Bundesamt für Energie
Office fédéral de l'énergie
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Swiss Federal Office of Energy

Programme
Active solar energy, Photovoltaics

Photovoltaic Programme 1998

Summary Report, Project List

Annual Project Reports (Abstracts)

elaborated by
NET Nowak Energy & Technology Ltd.
Waldweg 8, 1717 St. Ursen
(Switzerland)

April 1999

on behalf of
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PHOTOVOLTAICS

Programme 1998
Summary Report

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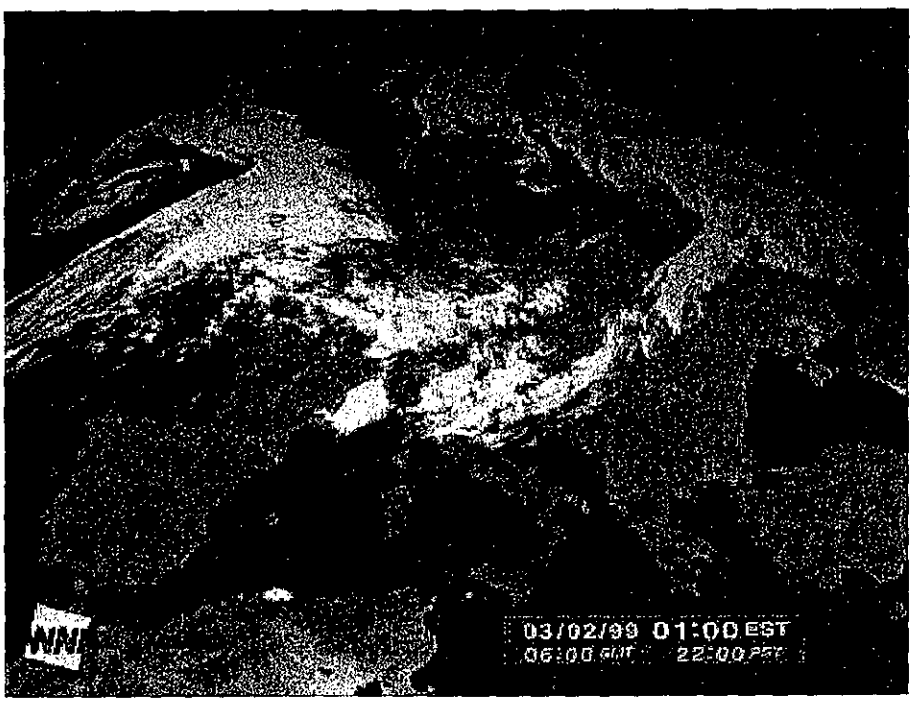

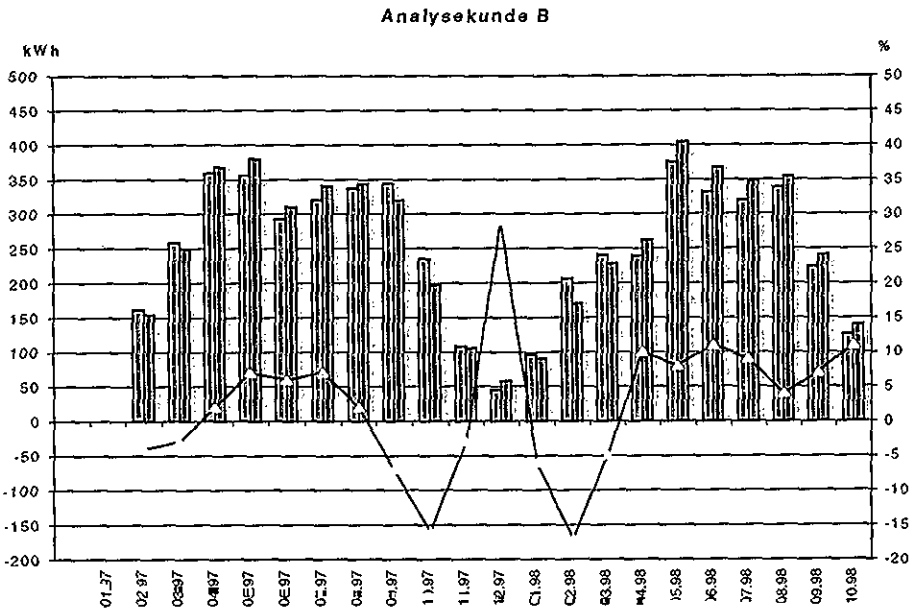

International co-operation: Use of satellite data for photovoltaics
European co-operation has been strongly increased during the report period. As examples, use is made of satellite data for radiation maps on the internet and for the simulation of PV systems (EU projects SATELLIGHT and PV-SAT, Copyright WNI and Enecolo)

1. Programme summary and targets for 1998

The endeavor to apply current work to industrial products and applications was continued within the photovoltaics program for 1998, and efforts made to further strengthen cooperation with industry and at international level. The handling of specific process and product-related questions concerning the development of improved solutions (cost, efficiency) in all areas of photovoltaics energy systems remained in the forefront. Parallel to this, the object of preparing documentation intended as a basis for decision-making for larger-scale implementation projects was further pursued. Building-integrated photovoltaics continues to be regarded as the principal field of application. Research and P+D together accounted for 78 projects during the report period, whereby all projects known to us have been included in this figure, irrespective of their funding.

The 5 program sectors are as follows:

Cells: The main emphasis is on thin film solar cells, and here, work continues to concentrate on those based on **silicon**, the principal material involved. The primary objectives are to improve the performance characteristics and to seek further avenues for implementing this work. The investigations on further types of thin silicon (string ribbon silicon, thin crystalline silicon) were intensified. In addition, the work on other material technologies (in particular compound semiconductors, dye cells) was strongly pursued. Thus, taken as a whole, Switzerland now has an exceptionally wide range of materials and technologies at its disposal mirroring the whole breadth of the international development effort.

Modules and building integration: New products and systems for the **integration of photovoltaics** into the built environment (roofs, facades, noise protection installations) continue to represent a major focus. Here, the choice of cell technologies for implementation purposes at the design stage is of growing importance, since this has a decisive influence on the design of integrated systems. Also, the number of available products continues to increase, and here, industry is becoming more and more involved.

Systems technology: Switzerland has a long-standing tradition in this field, with extensive experience in the creation of infrastructure for the assessment of newly developed products and plant, and disposes of measurement data for built installations extending over a period of more than 10 years. This permits continued quality assurance, particularly important at the present time of technological growth. It also enables the basis for essential improvements, standardization and safety of new products to be laid.

Other projects and studies: This sector includes work on the longer-term determination of the principal indicators in the photovoltaics field, i.e. environmental, implementation potential and market development questions. Furthermore, novel, combined, uses of photovoltaics (e.g. hybrid technologies, thermophotovoltaics) and advanced tools (design, performance control) are to be investigated.

International cooperation: International cooperation forms the kingpin of current work and is being pursued in all sectors. Participation in international developments and an intensive exchange of information within the international EU and IEA programs remained a central objective over the report period.

2. Projects and results for 1998

CELL TECHNOLOGY

The **micromorphous solar cell** project [1] (i.e. tandem cell with a microcrystalline top cell and an amorphous bottom cell) was successfully pursued at IMT, whereby several constituent aspects of this interesting thin film cell were improved. For single-junction (p-i-n) cells of microcrystalline silicon, the contact voltage V_{oc} was increased to 530 mV, and an efficiency of 8.5% achieved. It was possible to increase the deposition rate, a further key parameter in the micromorphous concept, to 25 Å/s for intrinsic, microcrystalline, silicon. Further, transparent oxide layers (TCO) were produced based on ZnO, making suitable process procedures for contacting purposes available. Using TCO, it became possible for the first time to deposit simple cells having satisfactory properties (V_{oc} = 880 mV, FF = 72%). Over and above these process relevant results, progress was made in material characterization, important in connection with the temperature dependency of the cell voltage on material structure (i.e. microcrystalline or micromorphous). Fortunately, the temperature dependency of the cell voltage is low both for micromorphous and microcrystalline materials. These results together with the efficiency achieved up till now (10.7% previously confirmed; 12% now measured at IMT) suggest that it may well be possible to achieve the objective of a stable efficiency of 12% for micromorphous cells in the final project year. In the complementary **NEST** [2]

project, an inverse film structure (n-i-p-n-i-p) was investigated for micromorphous cells. A further important aspect here is to gain an understanding of the light trapping in structured TCO layers and to optimize these. The TCO layers improve light absorption and thus enable thinner layers to be produced. In a further project supported by PSEL, the deposition of **amorphous cells on plastics substrates** (polyimide) [3] was investigated based on laser structuring and series connection of cells. The initial mini-modules (8 x 8 cm) gave an efficiency of 7.3% based on active area. Lamination and the feasibility of producing facade elements were studied by the industrial partner.

In a project at CRPP related to the IMT project, the area deposition of microcrystalline silicon and **enhancement of the deposition rate** [4] were further pursued. The reactor area of 35 x 45 cm permits those properties of VHF deposition that are particularly relevant to industrial practice to be investigated. This involves the requirements of the high-frequency amplifier and the corresponding HF matching, as well as the uniformity of voltage and gas distribution over the entire area. Extensive and (partly) new plasma diagnostic methods are being successfully deployed for this purpose.

At PSI, the applicability of processing methods developed in earlier projects for thin, high efficiency, silicon cells to **silicon** [5] was investigated. Silicon is manufactured by Evergreen Solar (USA) and is a further possible candidate for the production of low-cost solar cells. Hydrogen passivation was carried out on 200 µm thick polycrystalline string ribbon silicon. In the resulting process, an efficiency of 14% was achieved. By combination with gettering of impurities, an efficiency of 14.6% was achieved. In the EU **CRYSTAL** project [6], work is continuing on thin crystalline silicon cells. The primary activities at PSI are modeling the grid structure to improve light absorption, analysis of TCO layers (ZnO) and deposition of polycrystalline silicon on glass and quartz. For the latter, molecular-beam epitaxy (MBE) and plasma-enhanced vapor phase epitaxy (PEVPE) are employed.

In the EU LACTEL and WIDE GAP CPV projects at the ETHZ in Zurich [7+8], solar cells based on compound semiconductors are being studied. In the **LACTEL** project, process relevant aspects of electrodeposition of CdTe cells, particularly for metal grids using the silk-screen printing process, film growth using $CdCl_2$ treatment and cells on various TCO materials (ITO, FTO, ZnO) are the main objects of interest. Whereas satisfactory results were achieved on ITO and FTO, ZnO proved unsatisfactory. In the **WIDE GAP CPV** project, fundamental research on $CuGa_xSe_y$ films is being performed. Of primary concern are the structural and optoelectronic properties that result from suitable surface treatment. Two further EU projects on this subject were started at ETHZ towards the end of the report period.

Dye sensitized, **nanocrystalline, solar cells** (Grätzel cells) form a further, much discussed, material variant, that are being pursued under two existing and one new EU project. In the EPFL [9] project, **fundamental work** on the development of this concept, and particularly the introduction of solid electrolytes and new dyes, is being carried out. At Leclanché, the EU **Indoor Dye PV** project [10] is mainly concerned with new applications for interior use, and here, the possible replacement of batteries is being considered. The fundamental question of the **long-term stability** of this cell is being pursued in a new project at Solaronix.

Under the aegis of the National Research Program on Nano Sciences at the University of Bern, the objective of **artificial photosynthesis** [11] is being followed. This involves fundamental photoelectrochemical research to simulate natural processes. It proved possible to fill zeolite mini-cylinders having a continuous capillary system with chains of coupled dye molecules. The transmission of light made possible in this way is vary rapid and may in principle be used for devising novel solar cells.

Taken as a whole, international cooperation in the field of solar cells was heavily intensified during the report period. Owing to involvement of the industrial partners in these projects, questions of implementation, as well as those relevant to industry, are becoming increasingly prominent. At the same time, the principles underlying possible, long-term options for future cell technologies are being established. Representing as they do a common denominator of all thin film technologies, the importance of transparent oxide films (TCO) with their increased light trapping is now emerging.

SOLAR MODULES AND BUILDING INTEGRATION

The ALUCOSOL® project to develop a **facade integrated photovoltaics system** [12] that was carried out by Alusuisse Technology & Management (ATM) in cooperation with Swiss partners was completed within the report period. As the main difficulty proved to be the availability of a suitable semi finished product in the form of amorphous silicon cells, the initial objective to produce a prototype was discarded in favor of studying prior stages of the process. The deposition of amorphous cells, TCO and metallic films on aluminum was studied. A novel contact design using laser-pierced holes in the module, through which the conductors pass, was realized for the first time and found to be practically feasible.

New **flat roof** systems [13] were further developed at the LESO laboratory of the EPFL. The Solbac® and Sofrel® products were improved mechanically, geometrically and with respect to the fixture device. The Solgreen® system for grass roofs was optimized for some initial P+D applications.

In the **DEMOSITE** project [14], some of the older integrated photovoltaics systems were removed and replaced by more modern systems. A total of 20 different flat roofs, sloping roofs and facades can now be compared. The information and communication procedures within the project, which is part of the IEA PVPS program (Task 7), were revised for the purpose.

Further building-integration photovoltaics projects were realized under P+D projects (see below).

SYSTEMS TECHNOLOGY

Tests continued at the TISO laboratory of SUPSI **on commercial PV modules** [15] under realistic conditions. Continuous measurements including those standardized at Ispra are presently being carried out on 11 modules. Here, larger (or larger numbers of negative) deviations (e.g. > 10%) from the electrical specification occurred than had previously been the case. It was also confirmed that degradation of power and energy outputs occurs for certain modules on a monosilicon and polysilicon basis. The reasons for these observations are not yet clear and must be kept in mind. Further, TISO has published an extensive database [80] with specifications of all the principal PV modules. Long-period information is being garnered from the two PV installations (10 kWp m-Si, 4 kWp a-Si) at the laboratory.

Supplementary measurements of this type are being carried out at the Bernese College of Technology in St. Imier in cooperation with the Mont Soleil Association, where **prototype-stage products** are also being studied [16]. In this case, the measurements mainly concern the energy generated. As a new feature, several power converter configurations are to be tested and compared with the experience gained from the 560 kWp power station. In 1998, the power station produced 602'000 KWh with an average performance of PR= 78 %.

Comprehensive investigations on the **energy production of PV modules** [17] are also being performed at PSI. Thanks to the experimental facility and the analytical methods available, prognoses on **part-load** performance may be made, and this is particularly important for the design of installations for the purposes of contracting and solar stock 'exchanges'. Quantitative measurements are also being performed on prototype hybrid (thermal PV) modules.

The Bernese College of Technology in Burgdorf is continuing **testing of PV power inverters** [18]. In addition to grid-coupled inverters, comprehensive testing of island inverters is now possible, the most important parameters being HF emission, conversion efficiency, power factor, overload behavior and harmonics. For EMV measurements, a facility for DC grid simulation was built. The measurements on grid-coupled inverters are being supplemented by further parameters (self-starting test, no-load tripping, MPT efficiency), and long-term reliability further pursued. With the help of PSEL, **long-term information on PV plant** [19] is being collected based on operating data from 36 installations. In addition to information on the inverters, visible deterioration of modules (soiling, delamination) and cabling were recorded. The 1 kWp installation at the Jungfraujoch continued to perform excellently, producing 1500 kWh/kWp·a at PR > 86%. In the new EU **PV-EMI** [20] project, electromagnetic perturbations caused by PV installations, as well as test methods and regulations for these, are being studied with the objective of establishing European standards. Particular attention will also be paid to protection against interference from rapid electrical transients (e.g. caused by lightning).

A further EU project, the SCMIC, for the development of a **single-cell inverter** [21] was largely completed at the ETHZ in collaboration with Enecolo and Alussuisse. A new switching circuit was developed that accomplishes the critical DC-DC conversion, achieving conversion efficiencies of up to 97%.

Under the aegis of various EU projects [22-24], Alpha Real pursued system-relevant questions on the **reliability of systems and AC modules** and on simple devices for **testing PV plant**. The **reliability of safety circuits** to prevent islanding is to be investigated in a PSEL project [25].

On the whole, it can be said that as far as systems technology is concerned, and despite the advanced development status of photovoltaics, further improvements with regard to reliability, simplification, safety and standardization of products and systems are possible and necessary. Switzerland's extensive implementation experience is exerting a very positive influence, leading to new and promising solutions and increased international cooperation.

OTHER PROJECTS AND STUDIES

The long-term **environmental compatibility** [26] of photovoltaics was analyzed by Alpha Real using a dynamic assessment method in which complex energy and material flows were modeled. It was shown that from this point of view, photovoltaics represents a worthwhile investment of energy and raw materials, since the system returns several times the energy expended in its production, and no undesired material flows occur.

The combination of photovoltaics with other energy technologies, and particularly with thermal solar energy, is of increasing interest. In collaboration with Enecolo and Schweizer, the LESO laboratory of the EPFL is working on a new **hybrid collector** [27] that exploits the thermal advantages of amorphous silicon. Following on from an initial phase in which possible designs were developed, the current phase will look at specific contributory aspects that had earlier proved critical. For this, both the absorption of amorphous silicon and its stability at temperatures over 100°C were tested. Initial results indicate that in most cases the critical absorption value of 80% is not only achieved but significantly exceeded.

PSI is working on thermophotovoltaics (TPV) within the ambit of a FOGA project [39]. In this, a small size, operational, TPV generator of 1.4 kW thermal capacity was developed. Work concentrated on the development and modeling of a special emitter material based on ceramic textiles made from oxides of various rare-earth elements. The generator was driven by commercial silicon cells and coupled to the grid, achieving a conversion efficiency (thermal-DC) of 1.1%. The next stage will be carried out on a test rig of 20 kW_{th} in cooperation with HOVAL.

The **potential area** [28] available for photovoltaics on buildings was investigated in detail by NET within the framework of two separate case studies, one in an urban environment (EWZ, Zurich City) and the other in a country region (Canton of Freiburg) based on a newly developed method. This takes account both of the characteristics of the building materials and of the architectural suitability for solar applications. The results are classified according to the potential energy yield of the various areas and according to building type (function, roof design, size, age, etc.).

Under an EU project, TNC is studying the **potential of photovoltaics on noise protection walls** [29] along roads and railroads in Europe.

In two further EU projects, new instruments for solar energy utilization are being developed that employ remote satellite reconnaissance. In the **PVSAT** project [30], Enecolo is studying the feasibility of obtaining local radiation data from satellite photographs in order to simulate anticipated energy yields from PV installations. In the **SATELLIGHT** project [31], the University of Geneva is working on a radiation atlas on Internet to provide the time variations of radiation and illumination intensity and direction. This server should come into operation on 1 April 1999.

INTERNATIONAL COORDINATION WITHIN IEA

The participation in the PVPS photovoltaics program of the IEA, both at the project level of the various tasks and at executive committee level, was continued over the report period, with Switzerland playing an important part in program management and monitoring. In 1998, the program was subjected to an internal and external evaluation, leading in the main to a positive assessment. A few inadequacies were also, identified.

The **information work** [32] within Task 1 has now been entrusted to Nova Energie. Publications on the subjects of buy back rates, environmental aspects, research strategies and PV in a competitive market were completed and distributed [81-84] during the report period. A national report on photovoltaics in Switzerland for the period up to 1997 was prepared under Task 1 [85].

TNC is covering **operating experience** [33] work within Task 2. The database now contains 263 installations in 8 countries. The first comparative analyses were completed for both grid-coupled and island installations. A monitoring handbook is to be completed in the near future [86].

In Task 3, concerned with **island installations** [34], Switzerland is represented by Atlantis. Publications on the subjects of "lessons learned" with "showcase" projects, charge controllers and batteries were prepared [87-89]. A collection of slides of existing island installations in IEA countries on CD-ROM is also in the process of completion [90].

Enecolo is working on Task 5 that deals with technical questions of **grid coupling** [36]. The results of this international work will find their application in the relevant regulations and in the manufacture of inverters. In Task 5, Switzerland will be represented by EWZ from 1999 onwards.

Enecolo is also engaged in Task 7 concerning the **integration of photovoltaics in the built environment** [36]. This extensive Task covers all the important factors in PV integration (architectural design,

systems technology, non-technical barriers, demonstration). The DEMOSITE project (see above) at EPFL is also included in Task 7. Although this Task only started two years ago, initial positive results are now available. A collection of slides showing projects realized has been prepared [91].

Minder Energy Consulting participated in the preparatory work on a new IEA PVPS Task 8 project on the **feasibility of very large PV power stations** [37] in desert areas.

3. National cooperation

At national level, cooperation is now a standing tradition that involves institutes of technology and research (ETH, Universities, Colleges of Technology, PSI), private industry (industry, consulting enterprises) and the electricity industry. Increasing interest in the technology is forthcoming from these and further parties concerned (finance, politics, media). A national photovoltaics conference organized in cooperation with VSE, Swissolar, and the Mont Soleil Association provided an opportunity for information exchange during the report period. At program level, excellent cooperation exists with numerous federal offices (e.g. BBW, BBT, AfB, BAWI, etc.) and with the cantons, and this has benefited coordination within the program and helped to promote it.

4. International cooperation

International cooperation was established for all sectors of the photovoltaics program and was significantly intensified during the report period. Thanks to promotion from the Federal Office for Education and Science (BBW), the Swiss photovoltaics community is successfully participating in international EU research programs. In 1998, a total of 20 photovoltaics projects were in progress within the Joule-Thermie program, of which 16 concerned the Joule program (research) and 4 the Thermie program (demonstration). This amounts to 36% of total Swiss participation in the Joule Thermie program, which comprises 56 projects, or 44% of the dedicated funds within the program. As far as Switzerland is concerned, photovoltaics represents the largest energy technology sector in this program - a clear indication of the high quality of research in this field. Additional direct Swiss participation in photovoltaics under the Altener program (activities in close proximity to the market) began at the end 1998. Parallel to projects in the EU program, cooperation within the IEA PVPS program was also successfully continued (see above).

5. P+D projects

In 1998, 13 new projects were begun in the P+D program. The main focus is on 8 projects that are concerned with **PV integration** in buildings and noise protection installations. In these, equal weight is given to the development of PV system components for building integration and to realization of PV P+D installations. The remaining new projects are spread over the areas of studies/tools and measurement campaigns. In 1998, in connection with PV tools, the question of quality assurance in building and operation of PV plant was again taken up. Based on past and anticipated growth rates in photovoltaics, it is expected that the quality assurance sector will increase in importance as the number of PV installations expands.

A total of 39 photovoltaics P+D projects were in progress during the report period. As in the previous year, the main emphasis is on:

- Testing of new system components in the sector of **PV integration** in buildings and noise barriers
- Performance control of existing P+D installations based on detailed **measurement campaigns**
- **Development** of new system components for PV integration

The component development sector is the only sector to be more heavily represented than in 1997. It should be mentioned that for many projects in the PV building integration sector, the question of cost effectiveness, with its relevance to future dissemination of photovoltaics, is an important theme.

The following **P+D projects began in 1998:**

Installations

- 10 kWp 'SolGreen' installation integrated in a grass roof (newly developed structure for grass roofs, flat roof integration; management: ars solaris hächler) [50]
- 3,1 kWp roof integration with Sunslates (autonomous installation, building integration; management: Atlantis Solar Systeme AG) [72]
- AC noise protection installation in Amsterdam (combination of AC modules and noise protection; management of Swiss contribution: TNC Consulting) [53]
- 151 small grid-connected PV stations (small installations with string inverters, total peak power : 200kWp - 30 kWp of which in Switzerland; management of Swiss Contribution : Phebus Suisse) [54]

Component development

- Photovoltaics combined with external insulating elements (building integration; management: ZAGSOLAR) [73]
- SOLight module supports ("flat roof integration"; management: Energiebüro) [74]
- SOLRIF: Frame for standard modules for roof integration (roof integration; management: Enecolo) [75]
- Multifunctional building envelopes – PV hybrid roof (roof integration, PV air collector; management: S. Kropf) [76]

Measurement campaigns

- 1 MW "Solar Chain" at NOK (normalized data for 1997 - 2001; management: NOK) [64]
- 180 kWp installations at UBS in Suglio (comparison of various plant designs; management; Enecolo AG) [65]

Studies – tools – various other projects

- Feasibility study for implementation of the micromorphous cell in large area modules (management: Zühlke Engineering AG) [70]
- GRS Guaranteed Results for PV Systems (EU Altener Project, quality assurance; management Swiss contribution: Energiebüro) [77]
- PVSYST V3; ergonomics and functionality (PVSYST 2.0 follow-on project; management: EPFL) [71]

Depending on project status, activities were very varied. These ranged from detailed design, building and commissioning of installations and measurement systems, data acquisition and evaluation, and preparation of studies and tools in the PV field. Generally speaking, all projects are progressing satisfactorily towards achievement of the project objectives. It is however noticeable that a considerable number of projects have suffered substantial to massive delays. The main causes of delays in 1998 were problems with measured data acquisition. Delays also resulted from planning approval procedures, partly owing to complaints being lodged. In view of the frequent delays connected with measured data acquisition, the questions arise as to the extent to which standardized systems could be employed in the field of measurement and analyses, and whether these would enable an improvement in the present partially unsatisfactory situation to be achieved.

Current projects comprise:

Installations

- Hybrid 7 kWp PV installation in Domdidier (hybrid electricity/hot air installation, building integration; management: GEIMESA) [42]
- 6,4 kWp installation integrated in the roof of the Institute of Microtechnology in Neuchâtel (PV elements with amorphous cells, building integration; management: IMT) [44]
- 10,8 kWp installation with PV AC modules integrated in the roof of a farmhouse in Iffwil (PV elements with integrated inverters, hybrid electricity/hot air installation, building integration, management: Atlantis Energie) [46]
- 1 kWp flat roof installation with SCIBEL modules, designed in concrete (flat roof integration with new photovoltaics elements, horizontal orientation; management: Enecolo) [48]

- 11,8 kWp installation with AC modules, UBS Zurich (PV elements with integrated inverters, hot-spot protection circuit, "flat roof integration"; management: Alpha Real) [49]
- Three 10 kWp photovoltaics noise barrier installations (combined photovoltaics/noise barrier, 3 prototype installations; management: TNC Consulting) [51]
- Héliotram, 800 kWp PV installations in Lausanne/Geneva with DC direct injection into the tram supply grid (management: Sunwatt Bio Energie SA) [52]
- Héliotrope, 3 x 2 kWp PV installations in Le Locle (direct comparison of identical installations (building integrated, optional orientation, tracked); management: EICN, Le Locle) [55]

Component development

- 2 kWp installation with modular inverters (installation with newly developed AC PV modules; management: Bienne Technical College) [40]
- Development of a three-phase modular inverter (management: Alpha Real) [41]

Measurement campaigns

- PV installation at CMZ Stadtmühle Zurich, measurements (management: TNC Consulting) [57]
- Visualization and evaluation of the PV installation on the Rothorn; (management: HTA Chur) [63]
- Measurement campaign, maintenance and operation of the Mark I installation at Domat/Ems (management: TNC Consulting) [60]
- Measurement campaign, maintenance and operation of the Mark II installation in Riazzino (management: TNC Consulting) [59]
- Measurement campaign, PV installation Mark III in Giebenach (management: TNC Consulting) [61]

Studies – tools – various other projects

- 450 kW facade power station in Wittigkofen, Bern; management: Atlantis Energie Bern [66]
- OptiPV: study on optimum system design for cost-effective PV installations (management: Muntwyler AG) [67]
- Standards for PV systems (management: Alpha Real) [69]

In the report period for 1998, the following P+D projects were successfully completed:

- Hybrid roof integration in Erlach [43]
- 13,6 kWp roof integration at Rigi Kulm [45]
- Photovoltaics installation integrated in railway canopies (management: LESO - EPFL) [62]
- 9 kWp flat roof installation using Solbac at LESO [78]
- PV installation at the expressway service depot at Sierre [79]
- Measurement program for PV installation on the Adligenswil school building [56]
- Realization of a mobile measurement system [58]
- PV monitor and measurement data for various PV installations [68]

A number of P+D installations for testing PV system components for building integration are already in preparation for 1999. Further development-related projects are also planned.

6. Implementation

Increasing interest in wider circles, coupled with intensified industrial cooperation, has lead to continuity of implementation. The federal subsidies granted for installations, and for the 'solar electricity exchanges' that were introduced at many places, provided an important incentive and had a favorable influence on demand, notwithstanding the fact that the necessary continuity of promotion and availability of solar electricity in the country as a whole are still unsatisfactory. In Switzerland, some 12 MWp of photovoltaics capacity were installed at the end of 1998, of which 75% is attributable to grid-coupled installations. From experience gained over an extended period of time in connection with products and systems, as well as

with measurements, important tendencies have emerged that will prove highly significant for future development and quality assurance work, particularly in view of the current expansion rate of 30-40% per annum in the worldwide module market. Documentation intended as a basis for determining future action is now in preparation with a view to ensuring implementation over the entire wealth-creation chain including production of solar cells.

7. Assessment for 1998 / perspectives for 1999

The photovoltaics program for 1998 may be judged to have been a success despite the continuing limitations in of funding. Three important factors have contributed to this: successful participation in international EU programs; increasing interest on the part of industry, and market developments as a result of a combination of promotion measures and 'solar electricity exchanges'. In view of international market developments and the substantial promotion programs existing in some countries, and particularly in Netherlands and Germany, the question of adequate funding for development and implementation in the form of industrial products assumes ever greater importance. Only in this way can Switzerland's leading role in photovoltaics research, development and implementation, built up over many years, be successfully maintained. Securing adequate funding is not solely the task of the authorities, but must be achieved on the basis of mutual cooperation with industry and the electricity companies.

The 2nd PV World Conference and 15th European PV Conference took place in Vienna in 1998, and this again broke all records set up by previous events [92]. Also, a national PV conference took place in Switzerland, providing an opportunity for a review of the situation and an exchange of information [93].

The objective in 1999 will therefore be to maintain continuity and wherever possible to initiate activities relevant to implementation, to secure more flexible project promotion in keeping with the requirements of modern technology, and to take positive steps towards further implementation. As in 1998, the national PV conference in autumn will again provide an opportunity to discuss the status and future prospects of photovoltaics, and to exchange experience and information. In the same period, a further major international conference under the aegis of the IEA will take place, and here, opportunities for photovoltaics in a competitively oriented market will be considered at the executive level.

8. List of Current Research Projects in 1998

[1] A. Shah, IMT, Université de Neuchâtel: **Mikromorphous solar cell.** (AR) / ENET 9719431, http://www-micromorph.unine.ch

[2] A. Shah, IMT, Université de Neuchâtel: **NEST (New enhanced silicon thin-film solar cells).** (AR) / ENET 9799901, http://www-micromorph.unine.ch

[3] A. Shah, IMT, Université de Neuchâtel: **Amorphous silicon solar cells on plastic films.** (AR), http://www-micromorph.unine.ch

[4] Ch. Hollenstein, CRPP / EPF - Lausanne: **Large-area deposition of amourphous, photovoltaic silicon.** (AR) / ENET 9400051

[5] M. Real, Alpha Real, Zürich, J. Gobrecht, PSI, Villigen: **Swiss high efficient cristalline solar cell project, using PSI process for sheet ribbon Si material.** (AR) / ENET 9823643

[6] D. Grützmacher, PSI, Villigen: **CRYSTAL: Crystalline silicon thin film solar cells on low temperature substrates.** (AR), http://www.psi.ch/LMN

[7] H. Zogg, IQE, ETH - Zürich: **LACTEL (Large Area cadmium telluride electrodeposition for thin-film solar cells).** (AR) / ENET 9799903

[8] H. Zogg, IQE, ETH - Zürich: **WIDE GAP CPV (Wide gap chalcopyrites for advanced PV devices).** (AR) / ENET 9799902

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11. Further information

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12. Abbreviations used

Funding institutions	
AfB	Amt für Bundesbauten
FOGA	Forschungs-, Entwicklungs- und Förderfonds der schweizerischen Gasindustrie
P+D	Pilot and Demonstration
PSEL	Projekt- und Studienfonds der Elektrizitätswirtschaft
Public institutions	
ATAL	Amt für technische Anlagen und Lufthygiene des Kantons Zürich
BAWI	Bundesamt für Aussenwirtschaft
BBT	Bundesamt für Berufsbildung und Technologie
BBW	Bundesamt für Bildung und Wissenschaft
CRPP	Centre de Recherche en Physique des Plasmas Centre for Research in Plasma Physics EPFL
EAWAG	Eidgenössische Anstalt für Wasserversorgung, Abwasserreinigung und Gewässerschutz
EICN	Ecole d'Ingénieurs du Canton de Neuchâtel
EISI	Ecole d'Ingénieurs de Saint-Imier
EMPA	Eidgenössische Materialprüfungs- und Forschungsanstalt Swiss Federal Laboratories for Material testing and Research
EPFL	Ecole Polytechnique Fédérale Lausanne Swiss Federal Institute of Technology Lausanne
ETHZ	Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich
EWZ	Elektrizitätswerk der Stadt Zürich
ICP	Institut de Chimie Physique EPFL - Institute for Physical Chemistry EPFL
IMT	Institut de Microtechnique Universität Neuchâtel Institute of Microtechnology, University of Neuchâtel
IQE	Institut für Quantenelektronik ETHZ Institute of Quantum Electronics ETHZ
LESO	Laboratoire d'Energie Solaire EPFL - Solar Energy Laboratory EPFL
PSI	Paul Scherrer Institut
SI Lausanne	Services Industriels Lausanne
SUPSI	Scuola universitaria professionale della Swizzera Italiana
Organisations	
EU	European Union
IEA	International Energy Agency
PVPS	Photovoltaic Power Systems Implementing Agreement (IEA)
GAP	Global Approval Programme
Private institutions and companies	
EWE	Elektrowatt Engineering
NET	Nowak Energie & Technologie
NOK	Nordostschweizerische Kraftwerke

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ANNUAL REPORT 1998

Project Number: 19431
Contract Number: 59014

ENET Number:

Project Title: Mikromorphe Solarzellen

Abstract: The present 3-year project (1997-99) is concerned with the optimisation of microcrystalline/amorphous tandem cells ("micromorph" cells) with the goal of attaining a stable efficiency of 12% . During 1998 the following main results were obtained:

• establishment of a correlation between transport measurements (quality parameter $\mu^0\tau^0$) for microcrystalline silicon intrinsic layers and resulting solar cell efficiencies; study of the microstructure of such layers by TEM (transmission electron microscopy).

• intrinsic microcrystalline layers with low defect absorption and rates upto 25 Å/s, through a combination of hot wire deposition and VHF plasma deposition.

• increase of the open circuit voltage V_{oc} for single-junction microcrystalline solar cells to 530 mV with an efficiency of 8.5 % (deposited at 3.5 Å/s).

• improved transparent conductive oxide layers (ZnO) for front and back contacts of p-i-n and n-i-p solar cells; first amorphous silicon p-i-n cells on ZnO fabricated at IMT with V_{oc} of 880 mV and high FF of 72%.

• experimental study of the temperature coefficient of micromorph tandem cells and demonstration that the temperature coefficient can be here similarly low as for amorphous silicon cells.

Duration of the Project: 1.1.1997 - 31.12.1999

Responsible for the project: Prof. Dr. A. Shah

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ANNUAL REPORT 1998

Project Number: OFES 96.0340
Contract Number: JOR3-CT97-0145
ENET Number:

Project Title: NEST (New and Enhanced Silicon Thin-film solar cells)

Abstract: The present 2-year project (June 97- May 99) is concerned with the development and optimization of microcrystalline / amorphous silicon tandem cells ("micromorph" cells) in the so-called "inverted" configuration (e.g. substrate-TCO-n-i-p-n-i-p-TCO). Thereby, our laboratory (IMT) concentrates on the technology for the microcrystalline bottom cell, wheras the Forschungszentrum Jülich provides optimized amorphous top cells as well as TCO layers (ZnO) for both the top and bottom contacts. The Academy of Science in Prague is, in close collaboration with IMT, in charge of the optical characterization of the microcrystalline silicon layers; other laboratories participating in the project (Palaiseau in France and Patras in Greece) provide plasma and interface characterization and diagnostics facilities.
During 1998, the main activities were centered on the following topics:

- Optimisation of inverted microcrystalline cells deposited at a relatively high deposition rate of 6 Å/S. Efficiencies in excess of 6% have been obtained with a cell thickness of only 2 μm.
- Combination of the TCO and amorphous top cell technologies from Jülich with the microcrystalline technology of IMT, so as to produce complete inverted micromorph cells. Initial efficiencies above 10% have been achieved.
- Investigation of the light-scattering effect due to the natural roughness of microcrystalline silicon and of its potential for current enhancement in a solar cell.

Duration of the Project: 24 months, 1.6.97 - 30.5.99

Responsible for the project: Prof. A. Shah

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ANNUAL REPORT 1998

Project Number: PSEL No.88 **ENET Number:** --

Project Title: **Amorphous silicon solar cells on plastic films**

Abstract:

The aim of this project is to develop and to optimize the fabrication of amorphous silicon (a-Si:H) solar cells on plastic film substrates, as well as to evaluate the integration of such solar cells in PV metal-facades.

Results obtained in 1998:

- Series connection of amorphous silicon single cells on plastic substrates by 'post-structuration' could be implemented. Thereby, three different laser cuts, an insulating paste and silver 'bridges' were applied.
- An apparatus to detect and localise pinholes in finished modules has been built. Zones with a high probability of shunts could be identified.
- Modules with a power of 1/4 of a Watt were fabricated on 8cm x 8cm polyimide substrates. Active area initial efficiency is 7,3% (V_{OC}: 3.3 V, I_{SC}: 122 mA, FF: 62%, area: 36.9 cm^2); total area efficiency is 5.8% (total area: 46 cm^2).
- The ecological and, to a certain degree also, the economical potential of the use of modules without glass for building facade integration have been studied by our industrial partner E. Schweizer AG, Hedingen.
- Facade elements were fabricated on a laboratory scale, by laminating flexible modules (produced by IMT): this permitted our partner to study critical process steps like the bending of the metal sheets.

Duration of the project: 01.04.1996 – 31.03.1999

Responsible for the project: Prof. A. Shah

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ANNUAL REPORT 1998

Project Number : 2755
Contract Number : 63180

ENET Number : 9400051

Project Title : Large-area deposition of amorphous, photovoltaic silicon

Abstract:

The project aims to optimise micro-crystalline silicon deposition using Very High Frequency (VHF) plasma in large area reactors for production of solar cell panels. Micro-crystalline silicon deposition necessitates high power density, and various technical difficulties associated with kilowatt RF power had to be surmounted: first, a VHF optimum frequency of 70 MHz was determined, then an economic 1 kW generator was designed for this frequency along with a suitable impedance matching circuit and a custom-built vacuum feedthrough. This system will allow plasma operation with complete silane depletion, previously shown to be favourable for micro-crystalline silicon deposition.

At the chosen 70 MHz frequency, using a 35 cm x 45 cm substrate and the optimal electrode configuration, a film thickness uniformity of better than 5 % is obtained. Furthermore, a solution of the gas composition uniformity problem confirms that the existing gas showerhead and pumping port design is ideal.

The range of diagnostics now includes cavity ringdown and infrared reflection absorption spectroscopy, and a silicon tetrafluoride delivery system is ready for investigation of special gas mixtures with silane. A selective etch rate has been demonstrated for amorphous, as compared to micro-crystalline, silicon. Layer-by-layer deposition experiments also show a quasi-epitaxial enhanced growth for silicon on a micro-crystalline 'seeded' substrate. A plasma/surface model has been formulated to aid interpretation of experimental observations, and shows good agreement with depletion measurements. Finally, provided that the material quality can be improved, the novel High Current DC Arc technique also shows great promise for extremely high deposition rates well into the range required by industry.

Duration of the Project : 1.1.1997 - 31.12.1999

Responsible for the project : Prof. F. Troyon
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ANNUAL REPORT 1998

Project Number: 23643
Contract Number: 63179

ENET Number:

Project Title: Swiss High Efficient Crystalline Solar Cells On Sheet Ribbon Silicon Material

Abstract:
The possibility of improving the quality of Evergreen's 200μm thick p-type polycystalline silicon string ribbon (SR) using gettering and passivation schemes, is studied in this work. First, defects passivation is carried out using thin layers (~15nm) of SiO_2, H rf plasma and PECVD Si_3N_4. Solar cells are fabricated, using 1 Ω.cm resistivity SR wafers, following a simple process with uniform front emitter (n^+) at 875°C for 45 min, thermal dry SiO_2 at 870°C, back side H&Si_3N_4, photolithography, evaporated contacts, and antireflection coating of ZnS/MgF_2. Using this process a cell efficiency of **14%** (open circuit voltage of **577 mV**) is achieved on a 4 cm^2 area. Second, the impurity gettering is implemented by evaporation of 2μm of Al on the back of the wafers before the formation of the n^+ emitter at 875°C. Note, the rest of the cell's fabrication steps are exactly the same as described above. A solar cell efficiency of **14.6%** (open circuit voltage of **581 mV**) is realised on a 4 cm^2 area using a 3 Ω.cm resistivity SR wafers. It is worth mentioning here that, the optimum resistivity for polycrystalline silicon, found by most solar cell labs, is around 1 Ω.cm. Thus, if SR wafers with 1 Ω.cm were used rather than 3 Ω.cm, in the Al-gettering process, higher open circuit voltage will be obtained and an efficiency of 15% would have been reached.
The minority carrier diffusion length (L_n) measured with the surface photovoltage technique confirmed the cell's I-V data. A net improvement of 70% in L_n is obtained only due to H passivation, while L_n improved by 100% when Al gettering is combined with passivation.

Duration of the Project: Feb. 1, 1998 to Jan. 31, 1999

Responsible for the project: M. Real, alpha real AG, Zürich

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ANNUAL REPORT 1998

Project Number : **BBW 96.0266** **ENET Number :**
Contract Number :

Project Title : Crystalline Silicon Thin Film Solar Cells on Low Temperature Substrates **"Crystal"**

Abstract :

In 1998 the work of PSI within this project was focused on three topics :
1) Refinement of the calculation of rear surface gratings for solar cells
2) Analysis of thin conducting oxide films, in particular ZnO films
3) Deposition of poly-crystalline Si on glass and SiO_2 substrates.

The modelling of light trapping structures revealed, that efficient light trapping is possible, even for a cell thickness below 5µm 85-90 % of the light can be captured in the cell by using specialised tapered gratings at the rear surface of the solar cell. Furthermore, it is shown that ZnO films grown either by sputtering techniques or by chemical vapour deposition (CVD) in specific growth regimes exhibit a textured surface, which also appears to be useful for light trapping aside from there main function as a contact layer for the electrical contact of the solar cell. For the deposition of the crystalline Si films a newly designed plasma enhanced CVD was brought to operation. Polycrystalline Si films with a columnar structure were prepared at growth temperatures as low as 400°C on glass and SiO_2 substrates.

Duration of the Project : 1997 - 1999

Responsible for the project : D. Grützmacher

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ANNUAL REPORT 1998

Project Number: BBW Nr. 96.0256
ENET Number:
Contract Number: EU Nr. JOR3-CT97-0150

Project Title: Large Area Cadmium Telluride Electrodeposition For Thin Film Solar Cells (LACTEL)

Abstract:

Industrial production of large area CdTe/CdS modules requires the growth of uniform CdTe layers with very high deposition rates. The CdTe/CdS solar cells by electrodeposition process (industrial process of BP Solar) are made on tin oxide (FTO) coated glass substrates. Deposition of acid and heat resistant metal grids on FTO/glass is required for a "specific application". Metal lines (grids) have been screen printed using a variety of metallic pastes, including novel pastes based on the sol-gel processes. The properties of metal lines have been characterized and their thermal and chemical stabilities have been investigated.

CdTe/CdS solar cells have been fabricated by a vacuum evaporation process in which all the layers including $CdCl_2$ and Cu/Au are grown by evaporation methods. In order to evaluate the merits of different transparent conducting oxides ITO, FTO and ZnO coated soda lime glass substrates were used. ZnO has good opto-electronic properties as a transparent electrode but is found unsuitable for the CdTe/CdS superstrate solar cells because ZnO reacts with CdS and the stack absorbers more photons compared to CdS/ITO and CdS/FTO in the visible range. The "$CdCl_2$ treatment" increases the grain size and affects the preferred orientation of CdTe layers. Solar cell properties on ITO and FTO are sensitive to the amount of $CdCl_2$. Solar cell efficiencies on ZnO are low (about 2.5%) but high efficiencies in the range of 10 to 11.4% are obtained on ITO and FTO coated soda lime glass substrates.

Duration of the project: May 1997-April 2000

Responsible for the project: PD Dr. H. Zogg / Dr. A.N. Tiwari

Reporting on the project: A.N. Tiwari, F. -J. Haug, A. Romeo, H. Zogg

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ANNUAL REPORT 1998

Project Number: BBW Nr. 96.0254
ENET Number:
Contract Number: EU Nr. JOR3-CT97-0135

Project Title: Wide gap chalcopyrites for advanced photovoltaic devices (WIDE GAP CPV)

Abstract:

This project is about growth of epitaxial (single crystal thin films) and polycrystalline layers of $CuGa_xSe_y$ to understand the structural and optoelectronic properties of compounds with different stoichiometry for solar cells. $CuGaSe_2$ (E_g=1.68 eV) is an interesting material for the advanced photovoltaic devices, such as tandem solar cells in conjunction with $Cu(In,Ga)Se_2$. At IQE-ETHZ, we have established most of the deposition processes such as growth of high quality polycrystalline $Cu(InGa)Se_2$ absorber layers by vacuum evaporation, chemical bath deposition of CdS buffer layer, and growth of highly transparent ($T_{visible}$ >85%) and conducting (sheet resistance < 10 Ω/□) ZnO:Al layers by RF magnetron sputtering. We, at IQE-ETH have reproducibly made polycrystalline $ZnO/CdS/Cu(In,Ga)Se_2/Mo$/glass solar cells in the efficiency range of 13 to 14% (also measured at IPE and ZSW Stuttgart).

Heteroepitaxial $CuGa_xSe_y$ layers on Si and GaAs substrates have been grown and crack-free layers with good crystal quality (RBS $\chi_{min.}$ ~12% and XRD rocking curve width of 250 arcs) have been obtained. The microstructural properties of the epitaxial layers and substrates have been investigated with high resolution TEM. Electron microscopy of the $CdS/CuGaSe_2$ solar cells made with Cu-rich absorber layers have shown the Cu_xSe precipitates in the $CuGaSe_2$ matrix. These precipitates may limit the photovoltaic performance of solar cells made with Cu-rich $CuGaSe_2$ absorber layers.

Duration of the project: May 1997-April 2000

Responsible for the project: PD Dr. H. Zogg / Dr. A.N. Tiwari

Reporting on the project: Dr. A.N. Tiwari, F. -J. Haug, M. Krejci, Dr. H. Zogg

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ANNUAL REPORT 1998

Project Number : **BBW 95.0703** **ENET Number :**
Contract Number :

Project Title : Nanocrystalline photovoltaic cells

Abstract:

Research and development of dye-sensitised nanocrystalline photo-electrochemical devices for conversion of solar energy is ongoing in the Laboratory for Photonics and Interfaces (LPI) of the Institute of Physical Chemistry, EPFL. The concept, for which patent rights are vested in EPFL, has been communicated to industrial licensees for product developement. There is increasing interest from outside Europe, one of the licensees being Australia-based, and a new licensing agreement being signed with a Japanese organisation. Research on a related concept, sensitised nanocrystalline heterojunctions, is also reported.

Duration of the Project: 1.1.96 - 31.12.98

Responsable for the project: Prof. M. Grätzel

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ANNUAL REPORT 1998

Project Number: BBW 96.0431-1 **ENET Number:**
Contract Number:

Project Title: **Indoor dye PV's - Progress and evaluation of the experimental work at Leclanché S.A., in collaboration with European partners of the JOULE III programme**

Abstract:

In close collaboration between Leclanché S.A., the Swiss Polytechnical Federal Institute, Lausanne, the Energy Center of the Netherlands, Petten, DSM Netherlands, Geleen, the University of Uppsala, Pricer AB Uppsala, the Swedish Institute for Production Engineering and Research, Mölndal and Industria Plastica Monregalese, Mondoví, a research programme on dye sensitized nanocrystalline solar cells for indoor applications has been continued. The goal of this collaboration, to set up a concise proposal for a pilot production line for small, low-power PV modules, has been pursued.

Duration of the Project: 06.97 - 04.99

Responsible for the project: Dr. Marcus Wolf, Leclanché S.A.

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ANNUAL REPORT 1998

Project Number : 10441
Contract Number : 58375

Project Title : **Antenna-Solar cells**

Abstract :

We have achieved clear experimental evidence for the antenna function of zeolite L nanocrystals, loaded with the dye pyronine and modified by oxonine at both ends of the channel. It is expected that the direct proof of the antenna - solarcell principle will be achieved.

Duration of the Project : 1.1.97 - 31.12.99

Responsible for the project : Dr. Gion Calzaferri, full professor for physical chemistry

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ANNUAL REPORT 1998

Project Number: 14785 / 54318 **ENET Number:** 9854318
Contract Number:

Project Title: ALUCOSOL-Development of a Facade System with Integrated Solar Cell Modules

Abstract:
As no suitable solar cell technology was available for the realisation of the ALUCOSOL-project, the initial target of fabrication and testing of a demo-façade had already to be given up at the end of phase III. As a compensation it was planned to develop the idea of the large area deposition of a-Si:H on aluminium in connection with a suitable concept for the current collection and to go ahead with this concept up to the state of pilot modules.

Concerning the conceptional and theoretical considerations the targets of the project were mainly achieved. However, the practical realisation proved to be much more difficult and time spending than originally planned. Only partial aspects of the module fabrcation (deposition of a-Si:H on Al-sheets, laser-drilling of current conductions, etc.) could be examined. However, the gained results and perceptions led to the conclusion that the promotion of the ALUCOSOL idea has to be continued; a follow-up project should soon be defined.

Duration of the Project: Sept. 1, 1996 - Oct. 31, 1998

Responsible for the project: Alusuisse Technology & Management AG

Reporting on the project: Dr.-Ing. Michael Weng

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ANNUAL REPORT 1998

Project Number : 14869
Contract Number : 54392
ENET Number : 9554392

Project Title : Photovoltaics on flat roofs : a new approach

Abstract :

Three objectives were defined for this year :
- **Improving** already developed systems
- **Setting up** one pilot installation with the SolGreen system.
- **Publishing** the final report

Due to various delays in the project (not connected with the LESO), the pilot plant with Solgreen system will be installed in 1999. But a new variant for large installations has been developed.
The fiber cement system (Solbac) has been improved as well as the Sofrel.
The final report will be released by the end of the year.

Duration of the Project :
Planned : 1.7.1995 - 30.6. 1997
Extended : 1.7.1995 - 31.12.1998

Responsible for the project : Ch. Roecker

Reporting on the project : J. Bonvin, Ch. Roecker

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ANNUAL REPORT 1998

Project Number : 10583
Contract Number : 59873
ENET Number : 9400261

Project Title : Demosite and Demosite Flat Roofs (part III)

Abstract :

The DEMOSITE 1998 activity was a clear mirror of the present enthusiasm seen in the context of the photovoltaic world market. The Task VII of the IEA represents a new activity frame that helps improve the displayed palette at the exhibition. The main achievements for 1998 were :

- The upgrading of the **communication** : new graphical system, new set of color information sheets, new information panels near the stands, new directional signs on the site, design and first steps of a new promotion multimedia tool based on both a CD-ROM and an animated web site.
- The **set up** of three new pavilions (one on the parking lot area and two on the flat roof area). The dismounting of two pavilions which were no more up-to-date.
- The reinforcing of the **promotion** of the Demosite (conferences, publication) and the process to find **new exhibitors** in order to keep the state of the art at the Demosite.

Duration of the Project : 1.1.1997 - 31.12.1999

Responsible for the project : Ch. Roecker

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ANNUAL REPORT 1998

Project Number: 2183
Contract Number: 60154

ENET Number: 9100196

Project Title: Component and system testing for projects in the field of photovoltaics. TISO - period V: 1997-1999

Abstract:

Tests on the most common photovoltaic modules on the market were continued on a regular basis. Moreover, a new testing procedure was introduced in order to compare the energy produced (Wh/W) by the various modules: 2 modules, for each type, are exposed at MPP (Maximal Power Point) and their energy production as well as their electrical characteristics are constantly measured. Tests are currently being carried out on 11 types of modules (6 m-Si, 3 p-Si, 2 a-Si) and tests on 6 more types will begin in the near future.. Special measurements using a solar tracker have also been carried out on these and other modules.

During the course of the year, data has been gathered on grid-connected photovoltaic plants in Ticino. The aim of the study is to classify the existing plants with reference, above all, to their common features, by comparing the main operational data and identifying anomalies and/or malfunctions respectively. In addition, supplementary measurements – IR, Pm, PR, etc. – has been carried out on some plants (Suglio, Payerne, FFS Giubiasco).

At the testing centre, a new triple-junction amorphous plant (TISO 0.5kW) has been connected to the grid. The aim is to compare the behaviour of the first commercial amorphous modules (TISO 4 kW) with those of the latest generation (initial degradation, seasonal degradation and long-term degradation). In addition to regular measurements of the two TISO plants (10 and 4 kW), special studies on long-term degradation of m-Si and a-Si modules have been carried out in collaboration with other research centres (Ispra and Barcelona).

The contents of the database (DB TISO) which now includes more than 800 modules, has been updated and the information relative to the modules currently on the market has been collated for a new publication, the entire database is now available on software.

Duration of the Project: 1 January 1997 - 31 December 1999

Responsible for the project: Mario Camani

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ANNUAL REPORT 1998

Project Number: **12474**
Contract Number: **60314**

ENET Number:

Project Title: **Research on New Photovoltaic Technologies and on the Mont-Soleil Power Plant**

Abstract:

Goals of this project :

- To carry on with the tests in real conditions of new photovoltaic modules that have a high efficiency or an economical interest.
- To operate up to 6 small grid inverters of several types as part of or beside the running power plant, and to monitor them simultaneously in the same real environment, in order to know and compare their performances.
- To monitor and analyse the behaviour of the running power plant through its data acquisition system, including its maintenance, repair and improvement duties.
- To collaborate with other institutions working in photovoltaics, in order to broadcast and exchange data and experiences on systems in real or long-dated conditions.
- To teach technical skills to the students by involving them into the works.
- To present the various results in conferences, specialised literature and on the Internet.

Duration of the Project : 1.5.1997 - 30.4.1999

Responsible for the project : HES-BE Saint-Imier, Société Mont-Soleil

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ANNUAL REPORT 1998

Project Number:
Contract Number:

ENET Number:

Project Title: Characterisation of Photovoltaic Generators and Small On-Grid Systems

Abstract

Test results of photovoltaic (PV) generators (single cells, laminates, modules, shingles, car roofs etc.) under actual operating conditions are essential for correct product selection and reliable prediction of the electricity production. For this purpose an outdoor test facility was erected at Paul Scherrer Institute, PSI. It consists of a sun-tracked sample holder, electronic loads and PC-based measuring systems. Insolation is measured with pyranometers, pyrheliometers and reference cells. Characterisation of a generator under given test conditions means precise acquisition of its electrical behaviour at varying load. The generator's efficiency and all the relevant electrical parameters are derived on-line from a series of measured current/voltage(I/V) values. I/V-scans at constant insolation and at different generator temperatures enable the temperature coefficients of the efficiency and the electrical parameters to be determined. Thereafter I/V-scans at different insolations (10-1200 W/m^2) yield (via temperature correction) the insolation dependence of the efficiency at constant temperature. A complete scan takes 5 to 15 seconds. Samples of size varying from 1 by 1 mm up to 1 by 1.5 m can be tested at currents up to 32 A (190 A) and at voltages up to 120 V (10 V). For modelling purposes the results are represented in the form of correlations, e.g. the efficiency as a function of the operating parameters temperature, insolation and air mass. Results obtained in PSI's test facility were confirmed by the Fraunhofer-Insitut für Solare Energiesysteme, D-79100 Freiburg, Germany. The present report contains test results on some single cells and modules as well as on a PV/thermal hybrid system.
The test facility for off-grid inverters was developed further to cover also small on-grid systems.

For the work performed within this project, a **"Best Research Paper Award"** was received at the 7th International Energy Conference ENERGEX 98, Manama, Bahrain, Nov. 20, 1998.

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ANNUAL REPORT 1998

Project Number: DIS 2744 / 61703 **ENET Number:**

Project Title: Qualitätssicherung von Photovoltaikanlagen

Quality assurance of PV-plants

Abstract:

Most important results in 1998

- With the new test stand three different stand alone inverters with a rated AC power of 1200 VA were tested. Tests included DC to AC conversion efficiency at different power factors, EMI emissions on DC- and AC-side, generation of voltage harmonics and overload behaviour.
- Development of the high power (1000V=, 100A=) line impedance stabilisation network for the measurement of conducted RF voltages on the DC side was completed sucessfully.
- Islanding tests:The simplified test circuit proposed by HTA Burgdorf for islanding tests according to German and Swiss regulations was included in new German prescriptions. A new common test circuit allowing also test according to Japanese standards was proposed.
- Islanding tests with matched load with up to 18 inverters were performed. No islanding under any load condition was registered.
- Some grid-connected inverters produce voltage transients up to 760V when the connection to the line is interrupted. Such voltage transients may damage small loads connected in parallel to the inverter.
- New grid-connected inverters were tested thoroughly (e.g. Top Class Spark from ASP).
- Methods to measure MPP-Tracking efficiency of grid-connected inverters are being developped.
- Continuous monitoring of 9 inverters from different manufacturers at HTA Burgdorf's test site with 60kWp was continued.

Duration of the Project: April 1st 1997 to Sept. 30th 1999

Responsible for the Project: Hochschule für Technik und Architektur Burgdorf, Prof. Dr. H. Häberlin

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ANNUAL REPORT 1998

Project Number: DIS 19490 / 59074 **ENET Number:**

Project Title: **Langzeitverhalten von netzgekoppelten Photovoltaikanlagen**

Long Term Behaviour of Grid connected PV Systems

Abstract:

Purpose and Goals of the Project during 1998:

- Maintenance of the monitoring systems.
- Analysis of operation and possible problems at all grid connected PV plants monitored in the project.
- Analysis of inverter reliability in all PV plants monitored in the project.
- Detailed analysis of *permanent pollution problems* affecting array performance and energy yield observed at several PV plants in Burgdorf and Liestal.
- Inspection of newer PV plants for *beginning delaminations of solar cells* which might affect future energy yield.

Most important results in 1998

- Inverter reliability of grid connected PV plants decreased slightly compared to 1997 (more defects especially in older inverters that have been operated for several years).
- After a replacement of the string fuses with insufficient current rating by stronger ones at PV plant EBL, the plant operates very well and energy production is no longer affected by sudden defects of these fuses.
- Periodical inspection of the DC side of older PV plants would be desirable to avoid unexpected damages.
- *Permanent pollution of the PV generator at different plants in Burgdorf* (not only at the plant of HTA Burgdorf as believed last year) may result in a gradual reduction of performance (about 10%) after several years.
- *Beginning delaminations affecting PV array yield were discovered at several modules produced in 1993&1994.*
- PV plant Jungfraujoch has operated successfully with a 100% availability of energy production and monitoring data since Oct. 27, 1993. The plant has reached a new absolute production record in the 12 months' period from March 1997 to February 1998 (1541 kWh/kWp, performance ratio *PR = 85.2%).*

Duration of the Project: 1.10.1996 - 30.4.1999

Responsible for the Project: Prof. Dr. H. Häberlin,
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ANNUAL REPORT 1998

Project Number: BBW 97.0301 **EU-Nr.:** JOR3 CT98 0217

Project Title: PV-EMI: Development of standard test procedures for electromagnetic interference (EMI) tests and evaluations on photovoltaic components and plants

Abstract:
The objective of the "PV-EMI-Project" is the realisation of a standardized European approach towards the electromagnetic compatibility of solar photovoltaic systems by means of elucidating the legal situation, developing measuring concepts, doing concrete sample measurements and realizing *information dissemination to standardization committees and final users (industries, SMEs, plant owners). Project partners involved: Fraunhofer ISE (Germany),* HTA Burgdorf (Switzerland) and KEMA (Netherland).

Realized work in 1998 (HTA Burgdorf):

- Accurate review of standards and work which correspond with insolation coordination, dielectrical compatibility tests and EMC requirements. Review of national and international standards.
- Extension and improvement of equipment to be used for the tests and development of measuring procedures for laboratory measurments:
  - Planning and construction of a high impulse current generator for the simulation of the influence of direct and indirect lightning strokes onto 3 to 4 connected PV-modules. The construction will be completed in the beginning of 1999. With the new high impulse current generator it should be possible to reach $I_{max} \approx 120$ kA and values of di/dt_{max} between 20...50 kA/ µs with a charge Q of up to 1.2 As.
  - Realisation of a test stand for measuring conducted interference produced by PV-inverters. For reproducible EMI measurements line impedance stabilisation networks on the DC- and AC-side are used. The DC network was developped and constructed by HTA Burgdorf and Schaffner Electronik AG.
  - Preparations for surge/ burst immunity tests of PV-components (corresponding to IEC 1000-4-4/-5). For burst tests a new burst generator with a built-in coupling-/ decoupling network was purchased. For surge tests a coupling-/ decoupling network to be used with the existing 7 kV surge impulse voltage generator was procured. Larger coupling-/ decoupling networks (for higher current or three phase operation) will have to be developped in course of the project.

Duration of the Project: 01.06.1998 - 30.05.2000

Responsible for the project: Prof. Dr. H. Häberlin
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ANNUAL REPORT 1998

Project Number: BBW 95.0207-2 **Reference Number:**
Contract Number:

Project Title: Single Cell Module Integrated Converter System – SCMIC

Abstract:

A single solar cell provides an output voltage of 0.4 V to 2 V, depending on the material (amorphous or cristalline) and the type of cell (single or triple junction, etc.). Because of this unfavourably small voltage conventional solar modules are built of a series connection of several cells to get a higher output voltage of the module. This is resulting in numerous disadvantages like, expensive multi-step manufacturing processes and expensive laser cutting (for thin film cells), a large inactive area, a mismatching and partial shading cause severe energy losses, etc.

This leads us to a new module concept using only a single cell but a large area. Each solar module has its own power conditioning unit. Following benefits will result within this new concept:

- deposition on cheap, already mass produced substrates such as building elements
- continuous flow manufacturing process
- less waste products, thus saving material and grey energy
- Increased active cell area

Especially the costs as most important drawback on photovoltaic energy conversion make the proposed single cell concept look very promising. The SCMIC concept includes aspects, like no serial connection and thin film technology. This new approach promises remarkable cost savings of about 30% for the manufacturing process of the module.

Designing the new single cell module for a common output power leads to output currents of 100 A or more at 0.7 V to 2 V. New approaches in the electrical configuration of the cell and the power conditioning unit are needed for working with output currents of approx. 100 A at 0.7 V to 2 V.

In 1998, a completely new converter has been developed and tested at the Swiss Federal Institute of Technology in Zurich. Further prototypes have been built and improved. Inverter efficiencies of 90 to 98% have been achieved. NAPS France produced single cell prototypes. The electrical properties are so far not satisfying. Under collaboration with the ALUCOSOL-Project small samples using the concept of throughput connections have been realised at the Swiss Federal Institute of Technology.

Duration of the Project: October 1995 – September 1998

Responsible for the Project: Enecolo AG, LEM ETHZ, Alusuisse T&M AG
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BBW Project Number: 96.0293

ENET Number:

Project Title: Accelerated Reliability Improvement AC-Modules

Abstract:

The goal of this project is to improve the reliability of the AC-module by improving the reliability of both inverter and module, aiming at a lifetime expectancy figure of at least 10 years.

The first objective is the determination and improvement of the reliability and operational life -time of AC-module inverters. This will be done by (electrical) immunity tests and by environmental stress tests in a climatic chamber. These tests will be done to determine the operational lifetime and the most frequently occurring failure mechanisms in the inverter. The results from these tests will be used to make an improved inverter design for AC-modules.

The second objective is the development of a hot-spot detector to prevent large scale modules (>100W) from hot-spots without the use of by-pass diodes. Instead of limiting the voltage across a number of cells, as done with the bypass diode, the new method limits the current through the solarcells. A detector for a hot spot is needed to give an alarm signal for lowering the current in the affected string.

Prototypes of the voltage comparison method have been built and included in the 200W modulintegrated solarinverter Solcolino. The prototypes have successfully been tested at the Engineering School in Winterthur. The temperature sensitive method has been skipped due to technical and cost reasons.

The project will be carried out with partners from the Netherlands and Italy.

Duration of the project: 1.7.1997 - 1.7.1999 (prolonged until 1.2.2000)

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Annual report 1998

BBW Project Number: 95.0273

ENET Number:

Project Title: PV Checker: Research on low cost PV system checker devices for future application in the individual PV system monitoring

Abstract:

The goal of this project is to analyse the need for monitoring PV system performance and to evaluate and develop a low cost monitoring device which allows PV system owner to verify whether his system is working as expected or not. The real reason behind the project is that PV system owners have difficulties in assessing if their PV system is operating satisfactory and producing the maximum potential energy. This is especially true when the system is grid connected. PV systems do not make noise, are placed in the sun and generate electricity which is fed into the grid. It would be very helpful for the owner of the system if a kind of on-off indication would give him guidance whether his PV system is o.k. or not.

The partners agreed to put the effort on the evaluation of a sophisticated algorithm for the PV-Checker. In this context a sensitivity analysis on the Matlab/Simulink tool has been carried out at Alpha Real. It pointed out that an improved accuracy on the insolation measuring side has the more accuracy for the PV-Checker than an improvement on the AC-energy measurement side. The „return on investment" for the irradiation sensor is higher than for the Energy meter.

Encapsulation material for the evaluated irradiation sensor has been evaluated. An epoxy material such as Araldit and a Silicon glue as a more soft material. These two materials will be further used for tests and their transmission behaviour, especially when providing the sensor with a filter, will also be evaluated.

Duration of the project: 1.9.1996 - 30.6.1999

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ANNUAL REPORT 1998

BBW Project Number: 95.0272

ENET Number:

Project Title: Improving PV system reliability by a new concept including a novel arc detection unit

Abstract:

Since the PV array generates DC instead of AC and is a current source instead of a voltage source, arcs developed in DC array cabling subsystems are of great concern. In fact, despite of its youth, PV technology, has already a sinister history on fires caused by arcs. A novel arc detector has been invented by Real/Häberlin. The objective of the project is to define an overall PV safety concept, using the arc detector as a detection device to provide alarm signals in case of arcing. Results of various field tests of different arc detector designs have been tested. Other prototypes have also been given to Ecofys in Holland and Endecon in the USA to support field testing. The research program is sponsored by the European Commission under the project JOULE.

Within the EC-project the arc detector has been successfully tested on various sites in Italy and in Switzerland. At the Ingenieurschule Burgdorf the arc detector operated at a distance of over 200 m between the arc detector and the arc. ENEL in Italy confirmed 80 m in the field. In the Vasto power plant a DC-filter was added and subsequently the arc detector performed well. In other distances, when inverter DC harmonics are beyond accepted level given in IEC 55014/55022, the DC noise level can trigger the arc detector and lead to false alarm.

The project has been completed by the end of February. A final report shall be delivered soon.

Duration of the project: 1.1.1996 prolonged till '98

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ANNUAL REPORT 1998

Projekt Nr. PSEL 129

Reliability of Safety-circuits against Islanding

Abstract:

A central topic with dispersed generation of electrical energy is the question of islanding. Dispersed generators (grid connected PV-installations, grid connected co-generation and fuel cells) feeds their energy into the grid at the place of its formation.

The question of islanding, in particular the mutual influence of the detection mechanism of such dispersed power generation, shall be simulated and gain in conclusion for further developments of such detection circuits. The simulations will be compared with measurements at a suitable site and can also contribute to the validation of the model used in the numerical simulations.

In this reporting period a suitable tool has been evaluated. This work was more complex than planned because of the variety of tools available.

An example of a tree in the low voltage grid could be evaluated according to maps of the utility of Zurich. The grid parameters has been evaluated as well.

At the AC-modul installation in Zurich on the roof of an UBS-building (65 independent photovoltaic inverters are installed) islanding was inverstigated with matched load. It could be shown that the inverters did influence each other and islanding condition was shorter when more than one inverters was in operation. This measurements has been carried out together with Prof. H. Häberlin from the Ingenieurschule Burgdorf.

Dauer des Projekts:	Januar 1997 - September 1998

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ANNUAL REPORT 1998

BEW Project Number: 10949
Contract Number 50786

ENET Number: 9400381

Project Title: **A new method for evaluating the material and energy fluxes of large scale introduction of PhotovoltaicEnergy Systems**

Abstract. Photovoltaic (PV) Systems provide a direct route to convert solar radiation into electrical Energy, a process which takes place without releasing any emissions to the environment. PV is therefore often perceived as an ideal option to complement or eventually replace environmentally hazardous energy technologies, such as those based on fossil or nuclear fuel, both of which are also subject to depletion. Large scale implementation of Photovoltaic Systems for Power generation will induce significant material and energy flux.

The goal of this work was to provide a tool for cybernetic strategies for the metabolic evolution of new energy technologies such as Photovoltaic systems. The aim is to develop the methodology which provides answers and insights for the following questions:

- How can the metabolism of the large scale implementation of a new energy system such as PV be assessed in order to identify potential critical paths with regard to future material and/or energy requirements?
- What are the dynamics in material and energy management to realise large scale system within a concrete region.

Extensive analysis has already been conducted on the embodied energy of PV cells and modules of varying PV technologies and different system designs. The use of these energy analysis reflects the growing awareness of the need to evaluate technologies from an environmental standpoint. The current method applied is referred to as Life Cycle Analysis (LCA). Results of these works have also often been used to calculate the quantity of emissions released to the environment or the energy pay back time (EPBT). Both are important indicators to assess the actual state of technology. Current LCA methods, however, do only provide a snapshot of the situation at a given moment. In order to generate results which do provide answers to the above questions and which allow better insight in the system behaviour, the methodology of Material Flux Analysis, developed at the Swiss Federal Institute of Technology Zürich (ETH/EAWAG) was adopted (Baccini and Bader, 1996).

Duration of the project: 1.5.1994 - 31.10.1998

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ANNUAL REPORT 1998

Project Number: 16868
Contract Number: 66402
Reference Number:

Project Title: New generation of hybrid solar collectors (Phase 2: Measurements and analyses)

Abstract:

Although the idea of producing a solar collector for both electricity and heat is not new, the new generation is based on a totally new concept. The feasibility study (phase 1) has collected much information about all-important aspects (costs, technology, market, contacts with industries, ...) to prove that further development is worth being done. The results are encouraging since they show:

- A potential market does exist for the several described proposed applications (about 10 MW in 2005)
- The photovoltaic (PV) thin film technology is likely to be suited for this application from a technical and an economical point of view, provided that the long term stability of the cells at temperatures above 100°C are confirmed
- Several photovoltaic industries are ready to collaborate in this development at different levels of participation
- The technology packages are suited for the hybrid collector

These results from phase 1 show that the competitiveness for a hybrid collector depends on several requirements. They are:

- The absorption coefficient (value of absorption over the whole solar spectrum) of the photovoltaic absorber should be higher than 80%
- The stability of a- Si cells at temperatures in the range of 100-160 °C

The information needed for an optimised development is neither available in technical prospects or the scientific literature. For these reasons, the project team must carry out a series of measurements and technical experiments before going into product design (phase 3).

1998 two different absorption measurements (spectroscopic and microcalorimetric) were performed by the Institute IMT in Neuchâtel and the IOA in Lausanne. These measurements show the effective reflections of the different optical layers of photovoltaic devices. Most data from the measurement on several available PV raw materials (plates) of standard devices (glass-substrate, steel and polyimide) and on some laminated samples show most encouraging results for an ongoing project.

Duration of the Project: Phase 2: June 1998 – September 1999

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ANNUAL REPORT 1998

Project Number: 2726
Contract Number: 2726

ENET Number: 6100007

Project Title: **Photovoltaic Potential in the Building Stock**

Abstract

The goal of the project is the implementation of an approach to assess the solar-yield-differentiated photovoltaic potential in the building stock. The specific goals are:

- to create a tool for the assessment of the photovoltaic potential on the building surfaces,
- to discern the PV potential for different types of buildings (according to age, number of floors, type of use, roof shape, etc.), for various types of building owners, for different regional areas and for different categories of relative and absolute solar yield and other PV-relevant aspects,
- to provide general and detailed information and to assist the decision makers in the PV domain, e.g. utility companies, energy policy makers, PV industry, etc.

State and Outlook

This contribution proposes an approach to assess the solar-yield-differentiated PV area potential. It emphasizes the importance to know both the statistical and the empirical landscape of the building stock in order to perform implementation-oriented results. The tool has been adopted in two case studies and has proven that fairly accurate building data can be collected in an efficient way. According to the requirements of the various participants in the PV environment, results can be generated starting from the basic PV area potential up to the market potential, from general statements about the potential contribution of PV in a future energy supply system up to strategic information.

Two Swiss case studies - one in a typically urban context, the other in a typically rural context - were carried out. Some results of the photovoltaic potential are presented for the city of Zurich and for the canton of Fribourg.

Duration of the Project: 1.8.95 - 31.7.98

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ANNUAL REPORT 1998

Project Number : BBW 980216
Contract Number : EU NR. SME/1479/97-DE

Project Title : **European photovoltaic noise barrier potential study**

Abstract :

This project shall elaborate and investigate the application potential of photovoltaic sound barrier in six european countries (Germany, Switzerland, Netherlands, France, Great Britain and Italy). The Project is lead by TNC Energie Consulting GmbH, Freiburg i.B..

Overall Goals

- demonstrate the European potential for noise barriers along railroads and motorways
- disseminate the information amongst decision makers
- create new markets for grid-connected PV in Europe

Duration of the Project : June 1995 to Dec. 1998

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ANNUAL REPORT 1998

Project Number BBW: 97.0542
EU No: JOR3-CT98-0230

Project Title: PVSAT
Remote performance check for grid connected PV systems using satellite data

Abstract:

Small photovoltaic (PV) systems (i.e. in the power range of 1 to 10 kWp) regularly do not include any long-term surveillance mechanism. As most system operators are not PV specialists, partial system faults or decreasing performance may not be recognised. Regarding a number of several thousand systems being in operation today, remarkable losses in energy production may occur, the overall price per kWh would rise.
The envisioned project will set up a remote performance check for small grid connected PV systems. No additional hardware installation will be necessary on site. The site specific solar irradiation data will be derived from satellite images rather than from ground based measurements. On the basis of monthly irradiation sums, monthly values of PV system yield will be calculated and distributed automatically via postcard, fax or email (whatever is most suitable) towards the system operators. This procedure will remind the system operator periodically to check the performance of his installation. In this way, a high system performance will be ensured over the whole lifetime of a PV system.

The work necessary for the establishment of the PVSAT procedure is divided in five tasks

1. Set up of a calculation procedure from satellite image data to site and system specific solar radiation at ground level.
2. Comparison of satellite derived radiation data with data from interpolation between ground stations, as quality check for the results of Task 1.
3. Definition of a generalised plant description, applicable to grid connected PV systems and a corresponding numerical plant performance model for use with sparse input data.
4. Integration of the results of Tasks 1 to 3 into the operational PVSAT performance check system.
5. Test and evaluation of the PVSAT procedure energy users associations.

Step 1, 2 and 3 have started since mid 1998.

Duration of the Project: June 1998 to June 2001

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ANNUAL REPORT 1998

Project Number : BBW 95.0192 **ENET Number :**
Contract Number : JOULE 95 (PL950428)

Project Title : SATELLIGHT : Processing of Meteosat data for the Production of High Quality Daylight and Solar Radiation Data Available on a WWW Internet Server

Abstract :

This project can be considered as an extension of the Solar Radiation Atlas and the European Daylighting Atlas. It deals with the production of radiative and luminous data at a high frequency continuously over Western and Central Europe. The procedure will stand in processing satellite data provided by the Meteosat satellite, every half hour. The originality of the work will stand not only in the frequent and continuous coverage of Europe but also in the fact that satellite data will be processed to produce directional information from ground. For the first time, detailed information will be available throughout Europe regarding the variability of natural radiation and illumination, as well as the directionality of incoming daylight.

This information will be provided as a set of climatic maps of Europe showing frequency curves and as a database accessible on the Internet using a WWW server. This will insure a widespread access to the data while offering an easy to use graphical and hypertext interface. The data will be produced to help manufacturers to propose optimal solutions for the various European climates. Manufacturers of glazing, variable transmittance glazing, shading device, shading control and artificial lighting control will be concerned. The data will also be useful to designers and engineering firms to assess the performance of their solutions regarding facade design, roof aperture design, and optimal control of shading devices and artificial lighting.

The database will include all parameters related to light and high frequency irradiances. It will cover 2 full years of satellite data and it could be easily extended in the future, using the models proposed and validated by the group.

The WWW internet server will be operational end of March 1999.

Duration of the Project : 1996 - 1999

Responsible for the project : Dr. Pierre Ineichen (coordinateur: M. Fontoynont, LASH)

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Annual Report 1998

Project Number: 11427 **ENET Number: 1**
Contract Number: 63760

Project Title: SWISS Contribution to the IEA Implementing Agreement on Photovoltaik Power System (PVPS), TASK1

Abstract:
Support of Task 1's aim – to guarantee the exchange of information between the countries involved in the PVPS- Program – with the following publications, meetings and workshops:

- The National Survey Report NSR (Basis for the International Survey Report)
  The PV Statistics for 1997 reveal installed-power increases in all PV sectors. There are now over 10 MWp installed. Three module manufacturers and six inverter manufacturers are active in Switzerland. Further, a market volume of 25 Million CHF was reached by cell-manufacturing equipment companies. A large proportion of inverter production is exported. PV system-prices lie between CHF 12.- / Wp (On-grid) and CHF 17.- / Wp (small off-grid systems).
- PV-Power, a half-yearly Newsletter
  The PV Power magazine was distributed to 250 subscribers.
- Meetings
  Swiss PVPS experts met twice before the ExCo meetings. These meetings have proved valuable, and information exchange from task to task must be improved, especially at the international level.
  Task1 met in Hobart , Vienna and Salzburg with the main work put into the publication of the International Status Report ISR

Duration of the Project: 1998 -

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ANNUAL REPORT 1998

Project Number: 14805
Contract Number: 67820

ENET Number: 9554338

Project Title: IEA - Photovoltaic Power Systems (PVPS) Implementing Agreement, Task II, Swiss Cooperation, Phase IV.

Abstract:

Switzerland has committed itself to take part in the Photovoltaic Power Systems (PVPS) programme of the International Energy Agency (IEA), Task II.

The aims of the IEA-PVPS-Task II are outlined in the IEA PVPS Implementing Agreement of April 1994

Operational Performance PV Power Systems and Subsystems.

1. International data base on photovoltaic systems and subsystems.

   The database programme (PVbase 2.8) is now completed and totals system data and monitored data from 263 PV systems form eight countries and the EU.

2. Analytical reports on their performance.

   The report programme (PVreport 1.8) will be finalised early next year. Analyses of the data collected was carried out and a paper/poster was presented at the 2nd PV Word Conference in Vienna. Further analysis will be done for the final report to be published next year.

3. Produce a handbook covering monitoring techniques and normalised evaluation of PV systems.

   The work on the Monitoring Handbook is terminated and the handbook will be made available as an internal IEA PVPS publication in 1999.

Task II will run until the end of June 1999. A proposal for the continuation of Task II will be presented to the Executive Committee of PVPS.

The Swiss contribution to Task II from January 1999 to June 1999 shall be outlined in Phase V of this project.

Duration of the project:: Phase IV; Jan. 1998 to Dec. 1998

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ANNUAL REPORT 1998

Project Number : 22579
Contract Number: 61979

ENET Number: 9722579

Project Title: IEA PVPS Task III : Stand-Alone and Island Applications
Swiss participation, conclusion phase I and preparation new phase II

Abstract:

The goal of IEA PVPS Task III is to improve the use of PV systems in stand-alone and island applications. These applications are mainly dealing with rural electrification by utilities, governments or even private companies. They range from SHS (Solar Home Systems) to autonomous installations (PV or hybrids) supplying village grids. During 1998 Task III has focused on activities leading to concrete results. The objective was mainly to bring out a maximum of (external and internal) publications and to define precisely the new Task III work plan. Two Meetings were organised during the year: the first one in Barcelona and the second one in Helsinki. In order to implement the work Task III have been divided in 3 Groups of activity :

- Group A (Implementation R&D: surveys and developing countries) has to collect information on the state of the art of PV stand-alone systems, evaluate socio-economical aspects of PV projects, assist international organisations (WB, UNDP) with their programmes in developing countries for workshops, consultation services, etc... The priority has been given to : 1) a survey report, status of PV programmes and applications in 20 developing countries; 2) a CD-ROM slides collection edition representing stand-alone applications in the participating countries; 3) the co-operation between IEA (supported by DC Team) and main international organisations.

- Group B (Application R&D : showcase applications) selects prime national examples of PV projects, compares specifications, reliability, procedures for operation and maintenance, and presents operational strategies for a larger dissemination of PV systems. A book (Lessons Learned Book in 14 national Show case Projects) where Task III experts present and compare various showcases emphasising lessons learned has been published this year.

- Group C (Technical R&D : recommended practices) evaluate the efficiency, the reliability and recommends best practice methods for systems components such as batteries, inverters, controllers and high efficiency appliances for their specific use in stand-alone applications. The actions have focused on the publication of recommended practices and guides for charge controllers, batteries, and inverters.

Task III is going to be extend from 1999 to 2003 according to the new work plan and will be divided in 3 subtasks: 1) Quality Assurance; 2) Technical Issues and 3) Demonstration & Dissemination. The new Task III is going to work in close collaboration with Task IX. Task III will concentrate efforts on technical issues, whereas Task IX will consider all non technical aspects linked to PV stand-alone and island applications.

Duration of the Project: final report phase I Task III (Jun 1, 97 to Dec 31, 98)
preparation phase II Task III (Jan 1, 99 to Dec 31, 03)

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ANNUAL REPORT 1998

Project Number: 20552 **Reference Number:**
Contract Number: 60155

Project Title: IEA PVPS
Task V: Grid Interconnection of Building- Integrated and other dispersed Photovoltaic Power Systems

Abstract:

Task objectives are to develop and verify technical requirements which will serve as the technical guidelines for grid interconnection with building integrated and other dispersed PV systems. The development of these technical requirements will include safety considerations and methods of establishing reliable linkage to the electric grid at the lowest possible cost. The systems considered are be those connected with the low-voltage grid, the typical size being between 1 and 100 kWp.

In 1998 two meetings took place, where all reports in their draft version were discussed and dismissed. All draft versions were reviewed and published as internal or official reports. Based on the comprehensive and detailed results from the Task V work, a follow-up Subtask 50 was defined and will be started next year.
It will study problems arising from highly concentrated penetration of many grid interconnected PV systems in a certain limited area and will suggest technical requirements needed for the widespread introduction of PV systems.

Duration of the Project: Task V:
Final phase (until autumn 1998)
Extension Subtask 50:
(1. Jan.99 – 31. Dec. 01)

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Project Number: 20552 **Reference Number:**
Contract Number: 60155

Project Title: IEA PVPS
Task VII:
Photovoltaic Power Systems in the Built Environment

Abstract:

The IEA-PVPS-Task VII 'PV in the Built Environment' runs now for two years. The main Task objectives are to enhance the architectural quality, the technical quality and the economic viability of PV systems in the built environment and to assess and remove non- technical barriers for their introduction as an energy significant option. It is expected that the successful integration of PV systems into built environment will contribute significantly to the future spread of PV.

A lot of experience and information was gained in several topics throughout the year 1998. New products were introduced in the activities 'Design tools' and 'Commercial building integration concepts'.
Main contribution from Switzerland is the DEMOSITE at the EPF in Lausanne. At present more than twenty pavilions demonstrate different mounting systems for solar modules on roofs and facades. New pavilions are in planning including two new Swiss building integration systems, SOLGREEN and SOLRIF.
Beside the DEMOSITE issues on mounting technologies, potential studies and marketing are of special interest.

Duration of the Project:

Task VII:	1 / 1997 – 12 / 2001
First Phase:	1 / 1997 – 12 / 1999

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ANNUAL REPORT 1998

Project Number:
Contract Number:

ENET Number:

Project Title: **IEA PVPS Programme Task 8**

VERY LARGE SCALE PHOTOVOLTAIC POWER GENERATION SYSTEMS

Abstract:
According to a 1995 OECD/IEA report, the availability of global fossil fuel resources will not generally limit the energy supply until 2010. This will result in significant increase in CO_2 emission which could endanger the global climate.
Among the new renewable energy technologies photovoltaic technology (PV) is being considered as one of the most promising options with a potential to reduce in CO_2 emission in the future. In the short to medium term PV will mainly be used in small scale applications to satisfy local energy needs. However, in the long term the use of PV technology for very large scale bulk power generation could become feasible. The Climate Technology Initiative CTI therefore decided at the Kyoto Climate Summit Conference in dec. 1997 to co-operate with the IEA PVPS programme on the subject of large scale PV systems.
The concept of VLS-PV (Very Large Scale Photovoltaic Power Generation System) includes centralized multi-MW - or even GW - PV systems constructed in high-insolation areas such as arid zones or deserts. The energy collected will be transported over long distances to the load centers or fed into large international power lines. In the production areas additional activities could be generated such as agriculture and industry. Besides the energy production this could create new possibilities of converting actually unused areas into habitable land resources.
In 1998, IEA/PVPS Task VI has started a pre-feasibility study on the VLS-PV concept in order to identify the potential and the major impacts of the VLS-PV. The report will be finalized before May, 1999. Participant countries actually are Italy, Japan, Korea, The Netherlands, Norway, Portugal, Spain, Sweden and Switzerland.

Duration of the Project: **1.1.1998-31.5.1999 (Prefeasibility Study)**
1999 - 2003 (New Task 8)

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ANNUAL REPORT 1998

BFE Project Number: 23783

Project Title: Global Approval Program for Photovoltaics, PV GAP

Abstract:

The PV community, including National and Regional PV industry associations, supported by lending institutions (e.g., The World Bank, UNDP, etc.), decided to institute a high-priority global program to remedy the situation: The development of the Global Approval Program for PV (PV GAP), which is a PV industry-driven organisation that strives to promote and maintain a set of quality standards and certification procedures for the performance of PV products and systems, to ensure high quality and reliability. The need for a simplified, objective manual for use by small manufacturers of PV components wishing to implement quality manufacturing processes, primarily in developing and transition economies, has reached a critical point. In addition, a similar need exists for laboratories and testing organisations.

The United Nations Development Programme (UNDP) is providing support for PV GAP's work to (1) draft a set of internationally accepted guidelines and procedures for quality manufacturing processes for small manufacturing organisations; and, (2) develop procedures for qualifying laboratories to test and certify PV equipment and systems in developing and transition economies. The PV GAP/UNDP effort concentrates on the PV industry in a number of countries that represent a range of development challenges and opportunities (Argentina, China, India, Indonesia, and South Africa).

As a way to further develop and refine the procedures and documents developed under the UNDP contract, the PV GAP and the Swiss Federal Government are sponsoring a meeting May 3-4, 1999, in Geneva, Switzerland, bringing together representatives of the participating countries, representatives of the global PV industry, standards organisations, the World Bank, and other key actors. Information, along with logistics and registration materials for the Geneva meeting can be obtained by either visit the PV GAP web site, at <http://www.pvgap.org>, or contact the meeting chairman, Dr. Markus Real, at <alphareal@access.ch>.

Duration of the project: 13.4.1997 - 31.12.1998

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ANNUAL REPORT 1998

Project Number: 17222
Contract Number: 56790

ENET Number:

Project Title: **Pilotanlage 2 kWp für modulintegrierte Wechselrichter**

Abstract:

Pilot Plant 2 kWp for module-integrated inverters

The aim of the project is to test a new 200 W module-integrated inverter for direct grid-coupling (developed by the Berner Fachhochschule HTA Biel / Sputnik Engineering Nidau / Atlantis Energy Bern). 10 modules (2 kWp) have been coupled March 1998 with the network of the Energy Services of the city of Biel. The system is operational, but problems with data recording system forced us to postpone the begin of systematic measures to January 1999. During two years of operation and monitoring the collected data will be analyzed. The monitoring system was designed in accordance with the EU-Guidelines for PV System Monitoring. The goals are to test the performance of the system, the reliability of the inverter and to get information in order to optimize construction data of module and inverter.

Duration of the Project: October 1996 – March 2000

Responsible for the project: Berner Fachhochschule, HTA Biel

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ANNUAL REPORT 1998

BFE Project Number: 24226
Contract Number: 63943

ENET Number:

Project Title: **3-phase 1 kW PV String Inverter**

Abstract: One of the features which is unique to PV and which distinguishes it from conventional power plants is its high modularity. This characteristic enables the implementation of PV systems in much smaller capacity than with most other electrical generation technologies which typically exhibits pronounced economies of scale. The inverter which converts the DC into grid compatible AC is the only major component of a PV system which is sensitive to economy of scale.

However, there are substantial cost savings in using also modular inverter concepts instead of applying one central power conditioner unit. Some of the advantages of this new concept is that the DC cabling is normally working at lower voltage, certainly carries less amperes and exhibits therefore a much smaller risk of arcs causing fire or high voltage causing electrical shocks to personnel. Furthermore, if the dispersed inverters within a PV array can be situated outside, a special housing or cabinet for the inverter is not anymore necessary. Especially in larger applications, cooling issues are not relevant since the dissipated heat in each of the dispersed small inverters is rather small and can easily be achieved by natural convection, thus avoiding the otherwise expensive forced cooling devices.

These designs have been made based on single phase inverters, since this is the most straight forward approach. However, large capacity banks are necessary to store the energy from the DC to alternating current in a monophase system. The goal of the project was to develop a low cost, small scale, string integrated inverter for outdoor application, which can be made without any electrolyte capacitors and therefore meets the specification for long term, maintenance free operation. The rational for this approach is that in outdoor applications, electrolyte capacitors may suffer from elevated operating temperatures. The design for this new unique approach is now finished and components have been selected and prototype building is under way.

Duration of the project: 1.12.1996 - 31.5.1999

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ANNUAL REPORT 1998

Project Number: 14'556
Contract Number: 54'108

ENET Number: PV-P+D(95)010

Project Title: Système hybride simple PV/T 7kW$_p$ à Domdidier au Centre d'Entretien autoroutier de la N1
(*PV/T = système hybride simple Photovoltaïque / Thermique*)

Abstract:

Simple Hybrid System (PV/T) 7 kW$_p$ at N1 Motorway Maintenance Center, Domdidier/FR
(PV/T = simple hybrid system Photovoltaic / Thermic

The project of the system PV/T 7 kW$_p$ consist to put on a strip of the building a set of cells photovoltaics. It is constitued of 33 simple windows panels and each carry 144 photovoltaics cells ASE Alzenau, as a replacement for the normal garage's windows shed of the "Motorway Maintenance Center" at Domdidier/FR. The installation's power is 6'700 W$_p$.

The heat produced by the PV elements is recuperated by 2 ventilators, which blow the warm air down (on the garage's floor) in order to avoid the frost of the hall during winter. When the temperature is too high, the warm air is directly expelled outside of the building. That is simple hybrid system PV/T.

Duration of the Project: October 1995 to december 1998

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ANNUAL REPORT 1998

Project Number: 17 862
Contract Number: 57 447

ENET Number:

Project Title: Roof integrated amorphous silicon photovoltaic plant
IMT Neuchatel

Abstract:

The grid-connected PV plant of 6.44 kWp at IMT Neuchatel is the first of its kind in Switzerland: large-area amorphous silicon panels are aestethically integrated into the roof of a sixty years old building. The plant was implemented and commissioned in autumn 1996.

During the two years of operation the plant showed an excellent performance:
- availability since the start-up of 100 %,
- annual production yield of 1'050 kWh/kWp,
- coefficient of performance of 0.78.

These figures are remarkably high for a plant located on the Swiss Plateau and for panels operating at relatively high temperatures, resulting from the roof integration without backside ventilation. Amorphous silicon modules have, thus, proven to be particularly suitable for building integration. At higher operation temperatures amorphous silicon modules show production yields that are 15 to 20 % superior to those of crystalline silicon modules of identical nominal power rating.

The data acquisition system providing detailed data on the operation of the plant is functioning since the End of March 98. An analysis/study with regards to light-induced degradation (Staebler-Wronski effect) and to the operating temperature of the panels has been started.

Duration of the Project: 01.08.1996 - 31.12.1999

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ANNUAL REPORT 1998

Project Number: 18962 **ENET Number:**
Contract Number: 58855

Project Title: **Photovoltaic Power Plant Hotel Rigi Kulm (13,6 kWp)**

Abstract:

The photovoltaic power plant was connected to the grid on 31st March 1997. It is operating as expected and the data from the energy production are transfered via modems for evaluation.
The following topics are of special interest:

Energy Production: The result with a specific yield of 984 kWh/kWp for the 1st year of operation is good but less than was expected. One reason is that the snow staid on the panels with their 30° inclination, especially during March 1998.

Wind Stability and Tightness: Both items performed perfectly with the evaluated solar tiles, even with the highest registrated wind speed of 146 km/h on 12th October 1997.

Lightning Strikes, Over-Voltage Protection: After at least three lightning strikes on the building, we can speak of good experiences with our plant. The energy production was not impaired at any time, though there was some damage to the hotel installation.

Public Relations: The touch screen terminal in the hotel entrance proved to be ideal concerning the effect on the public. Because of the inauguration, the appreciation prize 1997 by Solar 91, the eco prize 1998 of WWF Schwyz and some conducted tours the plant has been well-publicized in the media.

P&D Project Completion: For further information please refer to the final report which will be published shortly.

Duration of the Project: **November 1996 bis November 1998**

Responsible for the project: Urs Bühler, leader of the technical commission

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ANNUAL REPORT 1998

Project Number : 20735
Contract Number : 60338

Project Title : PV-roof integration with module integrated inverters

Abstract :

In spring 1995 a new farm with an additional living house for the family Zaugg was built. Due to the favourable exposition the south roof offered good conditions for the use of active solar systems.

Due to the new PV roof installation, the tiles were replaced in a section of 10x14m by PV building elements. The heat collected under the roof is used for the hay ventilation. With the installation of the hybrid PV-thermal system the efficiency of the heating should increase considerably resulting in reduced working periods of the ventilation system. For this project PV-modules with integrated micro-inverters were used.

Three technological attributes are associated with this project: roof integrated PV system, PV-thermal hybrid system and the module-integrated inverter. It is the goal of the project to gain practical experience (electrical and thermal characteristics) of the micro-inverter in the special operating conditions of a roof-integrated, PV-thermal hybrid system.

Duration of the Project : 01.06.97 - 31.12.99

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ANNUAL REPORT 1998

Project Number: 19246
Contract Number: 58826

ENET Number:

Project Title: **Installation-pilote photovoltaïque sur toit plat à base de nouveaux supports en fibro-ciment**

Abstract :

This project has consisted in the set up of one pilot installation of the **flat roof integration system Solbac**. We had two objectives for this plant in 1998:

- **Measuring** the 9 kW installation and checking its production

-**Publishing** the final report, including mounting procedure analysis and measurements over one full year

The 9 kW pilot installation has been successfully measured and the final report has been published in time

Duration of the Project: 1st of January 1997 - 31st of December 1998

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ANNUAL REPORT 1998

Project Number: 22'620
Contract Number: 63'528

Reference Number:

Project Title: Solar Cell Integrated Building Element – SCIBEL

Abstract:

Building integration of PV modules does not only include architectural and technical integration into the building shape. Integration of the PV cell into well known building construction materials, results into a number of advantages such as less effort for PV installation on site, high aesthetic value, improved energy balance and reduced pollution.
SCIBEL aims at the integration of PV cells into standard pre-cast concrete elements. The SCIBEL module should also bring an advantage in cost reduction through savings in materials and in a new production technology.

Within the P&D Project new technologies of fixing the solar cells to the substrate and covering them for protection against hazardous environmental influences were one of the main points to investigate. 30 SCIBEL modules based on concrete plates were installed and will be monitored to gain data and experiences for this new promising application.
So far the measured data and visual experiences are sufficient to give a first analysis. Influence of dirt deposition on the module surface is low. The lamination method shows still a very good adhesion. And the energy data are within a tolerated range of the prognosticated figures.

Duration of the Project: 1. October 1997 – 30. June 1999

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ANNUAL REPORT 1998

Project Number : 21279
Contract Number : 63529

Project Title : AC-Modules: 11.8 kWp PV-Installation with 64 AC-Modules (Megalino)

Abstract :

After the installation of the 64 AC-Modules on the flat roof of the UBS building in Altstetten, the installation was connected successfully to the grid on the 21.4.98. D shortage of the inverters caused by a manufacturer-change delayed the hoc the grid.

The measuring box which was developed at the engineering school in Wint operation since first of June. The monitored parameters are:

- horizontal an inplane (30° incident angle) irradiation
- energy metering of the 11.8kWp AC-module Megalino installation
- energy metering of the 220Wp SCIBEL-installation
- ambient temperature
- reference module temperature
- reference inverter housing temperature

The performance ratio is compared to the one from the near 3kW central inverter in the neighbourhood. It showed that improvement installation should enhance the performance ratio; this will take effec

Islanding and interference measurements took place and enco be found that inverters stopped operating shorter than 500ms. An that the inverters were mutual influenced. A cluster of inverters sha half the time of a single one.

Duration of the Project : 1.10.1997 - 30.6.1999

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ANNUAL REPORT 1998

Project Number: 23703
Contract Number: 68140

ENET Number:

Project Title: **Pilot installation 10kWp Flat Roof System "SolGreen"**

Abstract:

Green flat roofs as water retension reservoirs usually do not allow to install PV on the same place. The SolGreen flat roof mounting system, developed by LESO-EPFL of Lausanne in co-operation with Enecolo AG, offers a modern and cost-effective solution to this problem. It can be installed on both new and existing green roofs.

This project will show the ability of the system to be installed on large flat roofs. On a new storage hall for construction materials the feet system of the installation will be combined with two different green roof - technologies.

The development of the feet system is going on, and the pilot installation of 10kWp at Josias Gasser Baumaterialien AG Chur will be constructed in April, 1999.

Duration of the Project: October 1998 - June 2000

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ANNUAL REPORT 1998

Project Number: 17225
Contract Number: 59391

ENET Number:

(ASTRA research project no. 59/96, 2747.01)

Project Title:
Three pilot 10 kWp integrated PV sound barrier fields

Abstract:

The project which had begun in 1997 with the construction of the first bifacial PV sound barrier was continued in 1998 with the erection of the second trial sound barrier at Wallisellen. Here for the first time a sound barrier was built along a railway line. 45 small inverters are used to show the advantages of a modular concept and to avoid big shadowing losses. An AC-Bus is collecting the power on the rear side. The zigzag type plant is constructed by Borra SA and Atlantis Energie AG and it is based on a concept idea of the two firms.

The monitoring equipment was installed in October. First results show, that in the winter months some shadows of near buildings, which are wandering along the field, make is difficult to give a fair value for the reference yield.

The installation of the monitoring system at the bifacial PV sound barrier Aubrugg was completed in the beginning of 1998. Thus the data of nearly one year is available now, showing that the final yield of this north-south leading PV sound barrier is about 10% smaller than those of a conventional east-west installation. This is mainly caused by the properties of the bifacial cell, which has two sides with different efficiencies, thus causing a kind of mismatch.

In 1999 the third pilot PV sound barrier field will be built at Brüttisellen, completing the construction part of the project. The monitored data of all the fields (including the three German fields, which were built in 1997) will be put together and evaluated for comparison. Furthermore the operational experience of all these installations will help to decide about new projects.

Duration of the Project: 1 January 1997 to 31 August 1999

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ANNUAL REPORT 1998

Project Number: Partie Genève : BBW 96.03.44-1
Partie Lausanne : BBW 96.0344-2

Project Title: **HELIOTRAM : 800kWp PV Power PLANTS FOR DIRECT INJECTION INLIGHT TRAIN LOW VOLTAGE D.C. NETWORKS**

Abstract:
Public transportation low voltage networks are particularly well suited for direct connection of PV systems because of their electrical characteristics and since the load of the network coincides with the PV production. As a result, very simple and therefore reliable PV power stations can be build to inject the solar production in such networks.
Under the framework of the programm Thermie 96, Sunwatt Bio presented and developped the projet called Heliotram, wich aim is the connected PV larger Plant for injection in light train low voltage D.C. networks.
The purpose of this project is to manufacture and install such PV power plants in Germany 250KWp (Hannover) and in Switzerland 250KWp (Geneva and Lausanne).

- Direct connection of the series of modules to the low voltage (600-750 Vdc) network (more than 1200V by cold weather and open circuit).
The present project intends to build larger plants using the same well tried principle.

- Incite the manufacturer of PV modules to certify their modules for a high voltage usage:
The PV modules in use for these plants will be continuously exposed to high voltages and thus require a good insulation between the frame and the cells. The development of modules allowing much higher voltage capability is very desirable and could permit the design of large plants for direct connection to some train networks.
All the rapid connectors for the modul had been certified for a tension up to 1500V DC which gives a certain reserve of security to all the cables of the modules.

- Testing DC high speed circuit breakers and power contactor DC for high voltage and large scale of intensity (for ex. 0.5A to 250A bidirectional by 1000V)

- In agreement with the other partners of the Heliotram project, the MPT system has been removed from all the installations. This, in order to simplify the installation and to give an optimal reliability to the entire system.

Duration of the Project: 1997 - 2000

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ANNUAL REPORT 1998

Project Number: BBW 97.0205

Project Title: Large scale integration of AC PV modules into a noise barrier along a highway near Amsterdam (PV NB 220)

Abstract:

Aim

- Installation of an innovative 220 kWp grid connected PV system, production of 176'000 kWh *per year*
- Reduction of system costs on an overall level through volume, integrated design and *prefabrication*
- Evaluation of technical, architectural and economical aspects
- Investigation of performance and impact on utility grid of a large number of parallel AC modules, including disturbances, harmonics, spikes, surges, etc.

Innovation

- Fully integrated design of the entire system from the beginning, including serviceability aspects
- Technical and organisational involvement of all project partners from the start: energie company, municipality, road directorate, building company, governmental organisations, PV consultants
- *Development and demonstratio of innovative design approach and prefabrication mounting* methods
- Architectural integration of larg AC PV modules into a new to build 1650 m long noise barrier, including engineering of rather high structures (4...5m) and crossing a river (200m of length on a bridge)
- Multi-functionality of PV modules: energy production and noise reduction

Duration of the project: Sept. 1997 to March 2000

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ANNUAL REPORT 1998

Project Number: BBW 97.0393-1

Project Title: **151 small grid connected PV stations for a total of 200kWp dont 30kW POUR LA SUISSE**

Abstract:
The technology of grid connected photovoltaic micro stations has already reached satisfactory reliability and efficiency. The purpose of this project is to decrease the system costs while keeping very long life time of stations.

A small but motivated market has appeared in France for these small grid connected PV systems if the total cost can be kept reasonable. With a large production of standard kits, this project will tend to fulfil this demand and generate more through the dissemination campaigns.

Small PV plants will be installed by private individuals, schools, companies and on public buildings. Their peak power range from 0.9 to 15 kWp or more.

These disseminated micro stations will be a starting point for meetings and public information on energy conservation and renewable sources of energy. If the total electricity production to be reached will remain modest, the public interest on the energy field is likely to be much greater.

The installation of analytical monitoring apparatus of the micro stations will allow to check real efficiencies of the kit in different configurations and will be used by students for practical work on PV power.

Duration of the Project: 1998 - 2001

Responsible for the project: Roger Diamond

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ANNUAL REPORT 1998

Project Number: 17482
Contract Number: 57068

ENET Number:

Project Title: Héliotrope EICN

Abstract:

On the site of the sport field of Le Locle two photovoltaic trees, each with 40 panels and 2 kWp are installed since September 1997 and produce energy for the network of the city.

One of these two trees is mounted on an axis and follows continuously the sun. In 1999 this equipment will be completed with a building integration of also 40 panels on the same site.

During 1998 the monitoring of the two trees in operation has been started. Detailed analysis of the measurements will begin after the realizations of the building integrated PV-installation.

Duration of the Project: 1996 - 1999

Responsible for the project: Georges JEAN-RICHARD

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ANNUAL REPORT 1998

Project Number : 18002
Contract Number : 57609

Project Title : PV-plant at the school of Adligenswil, measurements

Abstract :

On the top of the school of Adligenswil we have built a 3,3 kWp grid connected standard photovoltaic system, which is common for private homes. The system was built on a public building as a demonstration object for the school and interested persons. PV is integrated in the roof with the AluPro-system and doesn't influence the appearance of the building.
The system is running now for two years and the sofar produced energy indicates that the calculated yield will be reached in the future. The energy produced within the last 22 months is more than the schoolbuilding required in the same period.

Duration of the Project : January 1997 - December 1998

Responsible for the project : Hans Meier, Gemeindeammann

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Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 1998

Project Number: 18022
Contract Number: 60336

ENET Number:

Project Title: **32 kW grid-connected photovoltaic installation Swissmill (Stadtmühle CMZ) Zürich - Measuring programme**

Abstract:

The 32 kWp grid-connected photovoltaic installation on the Swissmill (before Stadtmühle CMZ) in Zürich went into operation in November 1996. It was the first installation implemented as part of the solar power stock exchange run by the Zürich power station (EWZ). The monitoring programme, launched in spring 1997, was continued in 1998. Monitoring will go on until sommer 1999. A detailed description of the PV installation can be found in the annual report 1997.

In the second year of service, the installation produced 21'616 kWh which exceeded expectations by over 3%. In1998, the specific annual yield was 724 kWh/kWp (facade 594 kWh/kWp, roof 844 kWh/kWp). The performance measured using reference cells was 80%.

A small part of the operational losses was due to ac-switches, which interrupted the powerline of some inverters after high start currents in the morning.

This project is sponsored by the Swiss Federal Office of Energy and Swissmill.

Duration of the Project: January 1997 to mid-1999 (measuring programme)

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ANNUAL REPORT 1998

Project Number: 1263
Contract Number: 1263

ENET Number:

Project Title: Realisation of a Mobile Measuring System for the Evaluation of Pilot and Demonstration Plants

Abstract:

The main purpose of this project is to halve the cost for measuring and analysing a pilot or demonstration plant.

Without loss of quality, compared to fixed measuring systems, the mobile measuring system is saving costs on the following points :

a) Hardware	The measuring system will be used for several pilot and demonstration plants, instead of only one as it is the case for fixed installations.
b) Datalogger-SW	The datalogger software for the measuring program and the communication with the Computer has to be written only once.
c) Evaluation-SW	The evaluation software can be used for all the plants, only slight modifications must be done for the specific parameters.
d) Analysis & Report	The report and the analysis methods can be partially standardized and the results of different plants can better be compared.

The measuring system is built in to two wooden boxes with wheels at the bottom and can be moved easily by two persons. The upper case contains the measuring system, with the datalogger, the converters and the computer. The lower case contains all the sensors, the electrical connectors and all the cables.

To install the system on a new plant, a special program can be run to monitor all the signals and to adjust the converters. During the measuring period, the data is continuously transferred to the harddisc of the computer and the evaluation software can be run any time without interrupting the measurements.

Duration of the Project: September 1993 - Nov 1998

Responsible for the project: A. Eckmanns

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ANNUAL REPORT 1998

Project Number: 11065
Contract Number: 50879
ENET Number:

Project Title: 100kWp Grid-Connected PV-Installation along Rail Infrastructure in Southern Switzerland • Plant Monitoring and Evaluation • Operation and Maintenance of Plant

Abstract:

This 100 kWp grid-connected PV plant went into operation 1992. At the same time, an intensive monitoring programme was launched. After six years of operation and monitoring, comprehensive data has been collected and analysed. The monitoring system was designed in accordance with the EU-Guidelines for PV System Monitoring.

The PV array of this plant consists of six sub-arrays. Each sub-array comprises six strings of 24 Solarex MSX120 modules in series. The array-voltage at STC is 810 V dc with an earthed centre-point. A sub-string consists of 12 modules in series giving half the array-voltage. The DC current of these 72 sub-strings is also monitored.

In its six years (Nov. '92 to Dec. '98) of operation the plant has produced 542'192 kWh, on average 88'863 kWh/a with a specific annual yield of 847 kWh/kWp and a performance of 59 %. In 1994 a degradation of the array efficiency has been noted.

In 1995 177 of the 864 modules showed a fill factor < 58 and where replaced by the manufacturer. In 1996 more modules with a low fill factor where identified. In 1997 the manufacturer agreed to replace all the remaining 687 modules. These modules were replaced in May 1998.

After the exchange of the modules, intensive monitoring will go on for at least another year.

This project is sponsored by the Swiss Federal Office of Energy.

Duration of the project: Jan. 1992 to Jun. 1999

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ANNUAL REPORT 1998

Project Number: 10133
Contract Number: 50106
ENET Number:

Project Title: 100 kWp Grid-Connected PV-Installation along the N13 Motorway in Switzerland • Plant Monitoring and Evaluation • Operation and Maintenance of Plant

Abstract:

This 100 kWp grid-connected PV plant went into operation in autumn 1989. At the same time, an intensive monitoring programme was launched. After eight years of operation and monitoring, comprehensive data have been collected and analysed. The monitoring system was designed in accordance with the EU-Guidelines for PV System Monitoring.

The PV array of this plant consists of $7\,^{2}/_{3}$ sub-arrays. Each sub-array comprises twelve strings of 24 Kyocera LA 361J48 modules in series. The array-voltage at STC is 405 V dc. A sub-string consists of 12 modules in series giving half the array-voltage. The DC current of these 92 sub-strings was monitored from 1990 through 1992. The sub-strings are mounted on top of a sound-barrier along the motorway and the installation extends over a distance of 800 meters.

In its eight years (Dec. '89 to Dec. '98) of operation the plant has produced 991'854 kWh, on average 109'605 kWh/a with a specific annual yield of 1'041 kWh/kWp and a performance of 75 %. The plant performed extremely well with a minimum of maintenance required.

In 1995 an educational parcour on solar energy was officially opened.

Monitoring will go on for at least an other few years.

This project is sponsored by the Swiss Federal Office of Energy.

Duration of the project: Aug. 1989 to Dec. 1998, to be extended.

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Programme in Photovoltaic Energy Conversion

ANNUAL REPORT 1998

Project Number: 14884 **ENET Number:**
Contract Number:

Project Title: **100 kWp PV-Soundbarrier Installation Giebenach - Plant Monitoring and Evaluation**

Abstract:

The 104 kWp PV sound barrier at Giebenach (Mark III) went into operation in December 1995. During the Monitoring campaign it fulfilled the expectations to a big extent. In addition to the economic improvement of the project, compared to the first PV sound barrier installation along the N13 near Chur (Mark I, 1989), a very reliable plant with a high yield was constructed. The manpower needed for operation is small. Besides the periodic control of the electric components only the cut of the trees and shrubs in front of the field causes some work.
In the year 1998 the plant produced 98'770 kWh or 947 kWh/kWp of AC power. The performance stayed high with 86% (measured with reference cells).
The mechanical characteristics of the modules and the waterproofness of the connection boxes has to be observed further.
This report is the final report of the measuring campaign, which started in spring 1996 for 2 years. A further operation of the monitoring equipment and the evaluation of the results is of some importance, as the interest in the topic «PV Sound Barriers» has raised considerably during the past view years

Duration of the Project: December 1995 to April 1998 (measuring programme)

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ANNUAL REPORT 1998

Project Number : 2666
Contract Number : 2666
ENET Number : 9400641

Project Title : Photovoltaic Integration on Railway Canopies

Abstract :

One objective was defined for this project for 1998 :

Measurements report for the first operation year of the whole canopy.

The performance measurements of the whole installation started on November 1997. The installation has performed normally during one full year and the measurements report has been finalised on November 1998.

Duration of the Project : 1.1.1995 - 31.12.1998

Responsible for the project : C. Roecker

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ANNUAL REPORT 1998

Project Number: 14578
Contract Number: 63527

ENET Number:

Project Title: Visualisation and Analysis of the Data of the 4.1 kWp PV-Power Plant Rothorn

Abstract:

On the top of the Rothorn mountain (2865 meters above sea level), a 4.1kWp Photovoltaic Power Plant was built during summer 1994. Photovoltaic modules are integrated in the south front of the cable car building. They consist of translucide panels, which allow light to penetrate into the building. The monocristalline cells have a usable area of 27.4m^2 and are mounted vertically. The electrical energy is fed directly into the grid.

In order to inform interested visitors about the energy production and the actual data of the plant, a visualisation is realised in the middle station at Scharmoin. In addition the data is collected in the Rothorn station and transferred to the HTA Chur, where it will be analysed. There is a high energy yield expected because of the high altitude and the good alignment of the front of the building facing south.
In addition, the Photovoltaic Power Plant is special for the following reasons:

- attractive view point with many visitors and tourists,
- integration of photovoltaic panels into the wall of a building which is exposed to the elements,
- good cooperation between the Rothornbahn AG and the HTA Chur.

The visualisation and the data transfer have been tested. They are operating according to the specifications. The measurement campaign and the corresponding analysis of the data will start in January 1999.

Duration of the Project: 1997 until 2000

Responsible for the project: Max Schalcher

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ANNUAL REPORT 1998

Project Number: 26746
Contract Number: 66583

ENET Number:

Project Title: **NOK's 1-Megawatt Solar Chain**
Normalized Data 1997 to 2001

Abstract:

The aim of this project is the calculation of the monitored operational data of all pv-installations of the **1-MW-Solar-Chain** according to the current guidelines of the ESTI at Ispra and the IEA. It is the continuation of the preceding project "NOK's 1-Megawatt-Solar Chain, Normalized Data 1992 - 1196" (PSEL-project No. 81, BFE-project No. 14'516 / 54'074).

The report **"Normalized Data 1997"** was completed and distributed to the clients this year. It contains detailed evaluation of 1997's data as well as summaries over the whole period from 1992 until 1997. The reported stations are: NOK-Headquarters Baden, ISOKW Brugg, Alp Findels, Church of Steckborn, Disentis-Caischavedra (Desertasol), Migros-Winterthur and Neu-Technikum Buchs.
The detailed observation of the photovoltaic plants over their lifetime provides important experience concerning aging, degradation and long-term reliability of the components used.

Duration of the Project: January 1997 - March 2002

Responsible for the project: Stefan Roth

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ANNUAL REPORT 1998

Project Number : 23844
Contract Number : 63884

ENET Number :

Project Title : Monitoring of the 180 kWp PV-Power Plant of UBS Suglio / Lugano

Abstract :

The goal of the project is the monitoring of the behaviour of the so far largest building integrated photovoltaic power plant of Switzerland. This system consists of four parts :

- two parts on the roof, each of 73,5 kWp, with each a central inverter
- one part on the facade of eastern wing, 20 kWp
- one part on the facade of the western wing, 16 kWp

Three of the parts have central inverters, the facade of the western wing has string inverters. The direct comparison of the different inverter technologies can be made on site with the same modules.

Project works have begun in the second half of 1998. So far, preparation works have been made :

- working out of a monitoring system, bases on Excel
- elimination of problems in the data acquisition system

The results of 1998 :

- the monitoring-system is working
- almost all problems with the data acquisition system have been solved

First reliable results are available now from the time after November 1998.

Duration of the Project : October 1998 - December 1999

Responsible for the project : Enecolo AG, UBS; TISO - LEEE, Scuola Universitaria Professionale

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ANNUAL REPORT 1998

Project Number : 11064
Contract Number : 50878

Project Title : 450kW PV-Skyscrapers Wittigkofen

Abstract :
Five high rise buildings in the outskirts of the capital city of Berne, each 22 floors, in a two phase program will have their south facing façade, now in plain concrete, fully covered by photovoltaic building modules, which will generate a total power of 400 kW.

The project is meant to demonstrate the large potential for solar electricity generation in existing buildings and indicate the necessity for PV modules mass-production in order to allow for a substantial role of photovoltaic in the electricity demand coverage.

The opportunity for such a challenging project technology has been created by need of a major renovation of the façade, as a part of a maintenance program scheduled for the next years. The big photovoltaic façade will be connected to the city grid. A company to be established builds and operates the five power plants. The preliminary financing concept is based on three contributers: public subsidies, participation in the company without annual bonus from electricity yield, green pricing investors with annual bonus from electricity yield.

Apart from the technical issues which will have to be overcome, this project is supposed to explore all the non-technical barriers which will arise in relation to the multiple ownership of the building and the ownership of the photovoltaic façade power plant.

Duration of the Project : 26.5.94 - 31.12.99

Responsible for the project : B. Stucki

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ANNUAL REPORT 1998

Project Number: 20734
Contract Number: 60337

ENET Number:

Project Title: **OptiPV: Optimaler Systemaufbau von kostengünstigen PV-Anlagen**

Abstract:

The importance of optimized PV mounting systems for PV installations of medium output (1-100 kWp) increases after the market introduction of advanced thin-layer solar cells with efficiencies between 5 and 6%. For customary crystalline solar cells often mounting variants are developed which do not correspond with the demands of the module producers in every case. Then the producers can refuse the guarantees.

It is shown by the OptiPV-project that the overall costs of a PV installation can be reduced by 20-25%, the optimal combination of mounting structures and cell technologies provided. Within the project mono-, polycrystalline and amorphous tandem- or triple-Si-solarmodules have been compared concerning the expenditure of the mounting construction for flat- and slanting roofs. The calculation of the static stability at various wind pressures has been to the fore. It could be demonstrated that not all systems realized or available on the markets meet the requirements of the statics.

Reserves must be made in case of mounting constructions for flat-roof-installations with laminates concerning the keeping of the producers' guarantees and the insurability of the solar generator. Therefore a new open concrete-pedestal-system is proposed, as then one can do without laminates. By that the installation costs can be lowered below those of customary mounting systems of framed modules. A first application of this system could be realized at the end of 1997 in an installation of the ADEV Berne.

As a conclusion of the study two structographs for the construction of cost-saving PV installations on flat and slanting roofs are shown. By that planners are able to make prompt and simple evaluations on the mounting systems and cell technologies in question.

Duration of the Project: 1.5.1997 - 31.12.98

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ANNUAL REPORT 1998

Project Number: 10468
Contract Number: 50406

ENET Number:

Project Title: ***PV-Monitor***

Abstract:

In 1992 ***METEOTEST*** was commissioned by the Federal Office of Energy to present Swiss activities in the photovoltaic field to the public. ***METEOTEST*** subsequently developed and implemented the PV-Monitor concept.
In 1994/1995 technical improvements and the graphical presentation and the reporting format stood in the center of our activities. In 1996 the system was put into continuous operation with a restricted number of installations. A selected number of display systems (clients) used and tested the system continuously.
In 1997 the operational service was continued. As test for broader distribution on internet a homepage was taken into service. Automated procedures perform daily updates of graphical information. The page contains always the data of the past day (http://www.meteotest.ch/pvmon). The system was expanded in late 1997 to monitor 20 PV-installations.
During the year 1998 20 PV-stations were monitored on display systems and on our internet site. Some software optimizations were made. The project will not be prolongued in 1999.

Duration of the Project: april 1992 – december 1998 (finished).

Responsible for the project: Dr. Stefan Kunz

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ANNUAL REPORT 1998

BEW Project Number: 17967

ENET Number:

Project Title: Standards for Photovoltaic Components and Systems

Abstract:

PV is a young technology. Due to the immediate need in Switzerland for standards for grid connected PV systems, such standards have been developed by the Swiss National Standard Committee TK 82, due to the lack of relevant IEC published standards. Similar efforts have been observed in other Nations, such as in Germany, Austria, Netherlands, USA and Japan. With the recent publishing of the initial basic standards by the IEC, the incentive and need for individual countries to prepare their own standards is expected to diminish, as the IEC documents are now available for being referenced or adopted as National Standards in the various countries.

Although this is the ideal situation, it has to be feared that in the area of standards for grid-connected PV systems it may take several more years prior to reach international consensus, necessary for IEC publication. For this reason, national committees may need to continue to elaborate their standards to provide guidelines for their national industries and for their on-going implementation programmes.

It is therefore obvious that Switzerland, as other countries, has a high interest in supporting IEC efforts to even accelerate standard development procedure. Within IEC level, strong contributions have already been made to the elaboration of international standards. TC 82 of IEC has organisationally introduced two new working groups, Working Group 5 and Working Group 6. This is especially favourable for Working Group 3, since a great work load was concerned with BOS rather than systems, which is now being transferred to Working Group 6.

Within the national effort, issues such as working under life voltage condition (as it is the case for PV systems), inverter safety standards and AC module issues have been addressed during 1998.

Duration of the project: 1.1.1998 - 31.12.1998

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ANNUAL REPORT 1998

Project Number: 24043
Contract Number: 66401

ENET Number:

Project Title: Machbarkeitsstudie zur Umsetzung der Mikromorph Zelle in grossflächige Module mit produktionsrelevanten Prozessen

Abstract: The IMT has developed a new thin film solar cell. It has the potential to have higher efficiencies than conventional amorphous silicon solar cells also in large surface area scale up. This new cell structure is a tandem solar cell which consists of amorphous and microcrystalline silicon. It has been given the name a "Micromorph" tandem cell and has achieved stabilised efficiency of 12 % in the laboratory.

The aim of this study is to investigate the possibility for industrialisation of the Micromorph concept for potential investors. This will include:

a) the product
b) legal issues (incl. patents)
c) production plan
d) market study
e) risk analysis
f) financial plan

The expected benefits are increased investor interest and better understanding of the technological aspects that are important for production.

The report is due to be completed by the end of 1998.

Duration of the Project: 01.8.98 - 31.12.98

Responsible for the project: Dr. R. P. Maisch

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ANNUAL REPORT 1998

Project Number : 21280 **Enet Number :**
Contract Number : 65847

Project Title : **PVSYST 3.0 Ergonomie et fonctionnalité**

Abstract :
Three objectives were defined for this year :

- Starting with the Delphi 3.0 program
- Translate the mathematical routines of PVSYST 2 in Delphi
- Drawing the flowchart and defining one "green line" approach, to give the user a free choice of the precision level at which he would like to work and to guide him in his work.

Results :
A Delphi version of the program is running and the whole flowchart has been defined.
The implementation of the new interface is currently taking place.

Duration of the project : 1st of July 1998 - 30th of June 1999

Responsible for the Project : Ch. Roecker
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ANNUAL REPORT 1998

Project Number:
10230/50191

ENET Number:
Reference-Number: ET-SUB(93)013

Project Title: **Project management: Electrical colleges**

Abstract:

The measuring and monitoring program for electricians' training colleges with installed photovoltaic systems has been running since 1993. In 1998, a further 2 systems were added to the programme. There are now 24 systems in service with a total installed power of 191 kWp.

In 1998, the project included provision of the following services, in addition to supplying measuring equipment for the new systems:

- Bimonthly analyses of the individual systems to project managers
- Weekly download and saving of all collected data of the 24 installations
- ERFA Conference on 23 September in Interlaken
- Development of the new «PV-Box» data analysis software
- Production of 3 posters of individual systems as part of the touring exhibition

Duration of the Project: August 1992 - End 1998

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