

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
Martin Kämpfer, project assistant

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 can 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 2007, 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 **1453 kWh/kWp/a or 1449 h/a**, considerably more than in an average year. Compared to 2006, irradiation into the array plane was nearly equal, but performance ratio PR increased slightly.

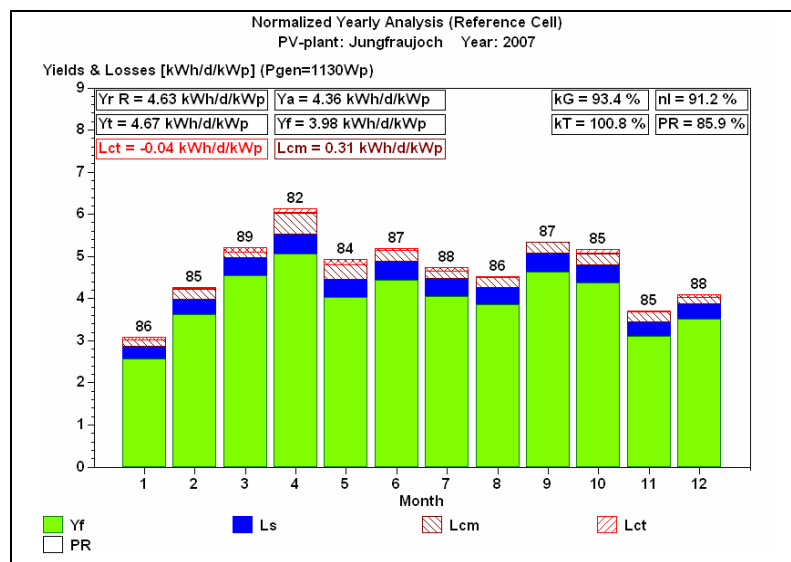
The long-term annual average from 1994 to 2007 of PV plant Jungfrauoch increased to 1413 kWh/kWp/a or 1413 h/a with a winter energy fraction of 46.4%.

	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Mean 1994- 2007
Y _f (h/a)	1272	1404	1454	1504	1452	1330	1372	1325	1400	1467	1376	1537	1449	1453	1413
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	85.9	84.7

Table 1: Annual energy production (referred to effective STC-power) and performance ratio PR (referred to reference cell irradiance measurement) from 1994 – 2007. Fourteen-year average values are also indicated.

Fig. 1:

Normalized monthly energy production for 2007.



In September 2007, an extended book about photovoltaic systems technology (in German) was published, which includes not only a detailed description of PV plant Jungfrauoch, but also long-term monitoring data of plant Jungfrauoch and of other PV plants in the Alps and at other locations in Switzerland, Germany and USA. A detailed description of the plant, measurement results of earlier years and definitions used can be found in earlier annual reports (2000 - 2006) 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 2007:

H. Häberlin: "Photovoltaik – Strom aus Sonnenlicht für Verbundnetz und Inselanlagen". AZ-Verlag, CH-5001 Aarau, 2007, ISBN 978-3-905214-53-6 and VDE Verlag, Berlin, ISBN 978-3-8007-3003-2" (in German).

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