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Selection of Coolant for Cooling System for Solar PV Panels

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ABSTRACT:

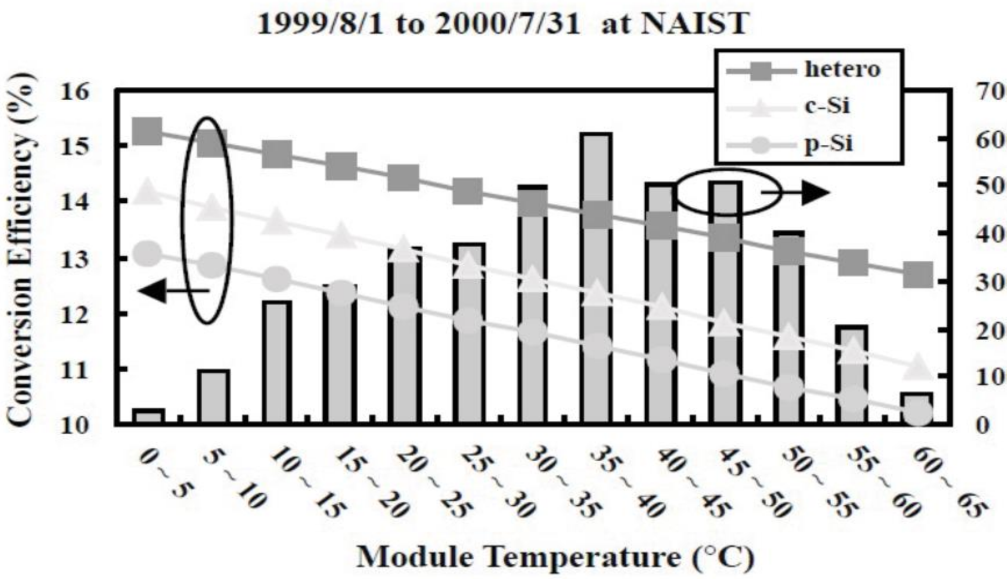
In present work an approach is made to optimize the cooling system by analytical approach. A mathematical model has been developed by using ms-excel. And different type of coolant has been implemented in order to find out the best suitable cooling medium for panel cooling. The environment parameter were taken from "Nasa source software" and "PVGIS" software the outcome of work suggest the best cooling medium for pv module in terms of performance and cost .

Key word ; solar panel, cooling , coolant ,solar Irrdance, heat losses, Energy.

INTRODUCTION (EFFECT OF TEMPERATURE ON PV-CELL) :

PV cells are affected by temperature in a negative way due to the negative temperature coefficient of crystalline silicon. This temperature coefficient is estimated to be

in the range of -0.4 to -0.5%/K [Lee et al., 2008]. This causes the efficiency of the cells (which are typically around 12% using a reference temperature of 25^0C) to decrease. It has been shown that a decrease in the temperature of the solar panel can cause a 2% increase in the efficiency of the PV cells, when the carrier fluid (such as water) has a mass flow rate of 0.01 kg/s [Joshi and Tiwari, 2007]. An increase in efficiency is vital to the development of solar panels, as it would save money while providing greater amounts of energy. PV cells have the potential to be extremely efficient. Even in the worst-case scenario, a PV cell has an efficiency limit of 28.9% [Tayebjee et al., 2010]. Figure 1.5 shows the linear relationship of efficiency versus the module temperature. "As can be seen, the conversion efficiency drops as the module temperature increases"



Variation of Efficiency as a Function of Module Temperature [Nishioka et.al., 2011]

Since the radiation absorbed by the solar panel is converted to thermal energy as well as electrical energy, it is important to perform an energy balance on the system to see how efficient the solar panel will be at different operating temperatures. This allows the designer to project how much electrical power will be generated, so the design can be refined in order to generate the proper amount for the solar panel's required load. The maximum power as a function of cell temperature can be graphed at different radiation levels.

LITERATURE REVIEW:

1. Effects of Active Cooling Techniques to Improve The Overall Efficiency Of Photovoltaic Module- An Updated Review by Mayank Kumar Tiwari…………………..2023

The aim of the review is to find out the cost-effective and efficient active cooling methods of solar photovoltaic (SPV) cell to improve their overall performance.. Cooling of the SPV panel is a function of optimum spraying timing, coolant flow rate, wind condition, the distance between flow points (nozzle) to the panel, and solar radiation. The major facts revealed that the efficiency of the PV panel is optimum within 25-30^{0}C, and the panel's performance decreases by 0.5% for each 1^{0}C rise of panel temperature from standard temperature. The best active cooling method revealed that the electrical efficiency of the PV module could be increased by 57% with a lowering of module temperature by 32% in hot summer.

2 Selection of a Photovoltaic Panel Cooling Technique Using Multi-Criteria Decision Analysis by Zakariya Kaneesamkandi……………………..2023

The main concern of the present work. Potential cooling solutions differ in terms of their criteria for performance evaluation, which are efficiency enhancement, costs, reliability, environmental aspects and ergonomics. Hence, there is a need to identify the optimum cooling method. Eight different cooling methods were identified, and the analysis was made with the multi-criteria analysis tool on the different possible attributes. Two different climate zones with different weight schemes are considered for the evaluation process, and the best to the worst cooling solutions have been identified. Five different scenarios depending on the importance given to each evaluation criterion are analyzed. The best cooling method to the worst cooling method has been arranged under each scenario. When the efficiency of operation was given maximum weight, aluminum fin cooling proved to be the best panel cooling method. When the emission reduction criterion was given maximum weight, thermosiphon cooling was the best cooling option. A comparison of the results indicates that thermosiphon works out to be the best option. The second-best method was found to be forced convection cooling when equal weights were applied and thermosiphon cooling when a 40% weight on efficiency enhancement criteria was applied, which is a more practical weight distribution. Phase change cooling and forced convection cooling had the poorest performance among the different cooling methods for all the weighing scenarios

3. Experimental investigation of a hybrid photovoltaic evaporative cooling (PV/EC) system performance under arid conditions by Deyaa M.N. Mahmood…………….2022

The proposed evaporative system tested a cellulose cooling pad of three thicknesses (50, 100, and 150 mm) with three water flow rates (1, 2, and 3 LPM), while the air velocity ranged between (2–3 m/s). The results, compared to a normal PV panel without cooling, showed an improvement in both the electric and thermal performance of PV/EC systems. The PV panel efficiency improved by 7.4%, 10.5%, and 11.2% for pads #1, #2, and #3 respectively. The average temperature reduction of pad #1 reached (15 ◦C), and was about (20 ◦C) for pads #2 and #3. The supplied air temperature difference was (5.5 ◦C, 9.2 ◦C, and 13.9 ◦C) for three pads respectively. The best supplied air dry-bulb temperature was 24.7 ◦C and 71% relative humidity for pad #3.

4. Experimental and numerical study of low concentration and water-cooling effect on PV module performance by Swar A. Zubeer…………………………………..2022.

In this study, experimental and numerical examinations of the performance of the conventional

photovoltaic panel, concentrated photovoltaic (CPV) system and water-cooled CPV system were performed. The tests are conducted under the climatic conditions of the city of Duhok, North of Iraq, on a sunny day on September 25, 2019. During the experiments, the average ambient temperature and average solar radiation were 32.6 ◦C and 930 W/m2, respectively. As well, MATLAB/Simulink modelling is developed by using PV module equations and the manufacturing data sheet. The empirical results showed that the ultimate panel temperature of the PV panel, concentrated PV system and water-cooled concentrated PV system is 57.5, 64.1 and 36.5 ◦C, respectively. In addition, the power output of the water-cooled CPV system and CPV system was improved respectively by 24.4% (effective 23%) and 10.65%. In addition, electrical efficiency was increased from 14.2% to 17% by using reflectors and water cooling with the PV panel. In the case of the water-cooled CPV system, open circuit voltage and short circuit current were increased by 9% and 5.2%, respectively. Moreover, the comparison between the experimental and numerical results agrees well.

5. Cooling system design for photovoltaic thermal management by using multiple porous deflectors and nanofluid by Mohamed Omri…………2022

A novel cooling channel system with multiple porous deflectors (PDs) and nanofluids is proposed for thermal management of photovoltaic (PV) panels. The PDs are elliptic in shape while alumina nanoparticle of cylindrical shape is considered in water which is used as the base cooling medium in the channel. Impacts of Reynolds number (Re: 200–1000), Darcy number (10−6− 10−2), PD number (1–5) and aspect ratio of the PDs (0.25–1) on the cooling performance are numerically assessed while nanoparticles are used up to solid volume fraction of 3%. The flow and thermal patterns are strongly influenced by installation of PDs with lower permeability and higher aspect ratio in the cooling channel. The average Nusselt number (Nu) rises by about 56.1% at aspect ratio of 1 when lowest and highest Reynolds number cases are compared while average panel temperature drops become 8.64 ◦C. When cooling channel with PDs operating at lowest and highest permeability are compared, 37% rise of average Nu and 10 ◦C temperature drop are obtained at aspect ratio of 1. When nanofluid is used instead of pure fluid as the cooling medium, further performance improvement are achieved which depends upon the aspect ratio of the PDs in the channel. The best cooling performance is achieved when five PDs with aspect ratio of 1 are installed in the channel operating with nanofluid at solid volume fraction of 0.03. This case provides 107.5% higher average Nu and 13.7 ◦C lower temperature as compared to reference case. The combined utilization of PDs and nanofluid in the cooling channel provides an excellent tool for the thermal management of PV. A modeling approach with modal base is successfully used for impacts of PDs on the cooling performance of coupled cooling channel with conductive panel system.

FORMULATION OF PROBLEM

Calculation of base plate temperature for various ambient temperature has been calculated by using following equation in Ms-excel

$Tb= [e^{(a+\_bU)}]+Ta$

U = wind velocity

2 calculation of cell temperature is done by following equation

$Tc= Tb +(I*\Delta t/I_0)$

$\Delta t= 3^0$ (Temperature difference between the cell and the module back surface at an irradiance level of 1000 W/m2)

3 calculation of radiative heat loss from fin

$Qradf = \varepsilon g.\sigma (Tg^4 - Ta^4)$

Tg = glass cover temp.

4 calculation of convective heat loss from fin

$Qconvf = (Tg-Ta)/Rconv$

5 calculation of convective heat loss from bottom of module

$Qconv\ b = (Tb -Ta) /Rconv$

6 . Calculation of radiative heat loss from bottom

$Qradb= \varepsilon b.\sigma (Tb^4 - Ta^4)$

Efficiency of module corelation has been established as

7 $\eta_{pv} = [1- 0.0045(Tpv- 25)]$

The electric power produce by module can be the function of efficiency as

8 $Pe = I \times \eta_{pv}$

Heat transfer from fin calculated by corelation or energy balace equation

9 $I = Qcon +Qrad +Pe+Qfin$

Heat transferred for fin can also describe as the equation 10 is useful to calculate the mass of the fin.

10 $Qfin = n.[k. Acs .m.(Tb - Ta).\tanh(ml)$

11 Perimeter of fin $p=2(b+t)$

Reynold number in an important criterion to I identify the flow type and calculated to find out the nature of flow between fins .

12 Reynolds number $Re= UL/\upsilon$.

13 Nusselt number $Nu = h.l/kf$

for $Re =1.115*10^5< 5.10^5$

14 $Nu = 0.664x\ Re1/2xPr1/2$

For $Re = 5.10^5< 10^7$

15 $Nu = Pr1/3(0.037Re0.8 – 850)$

16 $m= \sqrt{hp/kAcs}$

17 $\eta fin= \tanh(ml)/ml$

18 $T1= (Tb+Ta)/2$

19 $Q= m.Cp,\Delta T$

RESLUT AND DISCUSION

All the calculation has been made in order to optimize the number of fin and mass flow rate of coolant properties of coolant are applicable as mentioned in previous chapter, the calculation is performed by using various mathematical corelation by using MS-excel. and final results are presented in tabular and graphical forms for each selected coolant in this study.

And all calculation are compared finally in order to suggest the best cooling medium for selected solar panel. Solar iriddance data for Jabalpur (lat./23.18 lon.79.97) in taken from Nasa cource software.

Coolent properties taken are as shown in table below :

Table 5.1

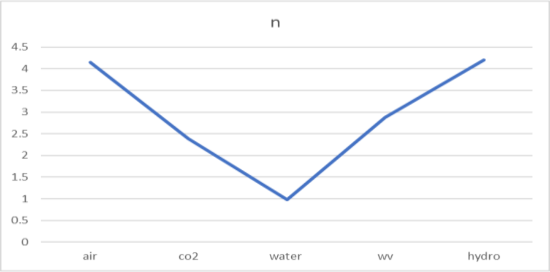
collant properties			Kinematic viscosity	
coolant	Kf	alpha	Kvis	cp kj/kg k
air	0.02514	0.00002074	0.00001494	1007
hydrogen	0.182	0.0001554	0.00003418	14310
co2	0.016572	0.000010588	0.00000804	1040
water vapur	0.18	0.00002036	0.0000216	1864
water	18.7	0.000000148	0.000001	4180
O2	0.02676	0.000022353	0.00001586	918
nitrozen	0.0262	0.000022044	0.00001563	1040

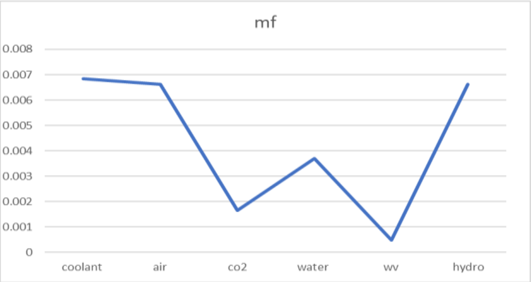
7. Comparison of all coolants

In this work a comparative study has been performed to evaluate the performance of different type of coolant in the cooking system of solar panel in order to optimize the performance of system the panel output was consider constant for all type of coolant in respect to calculate the number of fins and mass flow rate of the coolant in system the following table shows the annual average results of the considered system.

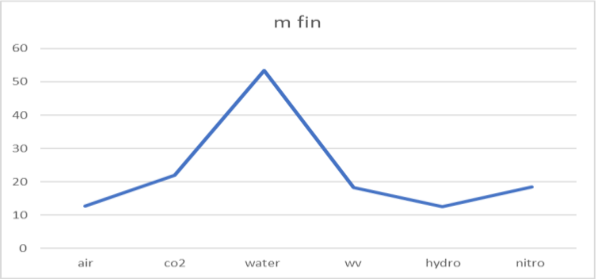
TABLE 5.8

	del T	I	pe	Qfin	m fin	n	mf
air	15.83809	456.1371	62.44789	393.4294	12.65159	4.141813	0.00683
co2	15.83809	456.1371	62.44789	393.4294	22.01251	2.380488	0.006613
water	15.83809	456.1371	62.44789	393.4294	53.35802	0.982055	0.001645
wv	15.83809	456.1371	62.44789	393.4294	18.17925	2.882437	0.003690
hydro	15.83809	456.1371	62.44789	393.4294	12.46964	4.202249	0.000481
nitro	15.83809	456.1371	62.44789	393.4294	18.43027	2.843177	0.006613

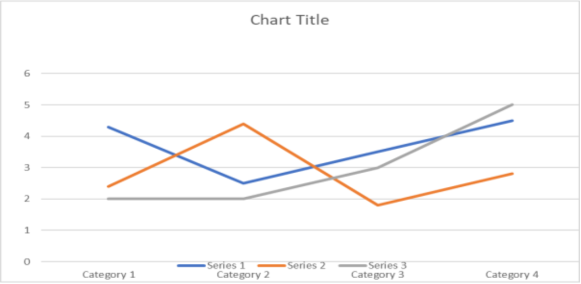




(number of fins required) (mass flow rate of coolant)



(mass of fins as per coolant)



(comparative performance of coolants)

The graphs above represents that the water require least number of fins but it require more mass flow rate and more mass of the fin but water vapor and CO2 requres less mass and mass flow rate , if we compare co2 and water vaper the co2 represent better results and it is economical as well so the application of co2 will be wise choice as a coolant in a solar panel cooling system.

CONCLUSION

solar cells generate more electricity when receive more solar radiation but the efficiency drops when temperature of solar cells increases. Hybrid photovoltaic and thermal collector is the solution to this problem. Simulation model for single pass, single duct solar collector with fins is developed and performance curves are analysed. The simultaneous use of hybrid PV/T and fins have a potential to significantly increase in power production and reduce the cost of photovoltaic electricity. Six coolants are passed though the duct or fins to identify the coolant which would give the maximum heat transfer, with minimum mass flow rate & minimum number of fins. The gas identified is Carbon Die Oxide . For Co2 , the system requires a mass flow rate of 0.0063 kg/s, which is the least of all other gas mass flow rate values & Number of fins required are 3.

FUTURE SCOPE

Solar PV module shows increase in performance with colling up to NOCT temperature range and to maintain that range cooling is a best tool. This work is focused on selection of coolant for fin type convective cooling method. More investigation can be performed practically or by simulation with cfd and other module to improve the performance of the pv module. some more advance coolant can also be applied to enhance the performance and power output.

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