ADVANCED CONSTRUCTIONS OF RADIATION CONCENTRATORS FOR PHOTOVOLTAIC SYSTEMS (REVIEW)

V. Poulek[1], M. Libra[1], A. Khudysh[2]

[1]Department of Physics, Czech University of Life Sciences Prague, Faculty of Engineering, Prague, Czech Republic,
[2]SOLEX-R. Ltd., Ryazan, Russia

Abstract
Different constructions of low concentration photovoltaic (LCPV) systems were designed and tested in our laboratory. The bifacial PV panels were used. Results are presented in the article. The electric energy production was increased by up to +167% in the case of pseudo parabolic concentration system in comparison with standard fixed PV panels. In summer, the operating temperature of PV panels was round about +95°C. The polysiloxane gel lamination technology was used to prevent degradation of the PV cells encapsulation and reliability troubles.

Key words: radiation concentrator, PV cell, bifacial PV panel, polysiloxane gel.

INTRODUCTION

Although the price of PV panels was reduced many times within last decade, the price of photovoltaic energy remains still high. Advanced PV systems with radiation concentrators are constructed. This is the way how the price could be reduced. So we have decided to design LCPV systems with bifacial PV panels. Bifacial PV cells were manufactured by the Solar Wind Company in Krasnodar, Russia. All systems use polar axis tracking system (POULEK AND LIBRA, 1998). Flat plate glass/glass bifacial PV panels for pseudo parabolic concentrator systems were laminated by the polysiloxane gel technology (POULEK ET AL., 2012). Three Low Concentration PV (LCPV) systems using bifacial flat plate PV panels based on monocrystalline silicon were developed in cooperation of the Czech university of Life Sciences Prague and SOLEX-R, Ltd., (Ryazan, Russia). Basic parameters of the LCPV systems are summarized in the Tab. 1.

Tab. 1. – Parameters of LCPV systems with bifacial PV panels

Concentrator	Number & power of PV panels	Bifacial cells size and layout	Operation temperature of PV panels	GCR	Bifacial ratio of PV cells front/back (%)	Energy gain	Lamination
Ridge (TRAXLE)	14 x170 W	125x125 mm^2 6 x 12	55°C	1.5	100/50	+72%	Glass/EVA/TPT
Pseudo parabolic I (TRAXLE)	4 x170 W	125x125 mm^2 6 x 12	95°C	4.1	100/60	+167%	Glass/silicone gel/Glass
Pseudo parabolic II (SOLEX-R)	2x175 W	125x62,5 mm^2 10 x 14	96 °C	3.6	100/65	+114%	Glass/silicone gel/Glass

Ridge concentrators with bifacial PV panels

The ridge concentrator with Geometrical Concentration Ratio GCR=1.5 (POULEK AND LIBRA, 2000) was developed to avoid troubles with V-trough concentrators (GCR=2). Fig. 1 shows scheme of the ridge concentrator. There is high wind induced torque by V-trough concentrators, which can destroy gearbox of the tracker. But there is low wind induced torque by ridge concentrators, because external mirrors were eliminated. Additionally the overheating of PV panels is substantially reduced by ridge concentrators, in comparison to V-trough concentrators (NANN, 1991; ANDERSON, 2013; TANG AND LIU, 2011). While summer operating temperatures of PV panels at ridge concentrators are below 70°C the temperature of panels at V-trough concentrators are above 95°C. The operating temperature +85°C is strict limit for all EVA laminated PV panels. There is no warranty above the operation temperature +85°C and lifetime of PV panels is substantially reduced.

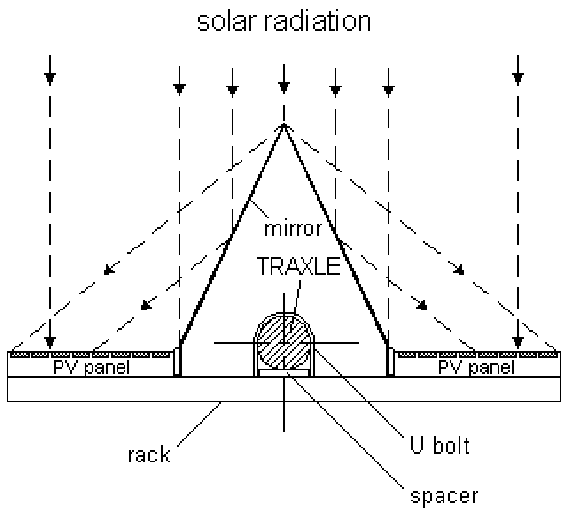

Fig. 1. – Scheme of the tracking ridge concentrator

The ridge concentrator was further improved using bifacial PV panels. The bifacial PV panels yield about +7% higher energy harvest because of additional albedo energy collected at the rear surface and because of reduced temperature of the panels. The bifacial panels are transparent for the infrared radiation above the wavelength 1100 nm so the operating temperature of bifacial panels is reduced by about 3÷7°C in comparison with standard monofacial PV panels.

Several ridge concentrator systems with bifacial PV panels were installed in the Czech Republic and Russia including the 0.5 MW_p PV plant. The energy harvest of the ridge concentrator systems with bifacial PV panels is enhanced by about +72% in comparison with standard fixed PV systems.

Fig. 2 shows energy production of the tracking ridge concentrator with bifacial PV panels in comparison with energy production of standard fixed panels during a sunny day. Fig. 3 shows our ridge concentrators with bifacial PV panels (0.5 MW_p PV power plant).

Pseudo parabolic PV concentrators with bifacial PV panels

The energy gain of ridge concentrator +72% or V-trough concentrator about +90% is not very high. So we have developed pseudo parabolic PV concentrators with bifacial PV panels with geometrical concentration ratio GCR= 3.6 and GCR= 4.1 respectively.

The first variant of pseudo parabolic concentrator with bifacial PV panels was developed in cooperation of the Czech University of Life Sciences Prague (CULS) and TRAXLE Solar Company.

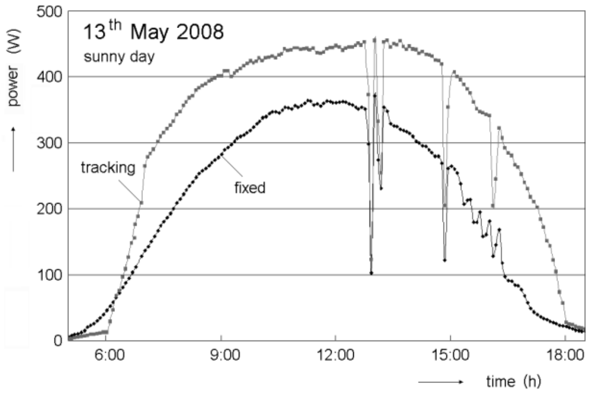

Fig. 2. – Time dependence of the power output of the tracking ridge concentrator with bifacial PV panels in comparison with standard fixed PV panels. The areas below the respective curves represent energy gain of the PV systems.

Fig. 3. – The tracking ridge concentrators with bifacial PV panels (0.5 MW_p PV power plant)

The bifacial PV panels were arranged parallel to the tracking axle and perpendicular to the solar radiation. Fig. 4 shows the scheme and Figs. 5÷6 show the photograph of the tracking concentrator. Although the bifacial PV panels transparent for infrared radiation have been used the temperature of the PV panels have been above +90°C during summer months at noon. The design of PV panels was similar to standard flat plate ones using 6x12 bifacial mono-Si PV cells sized 125x125 mm^2. But glass/glass design of the panel with silicone gel lamination was used instead of glass/EVA/TPT design. The silicone gel encapsulant will last many years at temperature +250°C. The energy gain +167% (in comparison with fixed standard PV panels) was measured. No degradation like yellowing/browning or delamination of the polysiloxane gel encapsulant was observed.

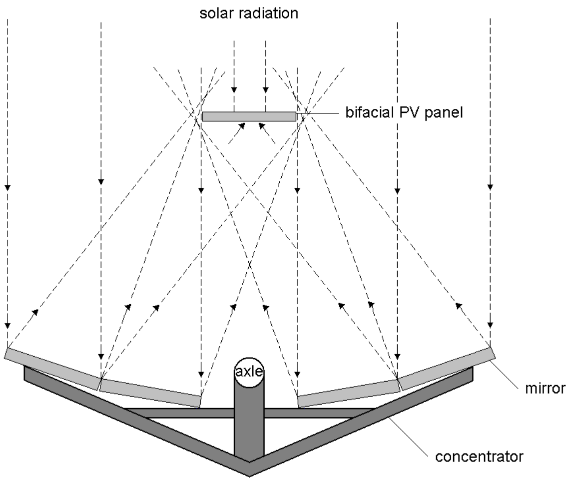

Fig. 4. – Scheme of the 1st variant of the pseudo parabolic concentrator with bifacial PV panels

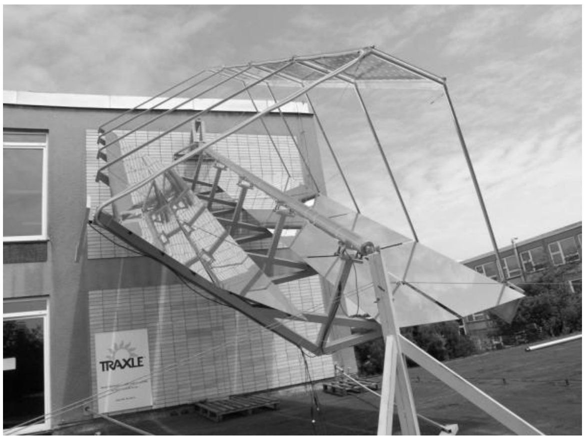

Fig. 5. – Pseudo parabolic concentrator TRAXLE with bifacial PV panels fixed to the building of CULS in Prague

Fig. 6. – Detail of the concentrated solar radiation

The second variant of pseudo parabolic concentrator design with bifacial PV panels was developed at the SOLEX-R Company in Ryazan, Russia (POULEK ET AL., 2015). The bifacial PV panels were arranged parallel to the tracking axle and parallel to the solar radiation. The design of PV panels was similar to standard flat plate ones using 10x14 bifacial mono-Si PV cells sized 125x62.5 mm^2. Fig. 7 shows the scheme and Fig. 8 shows the photograph of the concentrator. The temperature of bifacial PV panels was above +95°C in summer. So this design have to use silicone gel lamination of glass/glass PV panels otherwise the high temperature could cause reliability troubles. The energy gain +114% (compared to fixed standard PV panel) was measured.

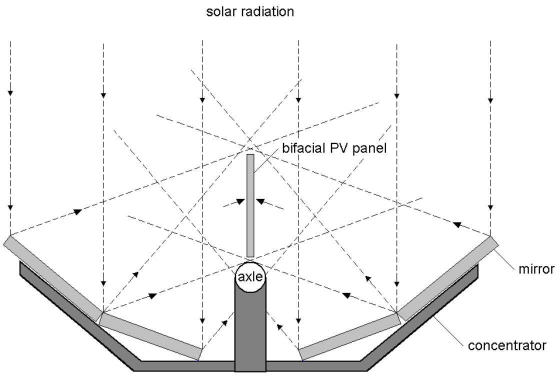

Fig. 7. – Scheme of the 2nd variant of the tracking pseudo parabolic concentrator with bifacial PV panels

Fig. 8. – Photograph of the 2nd variant of the tracking pseudo parabolic concentrator with bifacial PV panels in Ryazan

CONCLUSIONS

Three variants of tracking PV concentrators have been developed using bifacial solar panels. Silicone gel laminated bifacial panels were successfully tested in pseudo parabolic concentrator systems. Energy gain up to +167% was measured. Further improvements of the pseudo parabolic LCPV design are under development. Active cooling system will be introduced as well as advanced bifacial solar cells with front/back efficiency ratio 100/90. The energy gain can reach more than +200% in comparison to standard fixed PV panels.

REFERENCES

1. POULEK, V., LIBRA, M.: New solar tracker. Solar Energy Materials and Solar Cells, 51, 2, 1998: 113-120.
2. POULEK, V., LIBRA, M.: A New Low Cost Tracking Ridge Concentrator. Solar Energy Materials and Solar Cells, 61, 2, 2000: 199-202.
3. POULEK, V., STREBKOV, D.S., PERSIC, I.S., LIBRA, M.: Towards 50 years lifetime of PV panels laminated with silicone gel technology. Solar Energy, 86, 10, 2012: 3103–3108.
4. POULEK, V., KHUDYSH, A., LIBRA, M.: Innovative low concentration PV systems with bifacial solar panels. Solar Energy, 120, 2015: 113-116.
5. NANN, S.: Potentials for tracking photovoltaic systems and V-troughs in moderate climates. Solar Energy, 45, 1991: 385-393.
6. ANDERSON, T.N.: Natural convection heat transfer in V-trough solar concentrators. Solar Energy, 95, 2013: 224-228.
7. TANG, R., LIU, X.: Optical performance and design optimization of V-trough concentrators for photovoltaic applications. Solar Energy, 85, 2011: 2154-2166.

Corresponding author:

Ing. Vladislav Poulek, CSc., Department of physics, Faculty of Engineering, Czech University of Life Sciences Prague, Kamýcká 129, Praha 6, Prague, 16521, Czech Republic, tel: +420 22438 3288, email: poulek@tf.czu.cz