E.72. Mansoura Bulletin Vol. 10, No. 1, June 1985.

THE PHOTOVOLTAIC CELL AS A PEAK POWER GENERATING SOURCE

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ABSTRACT:

Photocells are one of the promising generating electric power sources in the future. When they are used to generate electricity during peak hour loads, the maximum power generated during peak load demand may be more important than the maximum total electric energy generated by such photocells during the whole day.

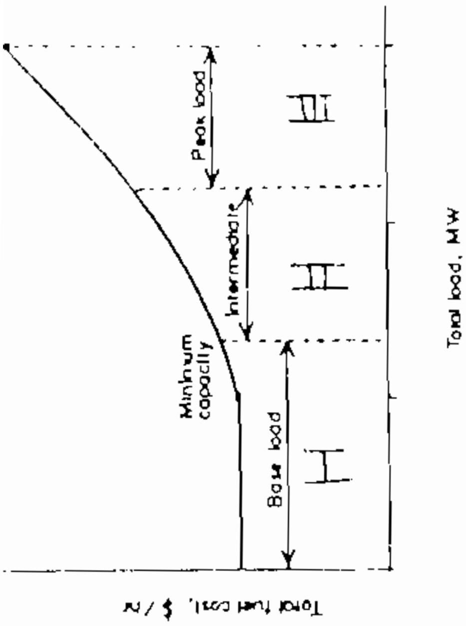
This paper presents the factors which affect the maximum electric power generated by the photocells and how it could be shifted to match loading conditions in some hot countries like Kuwait, in which the peak hour loads lie in the after noon, where the airconditioning loads predominate during such times of the day.

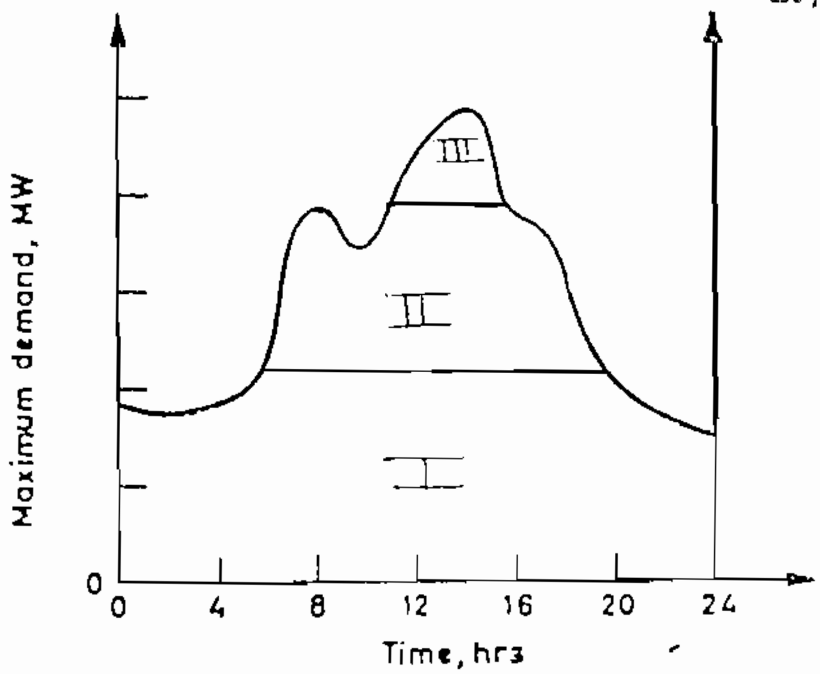
INTRODUCTION:

Figure (1) a represents a daily load curve for a summer day in a place, where the peak load due to the required air conditioning loads occur in the after noon, for example at 13.30, as shown in Fig.(1)a. Using conventional systems to supply such a load; the more efficient units will be used to deliver the base and intermediate loads I & II shown in the figure; while the peak load III will be delivered by the less efficient units. i.e. those of the highest specific energy consumption as illustrated in Fig.(1)b.

For such case photovoltaic generating units may compete the less efficient conventional units during the peak load hours. In such case the maximum power generated by the photocells during the peak hour periods may be more important than the total electric energy generated by the photocells during the whole day.

During the past ten years some work has been done on electrical load peak shaving. Some of the reported work suggested theuse of an integerated solar-utility system (1) where the electrical load is supplied by both a solar system and the electrical utility. This system was proposed for residential and commercial buildings applications. Others (2), (3) suggested to use battery storage systems which could serve up to five hours daily. A practical system (4) was suggested for peak-shaving for the New York grid using hydrogen cycle for energy storage and the authors have studied the economics of such a system and concluded that it is economically feasible. Fernandes (4) has compared the use of different available energy storage methods for peak-shaving and found out that the storage batteries and the hydrogen cycle are the most competitive methods for peak load shaving.

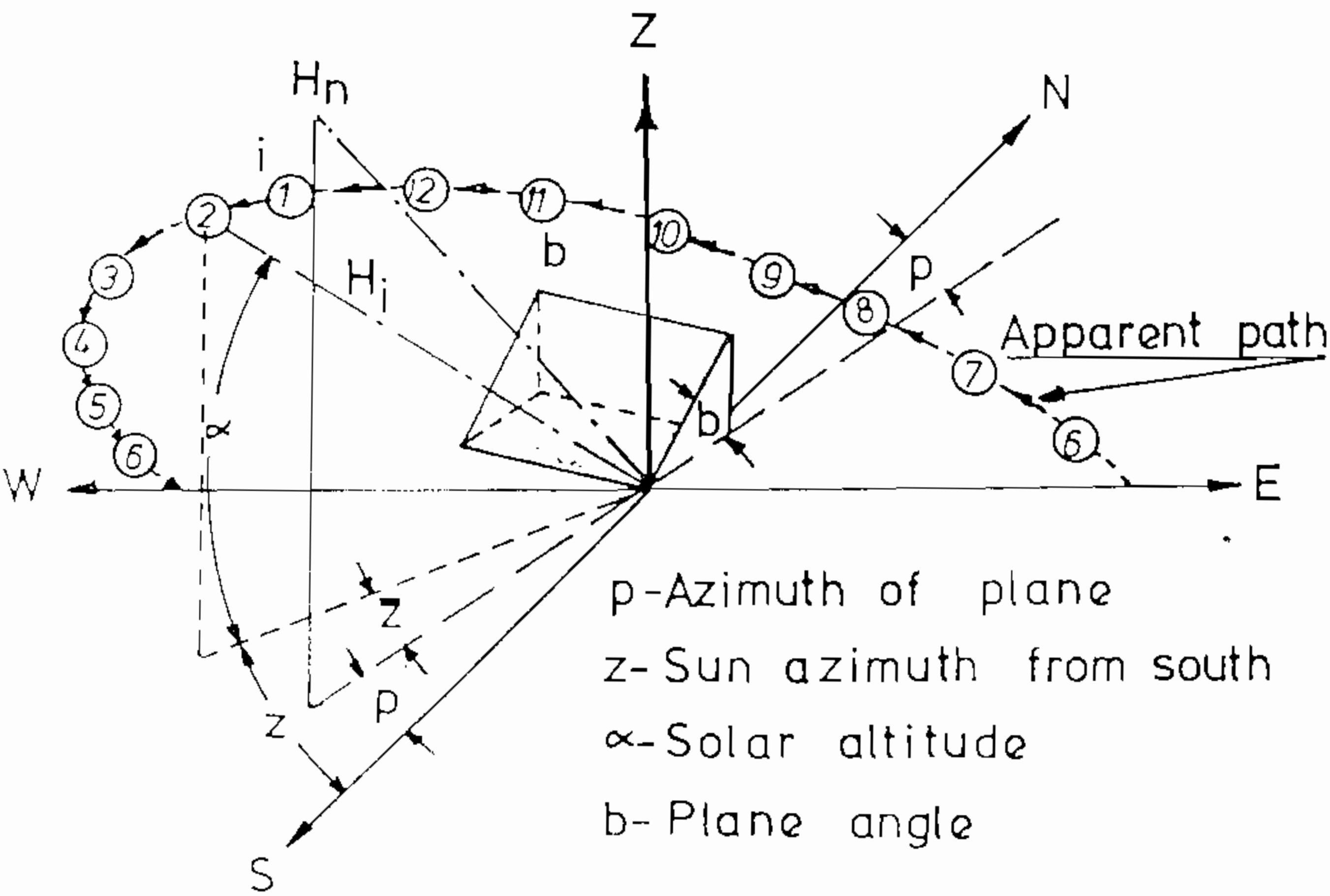




Typical daily load curve

Fig (1,a) Typical Daily Load Curve.

Fig(1,b) Specific Energy Cost For D-fferent Base, Intermediate And Peak Units.



Fig(5,a) Angle Diagram For Finding Solar Radiation On Sloped Surfaces.

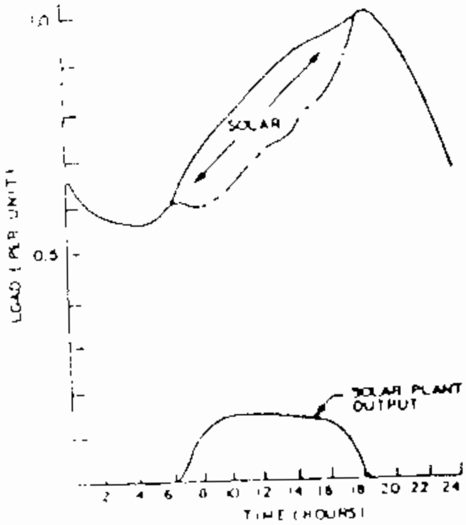
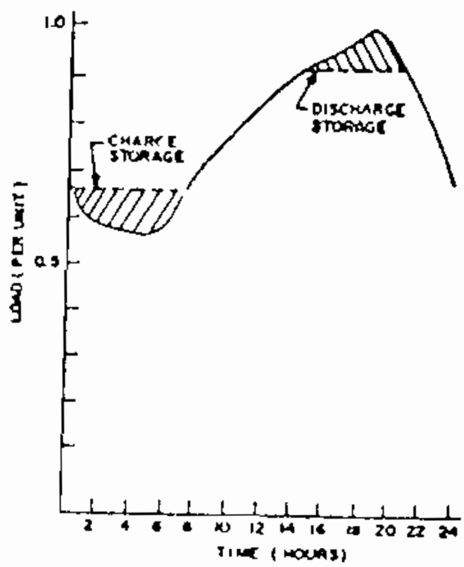


Fig (2)

Solar P.V.Plant Output Reshapes The Load Curve.



Fig(3)

Economic Dispatch Of Storage Battery System.

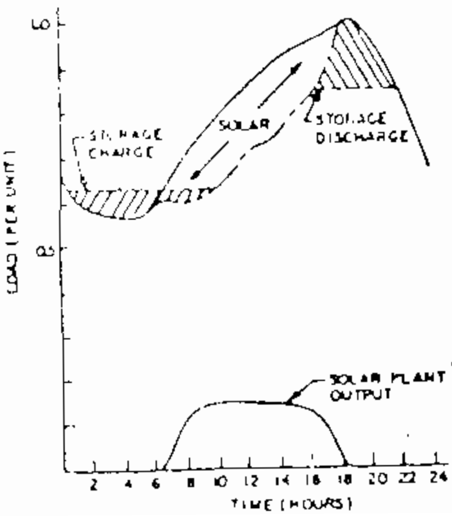


Fig (4)

Storage Dispatch When The P.V. Plant Output Is Considered. (Narrow Peak- Broader Valley.)

In this paper, it is suggested that the solar utility mix system be used for peak-shaving in Kuwait. In more specific terms, the author suggests thet photovoltaic cells be integerated within the airconditioning fecilities in order to supply part of their power needs during the peak load period. The aim of such system is to stabilize the demand of the airconditioning facilities on the utility at a predetermined rate and supply the excessive demand by the integerated photovoltaic system.

Figure (2) shows how solar P.V. plant output significantly reshepes the load which must be carried by the remainder of the generating units. (5), on a hypothetical power system. The adjusted load, although it exhibits the same extremes es the original system load tends to have a nerrower peak and broader minimum-load (valley). Thus a smaller megawatt hour storage capacity will be required to shave the peak load by given megawatt amount. The economic dispatch for the original system is shown in Fig.(3), while storage dispatch is illustrated in Fig.(4) for the adjusted load when the photovoltaic plant output is considered.

The Incident Solar Angle & The Sun's Position Relation: (6)

Eferring to Fig.(5)a,b the sun's position in the sky is conveniently expressed in terms of the solar altitude β, above the horizontal, and the solar azimuth, ϕ measured from the south. These angles in turn depend on the local latitude L; the solar declination, δ which is a function of the date; and the apparent Solar Time expressed as the hour angle, H, where H = 0.25. (number of minutes from local solar noon), deg.

The following equations relate β and ϕ to the three angles mentioned above:

$$\text{Sin}\,\beta = \text{COS}\,L\;\text{COS}\,\delta\;\text{COS}\,H + \text{Sin}\,L\;\text{Sin}\,\delta \quad .....(1)$$

$$\text{COS}\,\phi = (\text{Sin}\,\beta\;\text{Sin}\,L - \text{Sin}\,\delta)/(\text{COS}\,\beta\;\text{COS}\,L)...(2)$$

The solar position angles and incident angles for horizontal and vertival surfaces are shown in Fig.(6) where line OQ leads to the sun, the north-south line is SON and the east-west line is EOW. Line OV is perpendicular to the horizontal plane in which the solar azimuth, angle HOS (ϕ) and the surface azimuth, angle POS (ψ) are located. Angle HOP is the surface-solar azimuth γ .

The angle of incidence, θ, for any surface is defined as the angle between the incoming solar rays and a line normal to that surface. For the horizontal surface shown in Fig.(6), the incident angle θ_H is QOV; for the vertical surface, the incident angle θ_V is QOP. For any surface, the incident angle θ is related to β, γ and the tilt angle of the surface by:

$$\text{COS}\,\theta = \text{COS}\,\beta\;\text{COS}\,\gamma\;\text{Sin}\,\Sigma + \text{Sin}\,\beta\;\text{COS}\,\Sigma \quad .....(3)$$

where

Σ = tilt angle of the surface from the horizontal

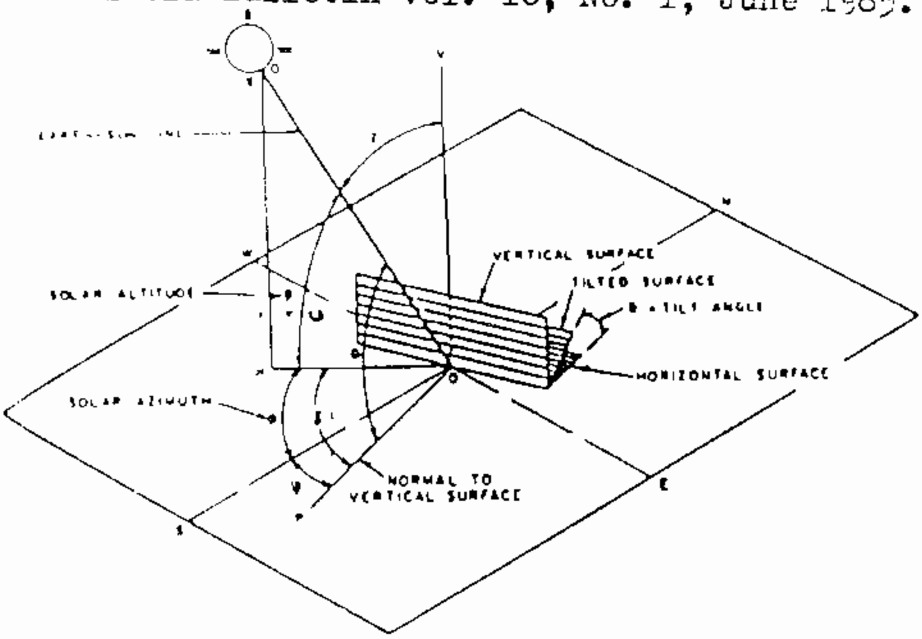
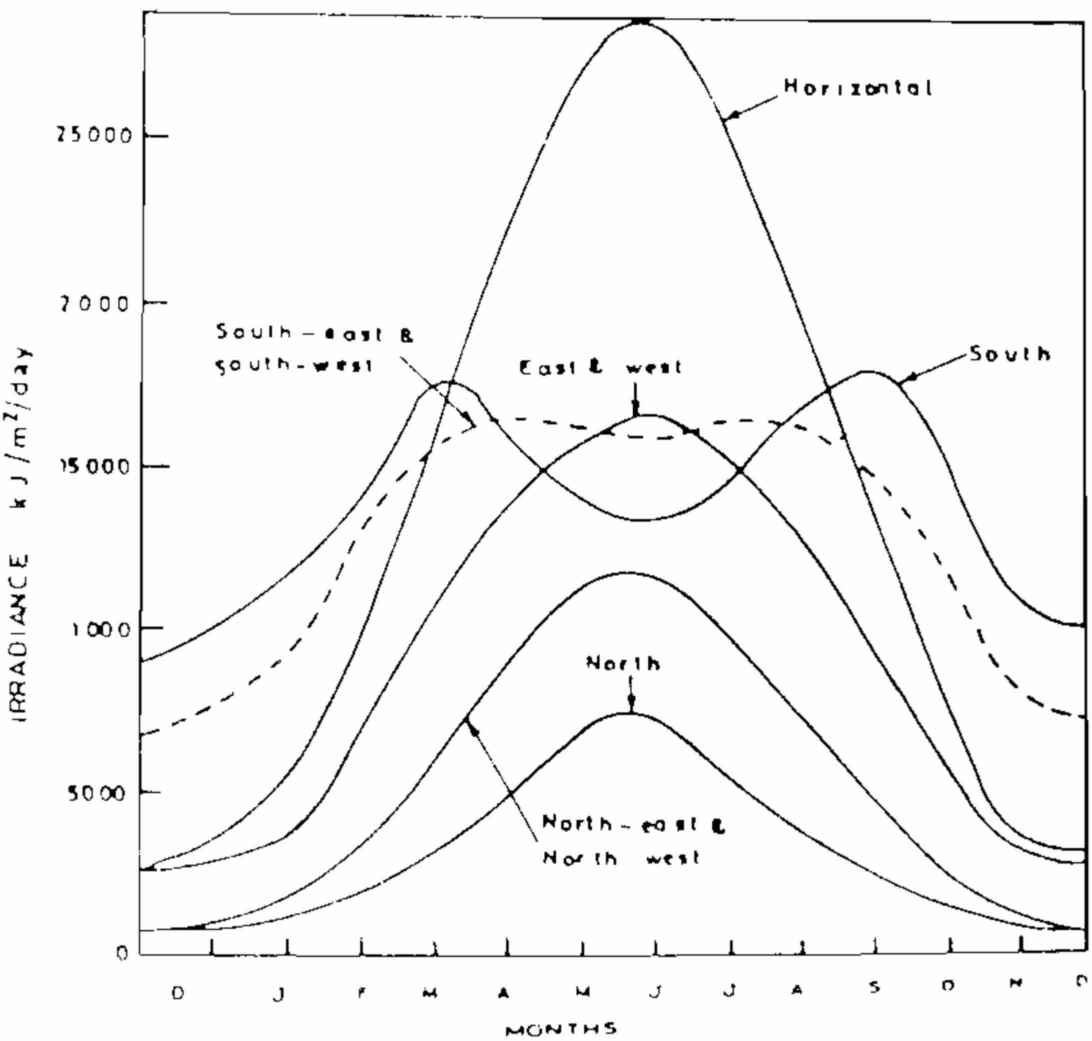
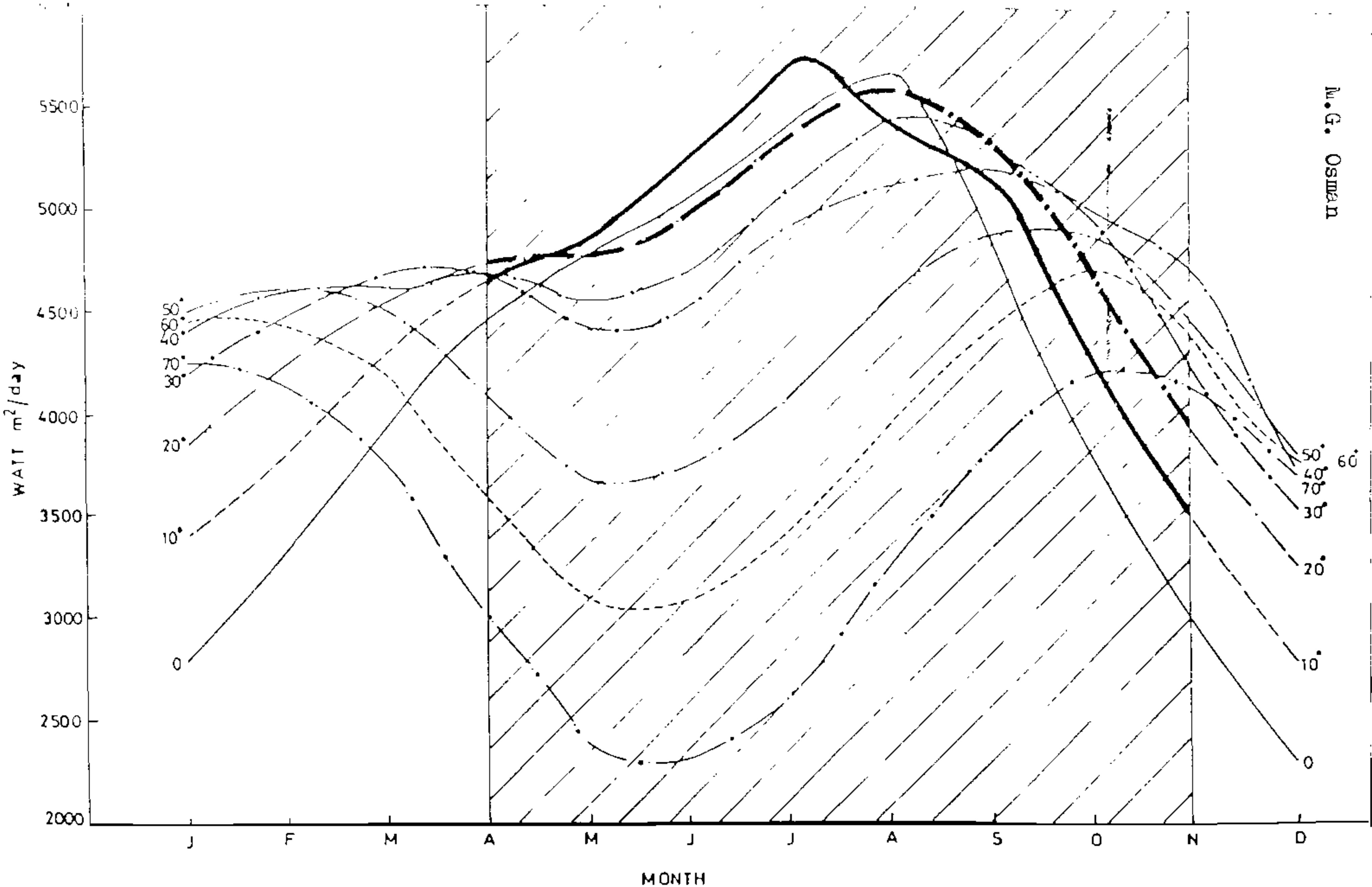


Fig (5,b) Solar Angles For Vertical And Horizontal Surfaces.



Fig(6) Daily Amounts Of Total Radiation On Horizontal And Vertical Surfaces W.R.T. Solar Azimuth Angles (0, 45,90,135,180).



Fig(7) Solar Total Radiation At Different Inclined Surfaces Facing South in Kuwait. (Average of 1978,1979,1980)W.R.T. Different Monthes.
15 Degrees Best Summer Tilt& 40 Degrees Best Winter Tilt.

When the surface is horizontal, Σ = 0 deg, and:

$$\cos \theta_H = \sin \beta \qquad .....(3)a$$

For a vertical surface, Σ = 90 deg, and:

$$\cos \theta_V = \cos \beta \cos \gamma \qquad .....(3)b$$

Figure (6) illustrates the daily amounts of total radiation on horizontal and vertical surfaces w.r.t. different solar azimuth angles (0°, + 45°, + 90° + 135° + 180°), where Fig.(7) shows solar total radiation at different inclined surfaces facing south in Kuwait (average of 1978, 1979, 1980) w.r.t. the different monthes and shows that 15° degrees is the best summer tilt and 40° degrees is the best winter tilt. In our case here we are going to consider Kuwait city as our place of application. Similar treatments could be applied to other places.

Photocell Performance & Test Results:

Performance of photocells are affected according to their material used, temperature of operation, intensity of light as have been discussed in a previous paper by the author (7), Fig.(8) illustrates how the maximum efficiency of the photocell is affected according: the material, energy gap and the operating temperature used (8). It could be seen from Fig. (8) that a Si photocell at temperature 273K, and E_g = 1.1 e.v. has an efficiency greater than a CdS photocell working at the same temperature and E_g = 2.4 e.v., while the reverse will occur, if the temperature is raised to 573 K for example (as when we use concentrators). This illustrates the importance of selecting the suitable photovoltaic material and energy gap E_g according to the climate and environmental local conditions of the place under consideration.

Figure (9) shows the efficiency response for CdTe photocell during one summer and winter clear days in Kuwait; where the maximum operating temperature did not exceed 360 K. By a similar computer or nomogram analysis as previously presented by the author (7) the corresponding electric power generated from such photovoltais cells during the whole year could be obtained.

It has been observed that the incident angle of the sun rays as illustrated in Fig.(6) and hence its intensity on the surface of the photocell is affected by the azimuth angle of the photocell plane.

Figure (10) shows how the maximum electric power output according to light intensity of such cell is shifted from the case of an azimuth angle 0° to 60° west for such cells in the three cases:

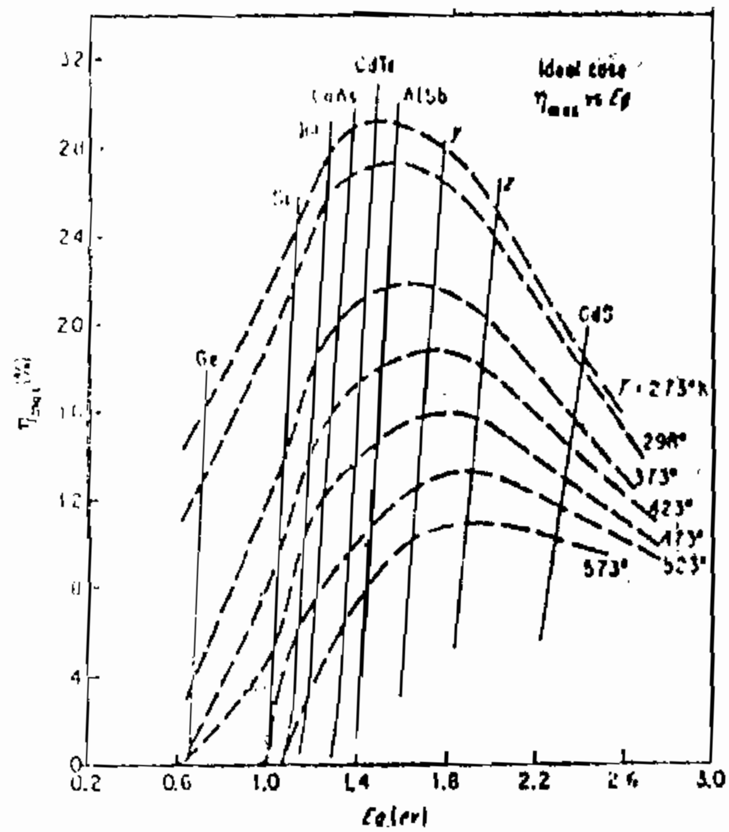


Fig (8) Photo cell Efficiency W,R,T, Energy Gap For Different Materials at Different Operating Temperatures.

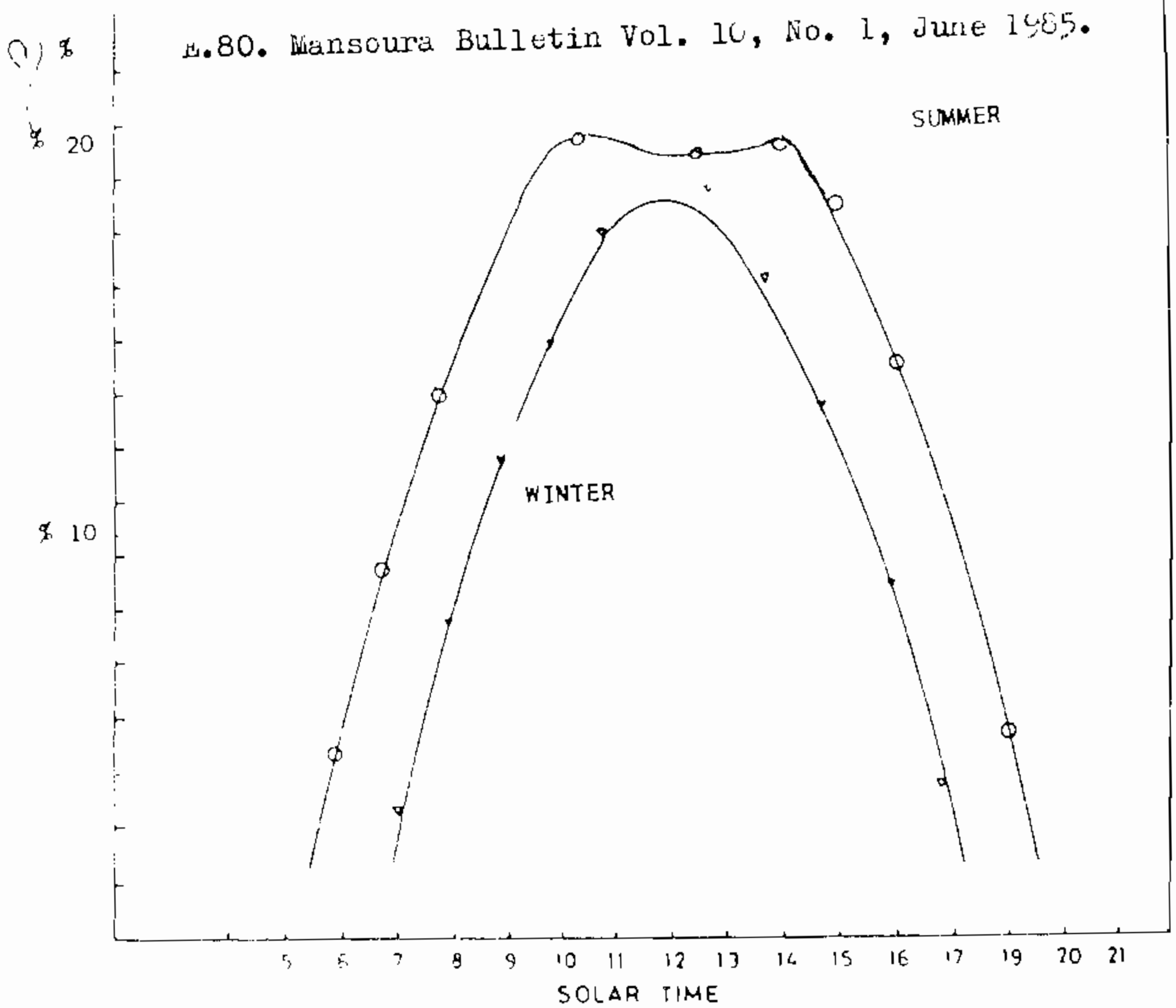


Fig (9) Efficiency Response For SdTe Photocell During One Summer And One Winter Clear Days In Kuwait (Max Operating Temperature 360 K).

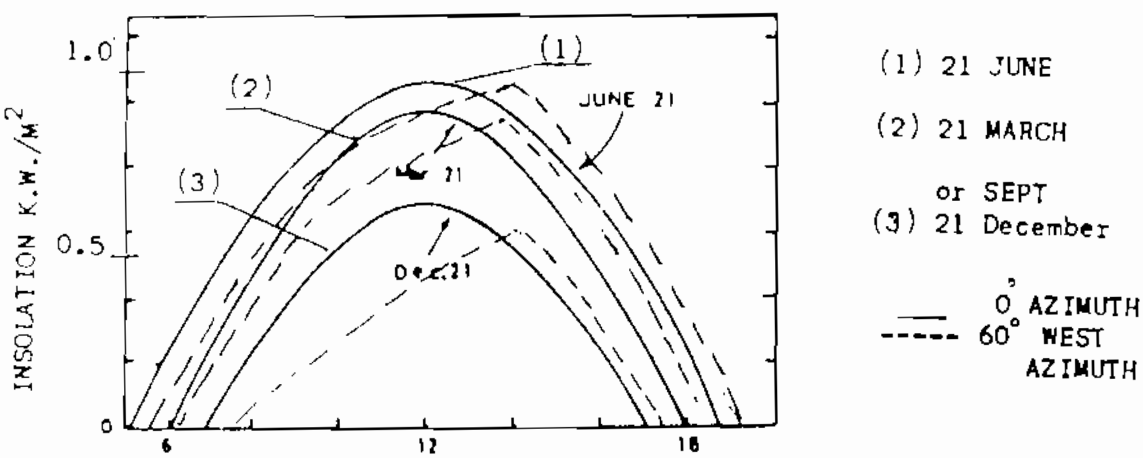


Fig (10) Time Lag Of Photocell Maximum Power Point At 60 Azimuth Angle (West) W.R.T. 0 Degrees Azimuth Angle For Summer, Winter Solistice And Vernal or Autmnal Equinox.

21 June, 21 March or September and 21 December solar days. Repeating such test results for different azimuth angles during the different seasons of the year, the shifting angle of the peak generated electric power and the corresponding energy generated w.r.t. the corresponding values at O Azimuth angle could be obtained.

Table (1) summarizes the test results obtained from which the recommended azimuth shift angle could be deduced similarly. N.B. As previously mentioned such test results may be changed according to the location, the load pattern, the environmental climatic conditions of the place under considerations.

CONCLUSION

1- Photovoltaic power systems have good potential in the near future to shave peak loads of utilities in hot countries where peak loads are in phase to some extent with the solar insolation peaks and to replace the most expensive peak units.

2- Suitable selecting of photovolteic materials and the corresponding energy gap is very essential according to the climate and environmental local conditions of the place under consideration.

3- Photovoltaic cells can be successfuly used as peak power generating unit in synchronism with the peak summer air conditioning loads (13.30 P.M.) by proper adjustment of the photocells angles with Azimuth with energy gain with respect to the total collected energy at O Azimuth angle.

4- Seasonal adjustment of Azimuth angles is necessary according to the phase of the load peak whether after or befor noon (West oe East Azimuth respectively).

5- Azimuth angle of the P.V. solar plant will be changed according to the plant location, environmental climatic conditions and load pattern of the place under consideration.

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TABLE (1).

PERIOD OF YEAR	AZIMUTH ANGLE (WEST)	INSOLATION PEAK SHIFT W.R.T.0^o AZIMUTH (HRS)	ENERGY CHANGE % W.R.T. 0 AZIMUTH
21 JUNE	0	----------	------------
	15	0.48	+0.48 (GAIN)
	30	00.92	+1.9
	45	1.4	+3.25
	60	1.7	+4.2
21 MARCH OR SEPTEMBER	0	----------	-----------
	15	0.48	_1.2 (LOSS)
	30	0.85	_3.85
	45	1.4	_11.0
	60	I.55	__13.7
21 DECEMBER	0	---------	------------
	15	0.4	_2.0 (LOSS)
	30	0.72	_7.5
	45	1.05	_16.5
	60	1.4	_27.6