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Performance Improvement Justification of a Concentrating Photovoltaic(CPV) System over a non-concentrating PV system

Ahmed T Naveed, Kang, Eun-Chul*, Lee, Eui-Joon*

*Korea Institute of Energy Research(naveed@kier.re.kr, kec8008@kier.re.kr, ejlee@kier.re.kr)

비집광형 PV시스템 대비 집광형 PV시스템의 성능 개선 효과 분석

아메드 나비드, 강은철*, 이의준*

*한국에너지기술연구원(naveed@kier.re.kr, kec8008@kier.re.kr, ejlee@kier.re.kr)

Abstract

PV 태양광 발전은 PV 재료가 고가이므로 일반 전력비용에 비해 상대적으로 비용이 높아진다. 저가형 광학 집광기술과 PV를 통합하게 되면, 비용뿐만 아니라 설치면적 등에서 유리하게 되나, 집광기의 단점이 함께 추가되게 된다. 집광기는 작은 수광각과 송신광선을 갖고 있어 PV 모듈에 필요한 태양광, 광학손실의 손실정도를 최소화하기 위한 신중한 시스템 디자인과 2축형 트레킹 장치가 필요하다. 고정식 비집광 시스템보다 더 많은 에너지를 얻기 위해서는 광학시스템의 손실율을 줄이고, 고효율의 PV 모듈을 이용한 PV 셀의 상호연결이 필요하다. 본 논문에서는 우선, 비이미지 프레넬 렌즈 집광기를 사용한 PV 시스템에 대하여 간단하게 설명한 후, 출력전력값을 이론적으로 예측하고 PV 효율과 시스템 성능을 제시하였다. 프레넬 렌즈 선형 집광기 통합 PV 시스템과 비집광 PV 모듈의 출력전력값과 시스템 비용을 비교하면, PV 전력비용을 줄일 수 있는 집광기의 이용이 유용한 것을 알 수 있다. 따라서, 집광형 PV 시스템은 미래의 에너지 이용에 매우 유리한 시스템이라 할 수 있다.

Keywards : concentrating photovoltaic(집광형 태양광발전), linear Fresnel concentrator(선형 프리즈넬 집광기), PV electricity(태양광 전력), solar energy(태양에너지)

Nomenclature

I_D : Diode current (A)
I_L : Light generated current (A)
V_{oc} : Open circuit voltage (V)

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I_{sc} : Short circuit current (A)
J_{sc} : Short circuit current density (A/cm2)
V_{mpp} : Voltage at maximum power point (V)
I_{mpp} : Current at maximum power point (A)
P_{mpp} : Panel power output at maximum power point (W)
G : Incident solar radiations (W/m^2)
Gr : Reference solar radiations (1000 W/m^2)
Tr : Reference temperature (298K)
K_T : Clearness index
A : Area of the PV cell
FF : Fill Factor (%)
CPV : Concentrating photovoltaic
n : Day number
W : Effective wind speed (m/s)
J_{mpp} : Current density at maximum power point (A/cm^2)
i, j : Number of series/parallel connected cells (-)
Ψ : Site latitude
β : Diode ideality factor
e : Charge on electron (1.60×10-19C)
k : Boltzmann's constant (1.380×10-23 J/K.mole)
T : Panel temperature
η : PV efficiency (%)

1. Introduction

Concentrated sunlight using cost-effective optical concentrating systems has the capability of reducing the photovoltaic (PV) electricity generation costs as under concentrated sunlight, the required area of expensive PV is reduced compared to conventional terrestrial PV systems. A number of concentration systems with various optical configurations have been designed and studied [1-3]. The PV concentrating system consists of optical concentrator or collector, receivers or PV module, cooling system and tracking system. The optical concentrator collects the light and focuses concentrated irradiance on the receiver which is an assembly of one or more high efficiency PV cells that accepts concentrated sunlight and incorporates the means for thermal and electric energy extraction. Global solar radiation is composed of beam and diffused radiations. It is well known that concentration necessarily leads to an unavoidable reduction of the acceptance angle of any collector system [4]. The acceptance angle is the angle formed by the incident light rays and the normal to the concentrator aperture plane for which 90% of the incident light is transmitted to the PV module. Concentrators are, thus, limited to collecting only those rays coming from a narrow solid angle cone centered on the solar disc, i.e. mainly beam radiation. Therefore, whenever a system is intended to operate with an effective concentration ratio larger than 6X it must be provided with sun tracking mechanism to collect a good fraction of available beam radiation [5]. The need for a tracking mechanism has the positive effect that, although concentrators collect only beam radiation, the total energy collected is quite close to that for fixed

PV module because of the better incidence angle of the rays on the collector. In solar energy rich locations, this increase of the energy collected can be so significant that it can compensate the added cost and complexity of a tracking system. The concentrating PV cell has to be of higher efficiency to compensate the optical losses and produce at least the same electricity as fixed non-concentrating PV module. However, the availability of high efficiency PV cell is not a concern. Photovoltaic cells with high energy conversion efficiencies have been developed and commercially marketed. Energy conversion efficiency of 37.9% at 10sun has been reported for multi-junction GaInP/GaAs/GaInAs compared to commercially available solar cells which can have efficiencies from 5% to 20% [6]. Recently, Spectrolab Inc. USA has also announced 39.0% efficiency at 236 suns [7]. The energy conversion efficiency of solar cells is affected by the operating temperature [8]. As the concentration level of sunlight is increased, the cooling of the solar cells becomes even more important to maintain the solar cell operating temperatures at an acceptable level. Operating the PV cell at high temperature can cause irreversible damage and make it unusable [9]. The concentrating solar cell module can be cooled down passively provided that solar cell temperatures do not reach more than 80°C at peak solar radiation and stagnation conditions [10]. A temperature limit of 120°C for high quality cells has also been suggested [11]. However, the cell manufacturers generally specify the temperature degradation coefficient and the maximum operating temperature for the PV cell and that limit should be observed for the operation of the solar cells under concentration. The combined heat and power concept of concentrating PV systems in which the waste heat is also utilized for heating or cooling purpose is another potential solution to reduce higher PV costs. Life cycle cost analysis of such system has demonstrated that pay back periods can be reduced to two third [12]. Antion et al [13] has described a model for characterization of the optical concentrator that can be used for CPV system. Each optical concentrator is designed according to a particular application and, thus, requires different analytical modeling. The estimation of the energy produced by the concentrating-PV system requires the theoretical modeling of the system. Solar energy data for the location, the concentrator and PV module characteristic parameters at standard testing conditions are the inputs of such simulation models. The characterization of the CPV system involves the measurement of concentrator geometric concentration ratio, its optical efficiency, solar radiation received at the solar cell in the plane of the PV module and electrical parameters of the solar module such as current, voltage and power at the maximum power point. Although much work has been done on the CPV systems but the characteristics of the system vary from location to location and for each system design. The world wide installations of CPV during 2004 were less than 1MW out of a total global PV market of 1200MW. However, significant development is that with high efficiency solar cells, well-developed hardware, better performance and lower installed costs, CPV is expected to penetrate global PV market at a higher rate [14]. Amonix Inc USA has recently installed several 35kW CPV modules in USA and plans to install 3MW in USA and 10MW in Spain during 2006 [15]. Similarly, Solar Systems Pty Ltd. will install more than 5 MW CPV in Australia in the year 2006 [16]. NREL foresees the emergence of CPV systems in the next few years at installed system costs of $3 per watt in near future [14]. In this review paper, after reviewing the concentrating systems and a theoretical model to predict the electrical output of a concentrated PV system consisting of linear Fresnel lens and high efficiency solar cells, the electrical outputs and costs of CPV and non-concentrating PV system available in literature are then compared to asses the merits of CPV system.

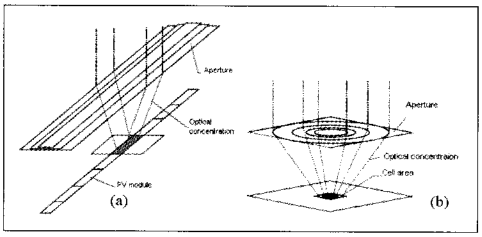

Figure 1. Fresnel lens concentrator geometries
a) Linear concentrator
b) point focus concentrator [9].

2. Fresnel Lens Concentrating PV systems

2.1. Point Focus and Linear Concentrating Systems

Concentrators focus the sunlight onto the PV module and can be reflective, refractive or combination of both. Optical lenses are commonly used for concentrating sunlight and are suitable for small concentrating systems. However, the cost and weight of the conventional glass lens increases with the size of the concentrating system and, hence, becomes impractical for larger applications. On the other hand Fresnel lenses are made by projecting the lens surfaces onto a plane or curved sheet in a way that rays encounter the same slopes as in the conventional lens and, therefore, are similarly refracted. Consequently, Fresnel lenses are lighter in weight and less expensive as compared to the conventional lenses [17]. Fresnel lenses are also being used successfully in concentrating PV applications. Fresnel lenses can focus the light onto a point or along a line depending on the design as shown in figure 1 [9]. Thus, Fresnel lens is used in point focus geometry where it concentrates sunlight on a small single solar cell [3] whereas linear Fresnel concentrating geometry is used for concentrating light on an array of solar cells [11, 18]. Schematic of a concentrating photovoltaic system in the medium concentration range utilizing the non-imaging Fresnel lens is illustrated in **figure 2(a)** [11]. A linear concentrating PV system developed by Entech using a large acrylic Fresnel lens (84cm wide) to focus sunlight at 21X concentration onto air-cooled silicon PV cell (4cm wide) is also shown in **figure 2(b)** [19]. A 100 kW linear Fresnel lens concentrating system near Fort Davis, Texas, USA provided power to CSW's West Texas Utility (WTU) electrical grid for several years. Such a system could provide about 220,000 kWh per year [19].

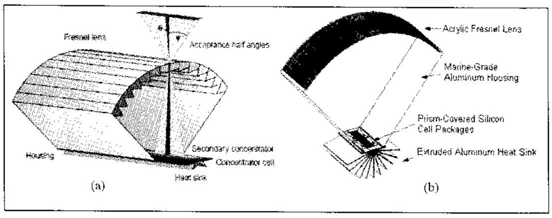

Figure 2. a) Schematic of a concentrating photovoltaic system of medium concentration using the nonimaging Fresnel lens [11]
b) concentrating PV system developed by Entech [19].

2.2. Irradiance available at the PV module plane:

In order to calculate the irradiance available, it is necessary to know the position of the sun at that particular location defined by solar altitude γ_s and solar azimuth Ψ_s expressed by the following equations [20]:

$$\gamma_s = \arcsin(\sin\delta\sin\phi + \cos\delta\cos\phi\cos\varpi) \tag{2.1}$$

$$\psi_s = \frac{\arccos(\sin\gamma_s\sin\phi - \sin\delta)}{\cos\gamma_s\cos\phi} \tag{2.2}$$

where δ is the solar declination expressed as:

$$\delta = 23.45\sin\left(2\pi\frac{284+n}{365}\right) \tag{2.3}$$

In this expression, n is the day number. The sunset hour angle ω_s is the hour angle corresponding to the time when the sun sets. For a given site latitude Ψ, it is given by the formula:

$$\cos\omega_s = -\tan\psi\tan\delta \tag{2.4}$$

The daily extraterrestrial radiation on a horizontal surface G_0 in MJ/m^2 can be computed for day n from the following equation:

$$G_o = \frac{86400G_{sc}}{\pi}\left(1+0.033\cos\left(2\pi\frac{n}{365}\right)\right)(\cos\psi\cos\delta\sin\omega_s + \omega_s\sin\psi\sin\delta) \tag{2.5}$$

where G_{SC} is the solar constant equal to $1,367W/m^2$. Before reaching the surface of the earth, radiation from the sun is attenuated by the atmosphere and the clouds. The ratio of solar radiation at the surface of the earth to extraterrestrial radiation is called clearness index. The monthly average clearness index K_T is defined as the ratio of the monthly averaged daily solar radiation on horizontal surface and monthly averaged extraterrestrial solar radiation on horizontal surface. K_T usually varies between 0.3 and 0.8. Solar radiation can be broken down into two components: beam radiation, which emanates from the solar disk, and diffuse radiation, which emanates from the rest of the sky and can be expressed as [17]:

$$G = G_b\cos\theta + G_d\sin\alpha \qquad (2.6)$$

Where G_b is the beam normal irradiance, θ is the angle between the sun and the PV module, α is the acceptance angle and G_d is the horizontal diffuse irradiance. The value of θ depends on the type of tracking system used and for a concentrator system with 2-axis tracking, the PV array is always facing directly towards sun during the day. In such case the angle between the sun and the PV module is 0°. For the same concentrator geometry, the acceptance angle will be different for varying sizes of the PV module.

The effective averaged irradiance at the PV module (G_x) depends on the irradiance available onto the concentrator G, the geometric concentration ratio X_g and the optical efficiency η_{op} and is expressed as:

$$G_x = G\, X_g \eta_{op} \qquad (2.7)$$

The overall optical efficiency of the concentrator η_{op} is the ratio of the power incident on the PV module(P_c) to the power at its aperture plane(P_{ap}). The geometric concentration X_g is the ratio of the concentrator net aperture area A_{NC} and the PV module area A_R and is expressed as:

$$X_g = A_{NC}/A_R \qquad (2.8)$$

2.3.Electrical output of PV array:

Photovoltaic modules consist of solar cells which are essentially large area pn junction diodes generating electric current through photo-generated carriers under illumination. The output current is the sum of the opposing diode current I_D and photo-generated current I_L. For a solar module with i and j silicon single crystalline solar cells connected in series and parallel respectively, the diode current I_D and photo-generated current I_L can be expressed as: [21]

$$I_D = 2^{\frac{T-T_r}{\rho}} \frac{I_{sc}}{j}\left[1 - \exp\left(\frac{eV_{oc}}{i\beta kT_r}\right)\right]^{-1} \qquad (2.9)$$

The parameter ρ in equation(2.9) is an empirical constant, whose value varies with the characteristics of the PV material and controls the temperature dependence.

$$I_L = \frac{G_x}{jG_r}\left[I_{sc} + \mu_{sc}(T - T_r)\right] \qquad (2.10)$$

Where 'β' is the ideality factor of a p-n junction and is given by:

$$\beta = \frac{e(V_{mp} - V_{oc})}{ikT_r}\left[\ln\left(\frac{I_{sc} - I_{mp}}{I_{sc}}\right)\right]^{-1} \qquad (2.11)$$

For good PV cells, β=1 and β=2 for bad ones. The iterative solution of the following expression is used to find out the V_{mpp}:

$$1+\frac{I_L}{I_D}=\exp\left[\frac{eV_{mpp}}{\beta kT}\right]\left[1+\frac{eV_{mpp}}{\beta kT}\right] \qquad (2.12)$$

$$I_{mpp}=I_L\left(1-\frac{kT}{eV_{mpp}}\right) \qquad (2.13)$$

The temperature of the cell can be calculated as [22]:

$$T=27.433G+1.1225(T_a-273.15)-2.555W+273.15 \qquad (2.14)$$

where W is the effective wind speed and T_a is the ambient temperature. By assuming that the PV panel is operating at its maximum power point, the output electrical power of the panel is:

$$P=\left[V_{mpp}I_L-V_{mpp}I_D\exp\left(\frac{eV_{mpp}}{nkT}-1\right)\right]i.j \qquad (2.15)$$

The fill factor and energy conversion efficiency are expressed as:

$$\eta=\frac{I_{sc}V_{oc}FF}{P_{in}/A} \qquad (2.16)$$

$$FF=\frac{I_{mpp}V_{mpp}}{I_{sc}V_{ov}} \qquad (2.17)$$

These expressions can be used to predict electrical output of PV module under non-concentrated sunlight. The temperature of the PV module can be calculated using the expression for known irradiance and effective wind speed data for a particular location using the expression (2.14).

Under concentration, the short circuit current increases linearly with irradiance and for a concentration ratio Xg, it is expressed as [11]:

$$I_{sc(conc)}=X_gI_{sc} \qquad (2.18)$$

The open circuit voltage $V_{oc(conc)}$ increase logarithmically as [11]:

$$V_{oc(conc)}=V_{oc}+\beta V_{th}\ln(X_g) \qquad (2.19)$$

where V_{th} expresses the temperature dependency of the efficiency of the cell. The efficiency of a PV cell at constant temperature under concentrated sunlight can be expressed as [11]:

$$\eta_{conc}=\frac{X_gI_{sc}V_{oc(conc)}FF_{conc}}{X_gP_{in(conc)}/A} \qquad (2.20)$$

where FF_{conc} is strongly dependent on the concentration ratio as [11]:

$$FF_{conc}=FF(V_{mpp(conc)})$$

$$V_{mpp(conc)}=V_{mpp}+\beta V_{th}\ln(X_g)-R_sX_gI_{mpp} \qquad (2.21)$$

R_s is the base series resistance. The FF decreases rapidly with increasing ohmic losses of higher series resistance due to the higher concentrations. In the expression (2.21), I_{mpp} may be approximated by $I_{sc(conc)}$.

The performance ratio PR is given by [2, 17]:

$$PR = \frac{P_{day}/P_r}{G/G_r} \qquad (2.22)$$

Thus, the performance ratio is the factor which when multiplied by the number of $kWhm^{-2}$ of beam irradiation received on the PV array aperture by rated power of the PV module in kW_p will result in the power output.

3. Comparison of concentrating PV and non-concentrating PV

3.1.Solar Input

The annual energy generation cost for a given PV system in a particular location is inversely proportional to the total amount of the solar energy available per unit area and to the conversion efficiency of such system. The solar concentrators can only transmit beam radiation and also the acceptance angle is very small. Therefore, it is important that sufficient beam solar radiation is available at the potential locations in South Korea for CPV systems. The recorded monthly mean daily solar radiation data on horizontal surfaces for Daegu and Mokpo is available in the RETScreen weather data base [23]. The solar radiation data was used to calculate monthly mean daily beam and global radiation over Daegu, South Korea (latitude 35.9°N) on a surface with 2-axis tracker and a fixed surface tilted at angle equal to latitude respectively as shown in **figure 3**. Similar solar radiation data for Mokpo, South Korea (latitude 34.8°N) is shown in **figure 4**. In order to estimate the beam radiation, 85% of the global monthly mean daily radiation on 2-axis tracking surfaces is considered.

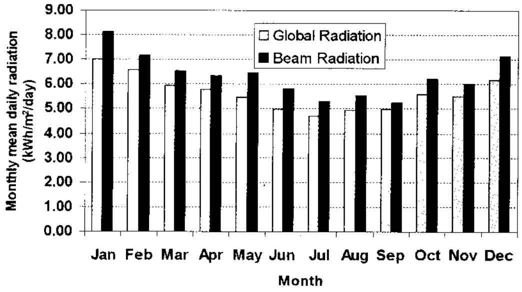

Figure 3. Monthly mean daily beam and global radiation over Daegu, South Korea (latitude 35.9oN) on a surface with 2-axis tracking system and fixed surface tilted at an angle equal to latitude respectively.

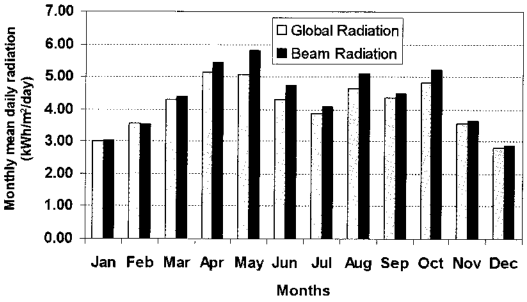

Figure 4. Monthly mean daily beam and global radiation over Mokpo, South Korea (latitude 34.8oN)on a surface with 2-axis tracking system and fixed surface tilted at an angle equal to latitude respectively.

The **figures 3** and **4** demonstrate that with 2-axis tracking mechanism, the collected monthly mean daily beam radiation is either equal or higher than the global monthly mean daily radiation on a fixed surface for both the locations during the entire 12 months of the year. Thus, Daegu and Mokpo are expected to be suitable for CPV applications.

3.2. PV Electrical Output

The electrical output of the PV module is improved under concentration. The short circuit current, open circuit voltage, fill factor and efficiency of a concentrating silicon PV cell on a clear winter day in January 2001 with beam solar radiation of 730W/m^2 and under concentration (10X) utilizing the non-imaging Fresnel lens are summarized in **table 1**.

Table 1. Characteristic parameters of a concentrating PV cell [11]

Concentration(sun)	Without lens*	1X	With lens 10X
Temperature (°C)	23	25	30
I_{sc} (mA/cm^2)	13	28.1	110
V_{oc} (V)	0.60	0.60	0.66
FF (%)	75	78	73
Efficiency (%)	8.0	13.2	14.9

* 730W/m2 beam irradiance

The experiment was carried out in Tokyo, Japan. These electrical parameters for 1X are also given in the same table 1. The schematic of the concentrating PV system is given in **figure 2(a)**. The concentrating PV system was mounted on a 2-axis tracker. The orientation of the system towards the sun was controlled by the remote optical sensing system for tracking. The optical sensor consisted of four photo-diodes arranged on the four sides of a plastic rod with a conical tip. One pair of photo-diode was facing east-west, the other pair faced north-south. The tracking system tracked the sun with accuracy of about 1/20 of a degree. The silicon solar was designed at Toyota Technological Institute (TTI), Japan for a concentration ratio of 20X. The energy conversion efficiency is clearly higher under the concentration. The current voltage characteristics of an evaporated grid solar cell, with an effective area of 29.5cm^2 and designed for a 20X linear concentrator under concentration ratios 4X, 10X, 14X and 18X are shown in **figure 5** [17].

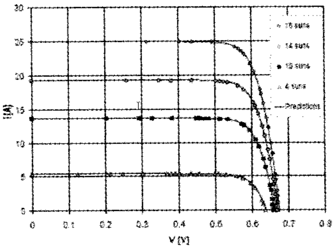

Figure 5. Current-voltage characteristics of a concentrating PV cell under 4X, 10X, 14X and 18X. [17]

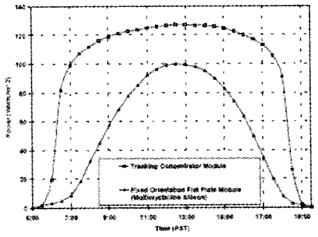

Figure 6. Electrical power produced by the concentrator and flat plate module during a typical sunny day [24].

The output power is improved from 2.5W under 4X to 12.6W under 18X. The

figure 6 shows the electrical power produced by the concentrating PV and non-concentrating fixed PV module during a typical sunny day located at Sunnyvale, USA [24]. The non-concentrating PV module was a 145W rated module consisting of 42 multi-crystalline solar cells of 225cm^2 each. The concentrator module was composed of one 650cm^2 Fresnel lens concentrating 27.5W/cm^2 onto a silicon point contact PV cell with an active area of 1.56cm^2. The concentrating PV cell was cooled down passively. Due to the tracking system, the power generation of the concentrator was much more uniform throughout the day than a fixed orientation non-concentrating PV system. The annual cumulative energy production of the concentrator was more than 37% greater than the non-concentrating PV module on a PV module area basis as shown in **figure 7** [24]. Thus, concentrator PV system outperformed the non-concentrating fixed PV module. These results clearly indicate that high efficiency concentrating PV module with 2-axis concentrating system produces more electricity as compared to fixed non-concentrating PV module.

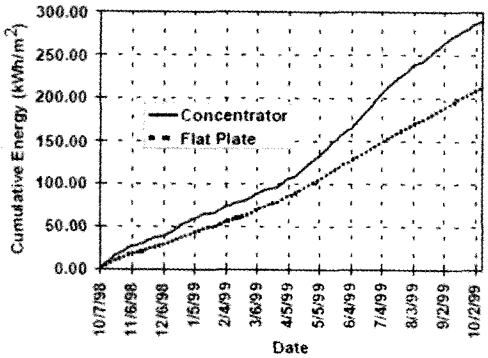

Figure 7. Cumulative annual energy production (kWh/m^2) of a concentrator and non-concentrating PV module in Sunnyvale, USA [24].

3.3. Concentration PV Cost

The concentrating PV modules can reduce the costs of the electricity generation as long as the concentrator is less expensive than the substituted PV cell. Fresnel lenses are used to achieve significant cost reductions and are most promising for systems of medium concentration. The dilemma of the concentrating system is that the higher the geometrical concentration ratio of the concentrator, the smaller is the solar cell needed to generate a fixed amount of electricity, but the higher is the system complexity, mainly in terms of the tracking accuracy and the related mechanics and controls.

Although concentrator cells become smaller, they are more expensive, due to lower production volume and higher cell complexity. Concentrator cells cost about two to ten times as much for the same area as flat plate crystalline silicon cells. While concentrator cells are more expensive than conventional ones, and cost is added for the concentrator and a tracking mechanism, the specific turn key cost of the project tends to decrease when concentration technology is used [11]. Since the concentrator technology is essentially the same for all ranges of concentration, the factors varying with the concentration ratios such as complexity of the tracking, radiation utilizability, and concentrator cell efficiency are used to asses the system costs. The resulting comparison of fixed non-concentrating photovoltaic systems (1X) with those of concentration factors 2X, 20X, 1000X is given in **table 2** [11]. In the table 2, the indirect cost is calculated as the 33% of the direct system cost. The output W_p at one sun is calculated by multiplying optical efficiency, CPV power conversion efficiency, radiation utilizability with 1000W. The PV system cost without concentrator is \$4.90/W_p. However, it is decreased to \$3.76/W_p when 20X Fresnel lens linear concentrator with a tracking mechanism is used. Thus reduction of about 23% in the per peak watt costis achieved when 20X linear Fresnel lens concentrating PV system is used as compared to non-concentrating PV system. Similar cost analysis is also provided by others [25]. However, due to recent advancements in the fabrication of concentrating PV with efficiency as high as 39% [7], and very promising new market trends for CPV, NREL has predicted the installed costs of \$3/W_p in next 2-3 years [14]. The cost comparison presented here may not be interpreted as the last word on the cost analysis as emerging new manufacturing technologies for the PV modules are resulting in cost reductions and it is hard to foresee whether the potential for cost reduction is greater for cells or for the concentrating technologies. A 100W Fresnel lens CPV system with a 2-axis tracking mechanism is being developed at KIER and system cost analysis for CPV system in South Korea will be presented once the system is developed and operational.

Table 2. Cost estimates for concentrating photovoltaic systems under different concentrations [11]

Concentration (sun)	1X	2X	20X	1000X
Fresnel lens concentrator(\$/㎡)	-	30	30	30
PV cells(\$/㎡)	320	160	25	75
PV Module(\$/㎡)	400	190	140	200
Array structures/tracking(\$/㎡)	80	80	155	230
Power conditioning(\$/㎡)	20	20	40	40
Land(\$/㎡)	4	4	4	4
Direct cost(\$/㎡)	524	294	384	544
Indirect cost(\$/㎡)	175	98	113	158
Total cost(\$/㎡)	699	392	452	632
Optical efficiency	0.90	0.75	0.75	0.80
Cell, power conversion efficiency	0.15	0.15	0.20	0.25
Radiation utilizability	1.0	0.9	0.8	0.8
Output (W_p) at one sun	135	101	120	160
Turn-key cost(\$/W_p)	4.90	3.88	3.76	3.95

4. Conclusions

The solar concentrator can reduce the required area of the costly PV materials, however, they have technical limitations as only the fraction of the beam radiation is transmitted to the concentrating PV module. In order to minimize the effect of optical losses and produce maximum energy, higher efficiency PV cells and 2-axis tracking mechanisms are used. The comparison of the monthly mean daily beam and global solar radiation data over Daegu and Mokpo indicates that with 2-axis tracking, CPV is expected to receive more solar radiation than the fixed non-concentrating PV system tilted at angle equal to site latitude during the entire year.

The comparison of the electrical outputs of concentrating PV system using 2-axis tracking with the fixed non-concentrating PV module located in USA indicates that CPV produced more energy. Also the power output of CPV was more uniform through out the day due to the tracking mechanism.

The cost per peak watt energy produced by non-imaging linear Fresnel lens concentrating PV systems using 2-axis tracking is also decreased considerably. It is estimated that cost of electricity generation are reduced about 23% when 20X linear Fresnel lens concentrating PV system is used as compared to non-concentrating PV system. Thus, the additional costs of the concentrator and tracking mechanisms are compensated by the higher output of the concentrating PV system.

Linear Fresnel lens concentrating photovoltaic system is a promising technology for generating electricity and is capable of outperforming the non-concentrating PV module in terms of electricity generation and costs. The reduction in costs of the PV electricity and better electrical outputs of concentrating PV systems are the prime motivations behind the ongoing work to develop a prototype of a 100W non-imaging Fresnel lens concentration system at Korea Institute of Energy Research (KIER). The experimental results along with the cost analysis of the concentrating PV system will be presented later.

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