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Analysis of Environmental Effects on a Solar Hydrogen Production System.

F. Areed
Electrical Engineering Department., Faculty of Engineering., El-Mansoura University., Mansoura., Egypt.

Analysis Of Environmental Effects On a Solar Hydrogen Production System

تحليل التاثيرات البيئية على منظومة انتاج الهيدروجين الشمسى

F. F. G. AREED

EL-Mansoura University-Faculty of Engineering,Egypt

ملخص البحث :-يناقش البحث تاثير العوامل البيئية المختلفة على منظومة انتاج الهيدروجين الشمسى. وقد تم تصميم منظومة انتاج للهيدروجين بمعهد الجيوفيزيقا بحلوان القاهرة . وتمت الدراسة على هذه المنظومة .

والعوامل المختلفة التى تؤثر على كمية الهيدروجين المنتجة هى :

١ – كمية السحب .

٢ –درجة الحرارة فى البيئة المحيطة.

٣–الرطوبة

٤ –التلوث.

البحث يناقش تفصيلا تاثير العوامل المختلفة على كمية الهيدروجين المنتجة وذلك من خلال القياسات المعملية التى اجريت تحت ظروف بيئية متعددة والمنظومة المقترحة تعتبر نموذجا يمكن تعميمه فى الأماكن الكثيرة المتوفرة فى جمهورية مصر العربية والتى تعطى لمصر اسبقية كاحدى دول العالم التى يمكن ان تكون مصدرا لإنتاج وقود نظيف هو غاز الهيدروجين فى القرن الحادى والعشرين وذلك لتوقع نفاذ المصادر الطبيعية للوقود مثل البترول والفحم وغيرها.

Abstract:

Development of new energy resources has become an important object.The prospect of separating hydrogen from water for utilization as a substitute for oil and other fossil fules has become a field of interest for energy planners and decision makers. The present work is concerned with studying and analysing a photovoltaic (Poly-Si manufactured by Solarex Co) solar hydrogen system installed over the roof the institute of Astronomy and Geophysics at Helwan,Egypt,Fig (1).The system is constructed to measure the temerature of solar cell at center of the panel and near its edges, using two thermocouples as sensors. The ambient air temperature was measured simultaneously with that of solar cells for

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comparison. The normal incident beam of global solar radiation is recorded by a doom sensor, which was installed in a parallel position. Also, measurements of the environmental and meteorological effects are performed every half hour, electrical parameters, were carried out before the noon time to sunset with variance in the solar radiation. The power output of solar cells arises from solar energy in the form of sunshine falling onto the solar cells. The amount of energy contained in sunlight just outside the earth's atmosphere is about 1.4 kw/m^2.A clear day bright sun light on the earth's surface contains about 1.0 kw/m^2. In actual use, solar cells convert between 5 and 20% of incident solar energy into electric energy, depending upon the specific solar cell construction and prevailing operating conditions.

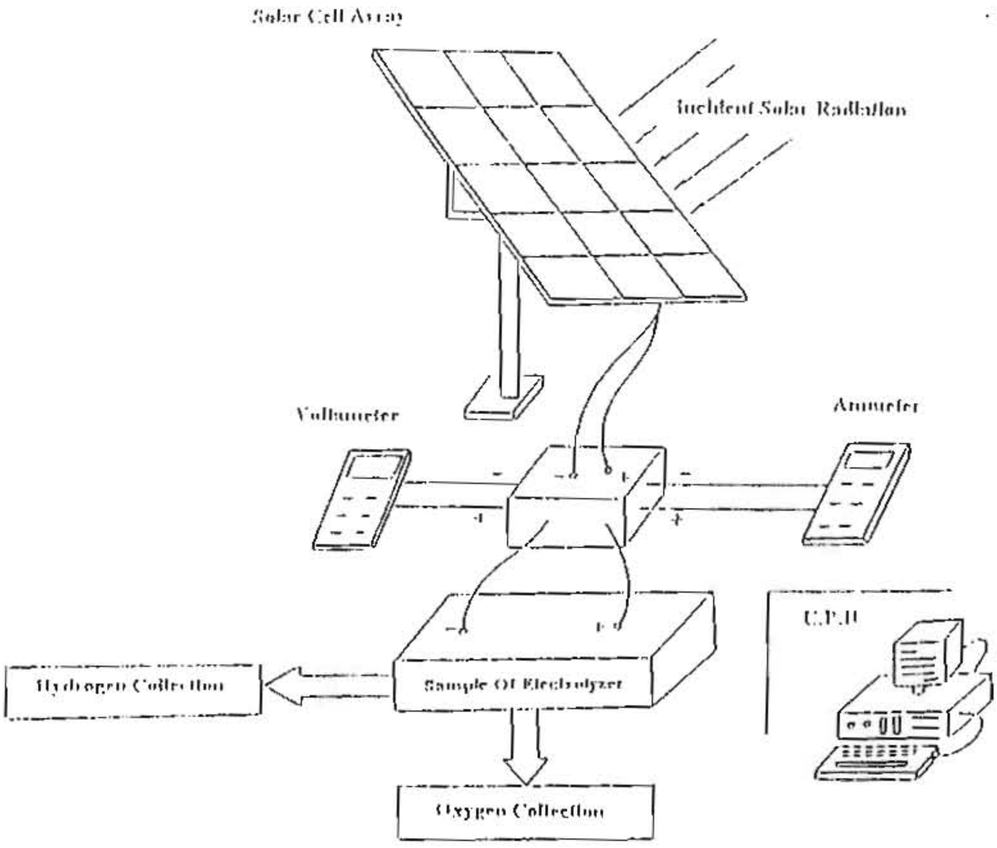


Fig. 1., Schematic Diagram Of Solar Hydrogen Production System

Key Words :

Photovoltaic system - Solar Cell - Hydrogen Production - Sensors - Clouds Wind - Cell temperature.

Introduction

Most environmental conditions have a detrimental effect on the long-term performance capability of solar cells. The most significant environments against which terrestrial arrays must be protected include high wind, corrosion aided by moisture, high temperature,.... etc.

Beneficial environments for terrestrial arrays include low air temperature and moderate wind velocities that increase the solar cell operating efficiency. Consequently, both detrimental and beneficial environments affect **the amount of hydrogen produced using PV- array.**

Results are promising to extend the experiment to a pilot project of solar hydrogen production in Egypt, where the country is characterized by high solar energy potential about (6 kwh/m^2/day on the average as annual mean) This recommends Egypt to be one of the best sites in the world for solar hydrogen production in future.

CLOUDS VARIABLE

The mean monthly cloud's denisty does not exceed 4 Oktas. The cloudiness is greater in lower Egypt than in upper Egypt and reaches its maximum in winter, while its minimum value is attained in summer. On many days at early morning low strut forms, especially over places in the Nile delta and Canel zone. This formation is due to less radiation and turbulence in the humidity and usually disperses with in two to four hours after sunrise, leaving generally, a clear sky untill the following morning.

The solar power received on earth, varies throughout the day as a result of changes in the incident angle of sunlight on a surface. A typical plot of solar power versus time on a clear day is shaped like a half of a sine wave with its crest at solar noon. On a partly cloudy day, the solar power level jumps up and down as the sun passes in and out behind clouds, so that the power/time -of- day plot becomes erratic, as shown in Fig.(2) In fig., (2) solar power momentarily can rise above the normal clear-day power level during instances of natural concentration, when indirect light is received from reflection of clouds. The Sky is not always clear the sun's direct-beam rays often are blocked by clouds. When the sky is cloudy, the amount of sun light that is readily convertible into electricity by a photovoltaic cell is reduced, by at least 50% during thin cirrus cloud, cover and by about 75% more during denser cloud cover. The curve illustrating solar power versus day time varies over different days of the year. The total sunlight hours divided by the total possible sunshine time is called the percentage of possible sunshine. So, that the hydrogen production curve also becomes erratic on a partly cloudy day, as shown in Fig.(3).

THE TEMPERATURE VARIABLE

Egypt is characterized by a hot desert climate in the summer, where, the maximum ambient air temperature ranges between 35°C in the North (Cairo) and 42 °C in the south (Aswan) on average. This hot climate decreases the output voltage and conversion efficiency of the silicon solar cell , during the optimum time of solar energy utilization [1,2]. Since, the operating temperature of solar cells in the field can vary over wide extreme, it is necessary to understand the effect of temperature on performance, (Green,1982) [3].

Daily regular records for the output voltages, showed that, there is a gradual depression in the output voltage at noon, corresponding to the time of maximum air temperature and minimum relative humidity. There is a

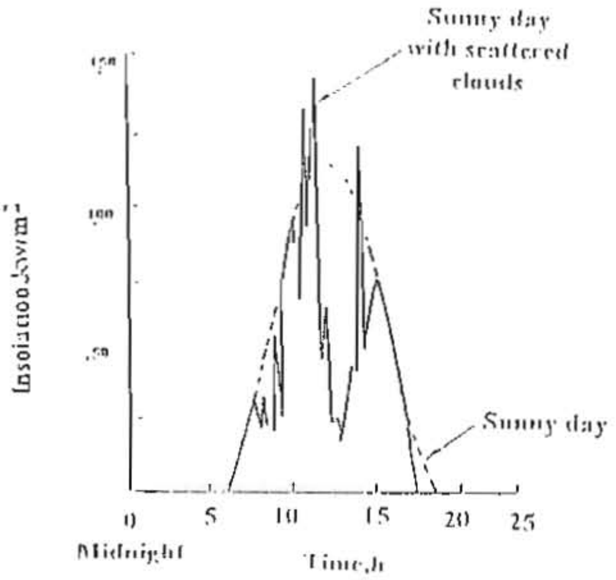


Fig.(2). Solar power on a latitude-tilted south-facing surface versus time of day for partly cloudy weather

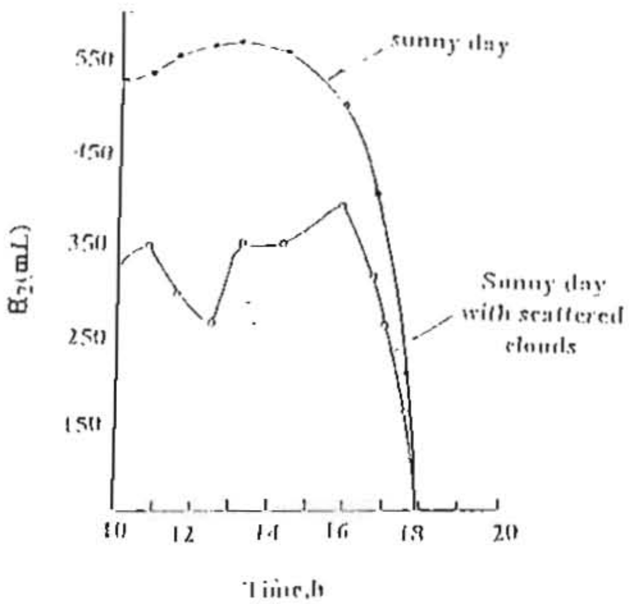


Fig.(3). Hydrogen production (mL) versus time of day for partly cloudy weather direct correlation between Voc decreasing and air temperature. The polycrystalline-module voltage drops at an approximate rate of 2.2 mV for every 1°C increase. While, solar-cell current is relatively steady despite changing temperatures. Since power is the product of current and voltage, we can deduce a simple fact : solar-cell power output increases as cell temperature decreases. A plot of the daily profiles of the output voltages, and the air temperature is illustrated in Fig.(4).

The daytime temperature of a solar cell is not simply equal to the ambient temperature, since solar cells are dark in color and therefore absorb a greater portion of the sun's energy. During the day, a solar cell operates hotter than the ambient temperature by a factor that depends on insolation. Solar cell temperature varies quite linearly with changes in insolation, as shown in equation (1) and the plot in Fig.(5).

$$Tc = Ta + KG \quad ....(1)$$

Tc : Cell temperature under no wind, °C

Ta : Ambient air temperature, °C.

k : Solar cell temperature coefficient.

G : Solar insolation w/m^2

Wind at a site can also affect cell temperature (the effect of wind will however, be ignored because it is small under average wind conditions Also, solar cell will operate slightly cooler, when it is delivering electricity than when it is not, since some of the sun's energy that would normally heat the cell has been transferred to the load.

But, how does our hydrogen production suffers under these conditions?. From Faraday's first law, the amount of substances - in this case $H_2(g)$ - which reacted with the electrodes are directly proportional to the quantity of electricity passing through the solution:

$$\Delta G = KQ = KIt \quad ....(2)$$

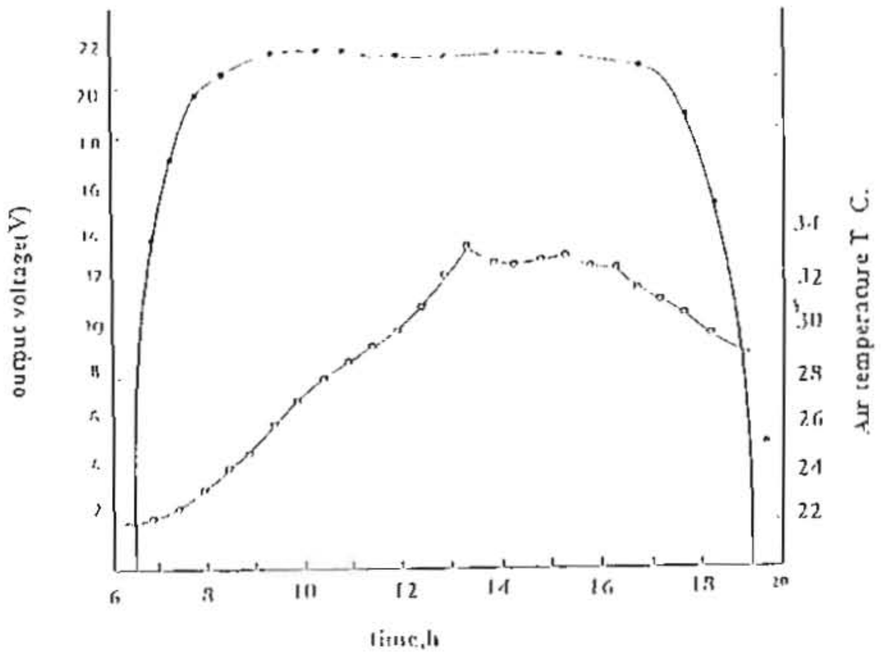


Fig.(4), The profiles of the Voc, and T_a C,in clear sky day

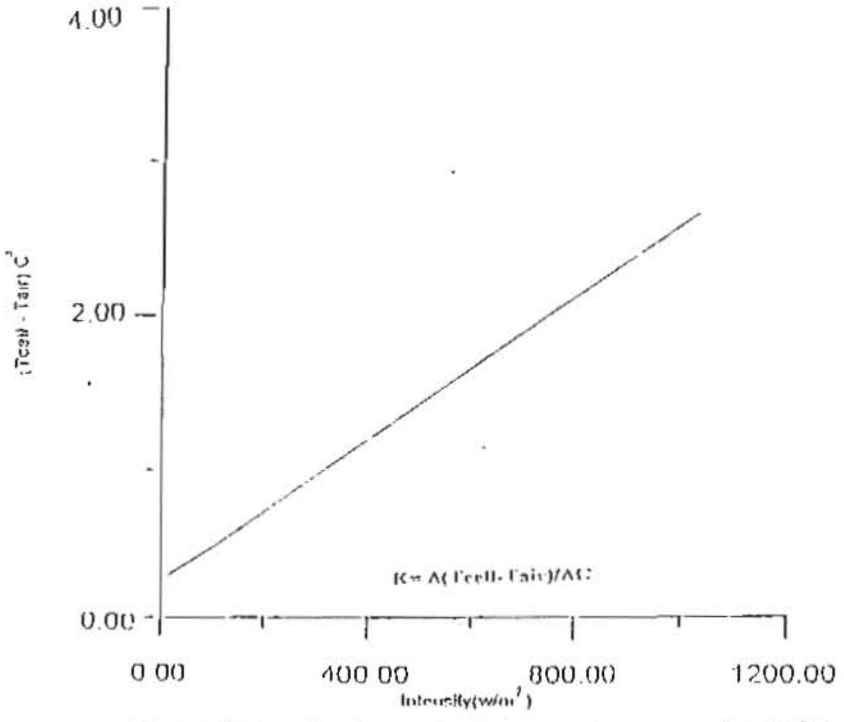


Fig (5), Solar cell minus ambient temperature versus insolation where ΔG is the amount of substance reached the electrode; K is a proportionality factor; Q is the quantity of electricity passed through the electrode- solution interface, I is the current; τ is the electrolysis time.

From the above, solar cell current is relatively steady despite changing temperatures, hence, hydrogen production from electrolyser by solar cell is also, relatively steady despite changing temperatures. Conversely, as the temperature of water in electrolyser increases, the degree of water dissociation becomes higher.

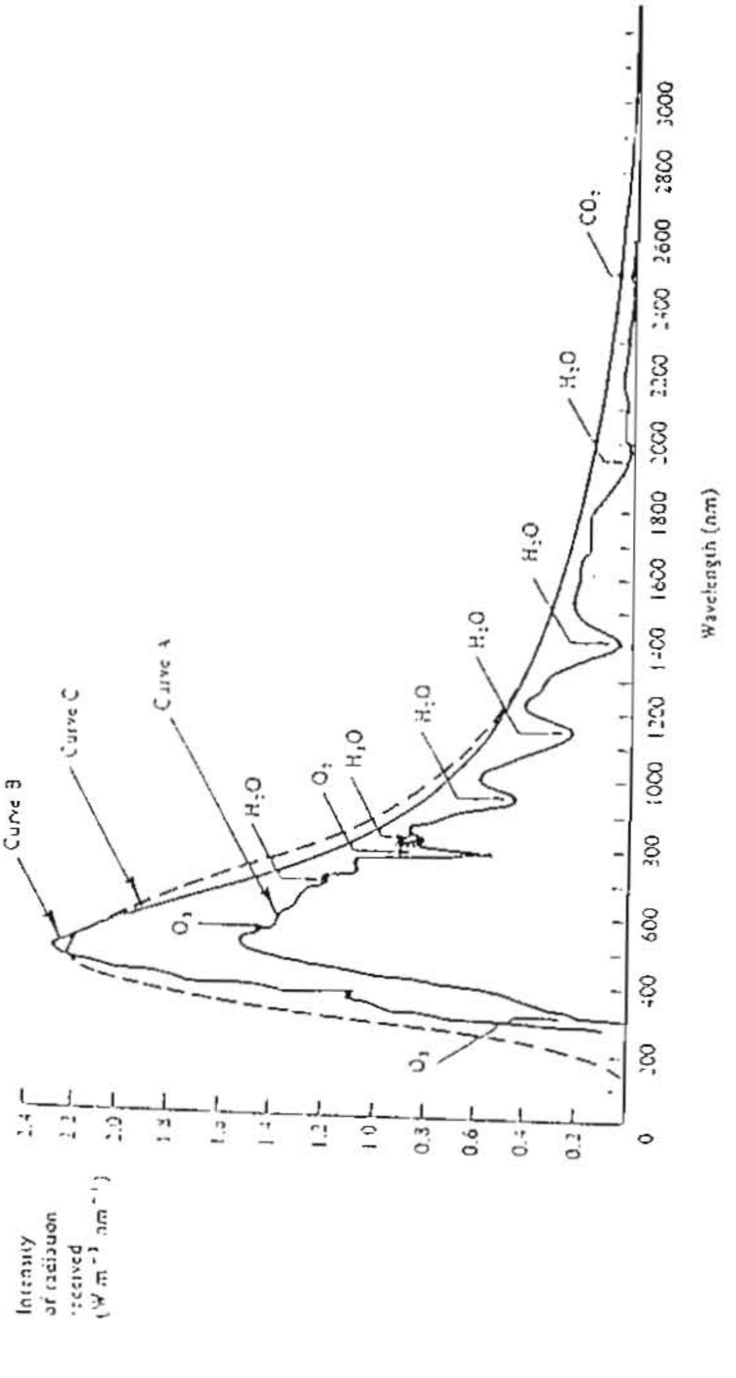
RELATIVE HUMIDITY VARIABLE

The moisture content of the atmosphere is commonly expressed by relative humidity.

Air with a constant water vapor content will experience a decrease in relative humidity with a rise in temperature [5]. Water vapor in the atmosphere is invisible to the human eye, but is " seen " by solar cells. The absorption bands visible in Fig (6), at approximately 0.93μm, 1.13μm, and 1.38μm wavelength, are primarily caused by water vapor.

EFFECT OF HUMIDITY

The primary effect of humidity on terrestrial solar cell arrays is corrosion, especially in the simultaneous presence of high temperature. Other effects, include growth of fungus. The growth rates are higher at relative humidity levels - (between 75% and 95%) and temperatures between 20°C and 40°C and the formation of a "sticky" surface film of moisture, tends to catch dust and dirt particles. Dust consists of multiple composite particles ranging from 0.1 to 0.8μm in diameter. Dust particles may be electrically conductive and are usually soluble in water. A small amount of dust on the solar cell covers, has a negligible effect on the sun light transmission to the solar cells. About 35% PV-power is reduced after



Figure(6) The effects of atmospheric absorption on the spectrum of the sun one month without panel cleaning. The reduction increases to 60% after six-months due to sand-dust accumulation on A-Si (module).

The effect of rain is usually beneficial, cleaning dirt off the solar cell array surfaces, this form of precipitation may occur anywhere in the world, ranging from essentially zero to several meters annual average.

POLLUTION VARIABLE

Air pollution has a pronounced effect on material, the major sources of pollution at Helwan are from three types of factories arranged as follows

1- Cement factories, which include four factories distributed from the north in Tura to the south in El-Tebeen .

2- Engineering industries (cars factory, pipes and tubes factory)

3- Iron and steel factories.

Fig (7), shows the locations of the factories, which represent the major source of pollution at Helwan with respect to observatory place of (NRIAG) This means that the level of pollution in Helwan region is higher compared with the international limit by about 1250 % to 2500% in industrial and populated regions, while the percentage increase for the carbon monoxide level is 250-1000% [5]

There is a regular increase for global radiation (G) from the south to the north of Egypt during all seasons. There is an exceptional decrease in two areas, Cairo area due to air pollution, and Eastern Owainat area due to the sand rising and storms in the deep desert, beside the effect of tropical clouds. The variation of "G" from north to south in Egypt has a wide range (3.7 to 5 Kwh/m^2/day) in winter, and narrow range (8 to 8.3 Kwh/m^2/day) in summer. For these reasons, Cairo is not a good site for PV-hydrogen production. Thus, the following question arises : Where should PV-hydrogen systems be located?

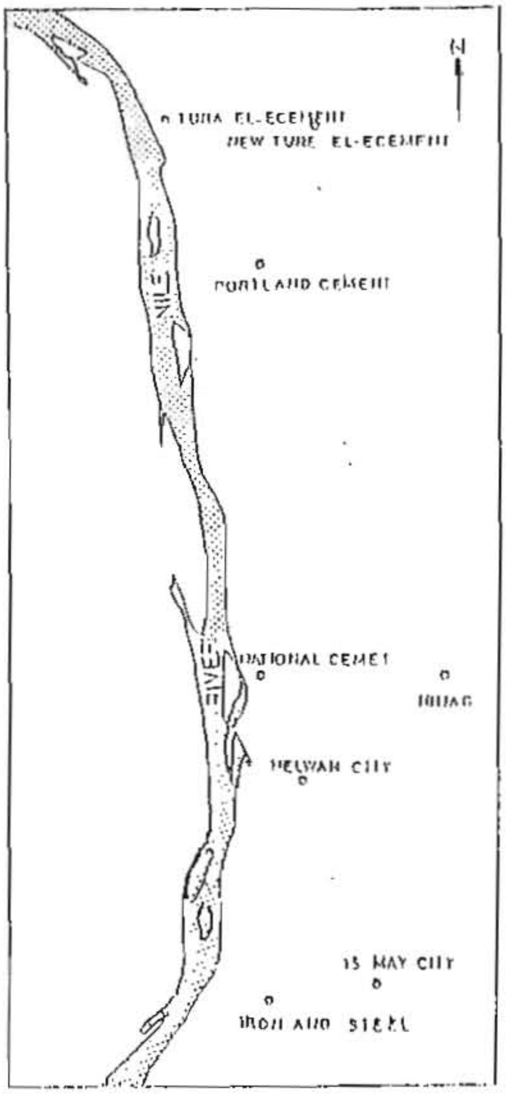


Fig.(7). The major sources of pollutants from factories at Helwan

The desert area surrounding lake Nasser is characterized as one of highest solar energy potential in all the world, where, its nominal annual insolation is more than 2500 Kwh/m².

No snow cover, ice pellets, or hail were recorded at Aswan. From the above, many facts put Aswan, in certain classification criteria, on the top among the most suitable areas in the world-wide for solar hydrogen production for the benefit of mankind during the next century [6].

GLOBAL RADIATION VARIABLE

Most of energy reaching a cell in the form of sunlight is lost before it can be converted into electricity. Most current work on cells is directed at enhancing efficiency, and lowering cost. Certain physical processes limit cell efficiency- some are inherent and cannot be changed. The major phenomena that limit cell efficiency are:

1- Reflection from the cells surface.

2- Light that is not energetic enough to separate electron from their atomic bonds

3- Light that has extra energy beyond that needed to separate electron from bonds.

4- Resistance to current flow.

5- Performance degradation at non optimal (high or low) operating temp.

6- Light-generated electrons and holes that are brought together by surface and material defects in the cells.

From test we can conclude that a solar cell's voltage varies little with high light light intensity, except in the beginning when light is initially applied, while solar-cell current is directly proportional to light intensity. A graph of current and voltage versus intenisty is shown in Fig (9)

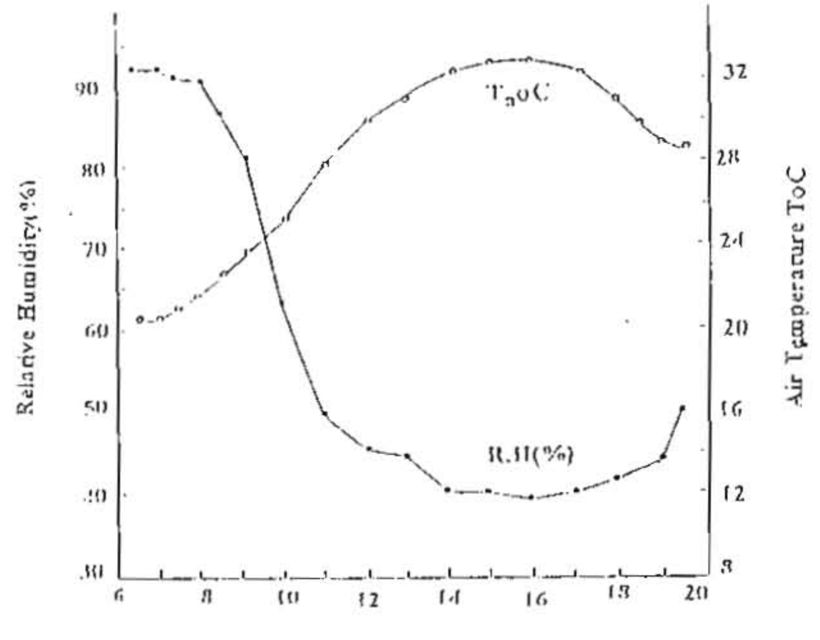


Fig.(8). The daily profiles of the air temperature and relative humidity recorded

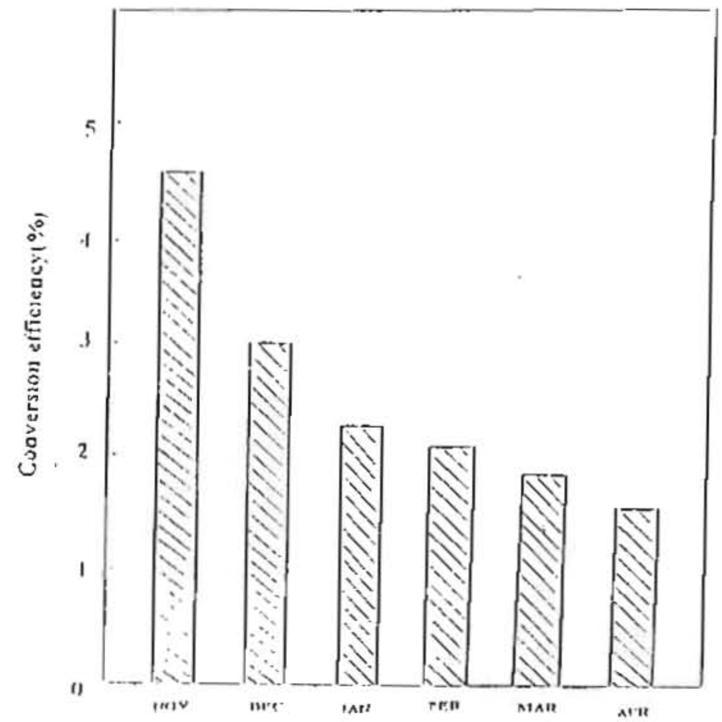


Fig.(8) The depression of the η after 6 months due to sand-dust accumulate of a-si

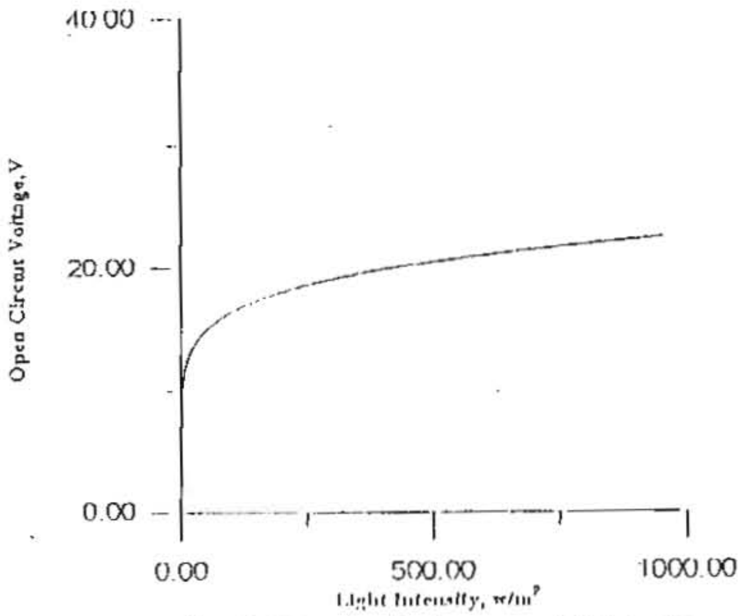


Fig.(9-a) Open circuit voltage versus light intensity

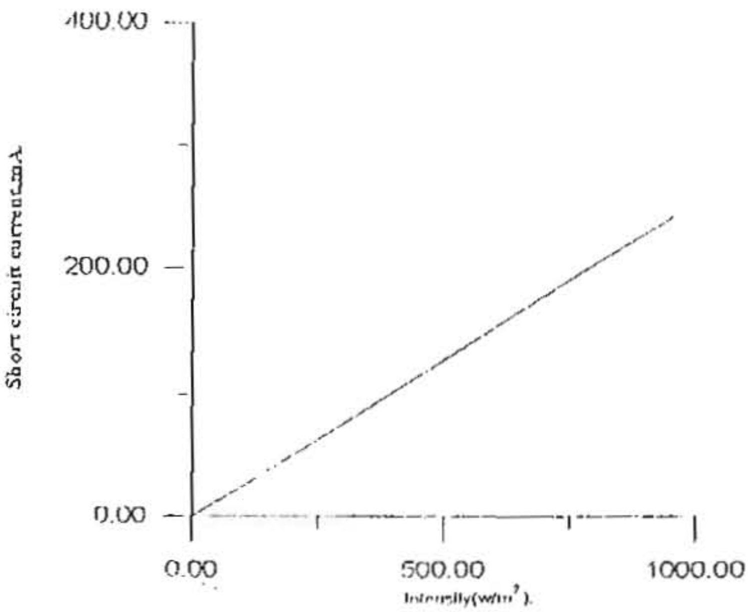


Fig.(9-b), Short circuit current versus light intensity

The amount of sunshine may be numerically expressed as an average over several years, one year, one month, and one day. Any of these numerical expressions, however, are by themselves insufficient to permit realistic sizing of solar cell arrays. Applying statistical treatments to observed data, the operating efficiency (η) is proportional to the amount of solar radiation incident on the panel face, G, as shown in Fig.(10).

Observed data demonstrates that cell voltage is varied little with high intensity, while solar-cell current is directly proportional to light intensity. Since, power is the product of current and voltage, we can deduce a simple fact : Solar-cell power output increases as light intensity increases. Consequently, hydrogen production from electrolyser by PV-power also increases as shown in Fig.(11).

CONCLUSIONS

From all the previous measurements and discussions, we obtain the following conclusions :

- The solar cell power and hydrogen production curve becomes erratic on a partly cloudy day.

- Solar-cell power output increases as cell temperature decreases, since the effect of the average temperature of the silicon polycrystalline module causes a drop in the output voltage parameter at noon. Thus, the resultant conversion efficiency decreases at noon in hot desert.

-The primary effect of humidity on terrestrial solar cell arrays is corrosion growth of fungus and the formation of a sticky surface that tends to catch dust A small amount of dust on the solar cell cover has a negligible effect on the sun light transmission to solar cell.

- Operating efficiency for both PV-array and electrolyser is proportional to the amount of solar radiation incident on the panel surface.

- Solar cell in the larger size tends to be lower in cost per unit cell area, but also lower in efficiency.

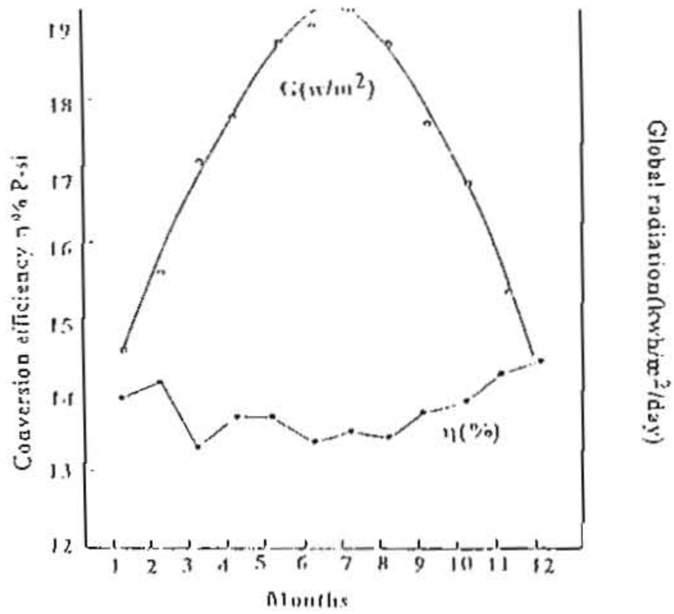


Fig.(10). The global radiation(G) effect on the η total year

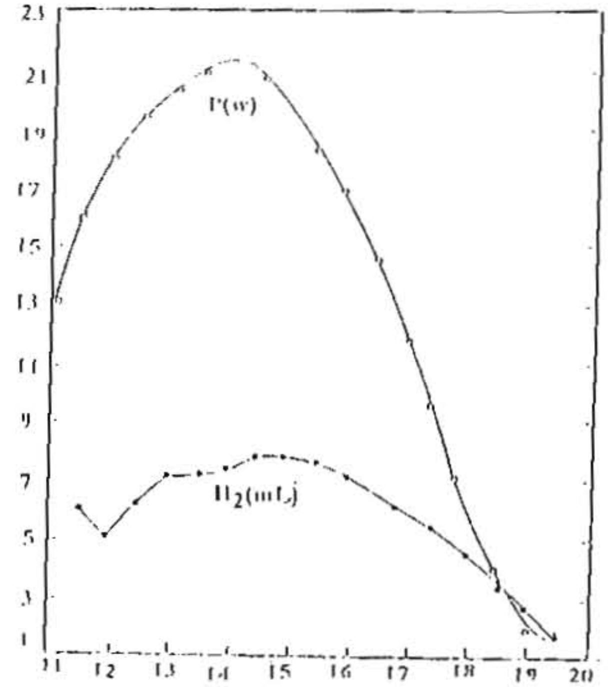


Fig.(11), Hydrogen production (mL) and power (w) w.r.t time

- The center temperature of the polycrystalline module reaches 48 °C at noon and is greater than the ambient temperature by about 18 °C (at insolation of 1000 w/m² on tilted panels).This causes a drop in efficiency of about 0.5% which is not sufficient to use a cooling system

- The relation between the central temperature and side temperature of a model shows a good linear correlation and a degradation factor of five degrees.

- Aswan could be considered one of the best suitable places for solar hydrogen project

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