (Saeedi et al. 2015) obtained an enhanced yield of 8.37 kg/m² from the active solar still model. (Eltawil et al. 2014) integrated PV, FPC, and heater to the solar still and obtained a yield of about 6–10 kg/m². An augmented yield of 12 L/m² was obtained from the study of (Abdallah et al. 2009) using solar still with superheat conduction metal vacuum tube. (Singh et al. 2016 recorded productivity in the range of 6–10 kg/m² from their solar still with double hybrid PVT collectors. (Moh'd & Al-Ammari 2016) examined the functioning of a solar still having basin attached with PV cells and finned condenser and obtained a yield of 6.8 kg/m². The studies using passive solar stills produced yields in the range of 4–5 kg/m². (Winston et al. 2018) recorded a productivity of 8.542 L from the active solar still with effective heating and cover cooling method. A yield of 8.1 kg was obtained from the current study involving solar still integrated with STC.

Table. 1 Relative study between the productivity of various PV/T solar stills

S.No	Author name	Experimental work done	Yield (kg/m ²)
1	(Dev & Tiwari 2010)	Solar still with FPC integrated PV module	7.223
2	(Kumar, & Tiwari 2009)	Active solar still (hybrid PV/T)	6 - 10
3	(Gaur & Tiwari 2010)	Most effective number of collectors to be used for integrated hybrid PV/T active solar still	7.9
4	(Kumar & Tiwari 2010)	Hybrid (PV/T) active solar still	7.22
5	(Sarhaddi et al. 2015)	Active solar still (PV/T)	8.37
6	(Eltawil, & Omara, 2014)	Solar still utilizing PV, FPC and air heater	6-10
7	(Abdallah et al. 2009)	Solar still integrated with Super Heat Conduction Metal Vacuum Tube	12
8	(Singh et al. 2016)	Active solar still (two hybrid PVT collectors)	6 – 10
9	(Moh'd A & Al-Ammari 2016)	PV cells attached to the solar still basin and integrated with finned condenser at outer surface	6.8
10	(Yari et al. 2016)	Incorporation of solar still and PV module	4.77
11	(Manokar et al. 2018c)	PV panel integration in an inclined solar still in passive mode	4.4
12	(Riahi et al. 2016)	Solar still integrated with AC-heater and PV module	5.7
13	(Winston et al. 2018)	PV/T active solar still with effective heating and cover cooling method	8.542
14	(Thalib et al. 2020)	Solar still with PCM	7.91
15	(Yazan et al. 2020)	Inclined solar still incorporated with STC	8.3
16	Thalib et al. (present study)	PISS integrated with the STC in active mode (present study)	8.1 kg

4. Conclusions

This study is based on the influence of different m_f of water in the ISPBS incorporated with the STC unit.

The following results have been reported:-

1. The panel temperature and solar radiation determined the power production from the PV panel. Rise in m_f of brackish water led to the enhancement in the performance of the PV panel but the still performance declined.
2. The daily distillate water output, energy, exergy and overall thermal efficiency of the arrangement falls by 14.68, 17.9, 19.3 and 9.5 % in each instance when water m_f is changed to 3.2 Kg/hr from 1.8 Kg/hr.
3. The power production of the panel, electrical efficiency and exergy efficiency of the system is improved by 9.78, 9.1 and 9.8 % in each instance.
4. The daily distillate productivity, thermal, exergy and overall thermal efficiency of the arrangement falls by 25.3, 35.2, 43.7 and 18.4 % in each instance when water m_f is changed to 4.7 Kg/hr from 1.8 Kg/hr.
5. The power production of the panel, electrical efficiency and exergy efficiency of the system is improved by 17.47, 14 and 14.3 % in each instance.

Abbreviations

CSS Conventional Solar Still

PV/T Photovoltaic/Thermal

TEC Thermoelectric Cooler

ISPBS Inclined Solar Panel Basin Still

STC Spiral Tube Collector

AISS ISPB still combined with STC

m_f Mass Flow Rate

PSS Pyramid Solar Still

ISS Inclined Solar Still

STC Spiral Tube Collector

CPC Compound Parabolic Concentrator

Nomenclature

A - Area (m^2)

h- Heat transfer coefficient (W/m^2K)

I – Current (A)

$I(t)$ – Solar intensity (W/m^2)

L– Latent heat of Vaporization (kJ/kg K)

M – Hourly productivity from Solar Still (kg/m^2 h)

P- Partial vapor pressure (N/m^2)

T – Temperature ($^{\circ}C$)

V – Voltage (V)

η - efficiency (%)

Subscript

a- Ambient

c- Convective

d- Daily

e- Evaporative

g- Glass

gi- inner glass

pv- Photovoltaic

s- Surface area of condensing cover

w- Water

Declarations

Declaration of competing Interest

The authors declare that there is no competing interest

Availability of data and materials

All data are given in the manuscript

Ethics approval and consent to participate

Not applicable

Consent for publication

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Authors Contribution

Mohamed Thalib Mohamed Rafeek- Writing-review & editing

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Muthu Manokar Athikesavan– Writing, Formal analysis,

Ravishankar Sathyamurthy- Project administration, Software, review & editing

Abd Elnaby Kabeel- Data curation, review & editing

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Figures

Figure 1

The schematic diagram of the AISS

Figure 2

Pictorial view of the AISS

Figure 3

(a) Diurnal alterations in solar intensity (b) air temperature

Figure 4

(a) Diurnal alterations in wind speed (b) cover glass temperature

Figure 5

Hourly alterations in (a) basin temperature and (b) water temperature for an AISS

Figure 6

Hourly alterations in distillate yield for an AISS

Figure 7

Hourly alterations in (a) thermal efficiency and (b) exergy efficiency for an AISS

Figure 8

Hourly alterations in panel temperature, PV panel electrical, thermal and exergy efficiency for the mass flow rate of water (a) 1.8 (b) 3.2 (c) 4.7 Kg/hr

Figure 9

Hourly alterations in (a) the overall thermal and (b) the overall exergy effectiveness of an AISS