

Name of research institute or organization:

**Berner Fachhochschule, Hochschule für Technik und Informatik (HTI), Photovoltaik-Labor**

Title of project:

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

Project leader and team

Prof. Dr. Heinrich Häberlin, project leader  
Christoph Geissbühler and Christian Renken (until June 2004)

Project description:

PV plant Jungfraujoch (1,152 kWp, 3454 meters above sea level) was planned and realised by HTI Burgdorf during summer and fall 1993. At the time of its erection it was (and perhaps it still is) 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/m<sup>2</sup>, 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%).**

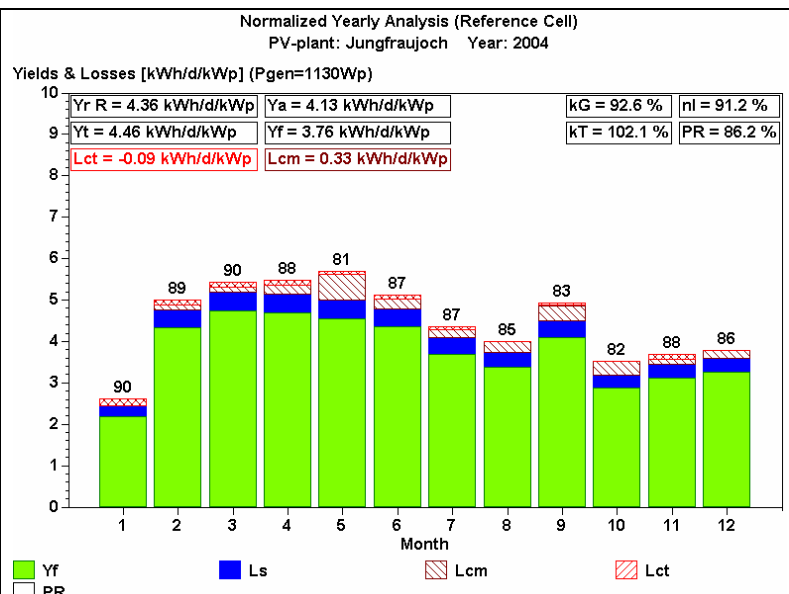
PV plant Jungfraujoch has operated successfully with a 100% availability of energy production and monitoring data since Oct. 27, 1993. Until Dec. 2004, the plant has operated successfully for more than 134 months. In 1996, by means of some modifications energy production of the plant could even be increased compared to the first year of operation.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	Average 1994-2003
<b>Y<sub>f</sub></b> (kWh/kWp/a)	1272	1404	1454	1504	1452	1330	1372	1325	1400	1467	1376	1398
<b>PR = Y<sub>f</sub>/Y<sub>r</sub></b> in %	81.8	84.1	84.7	85.3	87.0	84.8	84.6	78.6	85.2	84.9	86.2	84.2

**Table 1: Annual energy production (referred to effective STC-power) and performance ratio PR from 1994 – 2004. Ten-year average values are also indicated.**

As in 2003 the 10<sup>th</sup> anniversary of the plant was reached, several contributions were written in 2004 discussing the results of the first 10 years of operation [1], [2], [3].

**Fig. 1:**  
Normalized monthly energy production for 2004. The energy production was a little less than the ten-year average value between 1994 and 2003, but this was mainly due to a relatively low irradiation, as the performance ratio PR was the second highest in 11 years (see table 1).



A detailed description of the plant, measurement results of earlier years and definitions used can be found in earlier annual reports (2000, 2002, 2003) and in several publications under [www.pvtest.ch](http://www.pvtest.ch) (many publications can be downloaded).

Key words:

Grid-connected PV plants, energy yield, high alpine

Internet data bases:

<http://www.pvtest.ch>

Scientific publications and public outreach 2004:

- [1] H. Haeberlin: "Grid-connected PV Plant Jungfrauojoch (3454m) in the Swiss Alps: 10 Years of trouble-free Operation with Record Energy Yields". Proc. 19<sup>th</sup> EU PV conference, Paris, 2004.
- [2] H. Häberlin: "Netzgekoppelte Photovoltaikanlage Jungfrauojoch: 10 Jahre störungsfreier Betrieb mit Rekord-Energieerträgen" (*in German*). SEV/VSE-Bulletin 10/2004.
- [3] H. Häberlin: "Hochalpine Photovoltaikanlagen – Langzeiterfahrungen mit Fassadenanlagen" (*in German*). Elektrotechnik 6+7, 2004.

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