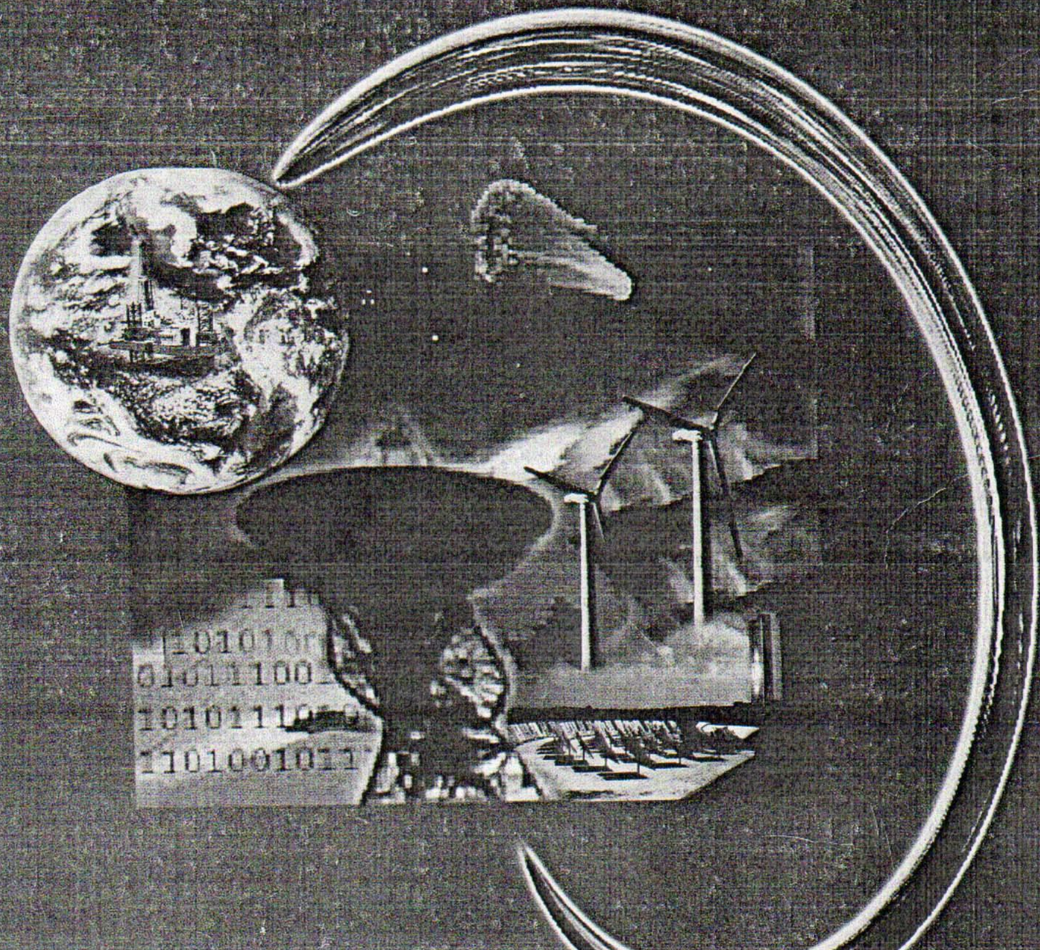
# NEU-CEE 2001

ELECTRICAL, ELECTRONIC & COMPUTER ENGINEERING

# SYMPOSIUM



**Organized by:**

**NEAR EAST UNIVERSITY**

**KTMMOB - Chamber of Electrical Engineers**

**23-25 May, Lefkoşa TRNC**

# PHOTOVOLTAIC – SOLAR THERMAL HYBRID SYSTEM: ENERGY GENERATION CAPACITY IN NORTH CYPRUS.

Assoc. Prof. Dr. Erzat Erdil
Mr. Mustafa İlkan
Eastern Mediterranean University

## ABSTRACT

This paper is devoted to study the potential electricity generating capacity of a hybrid system composed of a photovoltaic (PV) module and a solar-thermal collector. North Cyprus is chosen as a geographic location where relatively high rates of solar insolation throughout a year provide suitable grounds for utilizing such a hybrid systems, for both electricity generation and water heating in domestic dwellings. The residential sector in North Cyprus consumes the largest, about 34.4%, portion of the total electrical energy consumption. The average daily consumption per house is about 7kWh. Installation of a 1600 Wp PV system on a residential house generates enough energy for average daily requirements of a typical household. Such a system will have a module area of about 10 $m^2$. This large area of modules absorbs a considerable amount of solar radiation that generate heat. The energy conversion to heat constitute a loss in terms of utilization of solar energy for photovoltaic generation and also has a detrimental effect on the performance of a PV module. Thermal losses, however, may form a source of energy that can be utilized in water heating applications.

Thermal energy losses can be collected with PV modules that are equipped with transparent jackets, at the front surfaces, through which a fluid may be circulated. Hence, a hybrid system will generated electrical energy and at the same time provide means of extracting heat for water heating. Such a multifunctional system will be cheaper to install and required much less space than having a PV and a collector systems installed separately.

## 1.0 Introduction

The island of Cyprus is situated at the eastern part of the Mediterranean and has a rather warm and prolonged summer days and a fairly mild winter.
The daily average sunny periods range between 5.5 and 12 hours through the seasons, as shown in Fig.1.
The daily average global radiation, shown in Fig.2, is minimum at about 2.3 kWh/m2, in the months of December and January, and maximum at about 7.2 kWh/m2 in the months of June and July. Annual averages of daily sunshine duration and daily global radiation are about 9 hours and 5 kWh/m2 respectively, revealing a favorable condition for photovoltaic and solar thermal applications.

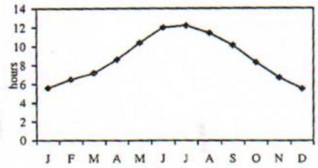



Fig.1. Sunny hours per day averaged for each month (1981-99)

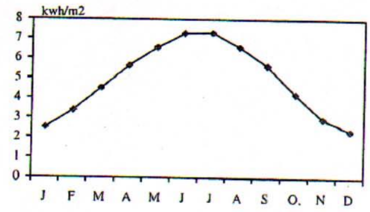



**Fig.2.** Daily global radiation averaged for each month(1981-99)

Solar energy has been widely utilized in Cyprus for at least during the past 40 years. People enjoyed using solar energy for domestic water heating at no fuel cost. The average daily energy consumption of a typical household in N. Cyprus is about 7 kWh, as shown in Fig. 3 below. This amount of energy can be produced in electrical form, with a 1600 Watt PV system [1] having an area of about 10 $m^2$.

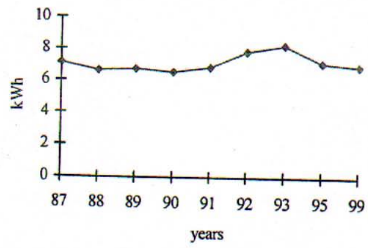



**Fig.3.** Average daily consumption of a household.

The photovoltaic modules available in markets are now well developed. The trend is to generate even more power per square area at a lower cost. The increase in demand and lowering of prices made them even more attractive and relatively large systems are now installed at moderate prices.

The world wide awareness towards the benefits of using clean energy has enhanced the sales of PV systems by many folds in the last 10 years [2].

Large areas modules absorb a considerable amount of solar radiation that also generate excessive heat. This excessive heat leads to lowering of the module efficiency. It can be prevented, however if the photovoltaic modules are equipped with a transparent jacket, at the front surface, through which a fluid is circulated by solar pumping or otherwise to absorb thermal energy. The system combines the function of a photovoltaic module and that of a hot-water collector.

## 2.0 System structure

The hybrid system was formed by adding a glass plate (double glazed, jacket) on top of a standard module and circulating a fluid in between the top of the module and the jacket.

Hence, absorption of heat by the fluid cooled the module on one hand, but at the same time provided a source of heat for domestic water heating.

The standard module, M, was rated at 55 Watt peak, having dimensions 130x47x5 cm. The jacket, J, was 130x47x1.5 cm. as shown in Fig. 4.

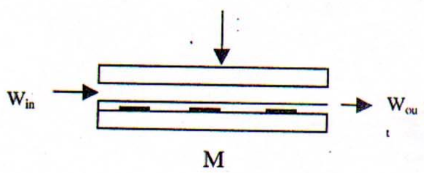



**Fig. 4.** Structure of the hybrid system.

The PV module was tilted 45 degrees and faced South for maximum solar insolation, I. Initially a pure water, W, was circulated at the rate of 36 liters per hour. An identical PV module was used as a control and measurements were performed on both the hybrid and the control modules at the same time and location.

## 2.0 Measurements

A data acquisition card was used to record a range of data. Meteorological information published by the related office was used.

The electrical characteristics of both modules and thermal performance of the hybrid system were measured. The data listed below were recorded at various times during 9.0 – 17.0 hours of a day and the average values were plotted. These were the temperature of the circulated water, at input/output $T_{in}$ ,$T_{out}$ , the ambient temperature, Tamb , and surface temperatures, , $T_{sc}$, , $T_{sh}$ , on the control and hybrid modules respectively, all in degrees centigrade, as shown in Figs.5,6.

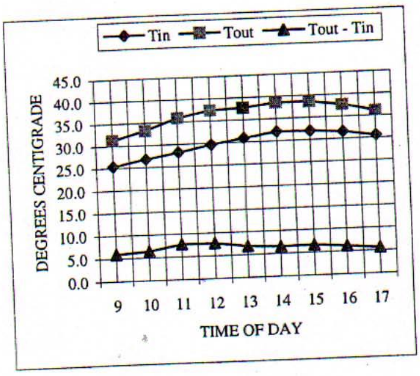



**Fig. 5.** Input/Output temperatures and the difference $\Delta T$ = Tout - Tin .

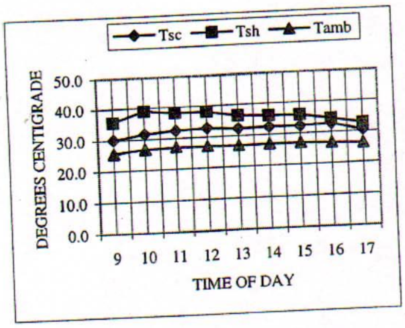



**Fig. 6.** Surface temperatures Tsc, Tsh and the ambient temperature Tamb .

Also, short-circuit currents, $I_{scc}$ , $I_{sch}$ and open- circuit voltages, $V_{oc}$ , $V_{oh}$ of both the control and the hybrid modules respectively were recorded. The maximum operating power of each module was estimated as the product, (open-circuit voltage)(short-circuit current)(fill factor). The fill factor, FF, was taken as 0.7, which is typical of single crystal silicone cells. Figs. 7 show the power of control $P_c$ and that of hybrid as $P_h$ respectively.

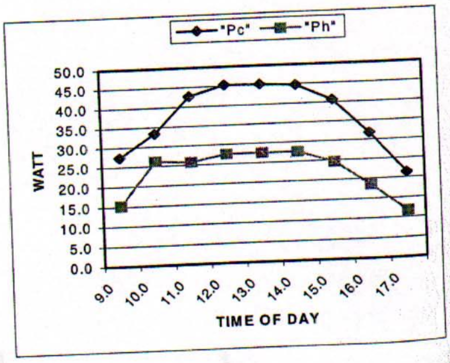



**Fig. 7.** Operating Power of control and Hybrid modules.

The electrical and thermal energy collected by the control and hybrid system were calculated and plotted together with other parameters of interest. The electrical energy, $E_c$ and $E_h$, of control and hybrid module respectively were calculated using numerical integration , as the area, under the power-time curve, taken at various one-hour periods, and plotted as in Fig. 8.

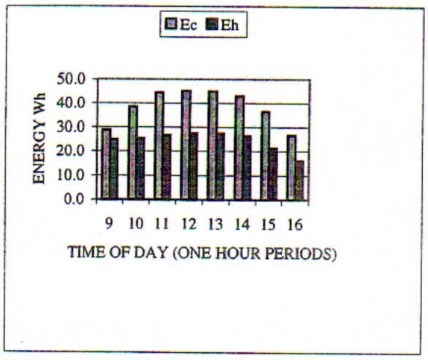



**Fig. 8.** Estimated energy collected by the Control, $E_c$ and Hybrid, $E_h$, modules.

The thermal energy collected by water in one-hour period, $Q_w$ ,was estimated and plotted as in Fig. 9.

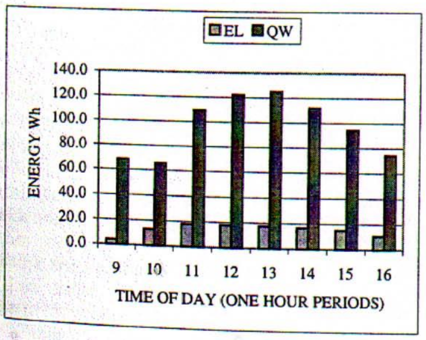



**Fig. 9.** Electrical energy loss, $E_L$, and thermal energy gain, $Q_w$, in the Hybrid module.

$Q_w$ was calculated as the product (water flow rate, in lt/hr) (4187J/kg. °C) (temperature difference, $\Delta T = T_{out} - T_{in}$ ), This curve, also shows the electrical energy loss, $E_L$, in the hybrid module due to absorption of radiation while passing through the glass-water jacket.

## 3.0 Discussion

It is clear from the plots shown in Figs. 5-9, that circulating water through the front surface of a PV module will lead to cooling of the module. The cooling effect was at maximum at noon, and appeared to be uniform between 6-8 °C, as shown in Fig. 5, at the flow rate (36 lt/hr) used. The drop in the operating temperature of the PV cells may also effect the electrical conversion efficiency, that will be revealed in another publication.

The mass of circulating water and the glass jacket both reduced the intensity of insolation reaching the PV cells. This was reflected as a drop in the electrical energy collected by the hybrid module and plotted in Fig. 8. The loss in electrical energy, $E_L = E_c - E_h$ , was however well offset by a large gain, $Q_w$, in thermal energy that was collected by the circulating water, as shown in Fig. 9 above.

Regarding energy extraction from solar insolation, off course the hybrid unit showed a much better performance. The advantage of using the hybrid system may be better displayed by plotting a factor which may be termed as Energy Gain factor, EGF. The overall energy gain, $E_G$, may be described as the difference $E_G = Q_w - E_L$ . This will give $EGF = E_G / E_c$ as plotted in Fig.10 below.

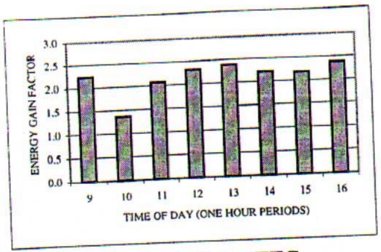



**Fig.10.** Energy gain factor EFG

The advantage in energy collection, however brings a disadvantage in terms of extra cost of the jacket. Nevertheless, the extra cost forms only a fraction of the module cost.

## 4.0 Conclusion

Measurements based on electrical characteristics and the rate of heat exchange in a hybrid module showed that the energy extraction from solar insolation can be improved.

The total electrical energy conversion suffered a drop due to some absorption of solar insolation by the installed jacket and a mass of circulating water.

The improvement was in terms of thermal energy gained by the circulating water.

The Energy Gain Factor, EGF, which reflects the ratio of total energy gain over the Control module reached the value of about 2.0 showing a 100% improvement in energy extraction..

## Nomenclature

| | |
|---|---|
| Fill factor | FF |
| Water temperature at input | $T_{in}$ |
| Water temperature at output | $T_{out}$ |
| Ambient temperature | $T_{amb}$ |
| Surface temperature of control | $T_{sc}$ |
| Surface temperature of hybrid | $T_{sh}$ |
| Control, short-circuit current | $I_{scc}$ |
| Hybrid, short-circuit current | $I_{sch}$ |
| Control open- circuit voltage | $V_{oc}$ |
| Hybrid open- circuit voltage | $V_{oh}$ |
| Kilogram | kg |
| Hour | hr |
| Joule | J |
| Watt | W |
| Measured power of control | $P_c$ |
| Measured power of hybrid | $P_h$ |
| Electrical energy by control | $E_c$ |
| Electrical energy by hybrid | $E_h$ |
| Energy collected by water | $Q_w$ |
| Electrical energy loss: | $E_L$ |
| Solar insolation | I |
| Glass-water jacket | J |
| Module | M |
| Water input | $W_{in}$ |
| Water output | $W_{out}$ |
| Energy gain | EG |
| Energy gain factor | EGF |
| Liter | lt |

## References

[1] Erzat G. Erdil,
Proceedings 13th EC Photovoltaic Solar Energy Conference,Nice, France (1995),494.

[2] Paul Maycock,
Renewable Energy World,V3,N4 (2000),90.