

Name of research institute or organization:

**Berner Fachhochschule (BFH), Technik und Informatik (TI),
Photovoltaik-Labor**

Title of project:

Long-term energy yield and reliability of a high alpine PV (photovoltaic) plant at Jungfrauoch (3454 m)

Project leader and team

Prof. Dr. Heinrich Häberlin, project leader
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Project description:

PV plant Jungfrauoch (1.152 kWp, 3454 meters above sea level) was planned and realised by the laboratory for photovoltaics (PV) of the Berne University of Applied Sciences (BFH) during summer and fall 1993. At the time of its erection it was the highest grid connected PV plant in the World.

Purpose and Goals of the project:

- **Test of PV components:** Operation in high altitudes is a very hard stress for all components due to extremely high irradiance peaks of more than 1.7 kW/m², heavy storms and thunderstorms, and large temperature differences. PV components surviving in such a harsh environment should perform more reliably under normal operating conditions.
- **Long-term operating experience:** Experimental demonstration that high PV energy yields for high alpine PV plants that can be not only be simulated, but can actually be obtained in practical operation over many years.
- **Intensive analytical monitoring** with redundant sensors to ensure maximum reliability in order to get long-term data about energy yield and reliability.
- **Maximum availability of energy production and monitoring data (AMD ≈ 100%).**

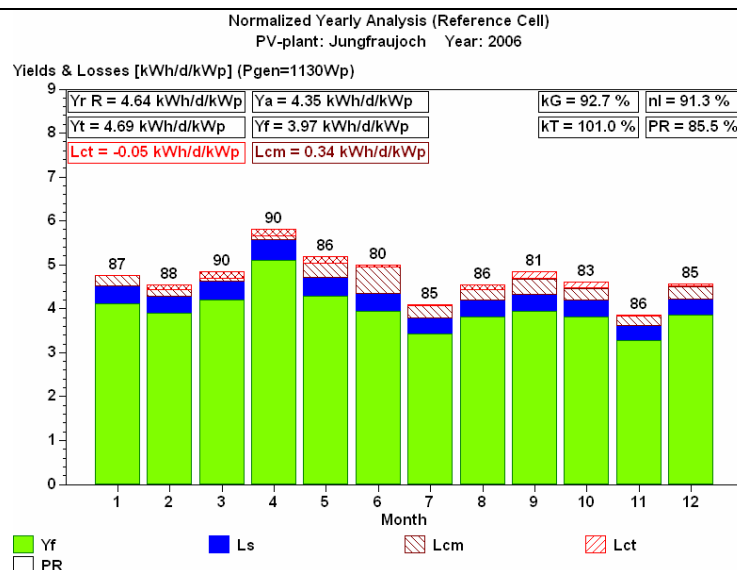
In 2006, after the new all-time record year 2005, PV plant on Jungfrauoch (rated peak power 1.152kWp, effective peak power 1.13 kWp, 3454 m above sea level) had again a very good energy production with a normalized yield of **1449 kWh/kWp**, considerably more than in an average year. Compared to 2005, irradiation into the array plane decreased a few percent, but performance ratio PR was still quite high. Like in 2005, winter energy fraction was again 48.5%.

In the average of 1994 to 2006, PV plant Jungfrauoch has produced 1410 kWh/kWp with a winter energy fraction of 46.4%.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	Mean 1994-2006
Y_f (kWh/kWp/a)	1272	1404	1454	1504	1452	1330	1372	1325	1400	1467	1376	1537	1449	1410
$PR = Y_f/Y_r$ in %	81.8	84.1	84.7	85.3	87.0	84.8	84.6	78.6	85.2	84.9	86.2	86.9	85.5	84.6

Table 1: Annual energy production (referred to effective STC-power) and performance ratio PR (referred to reference cell irradiance measurement) from 1994 – 2006. Thirteen-year average values are also indicated.

Fig. 1:
Normalized monthly
energy production for
2006.



In fall 2006, a major Swiss utility (Bernische Kraftwerke AG) has realized the very good conditions for PV at Jungfraujoch and is considering to erect a somewhat larger pilot plant at a suitable location there. For this decision, the long-term measurements of PV plant Jungfraujoch establish a good data base to project energy yield.

A detailed description of the plant, measurement results of earlier years and definitions used can be found in earlier annual reports (2000, 2002, 2003, 2004, 2005) and in several publications under www.pvtest.ch (many publications can be downloaded). Diagrams similar to fig. 1 for the years 1994 – 2006 and normalized diagrams for each month can be downloaded under www.pvtest.ch > PV monitoring data.

Key words:

Grid-connected PV plants, energy yield, high alpine

Internet data bases:

<http://www.pvtest.ch>

Scientific publications and public outreach 2005:

H. Häberlin: "Rekordernte auf dem Jungfraujoch". Elektrotechnik 3/2006
(paper can be downloaded from our homepage indicated above)

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