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Manyetik nanoakışkan fotovoltaik/termal (PV/T) sistemlerde performans kullanım incelenmesi

Investigation of performance on photovoltaic/thermal (PV/T) system using magnetic nanofluids

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Investigation of Performance on Photovoltaic/Thermal (PV/T) System Using Magnetic Nanofluids

Highlights

- *In this paper, nanofluids are offered as a solution to increase the heat absorbed in the thermal system*
- *Module 1 (PV/T) and Module 2 (PV) are designed with two photovoltaic panels of the same brand and same power ..*
- *It can be seen the increase in thermal efficiency is greater when nanofluid is used, but the increase in total efficiency is greater.*

Graphical Abstract

In Figure -7show that the variation of the electrical efficiency and thermal efficiency of the panel and thus the total efficiency

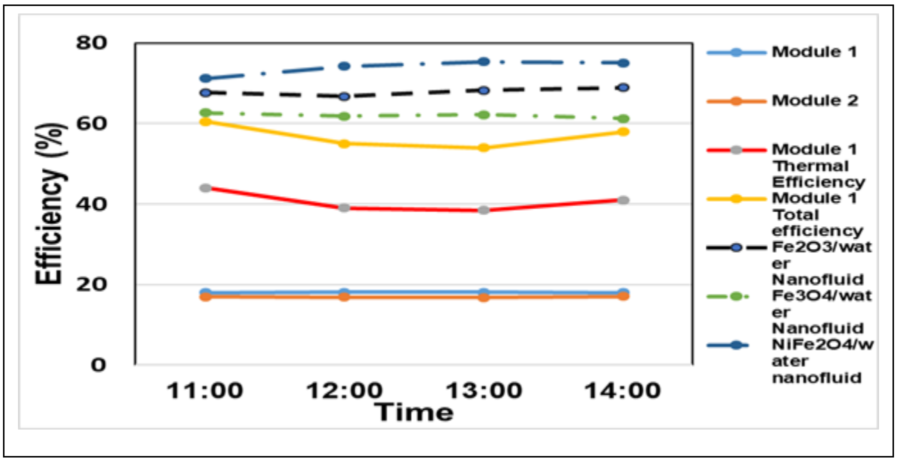

Figure . PV/T and PV efficiencies

Aim

In this study, by using nanofluids obtained by adding 1% Fe2O3, Fe3O4 and NiFe2O4 magnetic nanoparticles by weight to the basic fluid water, a bidirectional performance increase was achieved. By increasing the thermal heat transfer of the PV/T system while providing more cooling of the PV system. cal and thermal efficiency of the PV/T module

Design & Methodology

Experimental Set up; the names of the materials belonging to the experiment set, the modules they belong to and the parts properties are given . Fotovoltaic solar panels are mounted on the same platform.Preparation of the Magnetic Nanofluid;

Originality

The most important feature and originality of our study was that until this time the studies required numerical.The fact that the obtained hot fluid has many application areas such as space heating, heating of greenhouses, use in drying systems, use as a heat source in heat pumps also causes PV/T systems to gain importance.

Findings

By using nanofluids obtained by adding 1% Fe2O3, Fe3O4 and NiFe2O4 magnetic nanoparticles by weight to the basic fluid water, Since the amount of heat absorbed in the thermal system is high, an average of 10,4% temperature (ΔT) increase in the hot fluid temperature compared to the base fluid water was obtained in the NiFe2O4 nanofluid.

Conclusion

PV/T systems are one of the subjects that scientific studies have focused on in recent years. The main reasons for this are to increase the electricity generation performance of PVs, as well as to obtain thermally hot fluid from the system

Declaration of Ethical Standards

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

Manyetik Nanoakışkan Fotovoltaik/Termal (PV/T)Sistemlerde Performans Kullanım İncelenmesi

Araştırma Makalesi / Research Article

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ÖZ

Fotovoltaik/Termal (PV/T) sistemler, elektrik enerjisi üretiminin yanı sıra sıcak akışkan (genellikle su) ile üretimi sağlar. Ayrıca PV sistemlerin aşırı ısınması termal sistem tarafından çekilen ısı ile engellendiği için PV'lerin elektrik üretim performansı artmaktadır. Nanoakışkanlar, termal sistemde emilen ısıyı artırmak için bir çözüm olarak sunulmaktadır. Nanoakışkanların ısı transfer performansında önemli bir iyileşmeye yol açan başlıca fiziksel olaylar şu şekilde özetlenebilir: (i) Hazırlanan nanoakışkanın ısıl iletkenliği, katı metalin ısıl iletkenliğininkinden daha yüksek olduğu için belirli oranlarda artar. (ii) Akışkanın ısıl iletkenliğinin artması nedeniyle ısı transfer yüzey alanının artması, (iii) Akışkanın etkin ısıl kapasitesinin artması, (iv) Akışkanın ısıl iletkenliğinin artması ve yüksek sıvı aktivitesi nedeniyle türbülanslı hacim. Bu çalışmada, temel akışkanlardan biri olan suya ağırlıkça %1 Fe2O3, Fe3O4 ve NiFe2O4 oranlarında manyetik nanoparçacıkların eklenmesiyle elde edilen nanoakışkanlar kullanılarak, PV/T sisteminin termal ısı transferi arttırılarak, sistemin daha fazla soğutulması sağlanarak çift yönlü performans artışı sağlanmıştır. PV sistemi. Deneysel çalışmada, nanoakışkanların yüksek ısıl iletkenliğinden yararlanılarak ısıtılan PV panellerden daha fazla ısı çekilerek NiFe2O4 nanoakışkanda elektrik üretiminde %14'lük bir iyileşme sağlanmıştır. Termal sistemde emilen ısı miktarı yüksek olduğu için NiFe2O4 nanoakışkanda sıcak akışkan sıcaklığında baz akışkan suya göre ortalama %104 sıcaklık (ΔT) artışı elde edilmiştir.

Anahtar Kelimeler: PV/T, nanoakuşkan, magnetic nanoparçacıklar, Fe2O3, Fe3O4, NiFe2O4.

Investigation of Performance on Photovoltaic/Thermal (PV/T) System Using Magnetic Nanofluids

ABSTRACT

Photovoltaic/Thermal (PV/T) systems provide hot fluid (usually water) production as well as electrical energy production. In addition, since the overheating of the PV systems is prevented by the heat drawn by the thermal system, the electricity production performance of the PVs increases. Nanofluids are offered as a solution to increase the heat absorbed in the thermal system. The main physical events that lead to a significant improvement in the heat transfer performance of nanofluids can be summarized as follows: (i) The thermal conductivity of the prepared nanofluid increases at certain rates because the thermal conductivity of the solid metal is higher than that of the basic fluid, (ii) The heat transfer surface area increases due to the increase in the thermal conductivity of the fluid, (iii) Increase in the effective thermal capacity of the fluid, (iv) Increase in the thermal conductivity of the fluid and turbulent volume due to high fluid activity. In this study, by using nanofluids obtained by adding 1% Fe2O3, Fe3O4 and NiFe2O4 magnetic nanoparticles by weight to the basic fluid water, a bidirectional performance increase was achieved by increasing the thermal heat transfer of the PV/T system while providing more cooling of the PV system. In the experimental study, a 14% improvement in electricity production was achieved in NiFe2O4 nanofluid by drawing more heat from the heated PV panels by utilizing the high thermal conductivity of nanofluids. Since the amount of heat absorbed in the thermal system is high, an average of 104% temperature (ΔT) increase in the hot fluid temperature compared to the base fluid water was obtained in the NiFe2O4 nanofluid.

Key words: PV/T, nanofluids, magnetic nanoparticles, Fe2O3, Fe3O4, NiFe2O4.

1.INTRODUCTION

Photovoltaic cells experience a decrease in efficiency with an increase in temperature due to increased resistance.

PV/T systems can be designed to remove heat from the PV cells, thereby cooling the cells and increasing their efficiency by lowering the resistance. The result is a cold-running PV panel with higher efficiency and longer lifespan, and the production of hot fluids that can be used for residential, commercial or industrial applications. Solar cells cannot convert most of the solar radiation coming to their surface into efficient energy, and the temperature in the cells increases and a decrease in electrical efficiency is observed. Therefore, the PV cell temperature can be lowered naturally or by cooling with a forced refrigerant, which is usually water. For monocrystalline (c-Si) and polycrystalline (pc-Si) silicon

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solar cells, the efficiency decreases by about 0.45% for every degree increase in temperature. For amorphous-silicone (a-Si) cells, the effect is less, with an increase in temperature of about 0.25% depending on the module design. This undesirable effect can be partially avoided by proper heat extraction with fluid circulation [1].Creating a hybrid system by using photovoltaic panels together with thermal systems is a solution for increasing efficiency. It is also well known that using a hybrid system reduces the need to use an external source of electrical energy.

As a result of the literature review, many studies have been carried out to remove excess heat from the system by using gas (usually air) and liquid fluids (usually water).When the experimental studies in the literature are examined, many studies using water as a refrigerant achieve higher efficiency than other studies. Air cooled PV-T panels are easier to implement, they do not need a liquid cooling circuit. Air is affordable, clean and usable for almost all applications on Earth. However, in terms of efficiency, they are more inefficient than water-type cooling systems.The main reason for using nanofluids cooling in our experimental study is to obtain more efficiency. Today, many researches, experimental and numerical studies on the subject have been and still are. İbrahim et al. have included a classification of PV/T systems in their research [2]. By using a water-cooled system, they increased the PV performance.

Serhaddi F. et al. [3], the calculation of electrical and thermal parameters, exergy components and exergy efficiency of a PV/T air (air fluid) collector was made as energy and exergy analysis in detail. In the study, a computer program was developed to calculate the thermal and electrical parameters of the PV/T collector. The electrical efficiency, thermal efficiency, total efficiency and exergy efficiency of the PV/T collector for certain climatic, operational and design parameters were found to be 10,01%, 17,18%, 45%, and 10,75%, respectively [3].Kim et al. [4] carried out an experimental investigation of the PV/T collector whose PV panel is of monocrystalline material. The fluid used to generate thermal energy in the PV/T collector is air. As a result of the analyzes made, it has been determined that the thermal efficiency of the PV/T collector is 22% and the electrical efficiency is 15% [4].

Saygin et al. [5] experimentally investigated a modified PV/T collector through which air is passed as a fluid in their work. The ambient air taken from a space in the middle of the collector is passed through the upper and lower parts of the PV panel, and is discharged through a channel after the thermal energy in the PV panel is taken. As a result of the analysis, the highest thermal efficiency of 48% was obtained in the case where the mass flow rate of the fluid is 0.037 kg/s and the distance between the PV panel and the protective glass layer is 3 cm [5].

In an experimental study by Ahn et al. [6] to examine the PV/T performance, the fluid (air) leaving the system was mounted in the heat recovery section to preheat the fresh air at the outdoor air inlet. As a result of the study, the thermal efficiency was 23% and the electrical efficiency was 15% [6].

In their study, Kabul and Duran [7] aimed to increase the efficiency, which decreases with the increase in the temperature of the PV cells, to increase the efficiency by cooling the system with the help of water, and to cool the panel with the fluid (water) passed through the cooler pipes placed on the back (back) surface of the PV panel.

Ma et al, [8] in their study, which they prepared considering that PV/T systems can be an energy input for heat pumps and thus will be an alternative to energy recovery applications, the key parameters for each of the PV/T system control strategies are PV/T system energy gain, total energy consumption, investigated their effects on the average heat pump coefficient of performance (COP) and overall system performance.Yao et al. [9] used phase change materials in the heat pump connected to the PV/T module in their study and integrated them into the heat storage system and investigated the thermal and electrical efficiency of this combined system.Bellos et al. [10] aimed to increase the system performances by using Cu/water and Al2O3/water nanofluids in their study investigating a solar assisted heat pump driven by nanofluid-based hybrid PV collectors for space heating and electricity generation purposes.

There are many industrial examples of systems based on solar energy. However, the use and production of electrical-thermal hybrid systems seems to be limited. Using PV/T modules is more advantageous in terms of electrical efficiency and total efficiency (electrical + thermal efficiency) instead of standard PV panels.

In this study, it is aimed to increase the thermal efficiency of the system by using nanofluids in which 1% magnetic nanoparticles are added, instead of the cooling fluid used in PV systems, to cool the panels more and thus to increase the electrical energy obtained from the panels. Fe2O3, Fe3O4 and NiFe2O4 nanoparticles were chosen as magnetic particles. Experimental studies have shown that nanofluids formed by the addition of magnetic particles have significant effects on thermal performance compared to base fluid water

2. MATERIAL and METHOD

2.1. Experimental Set up

The names of the materials belonging to the experiment set, the modules they belong to and the parts properties are given in Table 1 as a list. While the photovoltaic panel is in both modules, the cooling water circuit is only in Module 1. The photovoltaic panels used in the experiment set have the same dimensions and the same properties. Photovoltaic solar panels are mounted on the same platform. Figure 1 shows both modules and Figure 2 shows the cooling circuit details. In addition, a schematic drawing showing the cooling circuit and modules more clearly is given in Figure 3 [11].

Figure 1. PV Modules

Figure 2. The cooling circuit

Module 1 (PV/T) and Module 2 (PV) are designed with two photovoltaic panels of the same brand and same power (Figure1). Module 1 has a serpentine tube array chiller located behind the photovoltaic panel. Before the serpentine is formed, the copper pipes are crushed to a certain extent to ensure full contact with the panel back, and the contact surface with the PV module is increased. Module 2, on the other hand, does not have any additional parts (Figure 2). The panels are placed on the same two profile pipes so that both modules can be at the same angle. The serpentine inlet in Module 1 was fed with mains water and the serpentine outlet was left free to the outside environment. A flow meter was used to control the water entering the serpentine Figure3 [11].

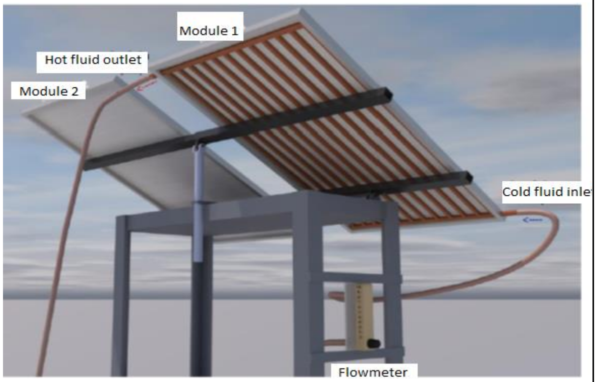

Figure 3. PV/T and PV modules

2.2.Preparation of the Magnetic Nanofluid.

In this work, the Two-Step method is used for the preparation of the MNFs. The top-down method is applied to produce magnetite (Fe_3O_4), (Fe_2O_3) and ($NiFe_2O_4$) nanoparticles. As well as a Spex type, high-energy ball mill, ball crushing techniques were carried out. All three Fe_3O_4, Fe_2O_3 and $NiFe_2O_4$ magnetic nanoparticles are scattered in distilled water as the base fluid with a concentration ratio of 1% (wt.). Furthermore, 0.2% (wt.) Triton X-100 was dropped into the mixture to prevent nanoparticles' agglomeration obstacles. Before starting the experiments, all suspensions were exposed to ultrasonic vibration inside an ultrasonic bath (ISOLAB Laborgeräte GmbH) for 5 hours.

2.3.Measurement of the Thermophysical Properties.

The physical characteristics of the Fe_3O_4/water and Fe_2O_3/water magnetic nanofluid such as density and specific heat are determined by applying the formulas discussed in Pak et al.'s (1998) work [12].

The density of the MNF is calculated by Equation 1 [12].

$$\rho_{MNF} = \rho_{base}.(1-\varphi_{MNP}) + \rho_{MNP}.\varphi_{MNP} \qquad 1$$

Where:

ρ_{MNF} = the density of the MNF (kg/m^3)

ρ_{base}= the density of the base fluid (i.e., water) (kg/m^3)

φ_{MNP}= concentration ratio (%)

The specific heat of the MNF is calculated by Equation 2. [12]

$$c_{p,MNF} = \frac{\rho_{base}.c_{p,base}(1-\varphi_{MNP}) + \rho_{MNP}.\varphi_{MNP}c_{p,MNP}}{\rho_{MNF}} \qquad 2$$

Where:

$c_{p,MNF}$= the specific heat of the MNF J/kg.K

$c_{p,base}$= the specific heat of the base fluid (i.e. water) J/kg.K

The specific heat of the magnetic nanoparticles $c_{p,MNF}$ of the Fe_3O_4 and Fe_2O_3 is calculated by Equation 3.

$$c_{p,MNF}{}^{\circ} = a + b.t + c.t^2 + d.t^3 + \frac{e}{t^2} \qquad 3$$

Where: t = temperature (K)/1000.

$c_{p,MNF}{}^{\circ}$ = Specific heat (J/mol K)

Mw (Fe_3O_4) = 231.533

Mw (Fe_2O_3) = 159.688

The value of the constants in Eq.1 for both Fe_3O_4 and Fe_2O_3 MNPs are given in Table 2.

Table 2. The value of the constants in equation 1. For both Fe_3O_4 and Fe_2O_3 MNPs.

Fe_3O_4	Fe_2O_3
a = 104.2096	a = 93.43834
b = 178.5108	b = 108.3577
c = 10.61510	c = -50.86447
d = 1.132534	d = 25.58683
e = -0.994202	e = -1.61133

Table 3. Thermophysical properties of the working fluids.

Thermophysical properties	**Fe_3O_4**	**Fe_2O_3**	**$NiFe_2O_4$**	**Pure water**
specific heat $c_{p,MNF}$ (J/kg.K)	4179.994	4116.54	4178.8	4180
Density ρ_{MNF} (kg/m^3)	1003.37	1009.735	1010.4	997

Thermophysical properties calculated using Eq.1 and Eq.2 are given in Table 3.

3. RESULTS AND DISCUSSION

Experiments were carried out in Ankara climate conditions. The ambient temperatures, global radiation changes and panel surface temperatures measured during the experiments are given in Figure 4. The average temperature of the panel surfaces between the Module 1 (PV/T) system and the Module 2 (PV) system in the experiments with the mains water is given in Figure 4. As can be seen from Figure 4, the maximum surface temperature difference is 14.2oC. It has been observed that the cooling of the panel has reached a significant degree. In the PV/T system, the amount of cooling was increased by using two different fluids, water and nanofluid.

According to the fluids used in the cooling circuit, the inlet and outlet temperatures of the serpentine are **given** in Figure 5 depending on time. In the experiments carried out according to the values of the measured day, primarily mains water was used as the cooling fluid. First of all, the calculations of the heat absorbed by the cooling system were made and it was determined with which cooling fluid the maximum heat extracted from the system would be obtained. The fluid temperature differences between the cooling circuit outlet and inlet were measured as in Figure 6. When Figure 6 is examined, the maximum temperature difference was measured as 7.7 oC in the NiFe2O4 nanofluid. In other nanofluids, the temperature difference is greater than in the base fluid water. As can be seen from this graph, the heat absorbed is higher in nanofluids compared to base fluid water. The variation of the electrical efficiency and thermal efficiency of the panel and thus the total efficiency is given in Figure 7. As can be seen from the figure, the increase in thermal efficiency is greater when nanofluid is used, but the increase in total efficiency is greater. efficiency is limited due to improvement in electrical efficiency. Percentage values of these improvements are given in Figure 8. While the change in total efficiency is highest in NiFe2O4 nanofluid, there are improvements in other nanofluids according to the use of base fluid water.nanofluids according to the use of base fluid water.

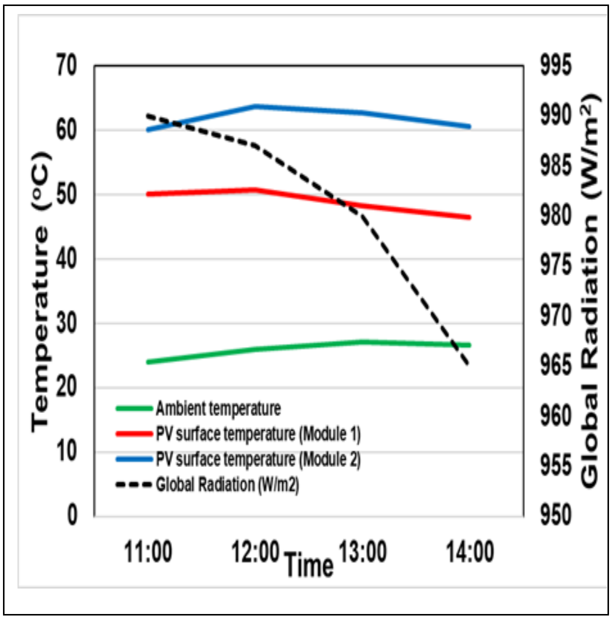

Figure 4. Temperatures measured on the panel

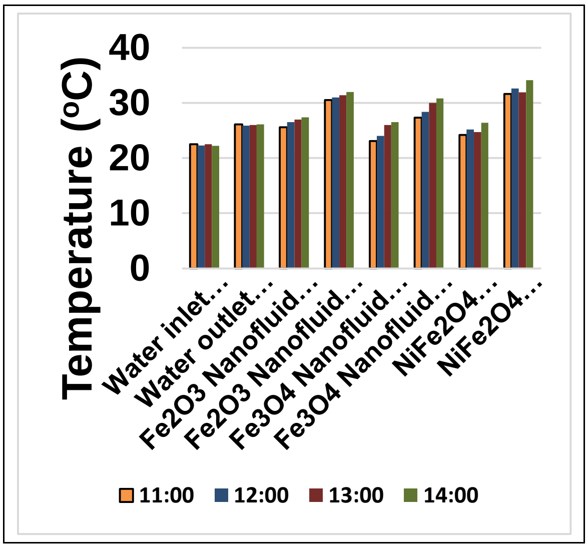

Figure 5. Serpentine inlet and outlet temperatures according to the fluids used in the cooling circuit

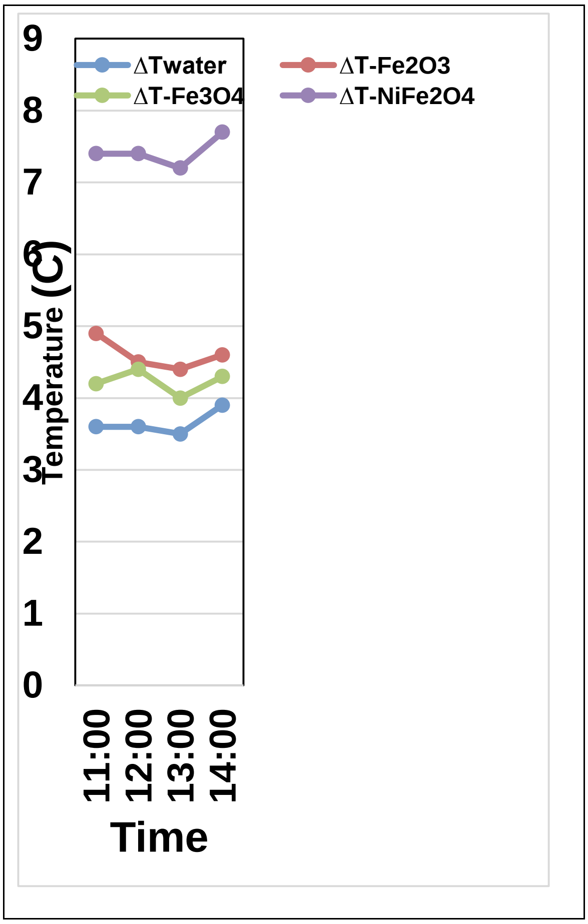

Figure 6. Temperature differences in cooling circut

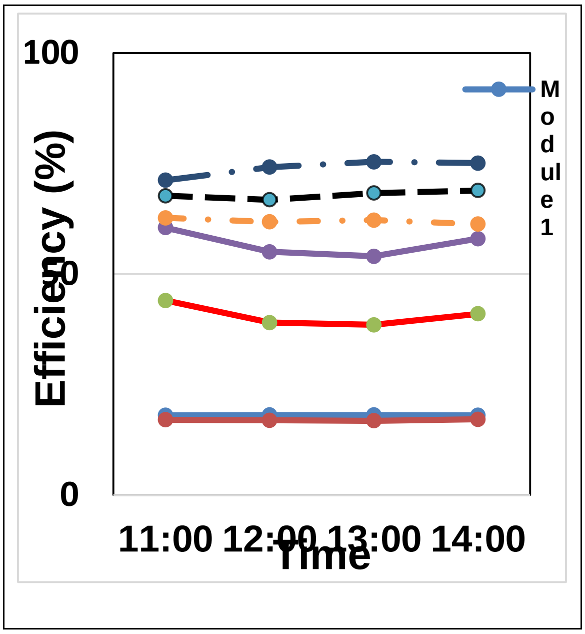

Figure 7. PV/T and PV efficiencies

The measured electricity generation efficiencies of PV panels with and without a cooling circuit (Module 1) are on average around 18% and 16%, respectively (Figure 7). In the case of using water as a fluid in the cooling circuit, the thermal efficiency is around 40%, and the electrical and thermal efficiency of the PV panel reaches 55% in total. With the use of nanofluid in the cooling circuit, this change in total efficiency reaches an average of 62% for Fe_3O_4 nanofluid, an average of 68% for Fe_2O_3 nanofluid, and an average of 75% for $NiFe_2O_4$ nanofluid (Figure7).

Therefore, the best improvement in total yield was obtained with 105% $NiFe_2O_4$ nanofluid. This is followed by Fe_2O_3 and Fe_3O4 as 25% and 15%, respectively (Figure8).

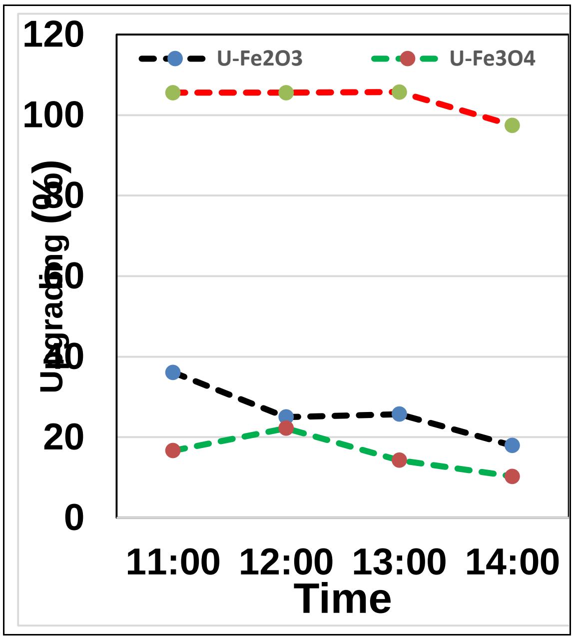

Figure 8. Improvement of thermal and total efficiency

4.CONCLUSION

PV/T systems are one of the subjects that scientific studies have focused on in recent years. The main reasons for this are to increase the electricity generation performance of PVs, as well as to obtain thermally hot fluid from the system. The fact that the obtained hot fluid has many application areas such as space heating, heating of greenhouses, use in drying systems, use as a heat source in heat pumps also causes PV/T systems to gain importance. As can be seen from the results obtained in this study, increasing the total efficiency (electricity + thermal) to be obtained from PV/Ts and increasing the hot fluid temperature obtained from the obtained thermal system will expand the usage portfolios. The fact that it will only provide passive heat gain simplifies the process.

SEMBOLLER VE KISATMALAR

PV/T: photovoltaic/thermal
Cp:specific heat
ρ:Matterial density
Cp_{MNF}:The specific heat of the magnetic nanoparticles
ρ_{MNF}: the density of the MNF
MNF:Magnetic nanoparticals
ρ_{base}: the density of the base fluid (i.e., water) (kg/m3)
φ_{MNP}: concentration ratio (%)
C-Si :monocrystalline
PC-Si: polycrystalline

ACKNOWLEDGEMENT

This study was conducted as a product of the doctoral thesis prepared .

DECLARATION OF ETHICAL STANDARDS

The author(s) of this article declare that the materials and methods used in this study do not require ethical committee permission and/or legal-special permission.

AUTHORS' CONTRIBUTIONS

Ettahir El Hadi Ali Omar SWESE: He made the necessary experimental calculations by writing the article.
Aybaba HANÇERLİOĞULLARI: Performed the experiments and analyse the results.

CONFLICT OF INTEREST

There is no conflict of interest in this study.

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