Investigation of Energy Generation at Test System Designed by Use of Concentrated Photo-Voltaic Panel And Thermoelectric Modules

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Abstract- Systems of concentrating solar energy (CPV) are photovoltaic systems that contain light-intensifying optical components. It is expected to increase performance of solar energy cell by improving sunlight intensity that falls on solar energy cell with these systems. A system of concentrating solar energy consists of a light-intensifying optical component, cell platform, also reciever, heat tank for thermal applications, main module body that consists these components as placed in approriate manner and sun tracking system. Each of these matters is still in need of research and development studies. In this study, concentrating solar system that is rarely prefered in practical use at area and thermoelectric generators were used together to develop a hybrid energy generating system. Thus, it has been researched the potential of energy generation as preferably less cost. Also, it has been determined that heat increase of water that is being used as cooling water can be evaluated in order to help thermal process and recovery as usable water due to potential of obtaining 30% of temperature increase from waste water. It has been found in study that concentrated solar energy cells can generate 15% more voltage and 60% more current than standard usage and three thermoelectric modules connected as series can generate average of 5,19 V of voltage and 0,47 A of current especially integrated to system on summers. On the other hand, it is predicted that this system will provide a light for similar studies because the system has no carbon emissions and sufficient energy efficiency.

Key words: Energy, renewable, solar, thermoelectric, hybrid**,** waste recovery, concentrating, heat.

1. Introduction

Thermoelectric modules are semiconducting materials that one of its surface heats and other side cooles when direct current is applied on it [1]. It is observed that when it is applied in reverse manner that was stated, namely cooling side is cooled and heating side is heated, thermoelectric module operates as generator and generates energy [2]. Generating energy by using concentrating solar energy systems is the method by which solar energy is concentrated by special lenses and then dropped onto the solar panel, resulting in more electrical energy generation than usual [3]. However, in this system sun ray breaks the panel due to heat power of concentrating solar energy and can not be useful. Beyond the fact that these two energy generators are attractive alternative energy materials, research and development studies on heat utilization and beneficial use of environmental technologies continue in the scientific World.

Outputs of the system named as the solar thermoelectric energy power generator (STEPG) has been analyzed in one study including performance of thermoelectric coolers. The system incorporates both fixed-reciever intermittent parabolic collectors (CPC), usual conventional flat-plate collectors, thermoelectric cooling unit (TE) and energy generator modules as well as appropriate connected pipes and control equipment. Arrangements for thermoelectric modules, maximum hot side heat and desired output power were identified as main input of the system. Module compilements were set up through software named TRNSYS. The results have not shown that very high system performance is achieved. However, it has introduced as a good and applivable concept for energy generation when it is considered for the country of Thailand. As a result of study, it has been shown that STEPG can be developed for larger scaled researches and economic data analysis could be done easily [4].

Operation together with thermoelectric modules and geothermal resources as a hybrid system could be possible [5] and it has been determined that required temperature difference for thermoelectric module is suitable for relevant test system. 6V voltage and 2,5 W electrical power was obtained when temperature from geothermal source reached to 70 ºC. The utility of energy obtained by system has been tried and applied to LED (Light Emitting Diode) lighting system. The energy difference in thermoelectric module increased linearly with temperature change as it is expected, while power change shows the parabolic graph data. Energy generation efficiency of large number of serial connected thermoelectric modules is increased due to temperature changes unexpectedly in geothermal plants. Thus, results have been obtained that termoelectric modules can also be used in hybrid applications such as waste heat recovery, motor vehicle and solar energy [6].

Solar cells generate energy with low efficiency as most 20% [7]. More than 80% energy caused by solar radiation in solar cell applications is thermally released to environment and can not be used for energy generation [8]. This energy that can not be used in an operation could be recovered by hybrid photovoltaic thermal (PV/T) applications as it has been stated in one study. The hybrid system which is created, combined pairs of PV modules and heat-extraction equipments and is expected to increase generation if the heating problem in photovoltaic modules can be controlled. Lots of methods can be used for heat extraction are thought but using water or air circulation method was suggested which is the most general model. Finally, system has increased the efficiency of solar cells by 10-30% as a result of cooling process. Hybrid system conducted much more electricity than heat generation and is sufficient to compare system with an ordinary thermal system. The most important factor in this result is the flow rate of refrigerant and application temperature. Exergy analysis of hybrid system gave opportunity to identify effects of each partial process on efficiency, system gain and maximum efficiency [9, 10].

Hybrid power systems which are insulated by use of a partial controller or regulator with synchronous compensator (STATCOM) have been investigated as drawing attention to present importation in another study. Dispersed energy sources such as wind energy, which are found irregularly in nature, are used by converting mechanical energy into electrical energy in a generator by means of an electromechanical energy device. But it is necessary a reactive power to operate generator. Common synchronous generators may not provide reactive power under normal operating conditions. Therefore, a reactive power source is required to respond to this sudden need. STATCOM's performance of generator induction in variable changing mode is examined as wind-diesel power system were thought to be sample in study. Results have shown that STATCOM loads and provides necessary reactive power and induction generator power which is at stand by with dynamic conditions as increasing input wind power that changes induction generator shift, however has capability to meet total demand of synchronous generator at initial stage[11].

The common concerns about use of Fresnel lenses in designed aplications are the cooling of system. A theoretical model was built to analyze the performance of system and to evaluate Thomson effect and temperature resistances of thermoelectric elements, designed by elements such as Fresnel lens, cavity reciever and heat pump. Environmental effects such as solar radiation, optical density and wind speed were investigated for absorption effects of ceramic layers in this model. Results showed that system could deliver 45.73W power output and operate at 3.289% efficiency [12].

A mathematical research of an optical test system including a heat transfer model was carried out using a condenser and a reciever pump in other study. A collector was used to supply data in design and temperature varied between 40^{O}C and 90^{O}C. Results showed that global efficiency of collector was under 20%. According the analyzes about energy loss, optical loss in lens system corresponds to 47% of whole system. Using empty reciever and performing a completely new isolated cycle from outside has been proposed to improve performance of system. According to calculations, these improvements can increase global efficiency of system to 55% [13].

It was observed that the temperature of an aluminum layer focused by a Fresnel lens increased to 517^{O}C in a study to elucidate the condensation power of Fresnel lens. 2 kg of water was turned in condensation range to use this energy for heating the water and comparison of linear lens and Fresnel lens with concentrating function was examined. 13.98% average efficiency was achieced by a linear lens setup and that was 16.48% average efficiency by concentrating Fresnel lens [14].

One of studies in which photovoltaic and thermal systems are used together is directed to a test system with plane mirrors. It was obserbed in plane mirrored system not only the cost is reduced but also adjustable condensation rates and uniform reflection could be achieved. The system was achieved an electrical efficiency of 22% and a thermal efficiency of over 47%. Experiments have shown that the temperature coefficient of open circuit voltage in photovoltaic module is -0.12V/^{O}C [15].

Similarly, it is believed that a solar cell with a triple junction structure located at focal point of Fresnel lens has the highest output power because solar light intensity is the highest at focal point. However, according to study, it was demonstrated that distribution of sunlight from Fresnel lens and seperation of applied light will cause changes in spectrum and homogeneity of radiation and will reduce the output power of solar cell. The correction of this negative effect was theoretically calculated and solar tracking simulation model and network model of three-junction solar cell circuit was designed in the study. Results showed that output power can be increased by 15% after optimization [16].

Operation of both solar energy systems and other renewable energy systems is possible as evidenced by mentioned studies [17, 18]. Solar energy cells have been investigated to convert intensity of radiation emitted by sun into energy with higher efficiency, in many studies. Concentrated solar energy systems are promising as more energy could be generated by solar energy systems. The biggest problem with these systems is that the overheating of concentrated solar rays damage solar cells. There are also PV panels that are commercially produced by some private companies integrated by concentrated solar power. The Fresnel lenses used in these panels, however, are in form of a magnifying glass of a few centimeters in size and are in positioned so that a lens focus can be made on each cell. Moreover, permanent solutions to problem of heating of cells are still in stage of research and development. In our study, a large-scale linear Fresnel lens was used in dimensions of 160x120 centimeters and a half-incision was performed. Growth of Fresnel lens size has resulted in an increase of 8 times of condenced light on the cell. In other hand, thermoelectric modules are circuit elements that generate electricity when temperature difference is obtained between their sides. In this case, temperature increase which is considered as a disadvantage for solar energy cell, could be considered as advantage for thermoelectric modules. Unlike other studies, a test system that can operate with both solar energy cell and thermoelectric modules by concentrated solar energy using a linear Fresnel lens has been designed in the study. The system allows large scale Fresnel lens, solar energy cell and thermoelectric modules to operate together. One of the most important achievements of the design is that to use waste water for cooling purposes and to direct to thermal process by increasing its temperature. Not only water, but also other luquids with high energy transfer coefficient or cooling by fans that consume less energy were also considered to cool the system [19]. However, in the design, it has been planned to recycle the water that is already in use and to be integrated into system as use water. In this way, as examples, it could be useful for greenhouse applications to meet required hot water supply to accelerate the aging of such specific agricultural product, for integrating the system in order to contribute to hot water cycle in an accommodation facility or for assisting in heating circulation water that circulates through cooling tower in a power plant. Since water that is very important in study is wastewater and use of this water is independent from system, energy expenditure to pump water has been neglected as it is already needed to use. Thus, an experimental study of a hybrid energy system that can be combined with a completely eco-friendly and multiple energy recovery system has been given to the literature.

2. Materıal And Method

2.1. Required Materials

Both heat energy and electricity energy gain are proposed in study that includes concentrating solar energy from a specific surface area through a lens to a smaller area. Fresnel lens, thermoelectric modules, solar cell and circulation unit were used for experiment and measuring instruments such as solarmeter, multimeter, thermometer and flow meter were used for tests. Generators used in this scope are thermoelectric generators of SP1848 model numbered 4 x 4 cm sized and Diamond G156S3 series monocrystalline silicon solar energy cells, measuring instruments, Ridgid 36153 infrared thermometer, SM206 solarmeter and DMM multimeters.

Fig. 1. Experiment and test equipments.

Table 1. Technical specification of equipment and measuring instruments

Solar Cell				
Code	20.60	20.40	20.20	20.00
Short Circuit Current Isc (A)	9,67	9,65	9,63	9,61
Open Circuit Voltage Voc (mV)	657	656	654	651

Thermoelectric Module			
ΔT (^{O}C)	Voltage (V)	Current (mA)	Power (W)
20	0,97	225	0,22
40	1,8	368	0,66
60	2,4	469	1,13
80	3,6	558	2,01
100	4,8	669	3,21

Multimeter	
DC V	50.000/500.00/2400.0mV/5.0000/50.000/500.00/1000.0V (Input impedance: Approx. 100MΩ [50/500/2400mV], 10MΩ [5/50/500/1000V]) ±0.02%rdg±2dgt (Basic accuracy)
AC V [RMS]	50.000/500.00mV/5.0000/50.000/500.00/1000.0V (Input impedance: 11MΩ<50pF [50/500mV/5V], 10MΩ<50pF [50/500/1000V]) ±0.4%rdg±30dgt (Basic accuracy)
AC V [MEAN]	50.000/500.00mV/ 5.0000/50.000/500.00/1000.0V (Input impedance:11MΩ<50pF [50/500mV/5V],10MΩ<50pF [50/500/1000V]) ±1%rdg±30dgt (Basic accuracy)
DC A	500.00/5000.0µA/50.000/500.00mA/5.0000/10.000A ±0.2%rdg±5dgt (Basic accuracy)
AC A [RMS]	500.00/5000.0µA/50.000/500.00mA/5.0000/10.000A ±0.75%rdg±20dgt (Basic accuracy)
AC A [MEAN]	500.00/5000.0µA/50.000/500.00mA/ 5.0000/10.000A ±1.5%rdg±20dgt (Basic accuracy)
Infrared Thermometer	
Temperature Range	-50°C and + 800°C (-58ºF and +1472ºF)
Measurement Accuracy	-58°F ~ 68°F (-50°C ~ 20°C) ±4,5°F (2,5°C) ; 68°F ~ 1472°F (20°C ~ 800°C) ±1,8°F (1,0°C)
Solarmeter	
Resolution	0.1W/m², 0.1Btu/ (ft²-h)
Accuracy	±10W/m² / ±3Btu/(ft²-h)(±5% of the measured value)
Range	0.1-399.9W/m², 1-3999W/m², 0.1-399.9Btu/(ft²-h), 1-3999Btu/(ft²-h)

2.2 Installing Test Set

In order to benefit from concentrated solar energy, a moving mechanism which can take sunlight steadily has been invented especially at noon, where the most efficiency could be obtained by the sun [20]. Solar rays are known to heat cells in association with solar cells in panel [21]. Thermoelectric generators have been installed under a metal conductive plate as it could pass under panel, so that hot surface can come into contact with metal. It has been tried to operate generators efficiently with minimum thermal losses using conductive metal equipment and to pump waste water to bottom surface of system to cool the cold surface of generator and to circulate the water. However, it has been determined that protective layer of solar cell is cracked despite all attempts to cool it and cell gets damaged. In order to avoid this problem, solar cell has been brought into contact with water directly and distance of concentrated solar rays is shortened by placing thermoelectric modules on upper surface of water contact surface. Negative and positive electrical output terminals of thermoelectric materials have been extended by means of cables to enable measurement and observation.

Thus, a hybrid prototype has been designed in which two types of energy sources could operate in the same system. Amount of energy generation on solar cell with preferably linear Fresnel lens by concentrated solar rays is also tested separately. In this context, this system which was stated that energy production would decrease if sun rays were not taken at a steep angle, has been tested as performance of sunlight was taken at right angles and other angles. During the most productive periods, electrical changes generated by solar cell and thermoelectic couples were detected and recorded by measuring devices. The proposed test method is shown at Figure 2.

Fig. 2. Test setup.

Primary experiments were carried out in order to determine focal point of lens. The distance that gives the most effective light focus has been measured as about 70 cm. Experiment with solar cell showed that solar cell melted and protective glass surface cracked in focus at this distance.

Light focus has been tried to correspond to a circle as 20 cm in diameter to protect cell and integrate thermoelectric modules into the system, so lens distance has been reduced to 50 cm to achieve this concentration. Water circulation has been provided from bottom surface of both thermoelectric modules and solar energy cell to prevent system from overheating. However, despite energy generation in thermoelectric modules, upper surface of solar energy cell was affected by temperature and protective glass surface cracked anyway. It has been determined that cooling water as the most suitable method for transferring cooling water of circulation water to solar energy cell, the coolant should be provided with volumetric contact with cell but not superficially (Figure 3).

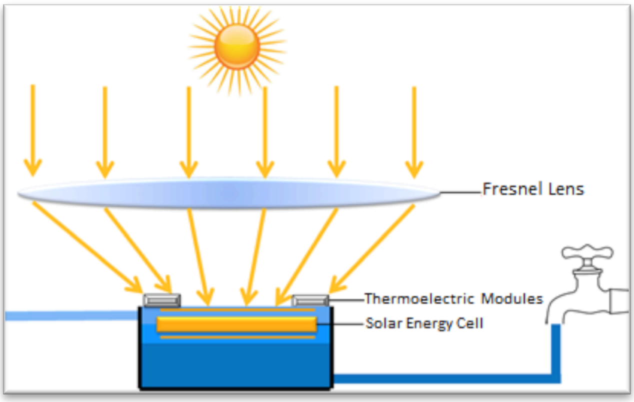

Fig. 3. Experiment diagram.

When the test method is determined, it has been ensured that solar energy cell must be located at upper part of water conversion unit and that upper surface must be filled with a thin water layer, considering further shrinkage of light due to density of water. Upper surface of circulation unit has been stretch-coated for fluid stablization and three thermoelectric modules have been placed in 8th and 12th centimeters from center of solar cell on cold surface. Thus, it has been aimed to keep all kinds of factors that may interfere with photon exposure of solar energy cell to minimum level.

Preferably days of open and low cloudy weather conditons have been selected for experiment. The same methods have been repeated several times according to weather conditions in order to increase accuracy. Temperature variation of low flow rated water respect to solar energy induced warming and flow rate have been investigated in general at the first stage of experimental period. Energy generation of generators have been observed in this case. Flow rate has been taken to be the highest and in particular thermoelectric modules have been strived to provide more energy with more temperature difference, in second stage.

3.Assessments

Measurements required for experiment have been carried out in two steps, before and after the noon, by using closed parabolic distribution of solar radiation ratio. It has been examined in first stage how concentrated solar energy can affect energy generators by changing coolant supply and in second stage the maximum amount of energy that could be generated by thermoelectric modules has been examined by keeping cooling water flow rate as high. Measurements of solar cell have been constantly renewed. Tests have been completed in all monthes of a full year with at least two experiments per month and test results have been analyzed by evaluating seasonal averages.

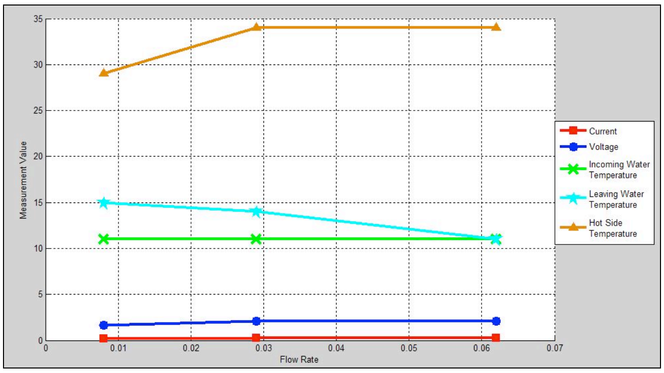

Fig. 4. Winter Seasonal Measurement (By Flow Rate).

Winter season measurements have been carried out in December, January and February. Since weather conditions are very low as temperature in this period, concentrated solar energy field had a decrease in heating of cycle water. Period in which water flow rate is 0,008 lt/sec is measured between the time 10:00 – 12:00, period with 0,029 lt/sec is between 12:00 – 12:30 and period with 0,062 is between 12:30 – 13:00 hours. According to this, cooling water could be heated from 11^{0}C to 15^{0}C in period when flow rate is low and in process of increasing the flow rate, this difference of heating water has been decreased rapidly and disappeared. Hot surface temperature has been constantly increased by time due to sunlight. Three thermoelectric modules connected in series have generated 1,66 V and 0,18 A at 10:00 – 12:00 hours, 2,06 V and 0,22 A at 12:00 – 12:30 hours and 2,12 V and 0,22 A at 12:30 – 13:00 hours.

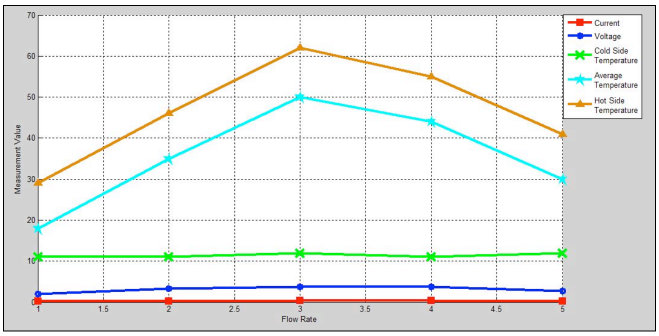

Fig. 5. Winter Seasonal Measurements (Flow Rate Constant).

In hourly measurements that's been recorded in second stage of day, test results numbered between 12:00 – 13:00 hours as 1st time zone, 13:00 – 14:00 as 2nd time zone, 14:00 – 15:00 as 3rd time zone, 15:00 – 16:00 as 4th time zone, 16:00 – 17:00 as 5th time zone and 17:00 – 18:00 as 6th time zone and recored to graph. No measurements have been made in zone 6 because sun duration was short during winter monthes. Flow rate of cooling water has been tried to be kept constant as high as 0,06 lt/sec in this period and temperature difference has been tried to be increased. A temperature difference 50^{o}C has been achieved during maximum temperature difference period and 3,08 V voltage and 0,36 A current values have been generated by three thermoelectric modules connected in series.

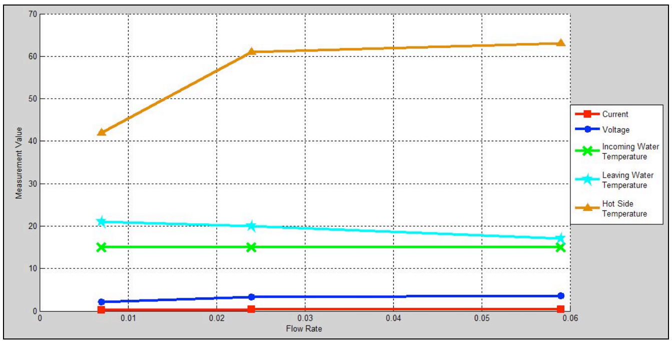

Fig. 6. Spring Seasonal Measurement (By Flow Rate).

Spring season measurements have been carried out in March, April and May. In this period when flow rate of cooling water is low, entering water temperature could be heated from 15^{o}C to 21^{o}C and this difference has decreased rapidly during increase of flow rate. Hot surface temperature has been increased constantly by time due to sunlight. Average energy generated by three thermoelectic modules connected in series has been measured as 2,09 V and 0,22 A at 10:00 – 12:00 time zone, 3,30 V and 0,32 A at 12:00 – 12:30 time zone and 3,65 V and 0,34 A at 12:30 – 13:00 time zone.

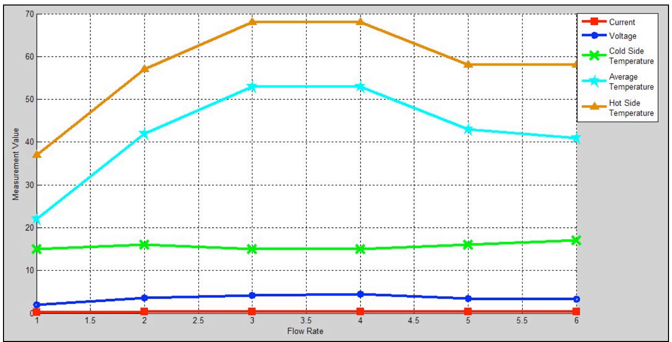

Fig. 7. Spring Seasonal Measurements (Flow Rate Constant).

Because of short sunshine duration during first two monthes in spring, no measurements were tried in 6th zone and this measurement has been only made in May and covers only May. Flow rate of cooling water has been kept constant at a rate of 0,07 lt/sec in this period. A temperature difference of 53^{o}C has been achieved during maximum temperature difference period and 4,41 V voltage and 0,36 A current values have been generated by three thermoelectric modules connected in series.

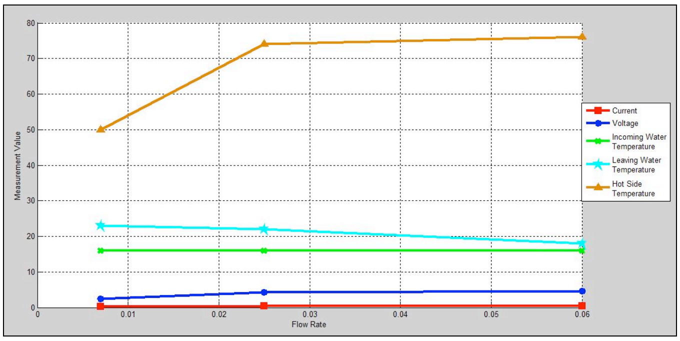

Fig. 8. Summer Seasonal Measurement (By Flow Rate).

Summer season measurements have been carried out in June, July and August. In period when flow rate of cooling water is low, entering water temperature could be heated from 16^{o}C to 23^{o}C and this difference has decreased rapidly as flow rate increased. Especially water temperature in August has been up to 34^{o}C. Hot surface temperature has been constantly increased by time due to sunlight. Average energy generated by three thermoelectric modules connected in series has been measured as 2,50 V and 0,28 A at 10:00 – 12:00 time zone, 4,25 V and 0,41 A at 12:00 – 12:30 time zone and 3,64 V and 0,44 A at 12:30-13:00 time zone.

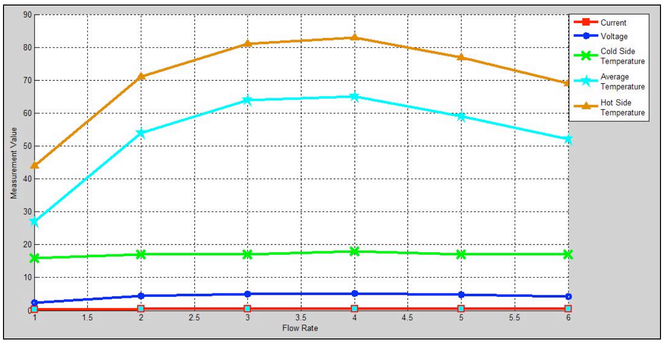

Fig. 9. Summer Seasonal Measurements (Flow Rate Constant).

Flow rate of cooling water has been tried to be kept constant at a rate of 0,06 lt/sec in second stage tests of summer period. A temperature difference of 65^{o}C has been achieved during maximum temperature difference period and an average of 5,19 V voltage and 0,47 A current values have been generated by three thermoelectric modules connected in series. Test results have reached its maximum values in August as the hottest month of this period and values of 6,11 V and 0,57 A have been generated.

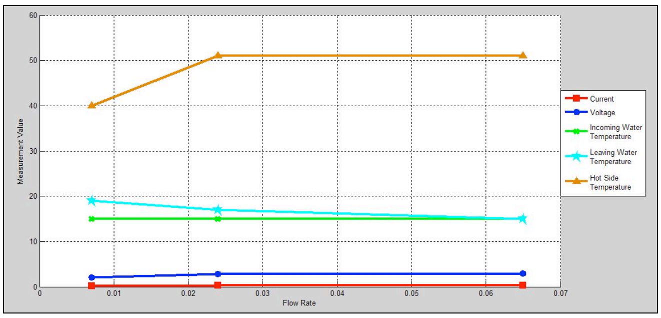

Fig. 10. Autumn Seasonal Measurement (By Flow Rate).

Autumn season measurements have been carried out in September, October and November. In period when cooling water flow rate was low, entering water temperature could be heated from 15^{O}C to 19^{O}C and this difference has decreased rapidly as the flow rate has increased. Hot surface temperature has constantly increased by time due to sunlight. Average energy generated by three thermoelectric modules connected in series has been measured as 2,01 V and 0,22 A at 10:00-12:00 time zone, 2,87 V and 0,30 A at 12:00 -12:30 time zone and 2,95 V and 0,29 A at 12:30 – 13:00 time zone.

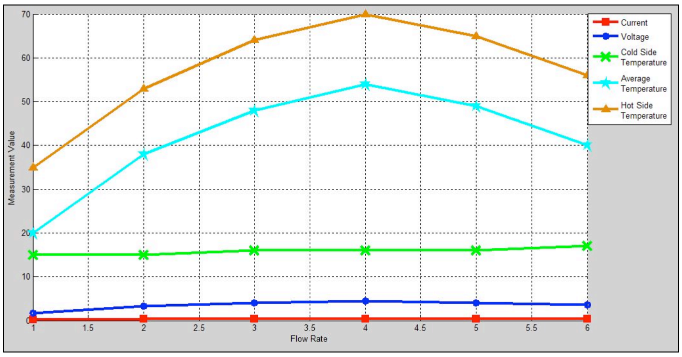

Fig. 11. AutumnSeasonal Measurements (Flow Rate Constant).

Flow rate of cooling water has been kept constant at a rate of 0,07 lt/sec during second phase of autumn period. A temperature difference of 54^{O}C has been achieved during maximum temperature difference period and a mean value of 4,43 V and 0,41 A current values have been generated by three thermoelectric modules connected in series. Measurements in 6th zone could not be made in November when spread of sunshine duration was short and average of September and October measurements have been used in this zone.

Table 2. Solar energy cell test results

Time	Voltage (V)	Current (A)	Voltage (Shade) (V)	Current (Shade) (A)
12:00-13:00	0,63	5,29	0,44	2,18
13:00-14:00	0,63	5,31	0,45	2,20
14:00-15:00	0,63	5,28	0,43	2,16
15:00-16:00	0,63	5,30	0,44	2,16
16:00-17:00	0,63	5,29	0,43	2,17
17:00-18:00	0,62	5,20	0,41	2,09

Generation in solar energy cell used in experiments under study has been measured continuously throughout the year. Generation increase in period when solar energy cell used by Fresnel lens and generation without lens have been investigated in experiments carried out. Table 2 shows the instantaneous current and voltage values generated by calculating annual average of the cell. The cell has been kept in a position where it could take solar rays at right angles throughout experiments and it has been observed that generation was very stable in clear air and did not fluctuate. In this context one solar cell can generate 0,63 V voltage and 5,30 A current. It has been examined that generation of solar energy cells in shaded zones that were not completely dark in sunny weather at experiments on shadow measurements. As it is known, Fresnel lens covers the area of sun rays about 25 centimeters while remaining areas are shaded. A solar cell has been placed in this area and measurements have been repeated to see if shaded area of Fresnel lens could be evaluated in practice. Shaded area generation has changed between 0,43 V and 2,16 A.

Table 3. Power generation in concentrating solar energy cells

Time	Voltage (V)	Current (A)	Water outlet temperature (°C)	Lens distance (cm)	Water temperature (°C)	Cooling water flow rate (lt/sec)
12:00-13:00	0,72	8,63	16	50	16	0,07
13:00-14:00	0,73	8,64	17	50	16	0,07
14:00-15:00	0,73	8,63	17	50	16	0,06
15:00-16:00	0,73	8,63	17	50	16	0,06
16:00-17:00	0,72	8,63	17	50	16	0,06
17:00-18:00	0,71	8,61	17	50	16	0,06

Focal point detection of lens has been first performed in order to use energy concentrated by Fresnel Lens. Focal spot of lens was at distance of 70 cm from lens surface and it has been observed that high energy-efficient can be obtained as few seconds enough to melt a tin plate in this point. It has been deemed appropriate to place solar energy cell at a distance of 50 cm, which will allow the entire solar energy cell to be exposed to sunlight, after solar energy cell has cracked and protective glass layer was broken in focal distance. Platform has been manually positioned to receive solar energy at right angle during the day. As a result, it has been observed that voltage value increased by 15% to 0,73 V and current value increased by 60% to 8,63 A.

4. Conclusion

In this study, the performance of thermoelectric generators, solar energy cells and solar energy concentraters which can generate electricity by utilizing temperature difference has been investigated and it has been tested by means of practical application on designed test set that generated heat values could be controlled by changing water used for cooling purposes. The system has been exposed to cooling water in order to avoid problem of heating solar cell and to obtain a temperature difference for thermoelectric modules, also temperature increase in cooling water has been tested by flow rate control. However, despite the fact that solar radiation exceeds 2000 W/m² at 50 cm distance of concentrating system, available energy can not be fully used and solar cell technology still needs to be evolved to full capacity gains. It is a necessity to integrate solar tracking system in order to ensure full efficiency of system in commercial application. Season in which the system could be used the most effectively is summer period when sun radiation is the highest. In this period;

- 5,19 V and 0,47 A of energy were generated by three thermoelectric modules.
- Generation of solar energy cell had an average voltage of 0,72 V and current value of 8,63 A.
- In solar energy cell, increase about 15% at voltage and 60% at current with respect to system without concentraters could be gained.
- Measurements of coolant flow rate tested at lower levels have shown that coolant temperature could be increased by 30%.
- Prototype of a test system has been set up by heating of coolant as sense in terms of recovery of waste water.
- This energy generation had advantages such as quiet operating, long operating life as 15-20 years and no need for detailed maintenance.
- Within the scope of study, it has been thought that establishment of a hybrid energy generation system that generates energy from both solar energy cell and thermoelectric modules and determination that circulating water could be transfered as hot water to usage area by heating them, as such systems are promising in terms of having their widespread use.

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