Photovoltaic Solar Energy Supply for a Danish Standard House

Final Report
(Contract No. ESC-R-097-DK)

Contents:

1. Summary

The project titled "Photovoltaic Solar Energy Supply for a Danish Standard House" running under EC-contract No. ESC-R-097-DK was not formally initiated until late February 1984.

Even with the very short time available for the project, - the project-contract expired on July 1, 1984 - the project group has been able to keep the timetable.

The PV-house was completed in June, 1984, and was officially put into operation in August, 1984, by the Danish Minister of Energy, Mr. Knud Enggaard, at a small ceremony also with the participation of the EC Energy Research Programme by Dr. A. Strub.

The PV-house is now operating with a load profile controlled by a computer. The load profile simulates the load of a 4-person family, living in the house.

As the EC has not yet put forward specific requests regarding the 5-year operational period, the PV-house will for the present be in operation as mentioned above.

2. Introduction

The EC-Commission has made a marketing study concerning the possibilities of photovoltaic (PV) energy supply of single houses.

The result was that a real market in the commercial sense exists, i.a. in the Mediterranean area when houses far from the public mains connection are considered.

With a view to examining the interest in a possible Danish PV-house project an application was made - via the Danish Department of Energy - to Jutland Telephone being the only company in Denmark which has carried on long-term experiments with major PV-plants.

An application from Jutland Telephone to various Danish industries resulted in a co-operation concerning the above-mentioned project with Jutland Telephone as contractor to the EC.

The project titled "Photovoltaic Solar Energy Supply for a Danish Standard House" was started late February 1984 and is carried on parallel with three similar projects in Italy, Greece, and Germany.

The project is expected to stimulate the interest of Danish industries in general as to production and application of PV-systems as energy source, primarily for application on export markets.

This report discusses the development and status of the project up to the end of the contract, July 1, 1984.

3. Project Group and Project Programme

In order to carry out the project Jutland Telephone has established a co-operation with 3 Danish companies:

Contractor:

Jutland Telephone	Jutland Telephone T-Power Supply Section Sletvej 30 DK-8310 Aarhus-Tranbjerg J Phone 06-293366 Telex 68647 jtas ar

Sub-contractors:

Lyac A/S	Accumulatorfabrikken LYAC Lyacvej 16 DK-2800 Lyngby Phone 02-871645
Alex Grosman A/S	Alex Grosman Transformervej 13 DK-2730 Herlev Phone 02-912525
Kalmargården A/S	Kalmargården Hellesvej DK-6740 Bramming Phone 05-174111

Project Programme

A photovoltaic energy supply system for a Danish standard house intended for export will be developed and put into operation.

The PV-system will be dimensioned for stand-alone operation of a single house under insolation conditions corresponding to the conditions prevailing in the Mediterranean area.

The house will be adapted especially for PV-stand-alone powering, and great importance will be attached to fitting the PV-arrays into the roof in the best possible way from an architectural point of view. The PV-system, as a whole, will be integrated in the house to the greatest possible extent.

The project will be based on commercially available solar cell modules, of European manufacture, and the PV-array will have a maximum power of 5 kWp. (*)

Within the framework of the project the Danish industries will develop concepts and equipment for project specific power control, power conversion, energy storage, and general supervision and control of the PV-system.

Great importance will be attached to humanizing the PV-system as much as possible, so the PV-powered house - to its inhabitants - will appear to be a normal house.

Thus the PV-system shall be as autonomous as possible, and it will be necessary to develop new concepts for supervision and control.

The output voltage from the PV-energy supply system will be of 220 V AC 50 Hz, three phases, in order to facilitate the use of standard, electrical household equipment.

The PV-energy supply system will be modular in form and function. Therefore, it will be possible easily to adapt the system also to mains-connected operation. The system can also easily be adapted to local insolation and load conditions.

The project will include the following main phases:

a) analysis and description of the load profile of a single standard house in the Mediterranean area (Sept. 1983)

b) system analysis, system dimensioning and design including specification of the main components of a photovoltaic energy supply system (interface specifications) (Sept.-Oct. 1983)

c) development of project specific concepts and main components (Oct-83-March 84)

d) installation of the photovoltaic energy supply system in a standard house intended for export (January-June 84)

After the completion (30 June 1984) the house will be operated for at least 5 years in Denmark. The house will be equipped with a data monitoring system which will be defined by the Commission. The data monitoring system will in particular record data on solar radiation, energy produced by pv generator, state of charge of batteries, efficiency of DC-AC inverter, energy consumption of the house, ambient and collector temperature, wind loads on modules etc.
The building company Kalmargaarden registered in Bramming will be the owner of the house.

(*) Peak power at 1000 W/m2; AM 1,5; 25^{0}C. For the verification of the peak power only the measurements performed by the Commission during the acceptance tests will be relevant.

4. Project Description

This project titled "Photovoltaic Solar Energy Supply for a Danish Standard House" running under EC-contract No. ESC-R-097-DK was not formally initiated (signing of contract) until late February 1984.

In order to reach the project objective, i.e. an operational PV-powered standard house, within the time limit specified in the contract, that is July 1, 1984, it has been necessary for the project group to initiate a number of very efficient and quickly working ad hoc working groups.

These groups have worked with the following project-related fields and the project description will follow this division:

1. PV-system - overall view

2. Photovoltaic house

3. PV-array

4. Power conditioning equipment

5. Batteries

6. Load profile and simulation of loads

7. Supervision and control equipment

8. Measuring and data registration

4.1. PV-System - Overall View

According to the project programme the PV-array shall have a peak power output of 5 kW, (1000 W/m^2, AM 1.5, 25^{0}C).

Based on this and based on the analysis of the load profile, see section 4.6., the project group set up the following presumptions and conditions for the dimensioning of the total PV-energy system:

1) The PV-plant shall be integrated in the house both technically and architecturally

2) The PV-powered house shall to the widest possible extent appear as a normal powered house for its users

3) The PV-system shall be dimensioned for "stand-alone" powering of the house under climatic conditions corresponding to those in the Mediterranean area

4) During operation of the house in Denmark, the lacking energy supply expected during the winter months will be supplied in strictly controlled amounts from the mains via a rectifier

5) As principle of regulation of power from the PV-array a DC-switching system shall be used for connection or disconnection of the necessary number of solar modules

6) The PV-system as such shall be modularized and flexible in concept in order to facilitate easy adjustments to various load profiles, climatic conditions, lay-out of actual house, etc.

7) The know-how and/or products of the participating companies shall as far as possible be developed, put into operation, and evaluated.

This resulted in the following block diagram of a PV-system.

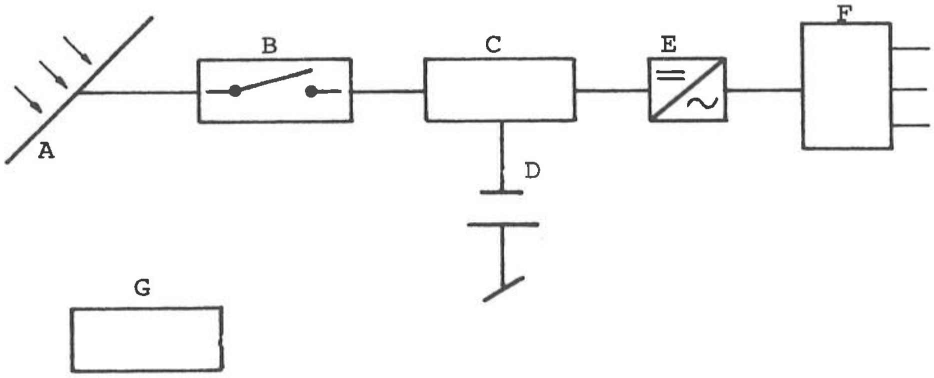


Fig. 1

Each block in fig. 1 is shortly commented.

A. The PV-panel consists of 261 modules divided into 9 parallel strings corresponding to an output of 5.01 kWp (25^{0}C).

B. The switch-arrangement is used for control of the PV-panel and for limitation of the power from the PV-panel. The switch arrangement is built up of parallel units permitting independent connection of 9 strings.
The switches are carried out as DC-contacts with magnetic blow-out.

C. The distribution module 1 includes measuring shunts, etc. for the measuring of the power production from all the strings. Besides it includes diode arrangement, battery fuses, various measuring shunts for battery, etc.

D. The battery consists of 2 x 36 blocks of 3 battery cells corresponding to a utilization capacity of approx. 400 AH 80 kWH.
The battery set up takes up a minimum of space and can easily be controlled visually.

E. The inverter system is built up of 0.5 1 kW modules in 20/40 kHz technics. The maximum output power from the inverter is 10 KW continuously, with a short time overload capability of 160%. The output power can be configurated as 220 V AC, one phase or 3 x 220 V AC, 3 phase. The present configuration is one phase corresponding to 220 V/45 A AC.

F. The distribution module II is a distribution and measuring unit for the PV-system output power.

G. The supervision and control unit, the DRO-4, makes a continuous, total supervision of the PV-system including the batteries.
The supervision and control are carried out in such a way that the project objective - which is to "humanize" the PV-system - has been fulfilled as far as possible, i.e. no specific demands.
The supervision and control unit also performs the simulation of loads and data registration.

Fig. 2 and fig. 3 show more detailed block diagrams.

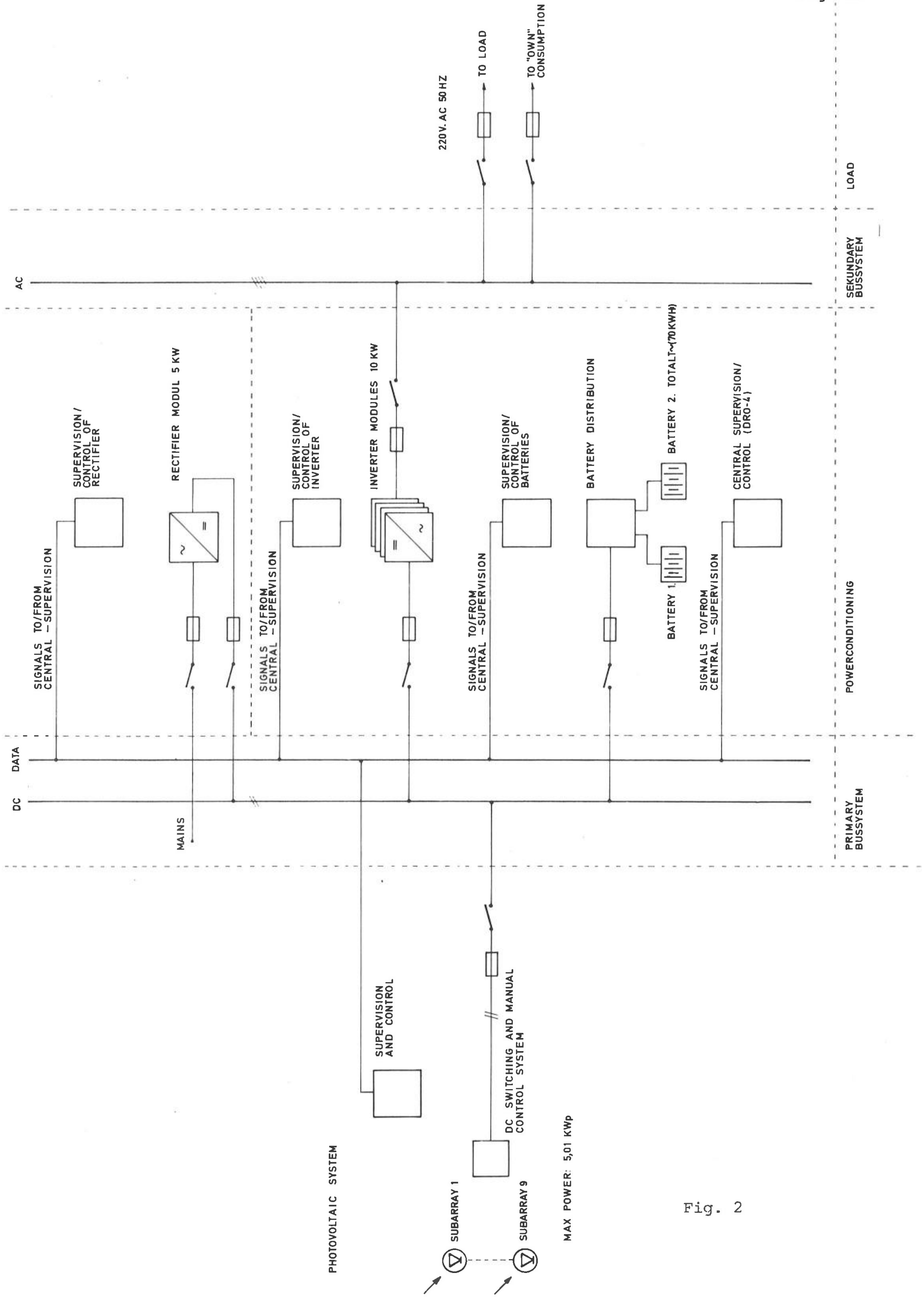

LOAD
SEKUNDARY BUSSYSTEM
POWERCONDITIONING
PRIMARY BUSSYSTEM
TO LOAD
TO "OWN" CONSUMPTION
220V.AC 50HZ
AC
DATA
DC
MAINS
SIGNALS TO/FROM CENTRAL -SUPERVISION
SUPERVISION/ CONTROL OF RECTIFIER
RECTIFIER MODUL 5 KW
SIGNALS TO/FROM CENTRAL -SUPERVISION
SUPERVISION/ CONTROL OF INVERTER
INVERTER MODULES 10 KW
SIGNALS TO/FROM CENTRAL -SUPERVISION
SUPERVISION/ CONTROL OF BATTERIES
BATTERY DISTRIBUTION
BATTERY 2. TOTALT~(70 KWH)
BATTERY 1.
SIGNALS TO/FROM CENTRAL -SUPERVISION
CENTRAL SUPERVISION/ CONTROL (DRO-4)
SUPERVISION AND CONTROL
DC SWITCHING AND MANUAL CONTROL SYSTEM
PHOTOVOLTAIC SYSTEM
SUBARRAY 1
SUBARRAY 9
MAX POWER: 5,01 KWp

Fig. 2

Photovoltaic Power Plant - Simplified Block Diagram

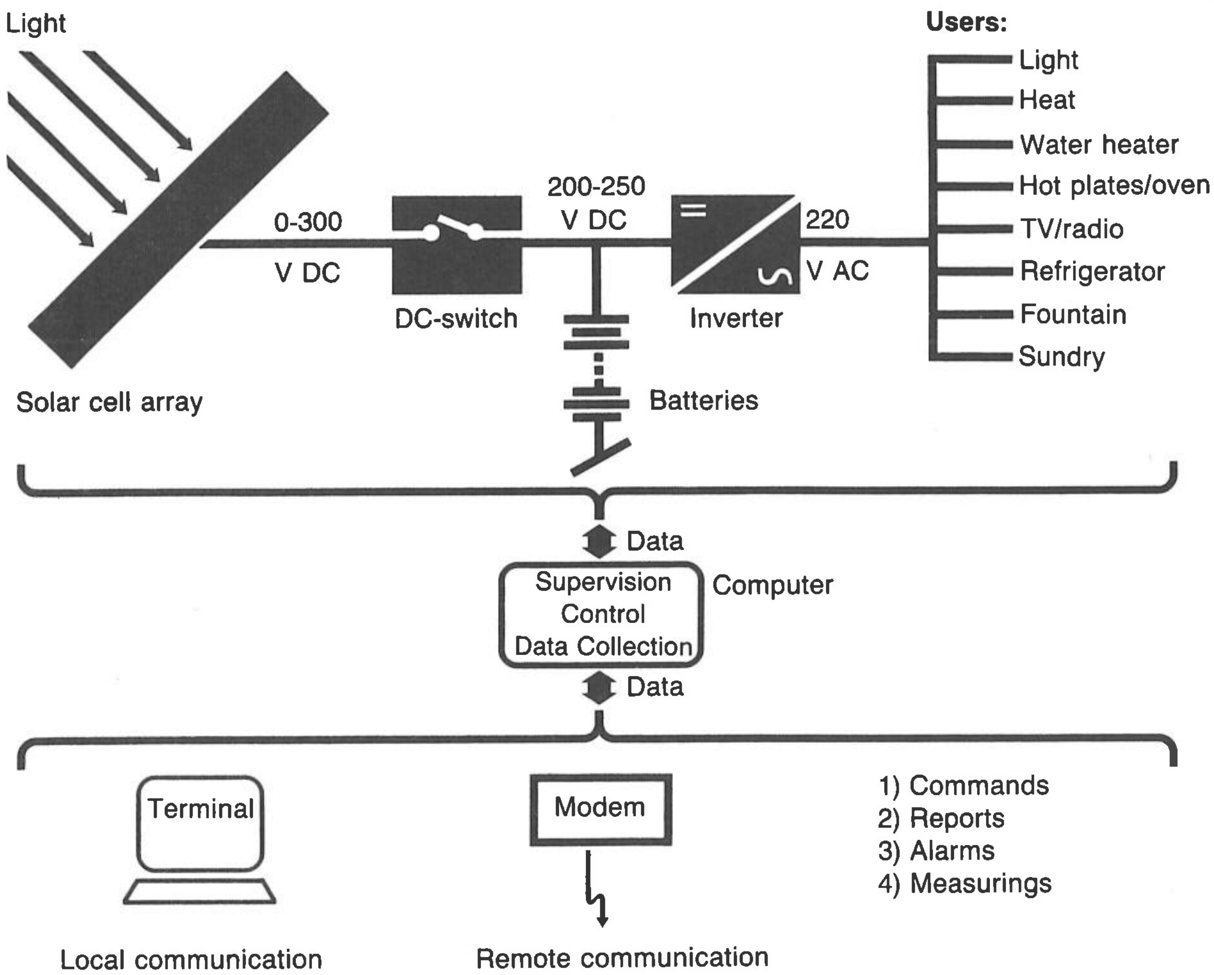


Fig. 3

4.2. The Photovoltaic House

4.2.1. Demonstration House

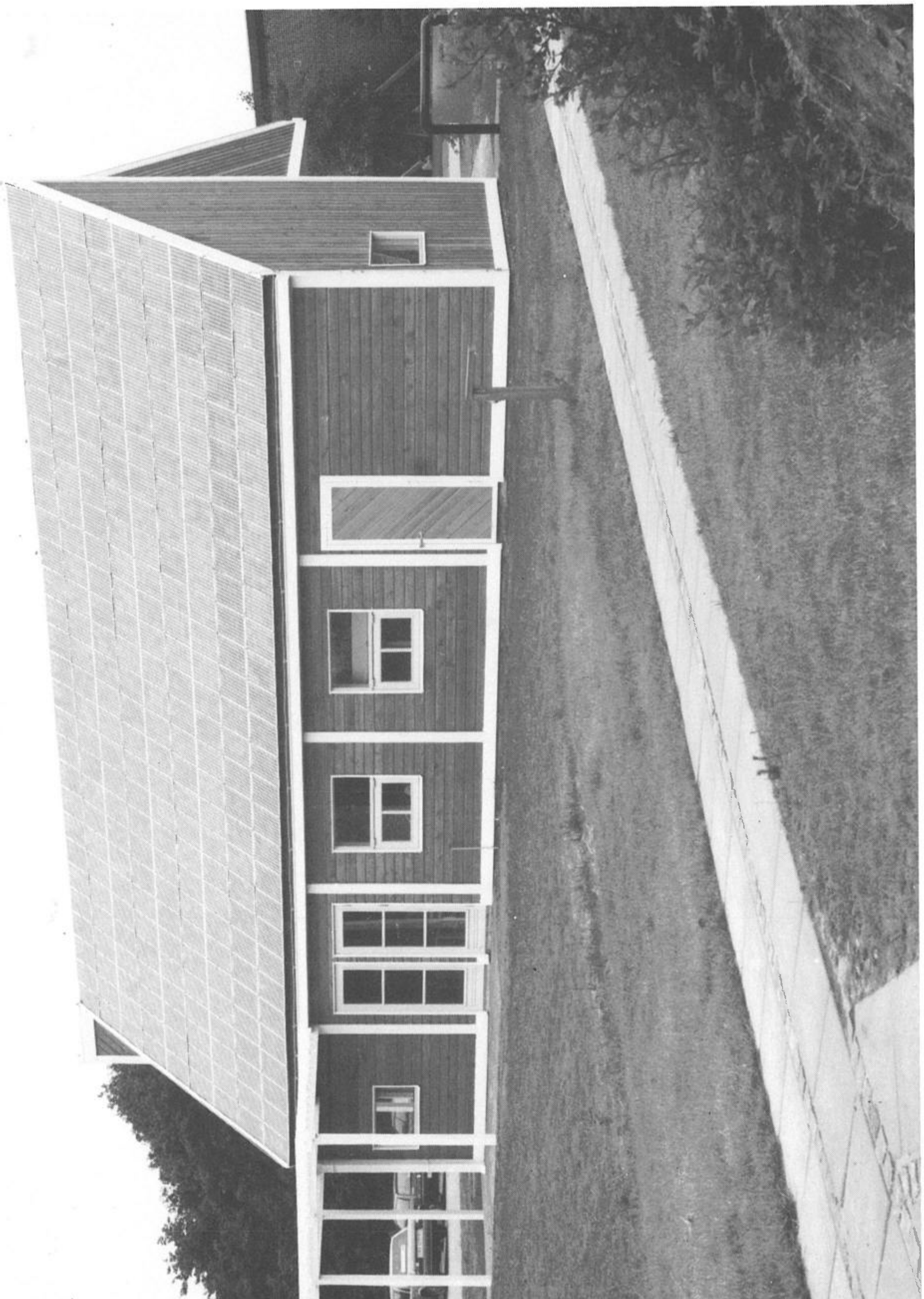
At the construction of the photovoltaic house great importance has been attached to create a compact house with a concentrated plan arrangement and an interesting front which comes up to the interesting effect of the solar cells.

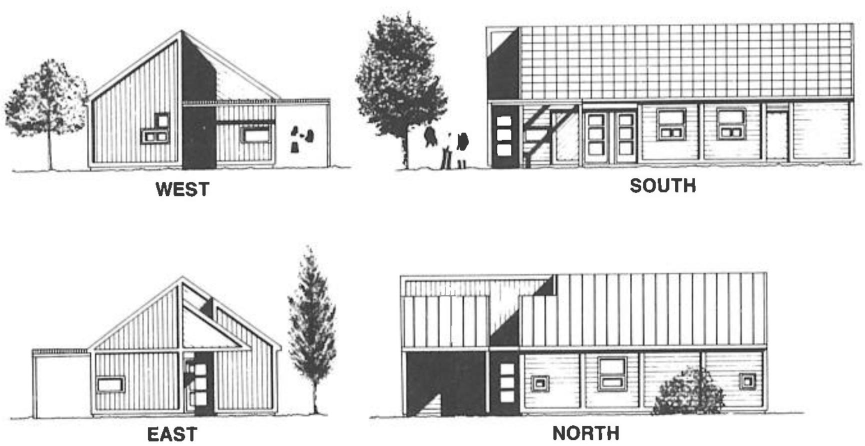
For functional reasons and to facilitate the presentation the technical equipment is placed in the scullery which has been renamed to the technical room.

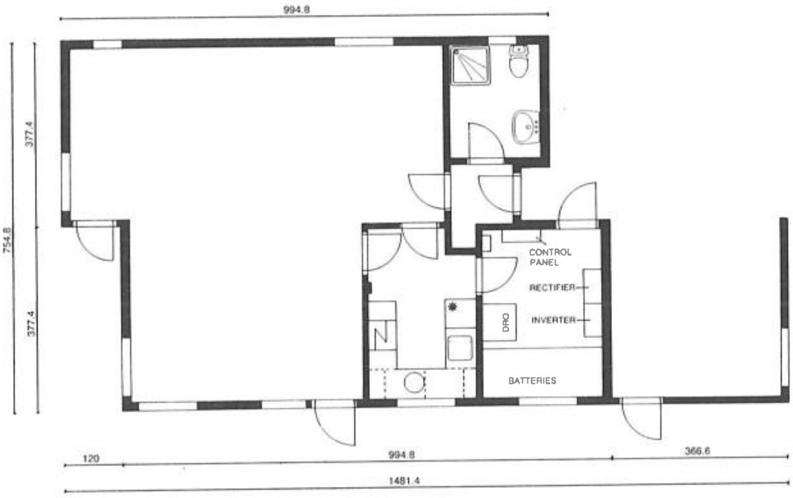
In a non-experimental house the technical equipment will be placed in the loft and apart from the nice solar cells on the southern roof surface, the house will appear as a normal single-family house. Furthermore, the living room and the rooms have been thrown together to form one room.

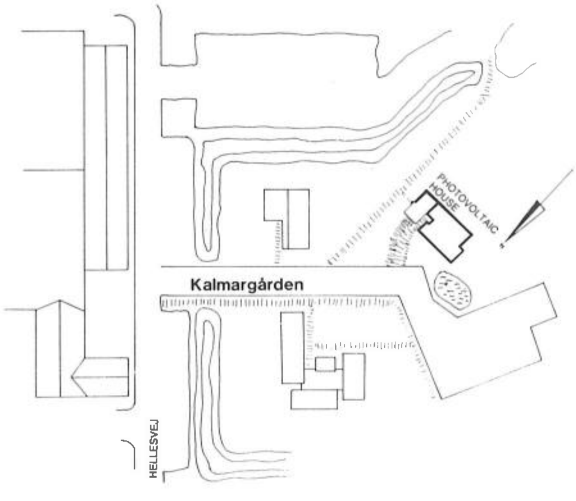
This has been made in order to have a room in the experimental house suitable for AV-presentation of the solar cell house.

In connection with a non-experimental house, the arrangement of the house will appear as "Proposal for Arrangement/Plan Arrangements for Photovoltaic House".




WEST
SOUTH
EAST
NORTH


994.8
377.4
754.8
377.4
CONTROL PANEL
RECTIFIER
INVERTER
BATTERIES
120
994.8
366.6
1481.4


PHOTOVOLTAIC HOUSE
Kalmargården
HELLESVEJ

4.2.2. Proposal for Arrangement/Plan Arrangements for Photovoltaic House

The plan arrangements are carried out with vertical displacement in the plan around the central axis of the house. The displacement results in i.a. good opportunities of extending the plan and gives a considerably reduced corridor space.

The main entrance is next to the carport. The carport can be constructed so it is possible to drive in from two sides.

This and a possible reversion of the house makes it possible to place the house at any site.

At the main entrance there is direct entry to the scullery from the carport or the porch. The porch has a wardrobe niche. The bathroom can be placed between the bedroom and the room or in connection with the porch as in the show house.

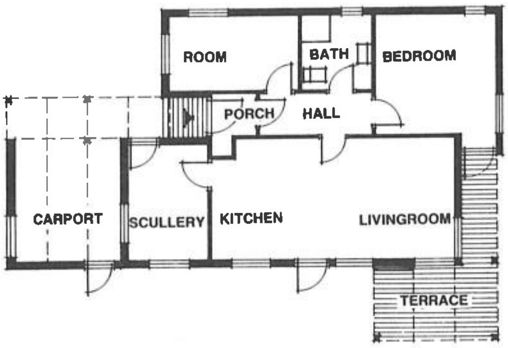
Exit is possible from the bedroom to a terrace with morning sun.
The living room and the kitchen are situated on the "warm" side with direct exit to the terrace. The kitchen is a U-shaped kitchen and from the dinette there is direct contact to the living room. The more secondary rooms, only being used for a short period, are situated north, thus forming an "insulating back" in the house. Thus, the light conditions of these rooms have not been disregarded, as both the room and the bedroom have windows towards other corners of the world than the northern direction.

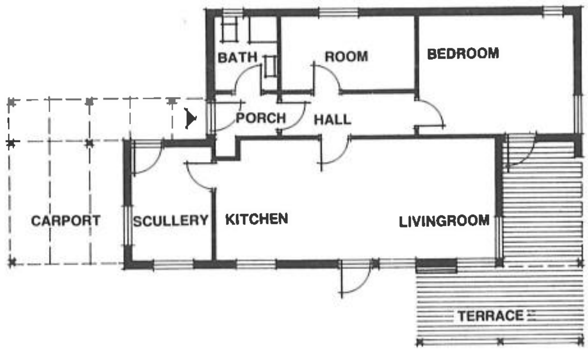
Rooms with the outer walls facing south have "large" areas of glass owing to the free heat from the sun. However, a "sliding shutter" has been placed in the living room which, during the cold period, can be slided for one of the glass doors. Consequently, it is possible to regulate the area of glass according to the weather. All rooms to the north have as small areas of glass as possible.

The front has been divided into modules with a view to a rational construction and mounting.
This also enables an interesting architectural division of the front. Moreover, the division into modules is advantageously in connection with a possible extension, both as to the building and particularly in connection with the architectural appearance.
Extension of the area of the house can primarily take place by extending the house so that either the living room is extended or an additional room is set up. The vertical displacement in the plan makes it possible to extend one room at a time.

Most materials of the solar energy house are based on wood owing to the construction and the mounting. The wood skeleton construction also gives a better insulation at a given thickness than an ordinary tile construction.

The house is built up of units which are easy to transport and mount. The units make it possible to avoid essential cold conductors in joints, etc. The roof construction is standard roof trusses with felt roof with the most suitable pitch of the roof for solar cells. A felt roof on one side and solar cells on the other will not disturb the general impression.


ROOM
BATH
BEDROOM
PORCH
HALL
CARPORT
SCULLERY
KITCHEN
LIVINGROOM
TERRACE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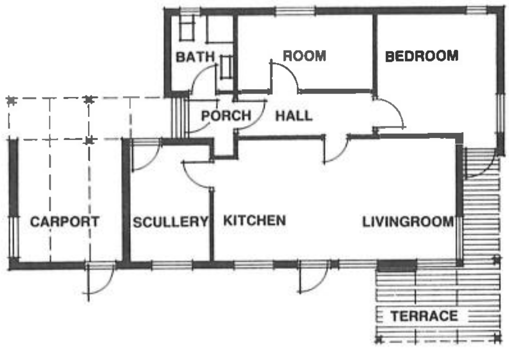
SCULLERY
KITCHEN
LIVINGROOM
TERRACE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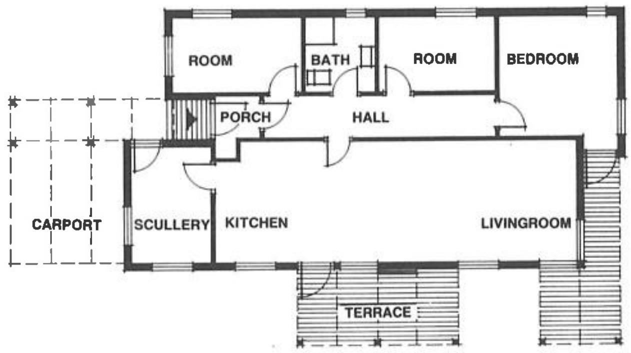
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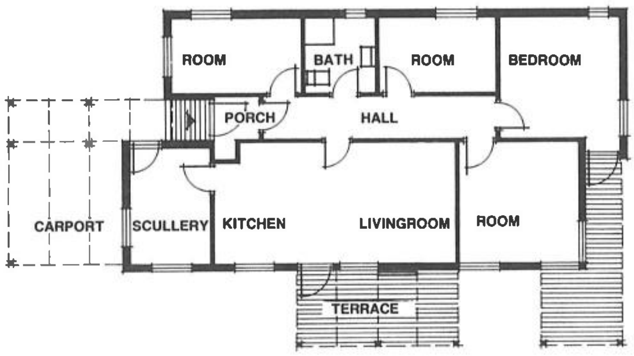

ROOM
BATH
ROOM
BEDROOM
PORCH
HALL
CARPORT
SCULLERY
KITCHEN
LIVINGROOM
ROOM
TERRACE

4.3. PV-Array

In order to fulfil the project objectives described in the project programme it has been necessary to make a survey of solar cell modules produced in the EC-countries at present, and to evaluate the possibilities available with respect to:

a) conversion efficiency
b) electrical characteristics
c) mechanical characteristics
d) possibilities of technical back-up at the producer
e) price
f) appearance from an architectural point of view.

An evaluation of the European PV-field covering these points resulted in the choice of module type PQ 10/20/0 from AEG-Telefunken.
By choosing a standard PV-module already well proved and well established on the market, the commercialization of the PV-powered house will be facilitated.
Some of the parameters entering the process of dimensioning the PV-array are briefly described below.

Dimensioning of PV-Array

Conditions:

1. PV-modules of the type AEG-Telefunken PQ 10/20/0 are used

2. The modules are not included in the roof construction as part of a watertight construction

3. The modules are to be integrated in the roof according to aesthetic guidelines

4. Replacement of the modules must be relatively easy.

Rough dimensioning of a PV-panel:

The EC requires an output of 5 kWp

Nominal output for module PQ 10/20/0 = 19.2 Wp (25^0C).

minimum 250 modules

Battery of 108 cells   corresponding to voltage limits of:

1.86 V/cell   200.9 V   (80% discharge of battery)

2.08 V/cell   229.6 V

2.35 V/cell   253.8 V

Module voltage at 25^{0}C and approx. MPP   8.5-9 V.

If complete charging voltage is to be obtained "without exceeding" MPP a series connection of minimum:

$\frac{254}{8.75}$ 29 modules

is required.

Number of strings = $\frac{250}{29}$ = 8.6 => 9

as the EC requires 5 kWp a total of 9 strings of 29 modules   261 modules corresponding to an output of approx. 5 kWp (25^{0}C).

Conclusion

261 modules PQ 10/20/0 are required to be connected electrically in 9 parallel strings of 29 modules and this is used in the project.

Figure 1.

Characterization of the PV-system (25^0C):

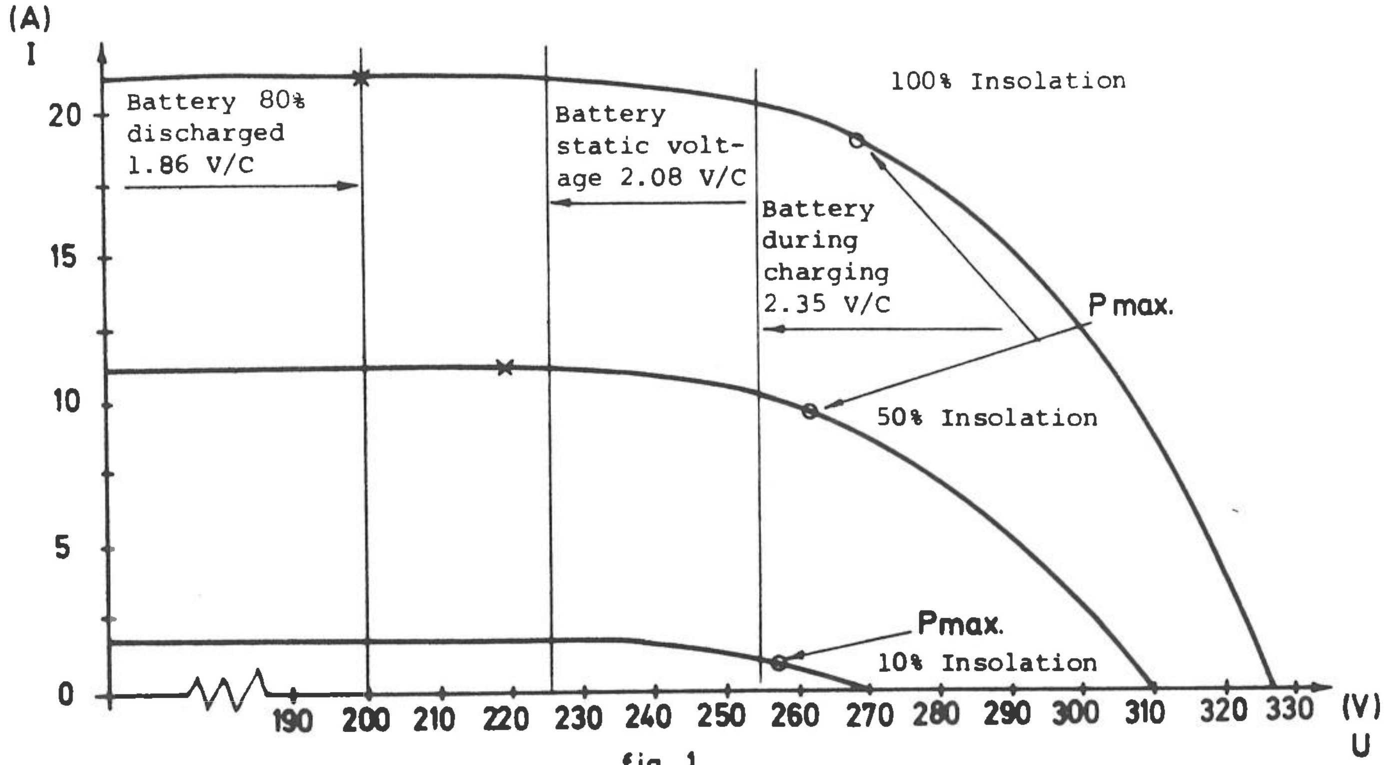


fig. 1.

Figure 1 shows a working characterization of the PV-panel and a battery of 108 cells.

It appears from the figure that it will be possible to work relatively close to the maximum output of the PV-modules without MPPT equipment, especially in the range between 0-50% insolation covering the greater part of the insolation in the Northern Europe.

Outline of mounting and structure of PV-modules

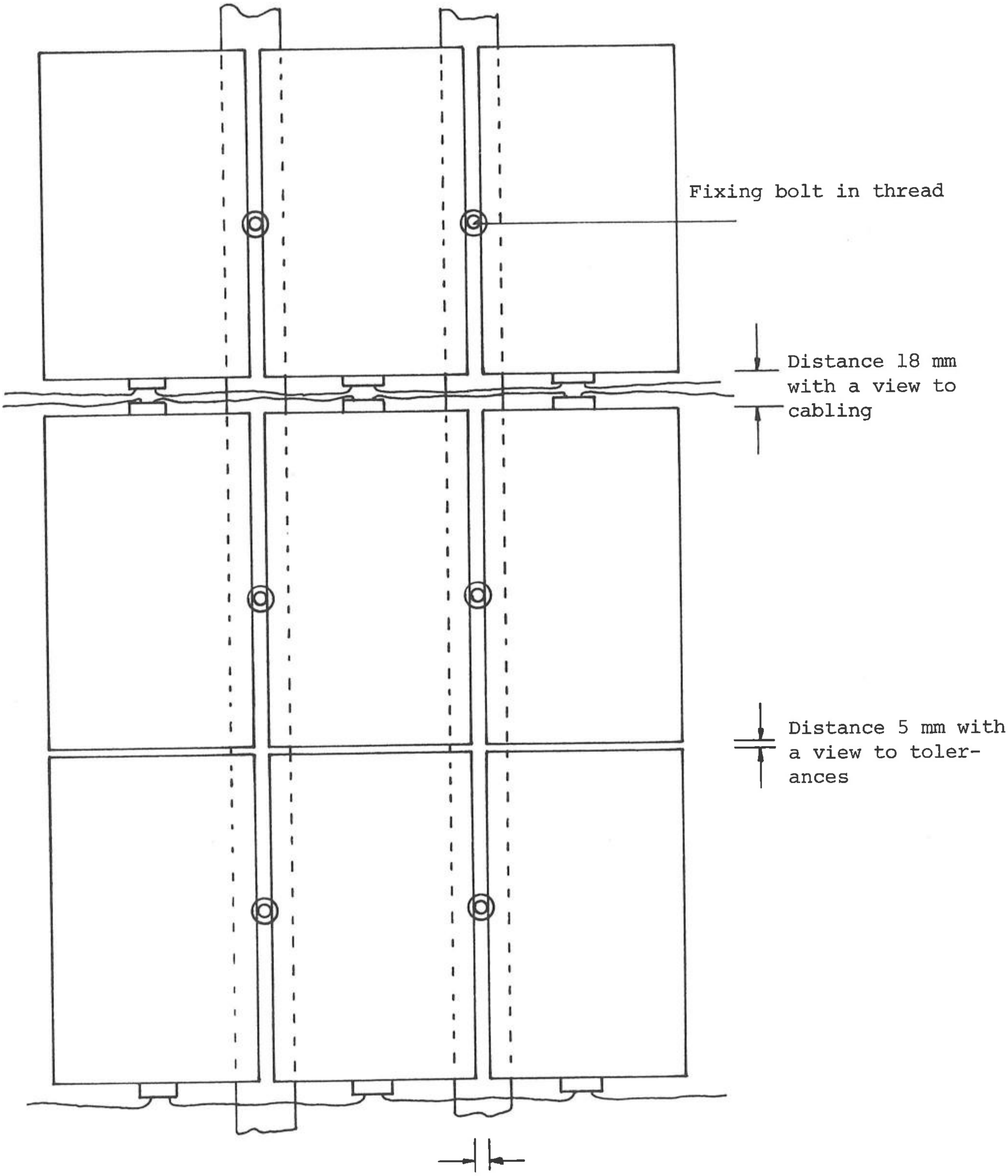


Fig. 2

Physical total dimension per module: height: 575 mm
length: 470 mm
depth: 11 mm

Total dimensions - PV-array

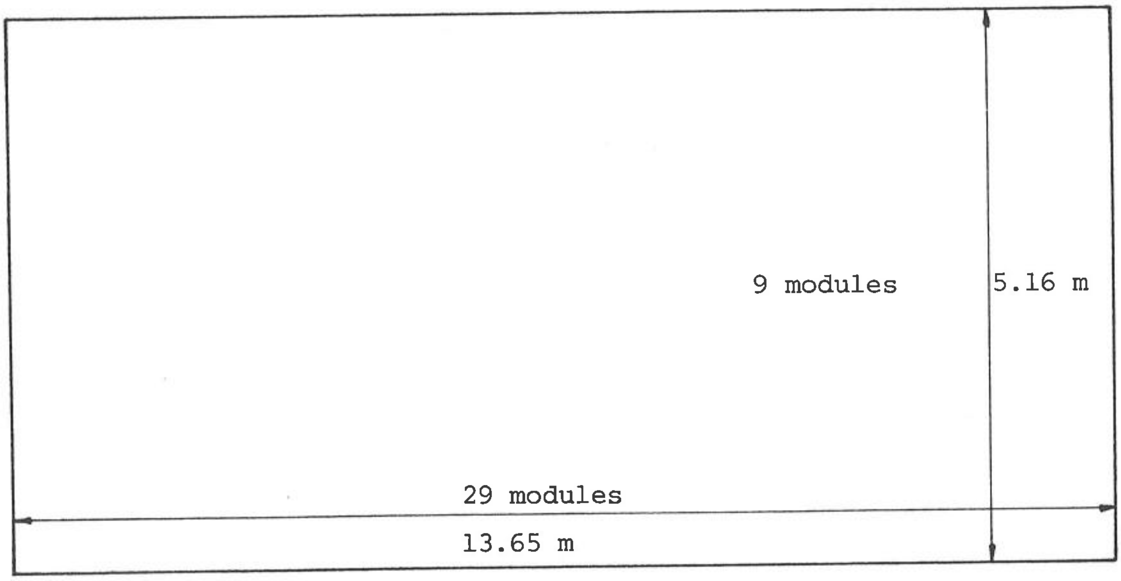


Fig. 3

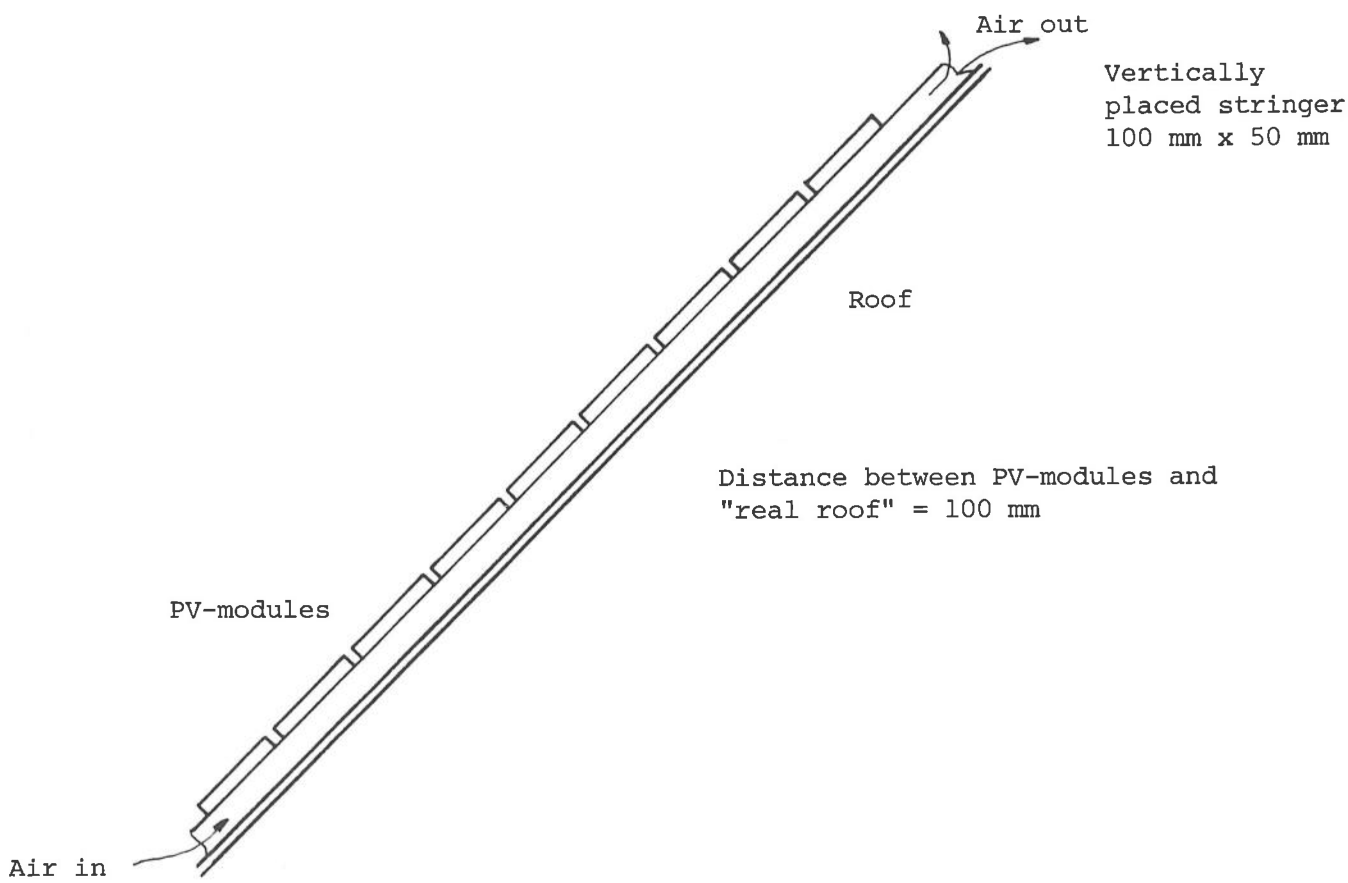
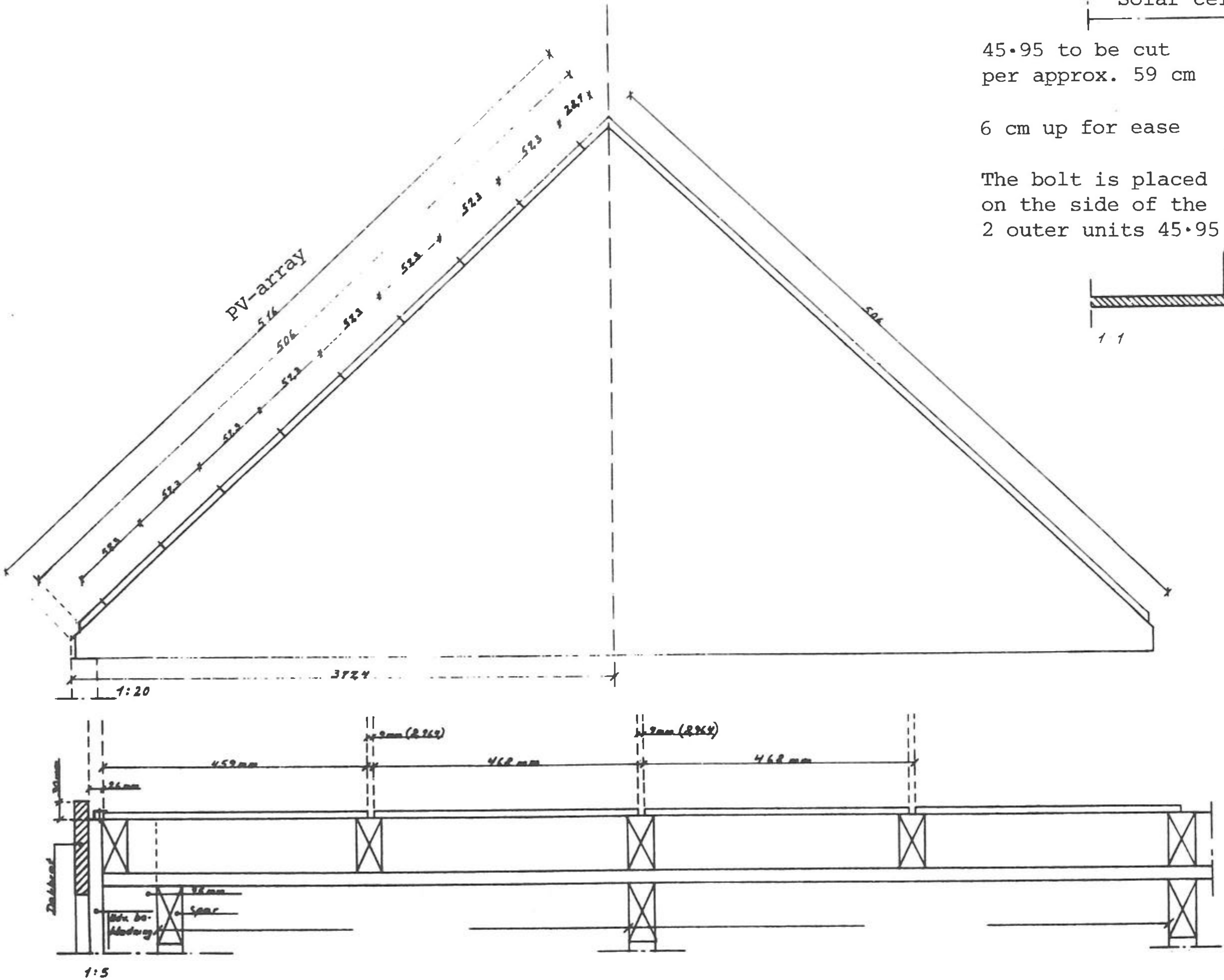
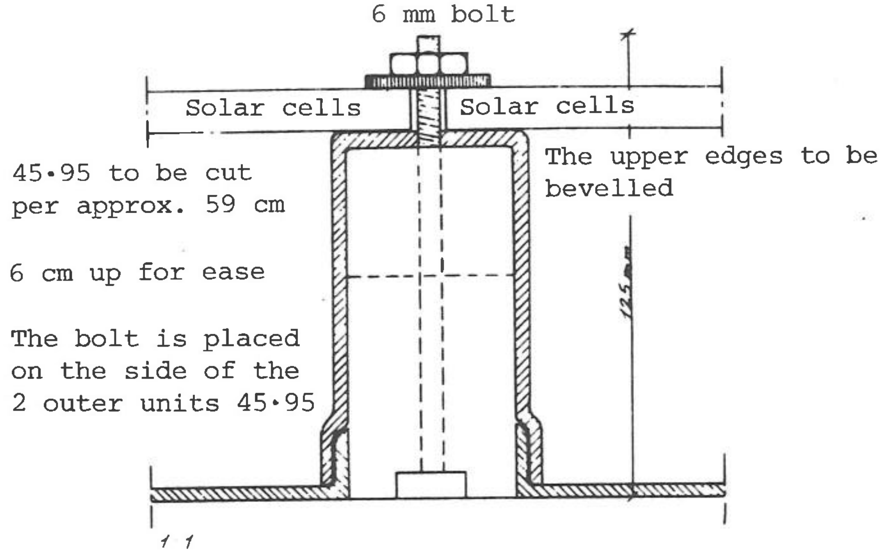
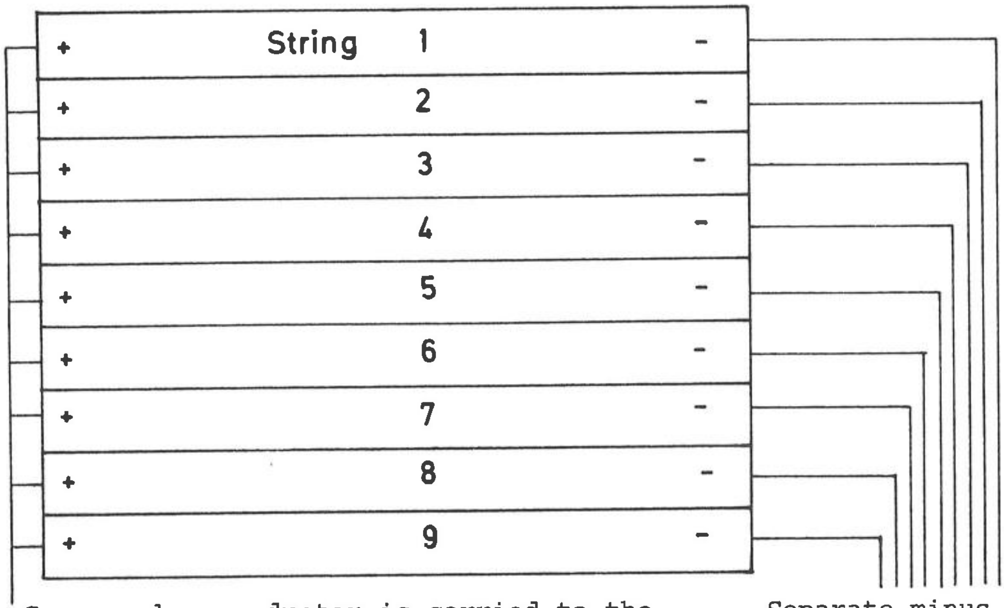


Fig. 4


PV-array
516
506
523
3724
1:20
459mm
468mm
468mm
1:5


6 mm bolt
Solar cells
Solar cells
The upper edges to be bevelled
45·95 to be cut per approx. 59 cm
6 cm up for ease
The bolt is placed on the side of the 2 outer units 45·95
125mm
1:1

Electric Configuration:



Common plus conductor is carried to the electronics room

Separate minus conductors are carried to the electronics room

Fig. 6

The configuration and cabling are made to minimize electrical "loops" and comprehensive over-voltage protection is implemented.

Data Sheet

Solar Generators PQ 10/20/0

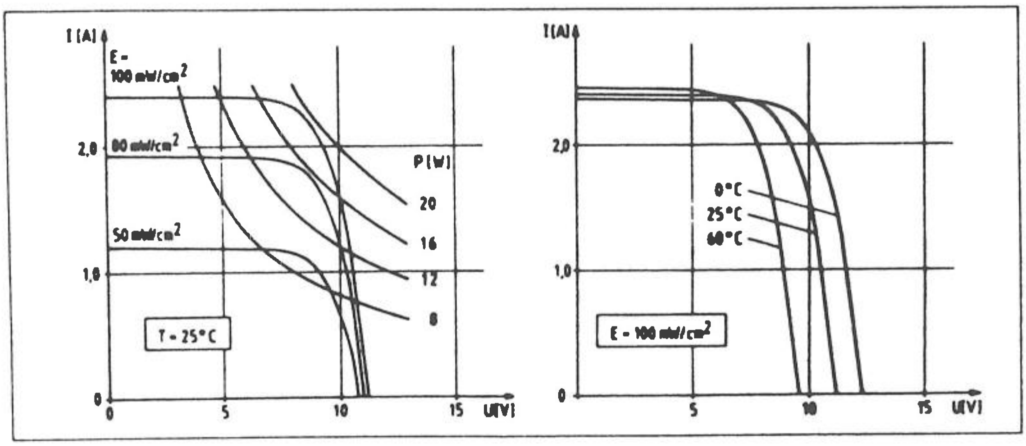
AEG

Electrical Data

Electrical data as a function of the operating temperature

Characteristic values (AM1 – 100 mW/cm²)	Operating temperature		
	0 °C	25 °C	60 °C
Open-circuit voltage (V)	12.3	11.2	9.6
Short circuit current (A)	2.37	2.41	2.46
Current at maximum power (A)	2.18	2.20	2.23
Max. Power (W)	21.3	19.2	16.2

Current/Voltage Characteristic



Voltage, current and power data as a function of temperature

Voltage	increases decreases	by 0.4 %/°C	below above	25 °C
Current	increases decreases	by 0.06 %/°C	above below	25 °C
Power	increases decreases	by 0.44 %/°C	below above	25 °C

Mechanical Data
Module Elements

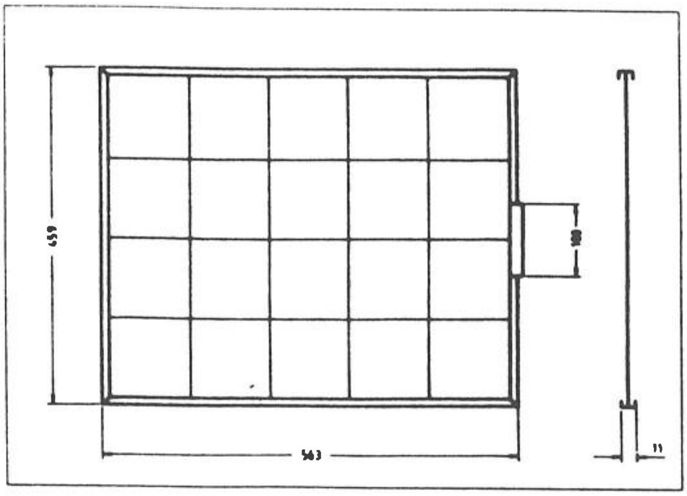
Solar Cells
Base material:
Multicrystal silicon

Size
10 × 10 cm^2

Capsules
Glass

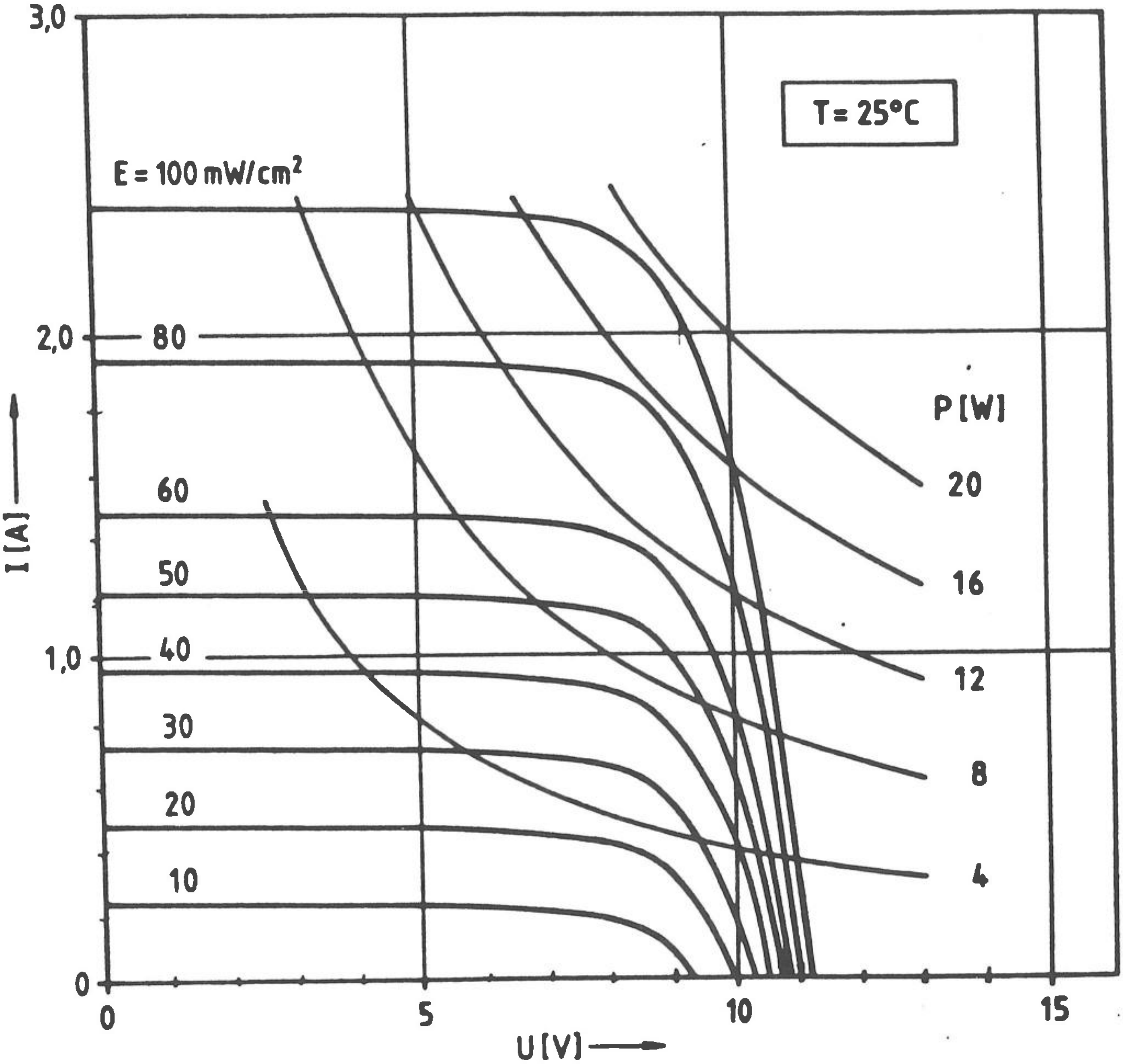
Frame
Stainless steel

Weight
3850 g



Dimensions

Solarmodul PQ 10/20/0



Kennlinienfeld bei verschiedenen Einstrahlungen

4.4. Power Conditioning Equipment

4.4.1. The PV-array Output Switch System

As mentioned in section 4.1., page 9, it was decided rather early in the project to use a switching arrangement for controlling the output power from the PV-array. Different controlling techniques including series/shunt regulators, DC/DC converters with and without MPPT (Maximum Power Point Tracking) and switching systems have been analysed in the project.

An "intelligent" switching system controlled by a computer was in this connection the best choice from the point of view of the project group. The switching system is a simple, rugged construction, and combining it with computer-control a rather high degree of total efficiency can be obtained. The switching system also enables easy manual as well as automatic supervision of the PV-array. In the "manual mode" the switching system makes it possible to disconnect one PV-string at a time (repair/servicing), and to measure open-circuit voltage and short-circuit current on each string. In the "automatic mode" the computer controls the connection/disconnection of each string to the primary DC-bus, see fig. 2, page 11, in a dynamic process according to algorithms stored in the computer. By comparing the outputs from the active strings the computer also continuously supervises the PV-array.

4.4.2. The Inverter System

The firm of Alex Grosman A/S has completed the development of a new type of inverter to be used in the Photovoltaic Energy Project.

The production of the individual units and the construction of the plant have proceeded according to plan and with a satisfactory result so that the completed inverter plant was ready for installation in the solar cell house in the last week of May.

Considering the very short period of time this project has been given from the final approval of the EC-contract and to the presentation of the complete product, we must admit that we only succeeded because of the very considerable effort from the participants of the project and because it has been possible for us in the inverter group to postpone other tasks.

As previously mentioned in the periodic report it was found, already at an early stage, that it was necessary to develop an inverter of 10 kW and not only of 5 kW as it was assumed at first, in order to be able to cover a normal family's need for power.

Owing to the above-mentioned it was natural to develop an inverter, built up of modules, easily adaptable for the actual need for power which we expect will be different dependent on where the solar cell plant is to be installed.

The inverter is based on PWM (pulse width modulation) with a switching frequency of 20/40 kHz with power mosfet transistors and we have thus obtained that the inverter does not operate with an audible frequency and that the control does not need much power.

At the final test of the power modules it was found that 32 printed circuits (power modules), each including half a bridge to build up a 10 kW inverter, had to be used.

These 32 printed circuits are divided into 4 groups of 8 circuits, forming 4 parallel inverters, and which can give 4 x 0.625 kW when fully loaded (continuously). Each group is connected to a transformer for 2.5 kW. The secondary windings of the 4 transformers are parallelly connected and form the output of the inverter.

The inverter is built up in a sheet iron table, the 4 transformers being placed at the bottom. 4 rows of 8 power modules, of 2.5 kW each, have been installed in slide bars and connected via multiplugs enabling an easy installation and service-friendly construction.

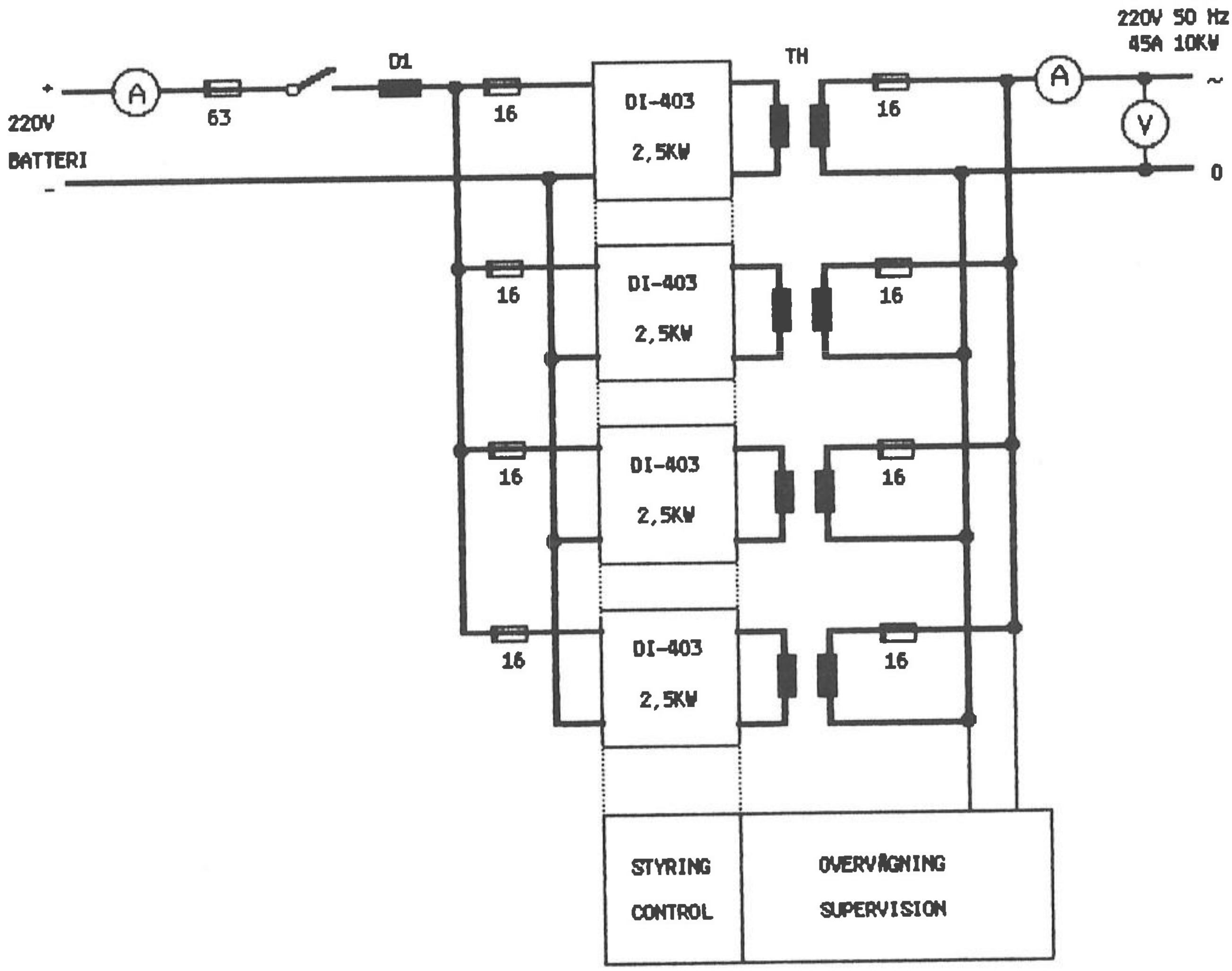
The control and supervision are placed above the power modules. The control is built up with a crystal-controlled frequency generator. The supervision of the power modules has been divided so that each row (2.5 kVA) is supervised. The supervision has been divided for each half of the bridge. The indication takes place by means of LED on the corresponding supervision print.

The voltage and frequency of the plant are supervised by supervision relays which disconnect the plant at the fixed limits.

The PWM-inverter can continuously be loaded with max. 10 kW. In connection with loading in the area between 10-16 kW the inverter can be loaded for approx. 2 seconds, and then the power modules are regulated down. They can be restarted internally or externally via the electronic supervision.

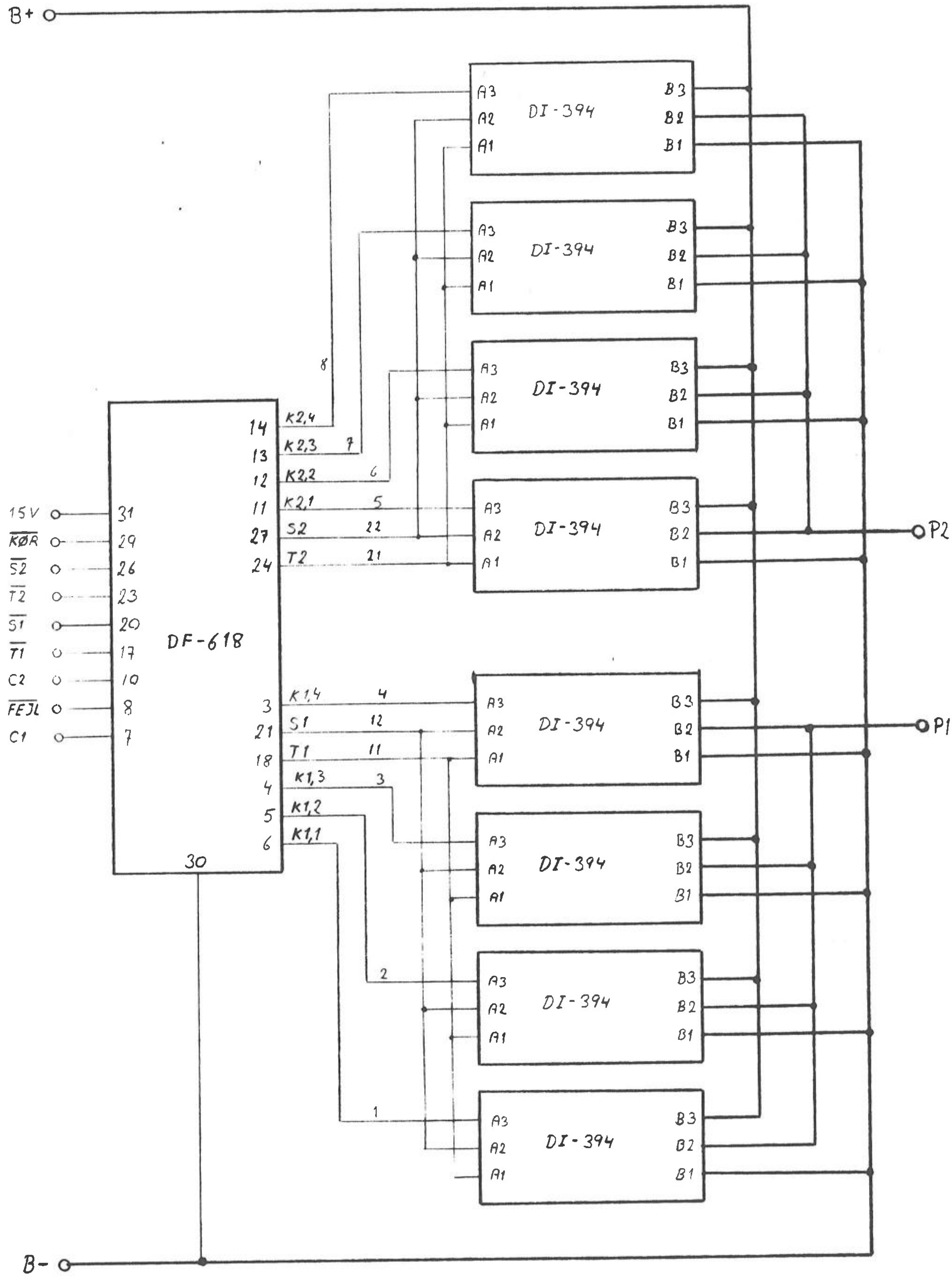
In connection with a load of 16 kW (160%) the plant limits the current. This power enables start of refrigerators and other equipment with a considerable starting current and blow of a 16A distribution fuse.

The distribution of AC-power from the inverter to the house is made according to Danish national safety-regulations, i.e. including earth leakage circuit breaker and selectivity in the fuses.

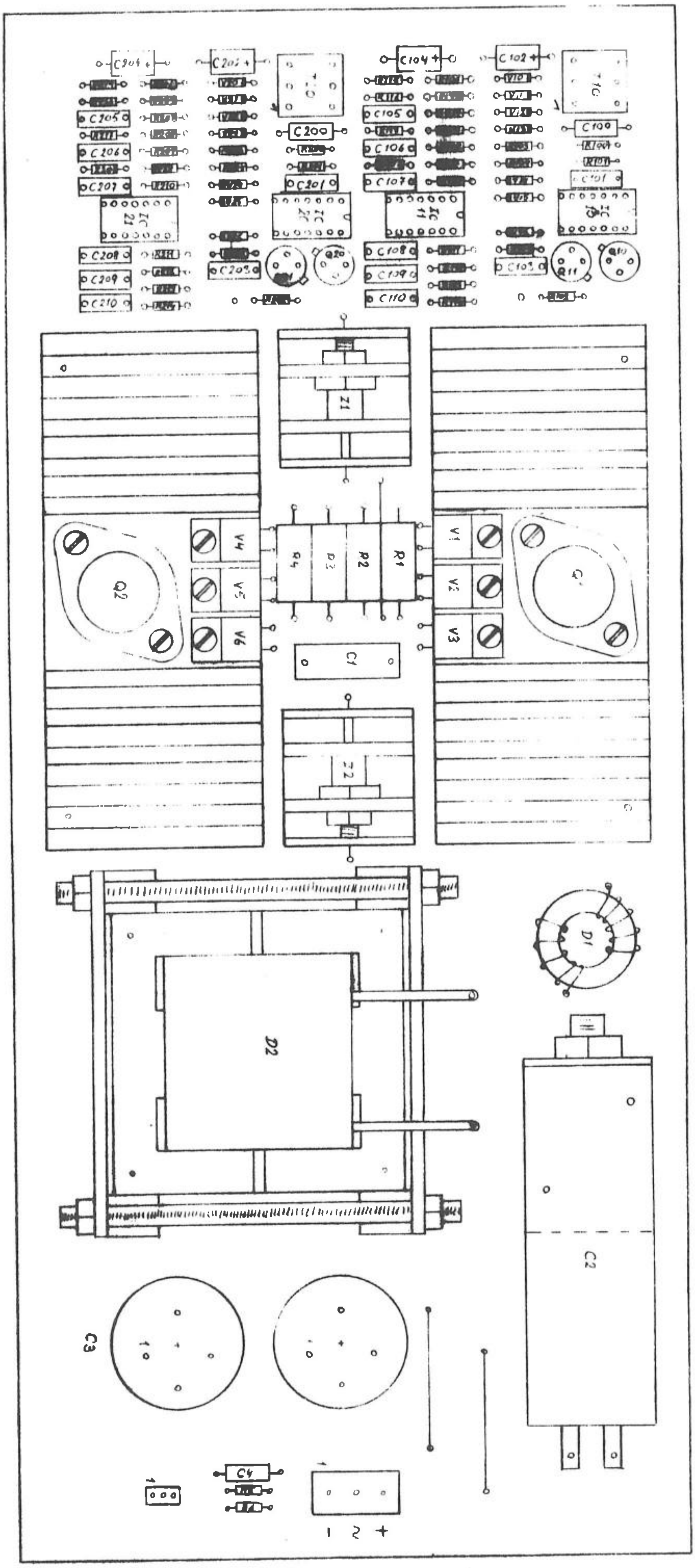


INVERTER TYPE PWM 220-10

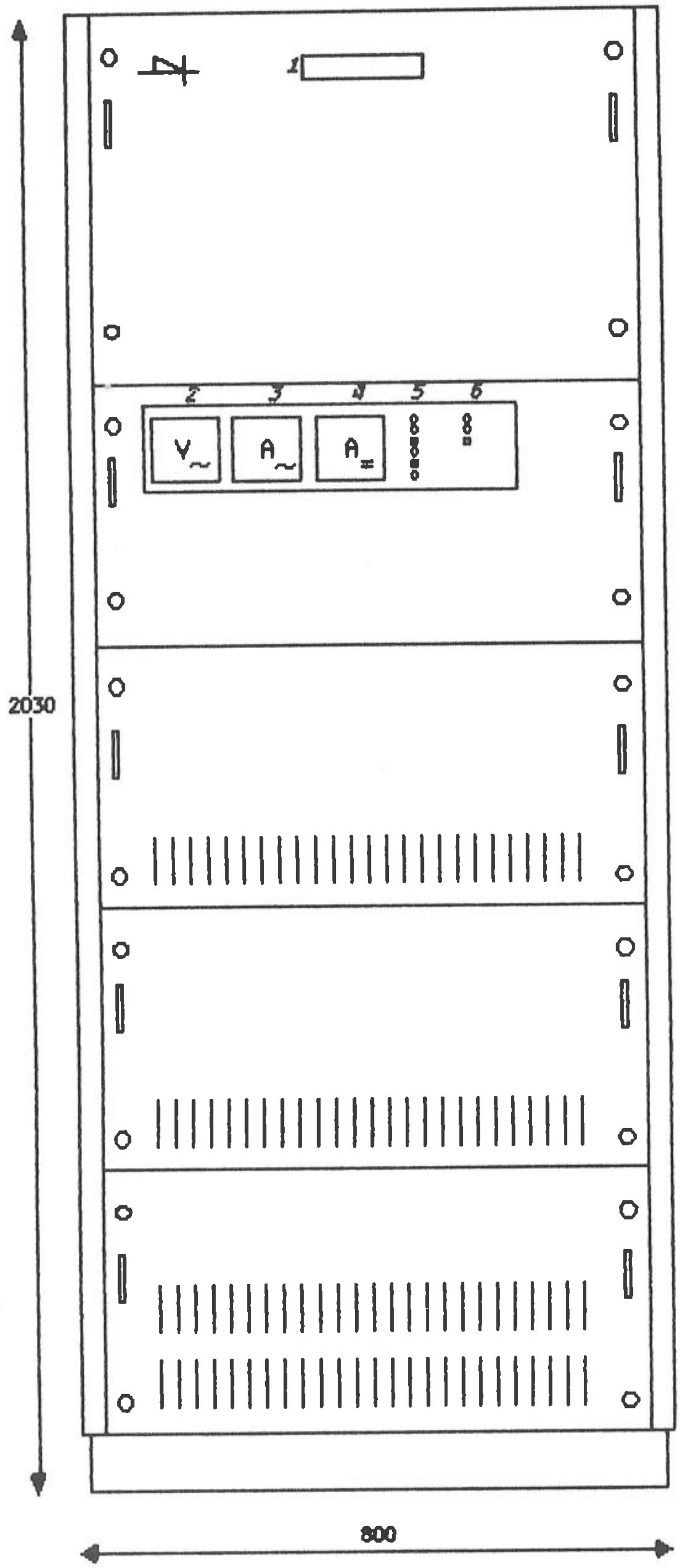
BLOKDIAGRAM



PWM-inverter 10 KVA, 2.5 KVA sub-system



PWM-inverter 10 KVA, 500 VA module



1. INVERTER	
2. AFG. SPÆNDING	OUTPUT VOLTAGE
3. AFG. STRØM	OUTPUT CURRENT
4. TILG. STRØM	INPUT CURRENT
5. INDE	ON
INVERTER FEJL	INVERTER FAULT
LAV BATTERI	BATTERY LOW
SPÆNDING	VOLTAGE
FREKVENS	FREQUENCY
SIKRING	FUSE
6. IND - UD	IN - OUT
AFSTIL	RESET
LAMPETEST	LAMP TEST

DIM. 800 x 530 x 2030 MM.

INVERTER TYPE PWM 220-10

4.5. Batteries - GRL Batteries for Photovoltaic Energy Project

Two antimony-free batteries, type GRL of 108 cells and with a capacity of totally 200 $Ah_{(10)} \sim 80$ kWh, are used.

The Positive Plate

The plate is made up of a number of tubes which contain the active material. The wall is a multitube bag woven of threads which are spun of polyester fibres. The multitube bag with thousands of micropores allow the electrolyte to pass freely, and effectively prevent any loss of the active material. The active material in the positive plates of the battery expands during discharge, but the multitube bag is strong enough to resist this expansion and do not crack. The frame and spines of the plate forming the grid are cast from a corrosion-resistant lead alloy.
A bar of acid-resistant plastic seals the tubes at the bottom and secures the spines of the grid.

The Negative Plate

The plate consists of a lead grid into which the active material is pressed. The grids are designed to hold the active material in position. The upper frame of the plate is fitted with plastic shields to prevent short circuits.

Separators

The life of the battery is very dependent on the quality of the separator. The new ribbed separators are made of microporous plastic. They are strong, flexible, and resistant to heat and acid. The electrical resistance of the separators is extremely low and acid diffusion is excellent.

Cell Containers

The containers are made of strong transparent plastic and have a high insulating strength and high resistance.

The acid reserve in the containers is so great that the batteries can go for long periods without maintenance.

The electrolyte is sulphuric acid with the specific gravity of 1.24 ± 0.01 kg/dm^3.
The minimum and the maximum levels of the electrolyte are indicated on the container.

The cells are connected with lead-coated copper connectors and are mounted with acid-resistant screws and nuts. A cover over each intercell-connector isolates the battery and prevents short-circuits. Terminal-connectors, on which the supply cables can be fastened, are delivered with the batteries.

Capacities

The capacities in charged condition are stated at $20\,^0C$ and at a specific gravity of 1.24 ± 0.01 kg/dm^3.
The battery must not be discharged with more Ah than correspond to the current rate shown on the capacity curve enclosed.
For capacity test the 5-hours rate is recommended.

Charging

The charging method depends on the specifications of the plant and can be as follows:

a) by floating voltage (2.22 - 2.24 V/cell)
b) by increased charging voltage (2.35 - 2.40 V/cell)
c) by disconnected load to the end of charging (2.60 - 2.80 V/cell)
d) in case of application in solar-plants there is a voltage limitation of 2.35 V/cell.

Charging current before gassing at 2.35 V/cell is not limited.

The temperature of the electrolyte must only for a short time exceed $40\,^0C$.

Deep Discharge Endurance Test

To prove this quality the battery is discharged at 100% C_3 i.e. at I_3 for 3 hours. Recharging is done at I_5 for 2.75 hours and additional charge at 0.5 I_{10} for 6 hours. (Charge rate 1.15). The offered Lyac stationary SG-cells obtain 600 - 900 cycles.

Specifications for Battery and Accessories

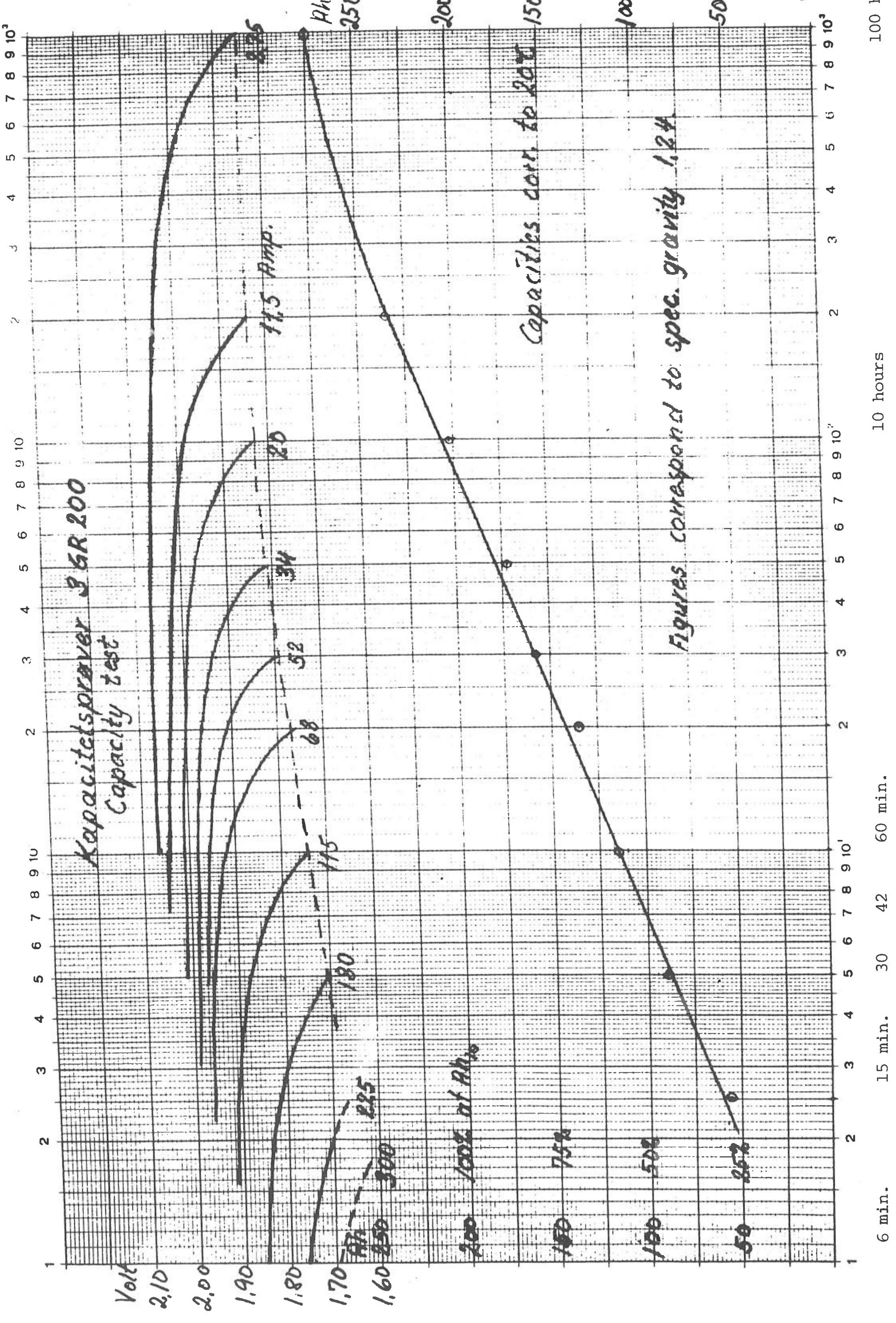
LYAC-special alloy for maintenance-free batteries.

Maintenance-free during 3 years.

With recombination plugs maintenance-free for about 15 years.

Self-discharge:	Less than 0.1% C_{10} per 24 hours at 30^0C.
Estimated life-time:	Over 20 years by floating voltage operation.
Temperature range:	
Delivery:	Filled with acid, charged, and capacity tested. Posts and connectors are isolated with plastic cover.
Putting into operation:	The battery has 100% capacity when delivered. Besides LYAC instructions must be followed.
Positive plates:	Tubular plates.
Negative plates:	Grid plates with LYAC's special paste.
Cell containers:	Styrolacrylnitril (SAN) - transparent.
Cell covers:	Styrolacrylnitril (SAN) - grey.
Separators:	Microporous plastic separators. Electrical resistance less than 0.2 μohm/cm^2.
Plate fastening:	The positive and the negative plates are placed on prisms.
Electrolyte:	Sulphuric acid (H_2SO_4). Specific gravity 1.24 ± 0.01 kg/dm^3 at 20^0C. Degree of purity of the acid according to DIN 57510.
Terminal posts:	LYAC-special-terminal posts with patented acid tight seals. Positive terminal is marked with + in the cell cover. The number of posts depends on capacity of battery.

Cell plugs: (Construction extra)	Recombination plugs for recombining gassing current of 5 A. Safe against overcharge. Efficiency during normal operation > 80%.
Filling water:	Deionized water - if, as an exception, it should be necessary to fill up. Maximum conductivity: 3 µS/cm.
Charging voltage:	For solar operation: 2.35 V/cell ± 1%.
Charging voltage temperature coefficient:	- (3-6) mV/K per cell.
Charging efficiency (Wh):	> 85%.
Charge acceptance:	Charging current of 1/1000 x I_{10} will contribute to building up the capacity.
Capacity curve:	According to enclosure.
Energy density:	22.8 Wh/kg.
Short-circuit current:	About 8 - 10 x C_1 (A).
Type tests:	Capacity test. Suitability for floating operation. Electrolyte reserve test. Short-circuit current test. Life test. Deep discharge endurance test.


Kapacitetsprøver 3 GR 200
Capacity test
Capacities corr. to 20°C
Figures correspond to spec. gravity 1,24
Volt
2,10
2,00
1,90
1,80
1,70
1,60
Ah
11,5 Amp.
20
34
52
68
115
180
225
300
100% at Ah10
75%
50%
25%
6 min.
15 min.
30
42
60 min.
10 hours
100 h

4.6. Load Profile and Simulation of Loads

One of the main objetives of the 5-year operational period will be an analysis and evaluation of the complex relationships between energy-production from the PV-array, available (or "usable") energy from the PV-system and different "user-patterns" regarding electrical appliances in the house.

This information could lead to an optimization of the dimensioning process for a "house-based" PV-system, and also to an optimization of the main key-components in the PV-system, the PV-array, the batteries, the inverters, and the supervision and control unit. Therefore, the project group has attached great importance to this aspect of the project.

In order to be able to control and register the energy consumption and the energy flow of the house no one will actually be living in the house.

The house is equipped with a number of normal electrical household appliances, i.a. refrigerator, oven, water heater, etc.

The pattern of use for the different electrical appliances in a house has been studied in order to find how many hours each day or each week, each electrical appliance is used in a normal household, i.e. a statistically "normal" 4-person family.

The installation and distribution of electricity within the house has been made very flexible, and it is possible by means of an electronic control unit to switch on and off an individual group of electricity consumers automatically according to a predefined programme, i.e. the load profile.

If for practical reasons some electrical appliances cannot be controlled automatically, e.g. the heating-plates, a corresponding "dummy load" is used.

Based on insolation data from the Danish test reference year the energy production from the PV-array has been calculated to approx. 5600 KWH with a yearly distribution as shown in fig. 1.

If the PV-powered house was placed in North Africa (20^0 N) an output of approx. 10100 KWH per year with a distribution as shown in fig. 2 could be expected.

From the figures it can be seen that the yearly energy production at 20^0 N is approx. twice as big as that at 56^0 N (Denmark), and the variation in energy production during a year at 56^0 N is approx. twice as big as that at 20^0 N. Even if the figures shall be regarded as very rough estimates they nevertheless stress the fact that "stand-alone" PV-systems under Danish climatic conditions will show a rather low degree of "total efficiency", i.e. amount of "usable" energy in relation to "producable" energy.

In connection with the fact that the PV-house is intended for use in the Mediterranean area, the above-mentioned has lead the project group to the following conclusion regarding the load profile for the PV-system.

The house will at present be operated with an average daily load of approx. 13 KWH, corresponding to a yearly load of approx. 5000 KWH.

As it can be seen from fig. 1, it will be necessary to supply "extra" energy in the period from September to March. This will be done strictly controlled via a mains connected rectifier.

Energy production from the PV-array in Denmark
(45° tilt)

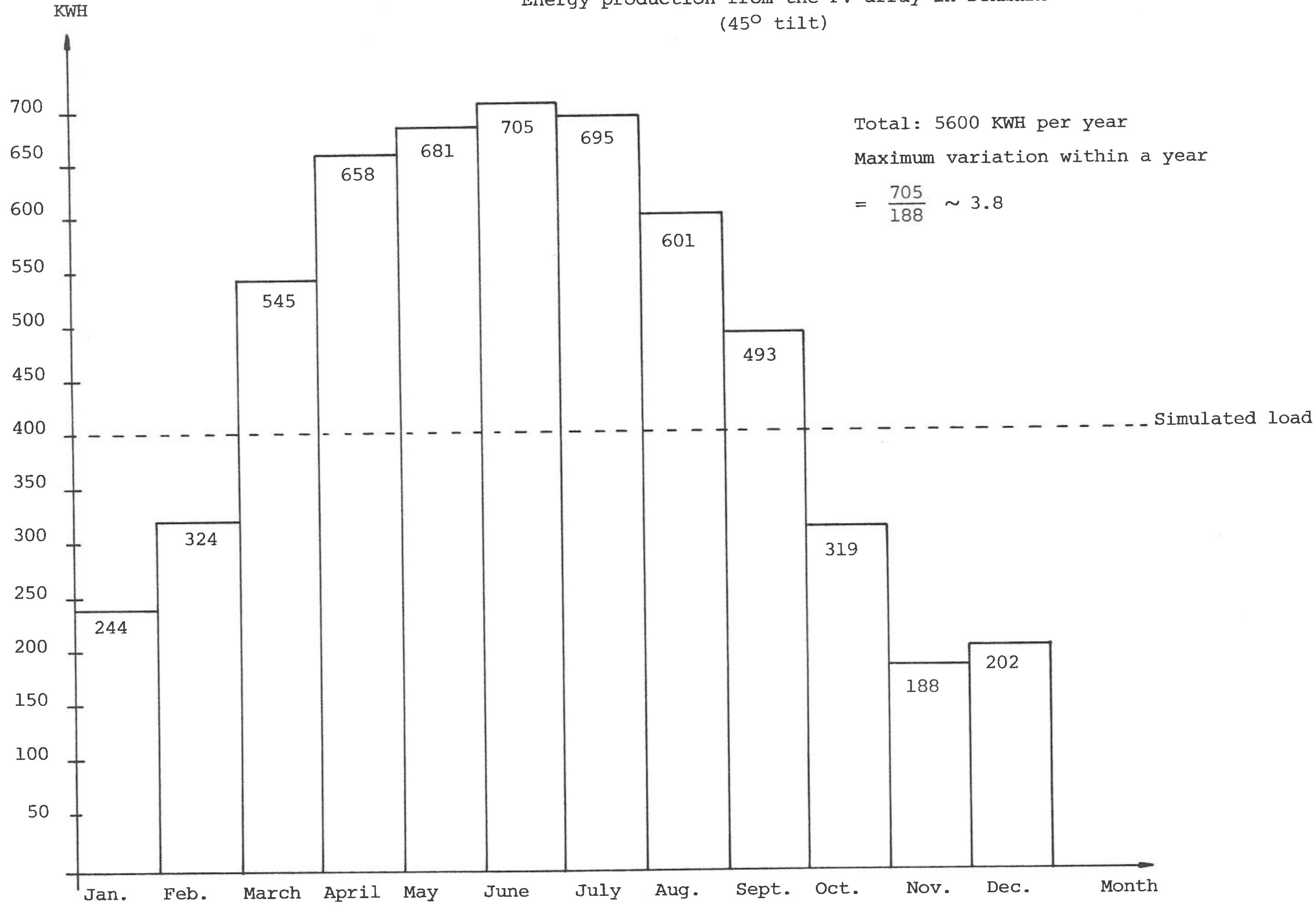


Fig. 1

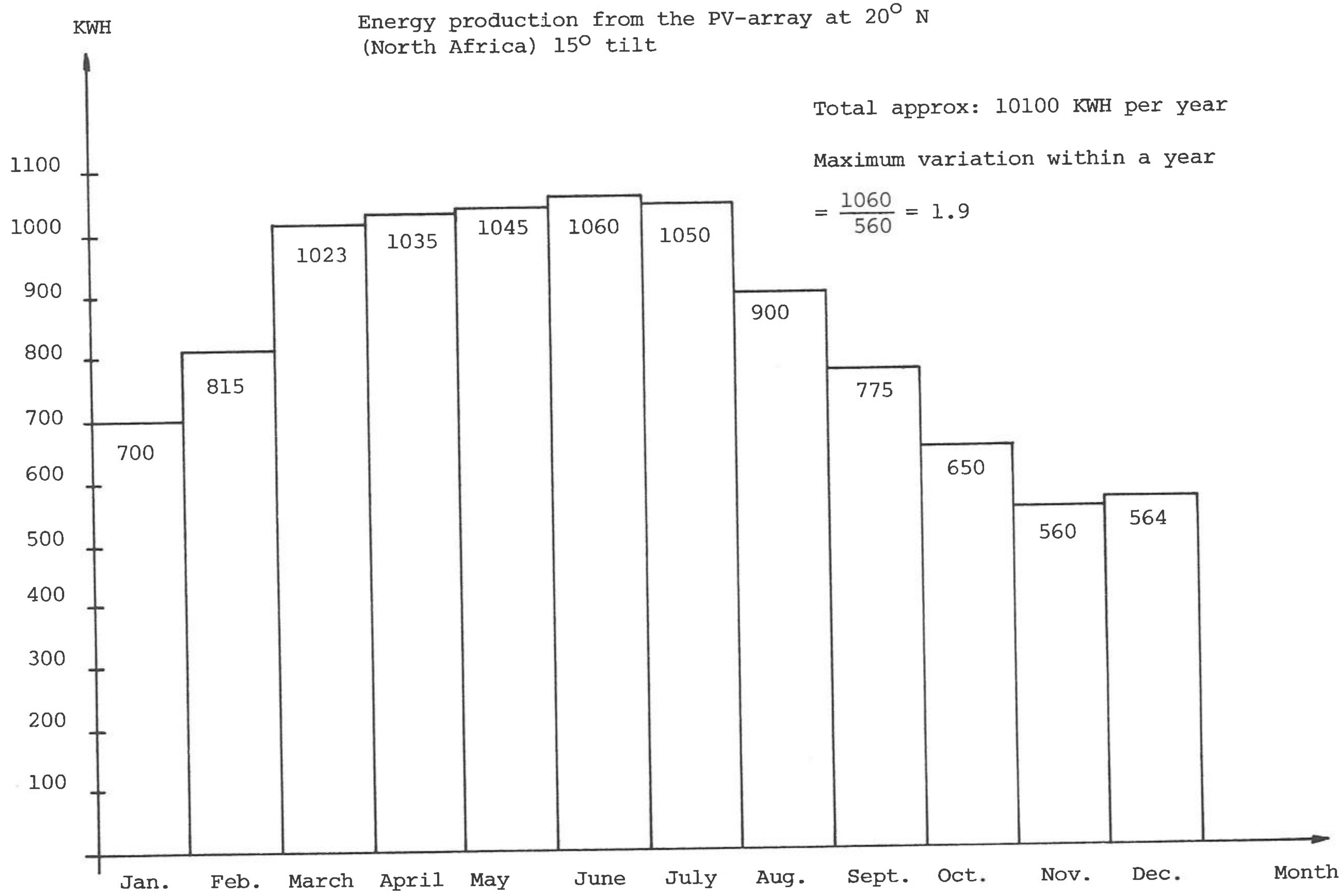

Energy production from the PV-array at 20° N
(North Africa) 15° tilt
Total approx: 10100 KWH per year
Maximum variation within a year
= 1060/560 = 1.9
KWH
1100
1000
900
800
700
600
500
400
300
200
100
700
815
1023
1035
1045
1060
1050
900
775
650
560
564
Jan.
Feb.
March
April
May
June
July
Aug.
Sept.
Oct.
Nov.
Dec.
Month

Fig. 2

4.7. Supervision and Control Equipment

The supervision and control equipment for this project is based on the DRO-1, developed at Jutland Telephone for supervision of telecom power supplies.

This newly developed microprocessor-based unit - which will be called DRO-4 - includes the following main functions:

1. Supervision of PV-array
2. Battery supervision
3. DC-voltage supervision and AC-voltage supervision
4. Load supervision functions
5. Battery-capacity measuring function
6. Control of power flow
7. Alarms and communication
   and also, especially for this pilot plant:
8. Comprehensive data measuring and registration
9. Both local and remote communication
10. Load simulation

4.7.1. Supervision of PV-Array

The PV-array will consist of a number of parallel strings, each again consisting of a series connection of the necessary number of modules.

The output current is measured continuously from each string and via a common voltage measurement the output power from each string is computed. The outputs from the strings are then compared, and if the mutual differences consistently are too great within a certain period of time, an alarm is given.

As a criterion of the acceptable difference the concept of variance is used. The variance of a given number of figures is an indication of how much these figures deviate from their common mean value.

The variance, based on relative values of output power for each string, is computed.

This form of supervision of the PV-array is then a continuously dynamic process, and consequently it is not affected by temperatures, slowly degradation of characteristics because of age, layers of dust, etc. Short time phenomenons such as partial shadowing of a panel because of birds, etc. will not cause alarms.

At very low insolation levels the variance increases very much because of tolerances in the PV-modules, and the supervision is therefore blocked.

4.7.2. Battery Supervision Function

Through measuring of the voltages of the whole battery and of individual blocks (3 cells), irregularities of a battery can be traced at a relatively early stage, i.e. before the irregularities may have a decisive influence on the functional capability of the battery in relation to the use of it in a PV-system.

In brief, the principle of the battery supervision is that all block voltages are measured at regular short intervals. An average block voltage is calculated and each individual block voltage is compared with this average value. If the difference between the block voltage and the average block voltage deviates consistently in a given period of time from a prefixed tolerance band an alarm is given.

Thus it is a "dynamic" process, the absolute size of the voltages being unimportant, i.e. the supervision is independent of the actual operational state of the battery, e.g. charge or discharging.
If a deviation from the above-mentioned permissible tolerance band is found, an alarm is given. Tolerance bands can be changed via the communication interface.

If the block voltages exceed a fixed absolute minimum or maximum limit, a major alarm is given immediately (exceeding of the dynamic range).

By means of a thermistor the temperature is measured in the electrolyte in one or more cells per battery. The thermistor has been imbedded in acid-proof material and placed just above the plates in the cells in question. An alarm is given if a measuring indicates that the value is at or exceeds a lower/upper limiting value. The limiting values can be changed via the communication interface. If the temperature measuring exceeds an absolute minimum or maximum limiting value, a "major alarm" is given (exceeding of the dynamic range).

Furthermore, the electrolyte level is measured in a single cell per battery by means of a level gauge. The level gauge is based on a differential transformer connection. If the level is at or below a lower limiting value an alarm is given. The limiting value can be changed via the communication interface. If the level measuring exceeds an absolute minimum or maximum limiting value, a "major alarm" is given (exceeding of the dynamic range).

4.7.3. DC-Voltage Supervision Function

The voltage supervision function consists of a number of different measurings, i.a. battery voltage measurings, auxiliary voltage measurings, etc.

These measurings are almost identical only with different limiting values and alarm category. If a measuring indicates that a value is at or exceeds a lower/upper limiting value an alarm is given. If one of the measurings exceeds an absolute minimum or maximum limit, a major alarm is given (exceeding of the dynamic range). The limiting values can be changed via the communication interface.

AC-Voltage Supervision Function (Inverter Output Voltage)

The inverter voltage supply is measured at the outlet to the house installation before main switch and main fuse. Furthermore, the voltage is measured after the group fuse and possibly earth leakage circuit breaker. By measuring in this way it is possible to distinguish between faults in the inverter and faults in the low voltage panel. The signals from the network supervision module, which are to be placed in the low voltage panel, are given as three digital signals and as LED indication on the front of the network supervision module. The combination of the three signals is decoded in the DRO-4. The following combinations converted into text may occur:

1. Inverter voltage normal
2. Inverter voltage abnormal
3. Earth leakage circuit breaker/fuse out
4. Inverter voltage abnormal and earth leakage circuit breaker/fuse out
5. Inverter voltage supervision defect.

4.7.4. Load Supervision Function

The load of the PV-system is supervised in such a way that a maximum load and an average load are registered, respectively. Time connections in this relation can be changed via the communication interface.

The registration of maximum/average current (the load) takes place according to the same directions, as only time parameters separate the two measurings.

Time integral registration of a load function for a given period of time is required.
This can be made by carrying out a certain number of instantaneous measurings per time unit and then calculate the average value for this time unit.

In this connection this time unit is defined as an interval. A certain number of intervals constitutes a time window.
To find the highest occurring time integral (integrated over one time window) within a given arbitrary time is required.

This can be made in the following way:

At the expiry of each interval the time integral (the average value) is calculated for the time window in question. This "new" time integral (B) is compared with the highest time integral (A) registered so far.
The highest value is transferred (copied) to the "highest occurring time integral" (A).

As an example the progress in connection with registration of an average current over 8 hours is stated below:

1. time window: 8 hours
2. interval: 10 minutes
3. scan time: 1 second (cycle time for scanning of channels).

A scan time of 10 minutes means that each interval will include 600 single measurings (current instantaneous measurings) called i_n. After the expiry of each interval the average value is calculated for the interval (time integral) in question, called M_n. A time window of 8 hours will include 48 intervals. After the expiry of each interval (excluding a start procedure) the current average value is also calculated for the time window in question, called I_B.

As mentioned above I_B is compared with the highest time integral registered so far, called I_B and the highest value is stored in I_A.

This method for registration of maximum/average current implies a system fault, i.e. a fault by virtue of used method.

The system fault is related to the connection between the size of time window and the size of interval and can be expressed in the following algoritm:

$$I_B \frac{\text{interval time x 0.5}}{\text{window time}} \text{ x } 100 \ (\%)$$

This is the worst conceivable uncertainty in the calculation.

4.7.5. Capacity Measuring Function

It is difficult to find the actual capacity of a lead/acid battery - even under the most favourable conditions - without carrying out an actual capacity test, i.e. to carry out a discharge of the battery. Normally, the capacity of the battery is controlled through a manual measuring of the specific gravity of the electrolyte, but owing to i.a. stratification in the electrolyte, differences in specific gravity between "inner" and "outer" acid it may be difficult to estimate the capacity condition of a battery.

In order to determine and remotely supervise the capacity in a lead/acid battery a concept is used including the following:

1. the battery supervision function, as previously described, to find the general operational condition of the battery,

2. an advanced control and supervision of the battery's state of charge to ensure a 100% charged battery within acceptable intervals,

3. a calculation of energy flow to and from the battery to ensure a correct indication of actual battery capacity at any time.

As the battery supervision function ensures correct function of the battery and the charge control function ensures that the battery at acceptable intervals is fully charged, i.e. has a capacity of 100%, it is possible - via a correct, continuous calculation of the energy flow - at any time to state the actual capacity of the battery with a very high degree of accuracy. Compensation for temperature variations is foreseen.

Dependent on the physical structure of the individual battery, especially including the amount of active material and the amount of electrolytes, the DRO-4 will be able to calculate an actual capacity correctly, i.e. within the range of +/- 5% with varying currents to/from the battery within certain limits.

Peukert's equation is used for the calculation of the actual capacity on the basis of the current to or from the battery. Peukert's equation indicates the TIME (in hours) for a complete charge or discharge of a battery of a given charging current.

Besides battery constants this time only depends on the current. I.e. if the current is measured e.g. every 10 seconds it is possible to calculate how large a fraction of full capacity the battery has been supplied with in 10 seconds. Consequently, if the nominal capacity is known it is also possible to calculate how many Ah's have been supplied.

Peukert's equation is:

$$t = \frac{C}{I^n}$$

C and n are constants which can be calculated for the individual battery e.g. from 1 to 10 hours' discharge currents.

During the time t the battery is charged 100%.
If the change of the capacity of 10 seconds is called dKAP, the following applies:

$$\frac{dKAP}{100} = \frac{10 \text{ (secs)}}{t \text{ (hours)}}$$

$$\Rightarrow dKAP = 100 \times \frac{10}{t \times 60 \times 60} = \frac{I^n}{C \times 3.6}$$

According to this the actual capacity (in % of the nominal capacity) is counted up or down every 10 seconds.

The actual battery capacity is also computed according to the temperature of the electrolyte. Low temperatures give decreasing capacity, and the actual capacity must therefore be computed according to both load currents and electrolyte temperature.

4.7.6. Control of Power Flow

The DRO-4 controls the power flow from the PV-array by means of a switching arrangement, as described in section 4.4.

The main parameter in this connection is the state-of-charge of the battery. If the battery is fully charged, computed as described in section 4.7.5., the actual load of the house, i.e. the inverter load, determines the number of PV-strings connected to the primary DC-bus, as the computer keeps balance between power demand and power input.

If the battery is not fully charged, the computer controls the switching arrangement in order to obtain maximum output power from the PV-array. The battery is therefore recharged as soon as insolation and load conditions allow this.

A rectifier module of 5 kVA is included in the PV-system in order to be able to obtain a reasonable load profile also in Denmark. This rectifier is automatically switched on at a predetermined state-of-charge of the battery, and switched off again when the battery is fully charged. The amount of energy added to the PV-system in this way is strictly monitored.

The DRO-4 also controls the AC-power flow from the inverter according to a predetermined load profile, see section 4.6.

In order to be able to use the PV-house as a "normal" house intermittently, the computer can be ordered to disable the load simulation program for one hour at a time by pushing a button placed on a display unit in the kitchen of the house.

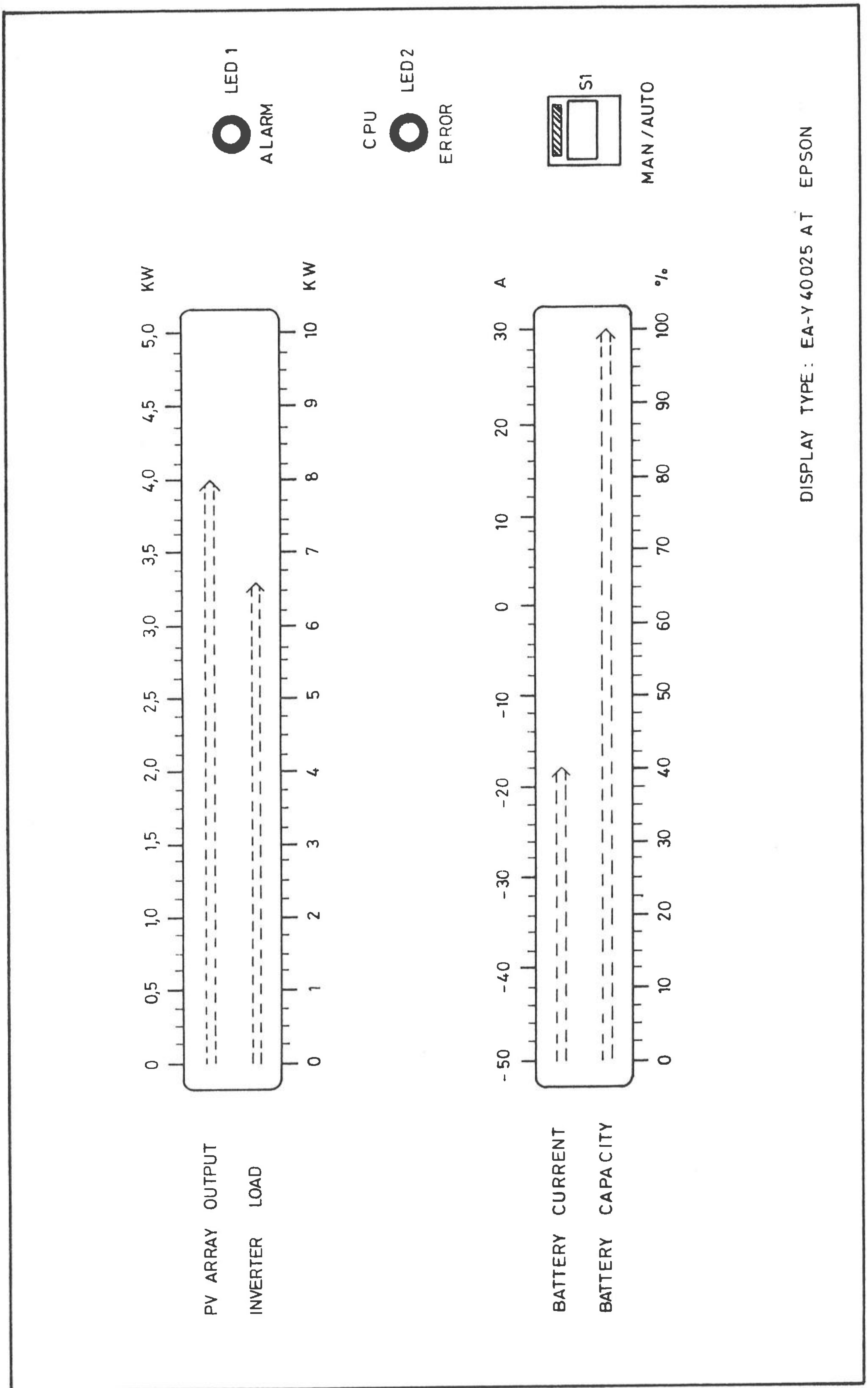
4.7.7. Alarms and Communication

Irregularities in the normal operation concerning both the DRO-4 processor system and the supervised PV-system will result in one or several alarms.

In the PV-house the alarms are indicated on the display unit placed in the kitchen, and this alarm indication in the form of one red LED will normally be the only indication.

In the demonstration system, however, an advanced and differentiated alarm system has been included in the DRO-4 computer. These differentiated alarms can be monitored locally via a data terminal or automatically be transmitted to Jutland Telephone via an auto-dialling modem and normal telephone lines. The computer can also be accessed from Jutland Telephone when required.

For an inhabitant of the house only the display unit, as shown in figure 1, page 52, is intended.


LED 1
ALARM
CPU
LED 2
ERROR
S1
MAN / AUTO
DISPLAY TYPE : EA-Y 40025 AT EPSON
KW
KW
A
%
PV ARRAY OUTPUT
INVERTER LOAD
BATTERY CURRENT
BATTERY CAPACITY
0 0,5 1,0 1,5 2,0 2,5 3,0 3,5 4,0 4,5 5,0
0 1 2 3 4 5 6 7 8 9 10
-50 -40 -30 -20 -10 0 10 20 30
0 10 20 30 40 50 60 70 80 90 100

4.7.8. Data Measuring and Registration

In order to obtain as clear a picture of the PV-system as possible at any time the DRO-4 computer also includes comprehensive data measuring and data registration facilities. Program storage and storage of "long-term" data are carried out via floppy discs.

A number of examples of printouts from the system are shown on the following pages.
The DRO-4 computer can briefly be characterized as having:

- 128 analogue inputs (fully floating)
- 32 digital inputs
- 32 digital outputs
- RAM: 40 K bytes
- PROM: 24 K bytes
- Floppy discs: 2 x 0.8 M bytes
- Processor: 16 bits/12 MHz.

A1;
REPORT A1 PEP-BRAMMINGE DATE: 840907 HOUR: 0946

MAIN INFORMATION

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
1	DC BUS VOLTAGE	230.5	V	260.0	200.0	00000	90
2	PV OUTPUT CURRENT	10.19	A			00000	108
3	DC LOAD CURRENT	1.1	A			00000	107
4	BATTERY CURRENT 1	+ 4.8	A			00000	118
5	BATTERY CURRENT 2	+ 4.1	A			00000	120
6	INVERTER OUTPUT POWER	0.60	KW	9.00		00000	106
7	RECTIFIER OUTPUT POWER	0.00	KW			00000	104

8 DC LOAD CUR.(HIGH.REC.) 19.4 A DURING 5 MIN.
9 DC LOAD CUR.(HIGH.REC.) 1.8 A DURING 200 HOURS
10 BATTERY MEAN CURR.ACT. BATT.1 + 4.2A BATT.2 + 4.1 A
11 BATTERY WORKING HR.ACT. BATT.1 0.0HR BATT.2 0.0 HR

NO.		VALUE	STATUS	ID.
12	BATTERY CAPACITY 1 ACT.**	200 **	00000	200
13	BATTERY CAPACITY 2 ACT.**	200 **	00000	210

? A2;

REPORT A2 PEP-BRAMMINGE DATE: 840907 HOUR: 0948

PV ARRAY INFORMATION

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
14	INSOLATION PLANE	549.7	W/M2			00000	88
15	PV STRING TEMP.	29.6	C	80.0	-20.0	00000	91
16	OUTDOORS TEMP.	10.9	C	80.0	-20.0	00000	123
17	PV OUTPUT POWER	2.46	KW	*ACTIVE STRINGS:9*		00000	240
18	SUMMED PV OUTP.POWER	95	KWh	*SURPLUS	0KWh		
19	DC BUS VOLTAGE	230.9	V	260.0	200.0	00000	90
20	PV SWITCH PARAM.ACT	ON230.0	V	OFF:250.0	V	DELAY: 5 SCANS	
21	PV SWITCH PARAM.NOM	STR.1 OFF:	235.0	STR.9 OFF:250.0			
22	PV CURRENT STRING 1	1.16	A	- ON -		01000	109
23	PV CURRENT STRING 2	1.21	A	- ON -		01000	110
24	PV CURRENT STRING 3	1.16	A	- ON -		01000	111
25	PV CURRENT STRING 4	1.19	A	- ON -		01000	112
26	PV CURRENT STRING 5	1.20	A	- ON -		01000	113
27	PV CURRENT STRING 6	1.21	A	- ON -		01000	114
28	PV CURRENT STRING 7	1.17	A	- ON -		01000	115
29	PV CURRENT STRING 8	1.17	A	- ON -		01000	116
30	PV CURRENT STRING 9	1.17	A	- ON -		01000	117
31	VARIANCE ACT.	2.8	MAX. 30.0	* EFFICIENCY 9%			

?BT;

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0949 PAGE 1

BATTERY INFORMATION

BATTERY 1

NO.	VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
32 BLOCK VOLTAGE 1	6.415	V	6.535	6.295	00000	1
33 BLOCK VOLTAGE 2	6.411	V	6.535	6.295	00000	2
34 BLOCK VOLTAGE 3	6.439	V	6.535	6.295	00000	3
35 BLOCK VOLTAGE 4	6.400	V	6.535	6.295	00000	4
36 BLOCK VOLTAGE 5	6.434	V	6.535	6.295	00000	5
37 BLOCK VOLTAGE 6	6.430	V	6.535	6.295	00000	6
38 BLOCK VOLTAGE 7	6.414	V	6.535	6.295	00000	7
39 BLOCK VOLTAGE 8	6.417	V	6.535	6.295	00000	8
40 BLOCK VOLTAGE 9	6.419	V	6.535	6.295	00000	9
41 BLOCK VOLTAGE 10	6.426	V	6.535	6.295	00000	10
42 BLOCK VOLTAGE 11	6.426	V	6.535	6.295	00000	11
43 BLOCK VOLTAGE 12	6.430	V	6.535	6.295	00000	12
44 BLOCK VOLTAGE 13	6.405	V	6.535	6.295	00000	13
45 BLOCK VOLTAGE 14	6.432	V	6.535	6.295	00000	14
46 BLOCK VOLTAGE 15	6.435	V	6.535	6.295	00000	15

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0949 PAGE 2

BATTERY 1

NO.	VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
47 BLOCK VOLTAGE 16	6.429	V	6.535	6.295	00000	16
48 BLOCK VOLTAGE 17	6.415	V	6.535	6.295	00000	17
49 BLOCK VOLTAGE 18	6.392	V	6.535	6.295	00000	18
50 BLOCK VOLTAGE 19	6.430	V	6.535	6.295	00000	19
51 BLOCK VOLTAGE 20	6.434	V	6.535	6.295	00000	20
52 BLOCK VOLTAGE 21	6.428	V	6.535	6.295	00000	21
53 BLOCK VOLTAGE 22	6.398	V	6.535	6.295	00000	22
54 BLOCK VOLTAGE 23	6.394	V	6.535	6.295	00000	23
55 BLOCK VOLTAGE 24	6.430	V	6.535	6.295	00000	24
56 BLOCK VOLTAGE 25	6.432	V	6.535	6.295	00000	25
57 BLOCK VOLTAGE 26	6.400	V	6.535	6.295	00000	65
58 BLOCK VOLTAGE 27	6.435	V	6.535	6.295	00000	66
59 BLOCK VOLTAGE 28	6.398	V	6.535	6.295	00000	67
60 BLOCK VOLTAGE 29	6.411	V	6.535	6.295	00000	68
61 BLOCK VOLTAGE 30	6.421	V	6.535	6.295	00000	69

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0951 PAGE 4

BATTERY INFORMATION
BATTERY 2

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
74	BLOCK VOLTAGE 1	6.429	V	6.535	6.295	00000	33
75	BLOCK VOLTAGE 2	6.399	V	6.535	6.295	00000	34
76	BLOCK VOLTAGE 3	6.427	V	6.535	6.295	00000	35
77	BLOCK VOLTAGE 4	6.390	V	6.535	6.295	00000	36
78	BLOCK VOLTAGE 5	6.431	V	6.535	6.295	00000	37
79	BLOCK VOLTAGE 6	6.391	V	6.535	6.295	00000	38
80	BLOCK VOLTAGE 7	6.436	V	6.535	6.295	00000	39
81	BLOCK VOLTAGE 8	6.429	V	6.535	6.295	00000	40
82	BLOCK VOLTAGE 9	6.399	V	6.535	6.295	00000	41
83	BLOCK VOLTAGE 10	6.408	V	6.535	6.295	00000	42
84	BLOCK VOLTAGE 11	6.412	V	6.535	6.295	00000	43
85	BLOCK VOLTAGE 12	6.421	V	6.535	6.295	00000	44
86	BLOCK VOLTAGE 13	6.410	V	6.535	6.295	00000	45
87	BLOCK VOLTAGE 14	6.410	V	6.535	6.295	00000	46
88	BLOCK VOLTAGE 15	6.439	V	6.535	6.295	00000	47

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0952 PAGE 5

BATTERY 2

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
89	BLOCK VOLTAGE 16	6.408	V	6.535	6.295	00000	48
90	BLOCK VOLTAGE 17	6.401	V	6.535	6.295	00000	49
91	BLOCK VOLTAGE 18	6.434	V	6.535	6.295	00000	50
92	BLOCK VOLTAGE 19	6.427	V	6.535	6.295	00000	51
93	BLOCK VOLTAGE 20	6.414	V	6.535	6.295	00000	52
94	BLOCK VOLTAGE 21	6.388	V	6.535	6.295	00000	53
95	BLOCK VOLTAGE 22	6.429	V	6.535	6.295	00000	54
96	BLOCK VOLTAGE 23	6.412	V	6.535	6.295	00000	55
97	BLOCK VOLTAGE 24	6.428	V	6.535	6.295	00000	56
98	BLOCK VOLTAGE 25	6.407	V	6.535	6.295	00000	57
99	BLOCK VOLTAGE 26	6.415	V	6.535	6.295	00000	76
100	BLOCK VOLTAGE 27	6.414	V	6.535	6.295	00000	77
101	BLOCK VOLTAGE 28	6.413	V	6.535	6.295	00000	78
102	BLOCK VOLTAGE 29	6.435	V	6.535	6.295	00000	79
103	BLOCK VOLTAGE 30	6.433	V	6.535	6.295	00000	80

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0952 PAGE 6

BATTERY 2

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
104	BLOCK VOLTAGE 31	6.434	V	6.535	6.295	00000	81
105	BLOCK VOLTAGE 32	6.429	V	6.535	6.295	00000	82
106	BLOCK VOLTAGE 33	6.397	V	6.535	6.295	00000	83
107	BLOCK VOLTAGE 34	6.400	V	6.535	6.295	00000	84
108	BLOCK VOLTAGE 35	6.436	V	6.535	6.295	00000	85
109	BLOCK VOLTAGE 36	6.411	V	6.535	6.295	00000	86
110	BATTERY VOLTAGE	231.5	V	252.0	198.0	00000	58
111	ELEKTROLYTE TEMP.	23.7	C	40.0	10.0	00000	59
112	ELEKTROLYTE LEVEL	87.9	% of 18mm		30.0	00000	60
113	ACTUAL CAPACITY **	200	AH(10)	**	20.0	00000	210
114	NOMINAL CAPACITY	200	AH(10)				

115 MAX.BLOCK VOLT. VAR. 60 MV FACTORS: RCT.: 2.0 PV.: 2.0 AT 99.0 %

REPORT B PEP-BRAMMINGE DATE: 840907 HOUR: 0950 PAGE 3
BATTERY 1

NO.		VALUE	UNIT	HIGH LIMIT	LOW LIMIT	STATUS	ID.
62	BLOCK VOLTAGE 31	6.408	V	6.535	6.295	00000	70
63	BLOCK VOLTAGE 32	6.413	V	6.535	6.295	00000	71
64	BLOCK VOLTAGE 33	6.404	V	6.535	6.295	00000	72
65	BLOCK VOLTAGE 34	6.401	V	6.535	6.295	00000	73
66	BLOCK VOLTAGE 35	6.394	V	6.535	6.295	00000	74
67	BLOCK VOLTAGE 36	6.381	V	6.535	6.295	00000	75
68	BATTERY VOLTAGE	231.0	V	252.0	198.0	00000	26
69	ELEKTROLYTE TEMP.	20.8	C	40.0	10.0	00000	27
70	ELEKTROLYTE LEVEL	89.9	%	of 18mm	30.0	00000	28
71	ACTUAL CAPACITY	** 200 AH(10) **			20	00000	200
72	NOMINAL CAPACITY	200 AH(10)					

73 MAX.BLOCK VOLT. VAR. 60 MV FACTORS: RCT.: 2.0 PV.: 2.0 AT 99.0%

The formating of the reports including long-term data is flexible, but the reports will include the following data per day (midnight to midnight):

Battery capacity, battery 1: simple mean value per day
Battery capacity, battery 2: simple mean value per day

Electrolyte temperature, battery 1: simple mean value per day
Electrolyte temperature, battery 2: simple mean value per day

Electrolyte level, battery 1: instantaneous value
Electrolyte level, battery 2: instantaneous value

Block voltages, battery 1: mean value and maximum/minimum at 6 a.m., 12 a.m., 6 p.m.
Block voltages, battery 2: mean value and maximum/minimum at 6 a.m., 12 a.m., 6 p.m.

Insolation in plan: summarizing per day

PV-output power: summarizing per day

PV-surplus power: summarizing per day

PV-efficiency: simple mean value per day of measurings exceeding 50 W/m^2

PV-temperature: simple mean value per day and instantaneous value at 6 a.m., 12 a.m., 6 p.m.

DC-track voltage: simple mean value per day

Inverter output effect: summarizing per day

Outdoor temperature: simple mean value per day, instantaneous value at 6 a.m., 12 a.m., 6 p.m.

Rectifier output effect: summarizing per day

Variance in the PV-system: instantaneous value at 6 a.m., 12 a.m., 6 p.m.

The above-mentioned data can be printed out for:

The last seven days and nights via an E-report
The last month via an F-report
The last six months via a G-report.

4.7.9. Communication

Special communication facilities have been implemented in this demonstration plant, see section 4.7.7.

4.7.10. Load Simulation

Load simulation, as previously described in section 4.6., has also been implemented in the DRO-4 computer especially for this project.

5. Operational Period 1984 to 1989

In the project contract the EC has required an operational period of at least 5 years for the total PV-house, but up till now (October 1984) the EC has not specified any requirements as to the activities of this operational period and has neither put forward financial support for these activities.

Therefore, until further information has been received from the EC, the project group will run the PV-house as described in this report, and will monitor and record operational data successively.

The project group expects that the EC in due time will bring up the matter of the objectives and contents of the operational period, the possible co-operation with the 4 other "PV-housing projects" within this EC research programme and the financing of the operational period including reports.

The project group is confident that PV-powered houses are viable alternatives already today in certain regions, and based on this and the interest already shown in our PV-house we hope that the EC with-in the near future will provide the necessary means for a succesful completion of the operational period.