Name of research institute or organization:

Bern University of Applied Sciences BFH, Dept. of Engineering and Information Technology, Photovoltaic Laboratory (PV LAB)

Title of project:

Long-term study on the efficiency of photovoltaic installations at high altitudes

Project leader and team:

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PD Dr. Eva Schuepbach, Senior Research Consultant

Project description:

1. Introduction

Since the 1980s, the PV LAB at BFH Burgdorf in Switzerland has continuously strengthened its research efforts on the performance measurements of alpine PV-installations. Currently, there is an enhanced interest in winter electricity production from alpine PV and its role for the implementation of the Swiss Energy Strategy 2050 [1]. In the frame of the Swiss Center for Competence in Energy Research on the Future Swiss Electrical Infrastructure, SCCER FURIES [2], a new project for an extension of the existing PV-installation at Jungfraujoch (capacity in 1993: 1152 Wp) is conducted. The new PV-modules have an area of 13m^2. Although this is only slightly (30%) bigger than the existing PV-installation from 1993 with 10m^2, the nominal power is higher by 140%. Figure 1 shows the position of the old and new PV modules on the façade of the Jungfraujoch Research Station building.

Figure 1. Position of the old (Joch1) and new (Joch2) PV-modules on the Jungfraujoch research building (Joch1: PV-installation of 1993; Joch2: PV-installation of 2014).

2. Activities in 2015

During the mounting of the Joch2 PV-installation in September and October 2014, the expensive measuring instruments were not fixed yet in order to protect them from being damaged by ongoing construction work. They were installed in July 2015, when the scaffolding was removed and the harsh winter was over.

3. First Comparisons of Energy Yields (Technology 2014 vs Technology 1993)

However, data from the new PV-installation (Joch2) already started in December 2014 and hence, first comparisons of the energy yield produced from the old (1993/Joch1) und new (2014/Joch2) PV-installation could be made between January 2015 and June 2015.

As the new PV-modules installed in 2014 (Table on the right) have an efficiency of about 21% as compared to the PV-modules installed in 1993 (with an efficiency of ca. 12%), the energy yield produced from the 2014 PV-modules is expected to amount to 2760 Wp as compared to 1152 Wp from the PV installation in 1993.

	Joch1	**Joch2**
Tilt:	90°	90°
Module:	Siemens M75	Sunpower X21 345
Inverter:	ASP TopClass 2500	SolarMax 3000P
P_{Gen}:	1'152 Wp (nominal)	2x1380Wp
Installation:	October 1993	September 2014

This is an expected increase by a factor of 2 [3]. But how is the normalised yield? Fig. 2 provides evidence that the new PV-modules (i.e., the technology mounted in 2014), have an increased performance ratio (PR) by about 30%.

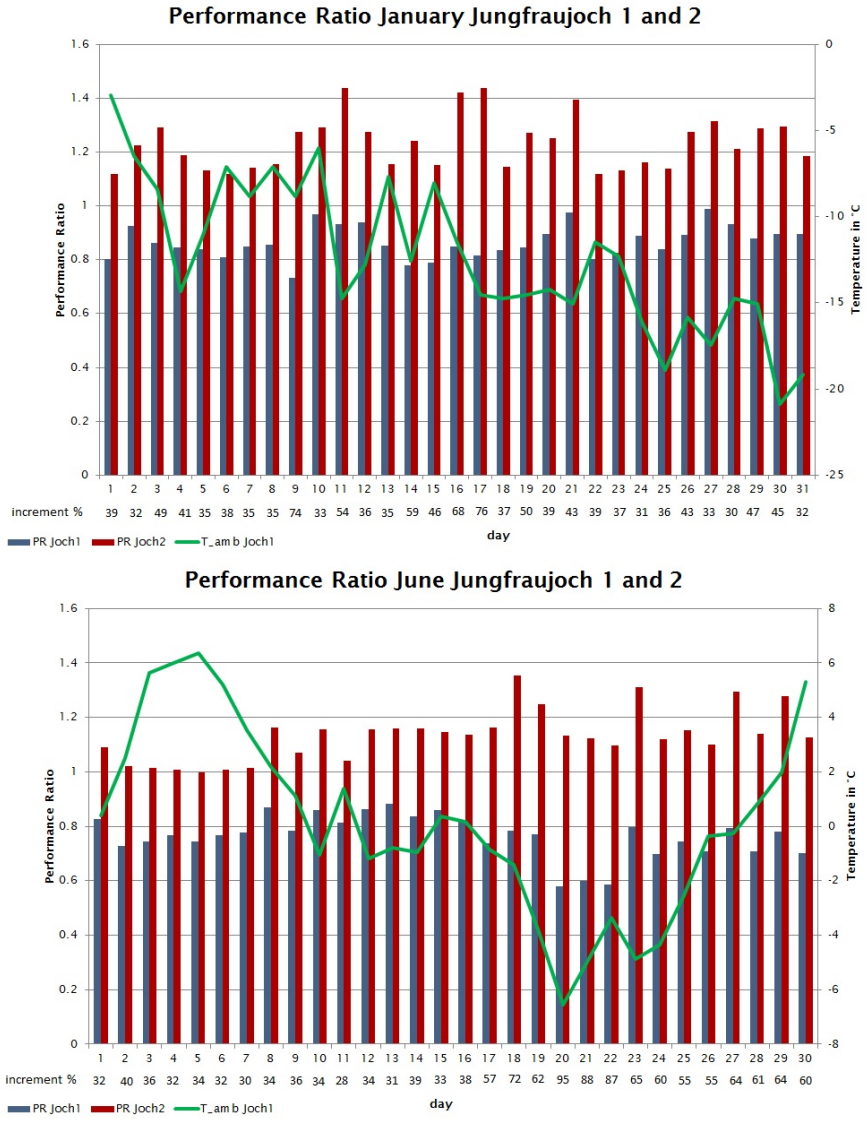

Figure 2. Performance ratio of energy yield produced at Jungfraujoch from new (2014) and old (1993) PV- modules in January 2015 (top) and June 2015 (bottom).

4. Research on the Economic Benefit of High-Altitude PV-Installations

Previous studies [4] revealed that the energy yield from high-elevation PV-sites (above 1500 m asl) in Switzerland can produce an energy output that is similar to PV-installations in southern Europe or Northern Africa. PV-installations like the one at Jungfraujoch can help to understand the economic benefit of high-alpine PV production in the context of economic winter electricity production in Switzerland. With the data gathered from the new PV technology mounted at Jungfraujoch in 2014-15, some burning research questions can now be addressed. Among them is a cost-benefit analysis, e.g., can the additional costs of alpine PV constructions be justified and economically covered in the future, as compared to the investment for hydroelectricity?

Fig. 3 compares the 24h-averages of electrical power and insolation among PV-sites from typical topographic regions in Switzerland. The data of the PV-sites is taken from the Swiss monitoring network with more than 35 PV-installations operated by the PV LAB at BFH [1, 4]. The network not only includes the high-alpine PV site at Jungfraujoch, but also lower-elevation PV-installations in the other topographic regions in Switzerland. These are the Swiss Basin, the Jura Mountains, and the Pre-Alps (Fig. 4).

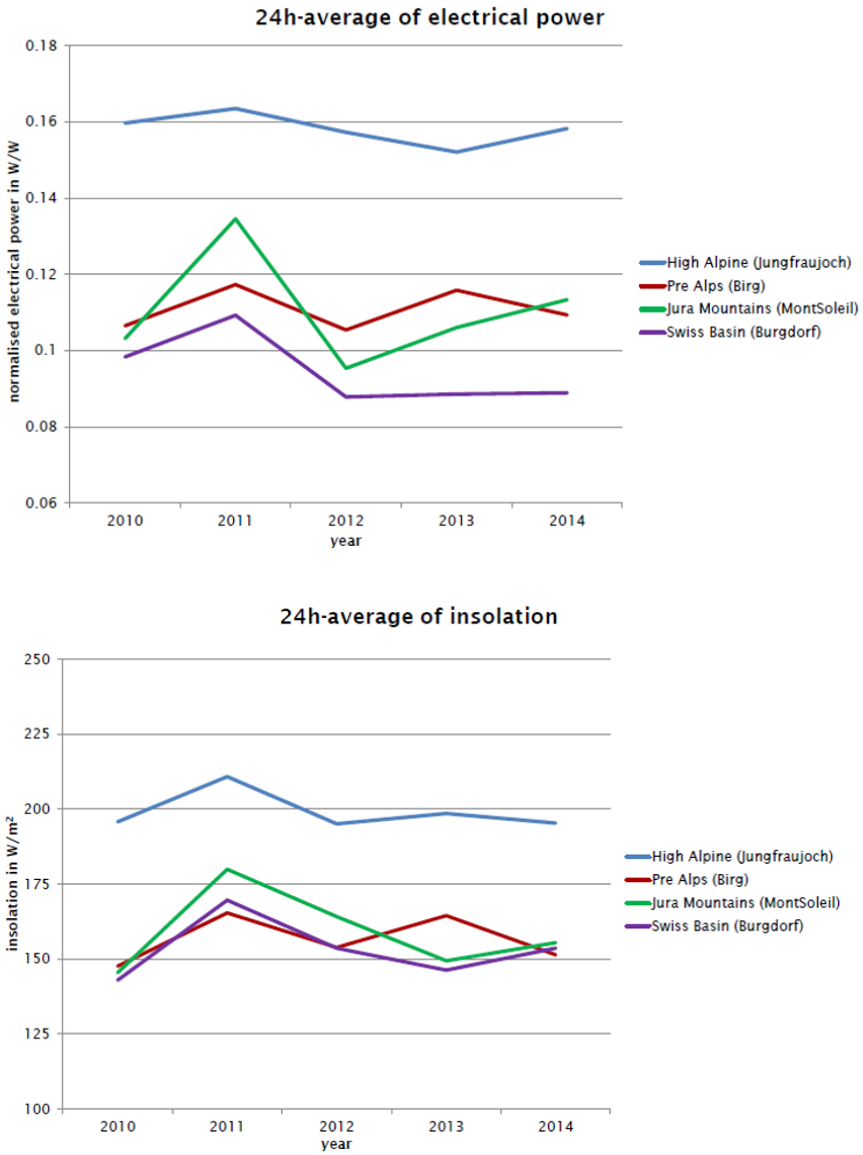

Figure 3. Electrical power and insolation of selected sites in typical topographic regions in Switzerland.

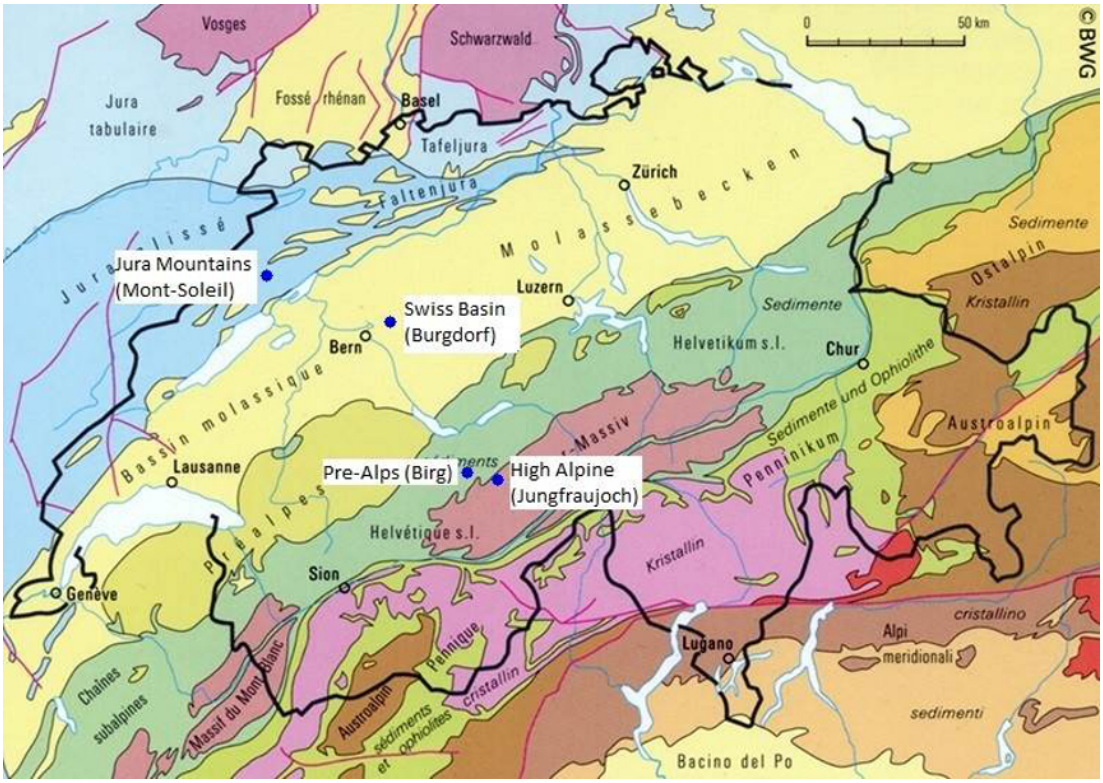

Figure 4. Topographic regions in Switzerland with location of PV-sites selected for comparison in Fig. 3.

The selected PV-sites representing these topographic (lower-elevation) regions in Switzerland are "Gfeller Burgdorf" (Swiss Basin), "Mont Soleil" (Jura Mountains) and "Birg" (Pre-Alpes). Specifications of these sites are listed in the Table below.

Site	lat/long	masl	Module	Inverter	Installation	Monitoring Start
High Alpine: Joch 1	46.55˚N, 7.98˚O	3'454	Siemens M75	ASP TopClass 2500/4 Grid III	27.10.1993	29.10.1993
Joch 2	46.55˚N, 7.98˚O	3'454	Sunpower X21 345	SolarMax 3000P	01.09.2014	01.09.2014
Pre-Alps	46.56˚N, 7.86˚O	2'677	Siemens M55	ASP TopClass 4000/6 Grid III	21.12.1992	22.12.1992
Jura Mountains	47.16˚N, 6.99˚O	1'270	Siemens M55	ABB	28.04.1992	01.06.2001
Swiss Bassin	46.96˚N, 7.46˚O	540	Siemens M55	ASP TopClass 4000/6 Grid III	24.06.1992	01.07.1992

3. Further Installation Work at Jungfraujoch

After completing the installation work of the measurement equipment and all measuring instruments (of the new and the old PV-modules) in July 2015, the measuring installation needed to be adapted so that both PV-installations (1993 and 2014) can be measured with only one new measuring equipment. Parts of the electronics of the the old measuring cabinet hence needed to be transferred to the new measuring housing, data loggers needed to be

replaced and their software adapted. This work (Fig. 5) was started in November 2015 and will continue in 2016.

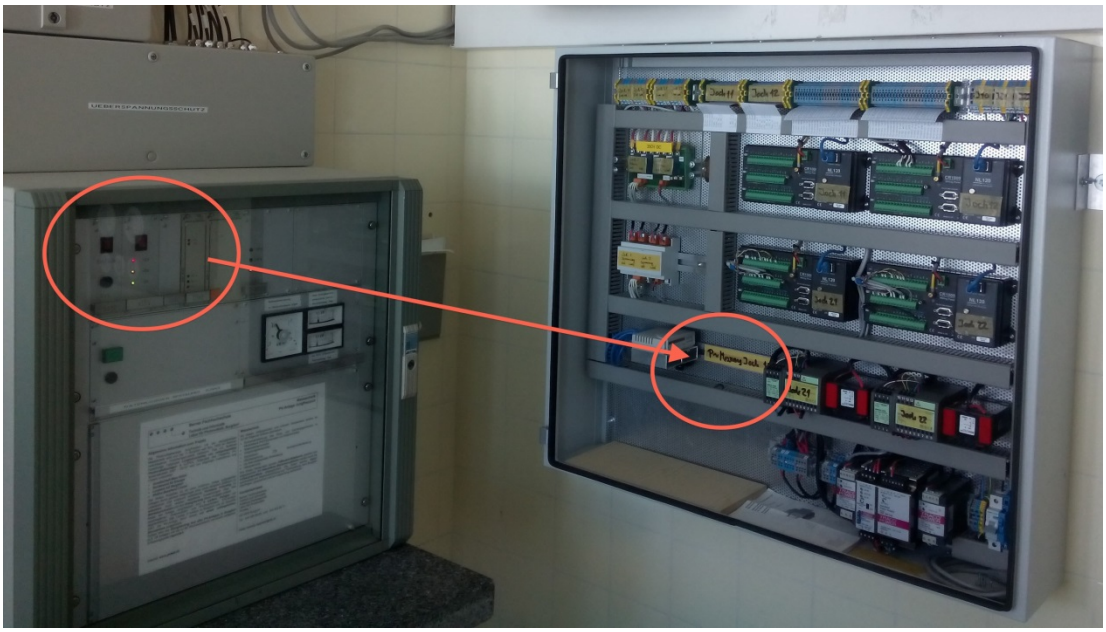

Figure 5. Parts of the electronics are now moved from the old housing to the new cabinet.

This transfer is not only a requirement by BFH in view of the long-term study of energy yields produced at Jungfraujoch, but also important for the renovation of the public display board at the entrance of the Jungfraujoch railway station (Fig. 6).

Figure 6 shows the Pointer Meters on this display board by a Panel PC that will show time-variation curves of the solar radiation and energy production. However, in order to show these curves, a complete change of the data signal transfer from the measuring installation to the display board is needed.

Figure 6. The two Pointer Meters in the middle of the board shall be replaced by a panel PC.

References:

[1] E. Schuepbach, U. Muntwyler, M. Jost, T. Schott, Proceed. 29th European Photovoltaic Solar Energy Conference and Exhibition, 22-26 September 2014, Amsterdam, The Netherlands (2014), 2689-2691.

[2] See activities on: http://sccer-furies.epfl.ch/

[3] U. Muntwyler, T. Schott, E. Schuepbach, Activity Report 2014, International Foundation High Altitude Research Stations Jungfraujoch + Gornergrat HFSJG, University of Bern, Switzerland (2014), 145-149.

[4] U. Muntwyler, 8th International Conference and Exhibitions on Ecological Vehicles and Renewable Energies, Monaco (2013).

Key words:

Photovoltaic technology, power production, winter energy yield, economic benefits, high alpine sites, long-term stability, Swiss Energy Strategy 2050, SCCER-FURIES

Links:

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