TYPICAL
INSTALLATION, OPERATION
AND
MAINTENANCE / SERVICE MANUAL

Solar Power System for Cathodic Protection

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Manual mlty001-01

1. CONTENTS

2. LIST OF ABBREVIATIONS

A	Ampere
ac	Alternating Current
Adc	Ampere Direct Current
Ah	Ampere-hours
AJB	Array Junction Box
°C	Degrees Centigrade
CAD	Computer Aided Design
CCU	Central Control Unit
CP	Cathodic Protection
dc	direct current
DDOD	Daily Depth Of Discharge (battery)
DOD	Depth Of Discharge (battery)
FET	Field Effect Transistor (switching device)
Isc	Current at Short Circuit
LED	Light Emitting Diode (indicator)
m	metres
mm	millimetres
Pmp	Power at Maximum Power Point
SS	Stainless-steel
SOC	State Of Charge (battery)
SPG	Solar Power Generator
V	Volt
Vac	Volt alternating current
Vdc	Volt direct current
Vmp	Volt at Maximum Power Point
Voc	Volt at Open Circuit
W	Watt
Wp	Watt peak (solar module)

3. PROJECT DATA

Supplier	:	Tss4U B.V.
Supplier reference	:	
GENERAL DATA		
Required power for the load	:	2500Wc at 48 Vdc
Latitude	:	xº North
Longitude	:	xº East
Altitude	:	25 m (average)
Tilt angle of the array	:	50º
SOLAR MODULE DATA		
Type	:	75 Watt
Manufacturer	:	x
Number of solar modules	:	352
Total installed Wp	:	25.700 Wp
Total solar surface	:	18.000 m^2
CONTROLLER DATA		
Type	:	CCU III MC48V
Nominal operating system	:	48 Vdc
Maximum total input current	:	486 A
Maximum output current	:	52 A
BATTERY DATA		
Battery capacity	:	4480 Ah at 10h
Type	:	x
Manufacturer	:	x
Average Daily D.O.D.	:	14.3% (20.5 % in autonomy)
System performance		(under conditions mentioned above)
Min. State of Charge	:	80.1 %
Average State of Charge	:	82.6 %
Min. Autonomy (with 20 % SOC)	:	3.0 days
Charge factor	:	1.47 (max. conditions) 1.29 (average conditions)
Recovery time (20-95 %)		
* including load	:	32.5 days (worst case) 14.6 days (average conditions)
* excluding load	:	3.3 days (worst case) 2.9 days (average conditions)

4. INTRODUCTION

4.1 System composition

For a complete system composition see attached survey of documents.

4.2 System description

The Solar Power System consists of four main components:

- the solar modules
- the CCU III charge controller
- CCU-R output regulator
- the battery

The major components of a solar power generating system are the solar modules, which directly convert (sun) light into electrical energy, and the battery to store the collected energy for the night and later use in periods of low or no insulation.

To optimise battery lifetime the battery is protected against overcharging and excessive discharge. The Central Control Unit (CCU), charge controller, performs both these functions. If the battery is discharged too deeply, the charge control switches off the load.

The solar modules are connected in series of 4 to obtain 48V. The battery-cells are connected in series of 24 to obtain 48V. The battery will provide electricity during the nights and for periods with low or no insulation.

The CCU-R output regulator regulates the output current/voltage to the required settings.

For a complete one-line diagram of the Solar Power System refer to drawing x (see attachments).

4.3 System design criteria

<u>Insulation</u>

The following resources have been checked in order to give a good indication of the meteorological circumstances of the locations:

- Solar & Wind no. 2 vol. 4

In addition to these local meteorological circumstances, special attention is paid to the harsh environment and the required high level of reliability. The charge factor (average generated power divided by the daily load) should be larger than 1.15 and at any time of the year the amount of generated energy should be more than the load. This is to guarantee a proper charge regime of the battery at all times and to aim for long lifetime expectancy.

The recovery time is another important factor. It shows the charging time of the battery from a low state of charge (20 %) to 95 % whilst the load is connected. This can be expressed under normal and under worst-case conditions. Details are given in the project data sheet.

Generated energy

The following parameters are taken into account for the calculation of the number of solar modules (generated energy):

- The effective current of a 75 Watt solar module taking into account the insulation levels, ambient temperature and battery voltage	: 4.0 A
- Diffuse percentage of insulation (CAD determined)	: 27-36 %
- Losses due to module (current) degradation in 5 years	: 2.5 %
- Losses due to dust accumulation and non-removable dirt on solar module	: 2.5 %
- Amount of surrounding surface reflections (albedo)	: 20 %

Stored energy

The following typical battery characteristics are taken into account to calculate the size of the battery bank:

- The battery capacity to support the load from lowest state of charge, until an end voltage of 1.92 V/cell under worst case conditions	: 3.0 days
- Maximum allowable daily depth of discharge of the battery for maximum battery life time (max. DOD)	: 20 %
- The minimum state of charge of the battery after the autonomy period, as a percentage of the effective capacity (min.SOC)	: 20 %
- Ah efficiency curve of the battery related to the state of charge	
at 50% State Of Charge	: 98 %
" 80% " " "	: 95 %
" 90% " " "	: 93 %
" 100% " " "	: 0 %

Load calculation

The daily load for the system is defined as being 1250 Ah at 48 Vdc.

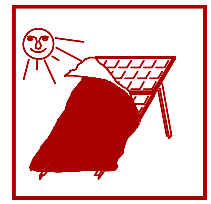
Note that the battery(box) must be shaded.
This is to avoid high temperatures of the battery-cells, which will decrease the battery lifetime significant.

5. SAFETY PRECAUTIONS

5.1 Solar modules

The open voltage of a solar array (solar modules connected in series and parallel) can reach a value of twice the system voltage. Normally 12 Vdc systems are electrical safe for persons, if non-isolated parts are touched by accident. 24 Vdc systems may affect sensitive persons and 48 Vdc systems are dangerous, if non-isolated parts are touched.

If the solar array is wired while the modules are exposed to sun light and the bare ends of the (+) and (-) wires are short circuiting, sparks may be produced. In some circumstances a continuous electric arc is possible. The more modules are connected in series and parallel, the greater this effect will be. Depending on the local situation this may cause hazardous situations e.g. start a fire or slowly burn your wires. To prevent all this,



DO NOT MAKE SHORT CIRCUITS AND COVER YOUR MODULES WITH AN OPAQUE MATERIAL DURING INSTALLATION, OR DURING REPAIR/REPLACEMENT WORKS.

5.2 Batteries

Do not short circuit battery terminals! This will always result in hazardous situations, like personal harm, damaged and/or completely burned battery poles, connectors and wiring.

So do not connect the battery before instructed to do so.

The battery is sealed and contains no free electrolyte. Under normal operating conditions there is no acid danger. However, if the battery case is damaged, or open batteries are used, acid could be present. This electrolyte (acid) will affect your skin, eyes, clothes, the floor, battery rack etc. If spilled, see battery instructions by the manufacturer.

The batteries should be installed at well-ventilated places because batteries produce gasses during charging.

5.3 Safety

- Shock Hazard - high voltages may be present. Remove all jewellery. Use insulated tools. Wear insulated gloves, apron and safety goggles (in case of open batteries) when installing or working with batteries.

- Sulphuric acid is harmful to the skin and eyes. Flush with water immediately and consult a doctor if splashed in eyes.

- Loose or dirty connectors and/or connections can cause battery failure.
  Keep all connectors/connections clean and firmly fastened. Remove all acid corrosion.

- Do not lift battery by terminals or tamper with post seal or cell valves.

- We advise to use a **DRY-CHEMICAL extinguisher** to extinguish battery fires, however if this is not available you can also use a **CO_2 extinguisher**.

- Clean outside battery surface and outside cabinet surface with soapy water only. Do not use solvents.

5.4 Receipt of shipment/preparation

Immediately upon delivery, examine for possible damage caused by transport and/or handling.

Damaged packaging material (e.g. crates) or stains from leaking electrolyte can indicate rough handling.
Make a descriptive note for the expeditor and a copy for the supplier on delivery receipt before signing.

If batteries, either on a pallet or contained in a crate, are found to be damaged, request an inspection by the carrier and make a damage claim. Within 15 days of receipt open all crates and fully inspect for damage. Open front panel of cabinets and inspect for concealed damages within the cabinets. If damage is noted, request an inspection by the carrier. Delay in notifying the carrier may result in loss of right to reimbursement of damages.

The batteries can be stored at temperatures from 15 °C to 30 °C. The storage period should not exceed 3 months, at which time a charge provision must be made, preferably a permanent installation.

The selected storage area should be a clean, dry location. Storage at higher temperatures should be avoided, as it will effect the battery lifetime negatively.

6. DESCRIPTION SYSTEM COMPONENTS

6.1 Solar modules

See attached product information sheet.

6.2 CCU-III Master Control Unit

Introduction

The CCU III is the Shell Solar charge controller for medium size solar PV systems used in industrial applications.

The CCU III master control is provided with a maximum of three separate switchable solar modules inputs. The system voltage of this controller is nominal 12 Vdc, 24 Vdc or 48 Vdc.

Internally the positive wires of the solar modules are directly connected to the positive (+) busbar. The negative wires are connected via solid state FET's (switching devices) and reverse current protection circuits to the negative (-). The solar modules inputs and load output terminals are provided with transient voltage suppressers thus protecting the controller's electronics. (nearby lightning).

The CCU III Master Control Unit controls the charge current to the battery by way of three input solid state FET's. It protects the battery against the damaging effects of over-charge and excessive discharge by keeping the charge/discharge cycle within prescribed limits. The special charge regulating technique enables a more efficient use of the available energy and the battery is charged faster compared to conventional controllers.

The master control can switch off the load by means of pulse triggering a relay (16A max.) integrated inside the Master Control, in case of battery excessive discharge or system high voltage. The master control will switch off the solar arrays to prevent battery overcharge.

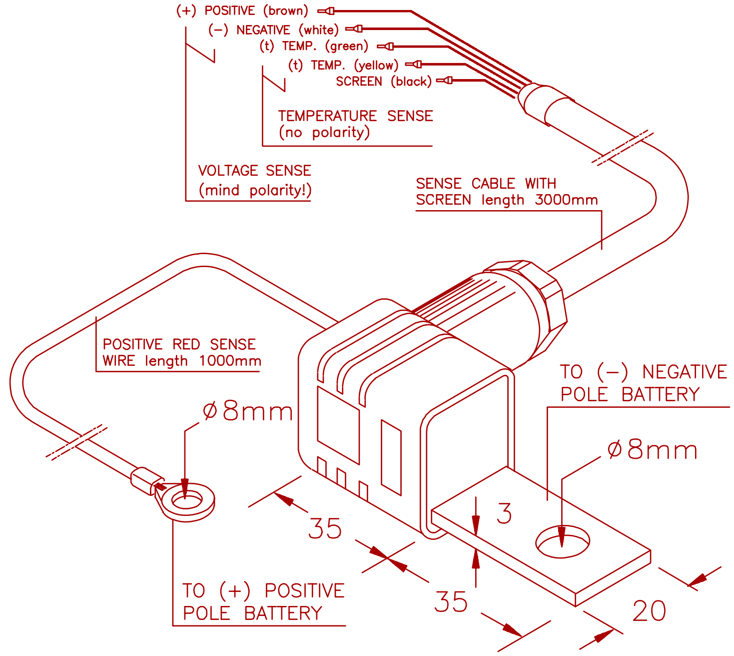
The reverse current protection circuits prevent the battery from discharging into the array overnight. Another built-in protection feature is the reversed polarity protection of electronics in case of reversing the battery, solar modules or both.

Other Features

- Advanced temperature compensated boost and float battery charge process.
- Load output with SOC dependent switch-off limit (excessive discharge protection).
- Field adjustable float charge level.
- LED indicators for: Battery charged, Sub-array 1, 2 and 3 disconnect, Pre-warning low voltage, general alarm / Load disconnect.
- "Flip of the switch" system diagnostic capabilities.

Sensor

A combined external battery voltage and temperature sensor is standard.
The connection diagram of the voltage and temperature sensor is shown in the figure below.



External voltage & temperature sensor for battery

Operation

The charge process is regulated by the charge controller which can switch on and off one, two, or three solar module strings. For maximum battery efficiency the charge controller performs a boost and float charge process. This means that initially the battery is charged to a somewhat higher voltage; after that, the voltage is kept at a float charge level by selecting the appropriate number of solar module strings. The charge voltage levels are temperatures compensated.

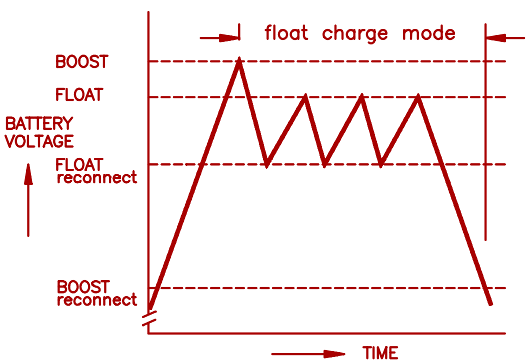


figure of the charge process

The switching frequency and resulting electromagnetic field is limited to prevent radio interference. When the battery connection is interrupted the modules will switch off within 0.1 seconds to avoid any damage to the appliances by the higher open circuit voltage of the modules.

A battery (system) voltage of more than the given values, (see System High Voltage) will switch off the (bi-stable) load relay. At low State Of Charge of the battery the CCU III will switch off the load. When the batteries are charged to a higher state of charge afterwards, the load is switched on again automatically.

Indicators, controls and other functions of the master control unit

LED's

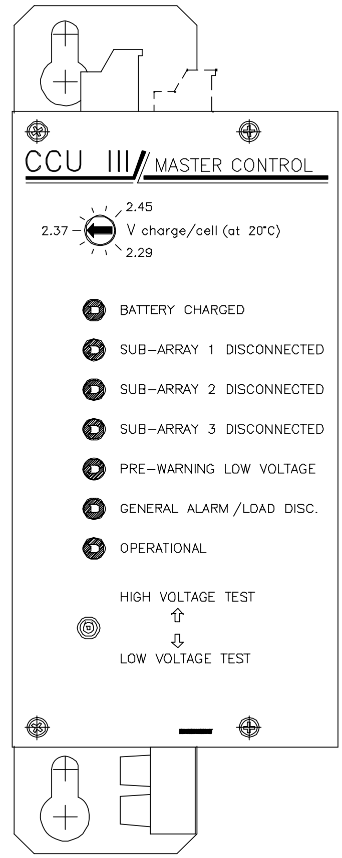


Figure of CCU III Master control

Yellow LED operational indicates that the external power supply is present in the correct polarity and the internal power supply, reference voltage and non-replaceable fuse on the PCB are OK.

Upper green LED, “battery charged” is "on" if the boost charge voltage level is reached and indicates the controller is in float charge mode. Normally this LED stays on until the battery is discharged with a few percentage of the total battery capacity, e.g. during the night.

Three green sub-array disconnect LED's: one or more LED's can be "on" during float charge mode and indicates the specific sub-array is disconnected. The CCU-III selects the number of connected sub-arrays in such a way that charge current is as high as possible without exceeding the float charge (gassing) voltage. The master control will react on changing solar radiation conditions within seconds. During boost charge mode all the green LED's are "off". If one or more slave units are present the corresponding LED's on those units will follow the master.

Red LED “pre-warning low voltage” will be "on" if battery voltage dropped dramatically and in a properly sized system it indicates an abnormal situation. This can be caused by e.g. extremely long low insolation period, dirty or damaged solar panels or higher energy consumption by the load.
If the option pre-warning low voltage alarm relay is mounted, this will be activated together with the LED. If an optional “non essential load” output is available, it will be disconnected.

Red LED “general alarm/load disconnect”. If this LED is "on" the internal 16A output relay, or the optional 50A (12/24V type) or 40A (48V type) output relay, will disconnect the load(s) and the optional alarm relay will be activated.
The alarm can be caused by two different situations:

A- Battery low voltage: in this case the red LED's "pre-warning Low Voltage" and “general alarm/load disconnect” and "on" and both the corresponding alarm relays are activated. For reasons see pre-warning low voltage.

B- System high voltage: in this case the general alarm/load disconnect and all green LED's are "on". Possible reasons for this situation: disconnected battery cable, defective battery fuse or a defective master control or slave unit.

Test Switch

The test switch simulates a high or a low battery voltage (not a system high voltage). The system voltage is measured on the battery power terminals inside the controller. With this switch the main functions of the charge controller can be tested. Moving the switch to the high voltage position, the green LED's will be "on" and the sub arrays be disconnected immediately (also on the slave units if present). The switch will return to its neutral position when released. The controller will need up to 15 seconds to resume normal operation. After moving and holding the switch to the low voltage position the pre-warning low voltage LED will be "on" after a few seconds and 5 to 15 seconds later the general alarm LED is "on" and the output relay(s) is (are) activated. After releasing the switch the controller needs up to 15 seconds to resume normal operation.

V-charge/cell potentiometer

The potentiometer is standard in the calibrated neutral position, i.e. 2.37 V/cell. The potentiometer affects both float and boost charge voltage setting. Dependant of the battery type, capacity, load and operating conditions the recharge time and water usage (flooded types) of the battery is optimised by adjusting the float charge setting. Therefore we recommend consulting Tss4U first before adjusting the float charge setting of the controller.

Specifications CCU-III Master Control

	12V type	24V type	48V type
Absolute maximum ratings			
Modules input	40 V	50 V	90 V
Battery input	25 V	40 V	65 V
Input current	3 x 9 A max.	3 x 9 A max.	3 x 8 A max.
Nominal Values			
System voltage	12 Vdc	24 Vdc	48 Vdc
Total array input current	27 A	27 A	24 A
Output current	16 A (standard)	16 A (standard)	16 A (standard)
Output current (max.)	20 A (20 sec.)	20 A (20 sec.)	20 A (20 sec.)
Operating Current Master	10 mA	10 mA	10 mA
Operating temperature	-10°C to +55°C	-10°C to +55°C	-10°C to +55°C
Storage temperature	-30°C to +70°C	-30°C to +70°C	-30°C to +70°C
Casing	Open frame	Open frame	Open frame

Values below are standard settings and are given for information only. In most cases these values are site and battery specific.

Settings	12V type	24V type	48V type
System high voltage	15.3 V	30.5 V	61.0 V
Boost @ 20 °C	14.5 V	29.0 V	58.0 V
Float @ 20 °C	14.2 V	28.4 V	56.8 V
Pre-warning low voltage	11.8 V	23.6 V	47.2 V
Disconnect output	11.5 V	23.0 V	46.0 V
Temperature compensation	-5 mV/°C/cell	-5 mV/°C/cell	-5 mV/°C/cell

Optional

Alarm relays with voltage-free contacts for pre-warning low voltage and general alarm.
The alarm status for different system conditions is as follows:

Condition (at 24V)	Pre-warning Alarm	General Alarm relay	Load (at 24V)

	relay		
Normal	Off	Off	On
Vbat < 23.6V	Active	Off	On
Vbat < 23.0V	Active	Active	Off
Vbat > 30.5V	Off	Active	Off

6.3 CCU-III Slave Unit

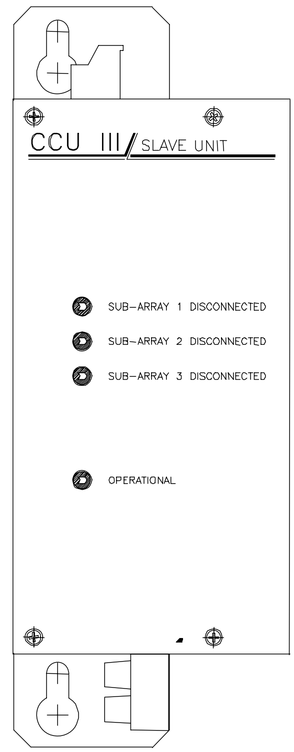


Figure of CCU-III Slave Unit

General

To extend the module input capacity of a CCU-III controller system, slave units can be added. The maximum number of solar modules, which can be handled, is almost unlimited: systems up to 31000 Wp is proven in the field.

Description

CCU-III slave units have three inputs for solar modules, each input is suitable for 10A max. or total 30A per unit. Basically a slave unit includes the power switches only and is controlled by the CCU III master. Three green LED indicators show the on/off status of the solar module input power switches, LED on indicates that the corresponding solar module sub-array is switched off. A yellow LED indicates the unit is operational and at least one sub-array supplies sufficient input voltage to charge the battery. During night a slave unit shuts down automatically and the yellow operational LED will be off in order to save energy. The same will happen in case the solar array switch is switched off.
Up to ten (10) slave units can be directly connected to a master unit, if more units are needed, the optional control buffer is required.
The CCU III slave unit is fully solid state with no moving parts or other sensitive components, resulting in very high reliability under extreme climatologic conditions.

Specifications CCU-III Slave Unit

	12V/24V type	48V type
Absolute maximum ratings		
Modules input	50 V	90 V
Battery input	40 V	65 V
Input current	3 x 10 A max.	3 x 8 A max.
Nominal Values		
System voltage	12V/24 Vdc	48 Vdc
Total array input current	30 A	24 A
Overload array input current, during 5 minutes	3 x 12 A	3 x 12 A
Output current	30 A	24 A
Operating Current	3 mA	3 mA
Operating temperature	-10°C to +50°C	-10°C to +50°C

Storage temperature	-30°C to +70°C	-30°C to +70°C
Casing	Open frame	Open frame

6.4 Output Regulator CCU-R

Introduction

A PV solar generator can provide adequate and economical solutions for cathodic protection systems using impressed current. All systems consist of a specified number of solar modules mounted on a support structure, a maintenance free battery bank, a battery charge controller and a cathodic protection (CP) output regulator.

The CP output regulator CCU-R fits within the CCU III controller range. In a PV solar powered CP system a CCU III charge controller optimises the charging and discharging of the battery. The CCU-R is added to this controller and regulates the output voltage and output current to the protected object. A small regulator includes a CCU III master unit and a CCU-R unit, covering an input capacity of 24 each 50Wp solar modules and a maximum output of 8A/48V. The system can be extended by adding CCU III slave units to increase solar module input capacity and CCU-R units to increase output capacity.
The Tss4U solution is based on a modular system approach, covering a wide range of output power and several extra options.

Operating principle of the CP output regulator

A high efficiency DC/DC down converter converts the battery voltage (which can be up to 61V) down to the required output voltage. The unit has two operating modes: constant current and constant voltage. For both voltage and current, a maximum can be set by potentiometers. The parameter (voltage or current) which first reaches its set point maximum will determine the operating mode. If soil resistance or other CP units on the same object or set points change, the operating mode will change automatically.
For example an underground gas pipe is protected with the set points adjusted to 5A max. and 10V max. The unit operates in constant current mode at 5A and 6V.
If, due to increasing soil resistance the output voltage increases to 10V, the CCU-R will switch to constant voltage mode at 10V and lower the output current. The actual operating mode is indicated by LED's.

To increase the output power, CCU-R (Slave-) units can be connected.
CCU-R Slave units are identical to master units with set point controls disabled. A maximum of 4 units can be connected in parallel (1000Wc).
A complete basic CP regulator system with one CCU-III Master Control, one CCU-III Slave and one CCU-R will fit in a suitable GRP enclosure 3 with dimensions 645 x 400 x 237 mm. Larger systems will be distributed over multiple GRP enclosures.

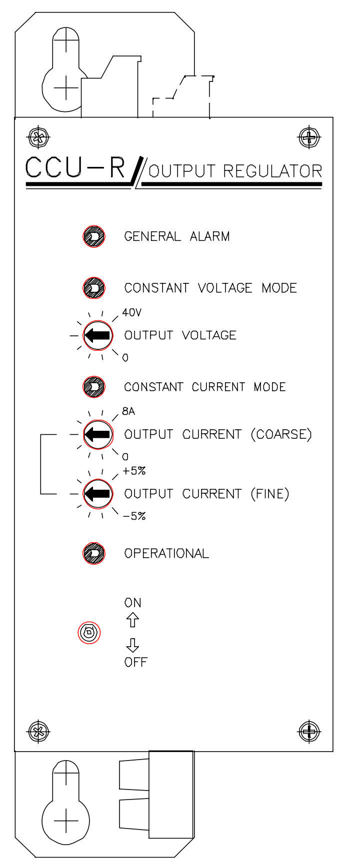


figure of CCU-R output regulator

The CCU-R can also be used as a voltage limiter for appliances of which the supply voltage range is less than the full battery voltage range.

Available options:
- Front panel meters for actual output voltage and output current.
- Digital meter module for nine system parameters.
- Timer unit
- Alarm relays
- Remote monitoring / 4-20mA outputs
- Long term autonomous data logging
- Protective filtering for output.
- Timer/Synchroniser for multiple units on same object. (p.m.)

Specifications CCU-R Output Regulator

Specifications	CCU-R 12V/24V	CCU-R 48V/8A
Max. input voltage	40 V	62 V
Min. Input voltage	11 V	15 V
Max. input current (fused)	15 A	10 A
Max. output current	12 A	8 A
Output voltage adjust. Range	Min. <0.1 V	min. <0.1 V
(not exc. actual battery volt.)	Max. 25 V	max. 48 V
Output current adjust. Range	0 - 12A	0 - 8 A
Max. output power	250 W	384 W
Conversion efficiency, typical	92 %	92 %

Enclosure

Standard CCU III module (Aluminium open frame)
Dimensions max. (h x w x d) 214 x 80 x 150 mm
Weight approx. 1kg

Environmental specifications

Operating temperature -10 °C to + 55°C
Operating relative humidity 5% to 95% non condensing

Controls and indicators

controls on front panel - V_{max} and I_{max} potentiometer
- on/off switch

LED indicators on front panel - operating
- constant Current mode
- constant voltage mode
- general alarm

Power connector - + in, - in, + out, - out

Control and feature connector inputs:	- current sense - voltage sense - on/off control - half cell control - master control
Control and feature con. outputs:	- I_{max} and V_{max} set point - slave control - alarm - current shunt - slaves off
Electrical protection	- reverse input polarity (with fuse) - overload (electronic + fuse)

6.5 Ref. cell control, timer unit & external switch off

The Reference Cell can measure the potential between pipe and earth by means of a copper/coppersulphate reference. This input signal is amplified and compared to a previous adjusted reference value. The output voltage/current of the output regulator is controlled by this comparator.

The cathodic protection potential achieved is compared with pre-adjusted limit values (high and low levels). As soon as the potential voltage goes over or under the pre-adjusted area, a red LED "out of range" will light.

The timer unit can be switched on by means of an on/off switch, if the timer is "on" the "on-off" period can be adjusted by means of four separate potentiometers.

The T-off coarse-switch and fine potentiometer are used for the "off" period and is adjustable between 0,1 second and 1 hour, the T-on coarse-switch and fine potentiometer are used for the "on" period and can be adjusted between 0,1 second and 1 hour.

If an external, voltage free, switch is connected to the "external switch off"-terminals inside the output box you can remotely switch off the output regulator.

6.6 Battery Fuse/Switch Box (BFSB)

The Battery fuse/switch box is designed for connecting two sub-systems to the load and for all battery interconnections. The advantage of using the BFSB is that the two sub-systems will be equally loaded. Also if one of the systems isn’t working properly (battery is down) no current from the other system will flow into that bad battery. Also the load will still be operational when one of the systems is (shut)down.

6.7 Output box

The output regulator is placed in the output box, which has also the metering for the output voltage and current. Also the earlier mentioned ref. cell control and timer unit are housed inside this box. The meter unit is directly powered by the input (=battery) voltage and can not be switched off independently.

6.8 Battery

The battery is of a vented lead acid type with grid plates and electrolyte. For detailed technical information refer to the attached manufacturer documentation.

7. INSTALLATION

7.1 Important

Before starting up installation:

* Check whether all switches in the enclosures are in the 'off' position.
* Before putting the system into regular operation be sure that the batteries are fully charged.

7.2 Necessary equipment and tools

Standard tools

- A multimeter.
- Various screwdrivers, open-ended and socket spanners, a knife, cable cutting tools.

Special tools

- AMP Rota crimp 600850
- AMP stripping tool 734185
- AMP Certi-loc 169400/169404

Installation note

- During installation precautions shall be taken to prevent the assembly from damaging.
- Check the system parts for transport damages.
- Clean equipment externally and internally if necessary.
- Check if all connections are tight.
- Check after the mechanical installation if all bolts and nuts are tight.

7.3 General

A complete solar system consists of solar modules, mounted on a support structure, a controller/distribution assembly in an enclosure, a battery bank with enclosure and the cabling.

Location and tilt-angle

The solar modules are generally tilted by a certain degree to the horizontal plane. This tilt-angle is calculated in such a way that the generated energy is optimised and averaged over the year.
To ensure correct working of the solar system (partial) shading of the modules should be avoided. Generally the solar modules are mounted in such a way that the solar array faces

to the equator, i.e. south for northern latitudes and north for southern latitudes.

For this system the tilt angle is 50° for the solar array.
The solar modules should face South.

Accessibility

A good access is necessary, for easy installation, inspection and/or maintenance purposes.

7.4 Preparatory work

Before installation of the complete solar system, perform the following activities first.

1. Positioning of the array.
2. Positioning of the control boxes.
3. Earthing connections.
4. Cable routing.

Ad 1)
The position of the array should be in accordance with the before mentioned guidelines (perpendicular to the north and taking into account possible shading effects).

Ad 3)
Metal constructions in power supply systems have to be connected to a proper earthing system. The two reasons for this are legal obligations and to protect the system against lightning discharges nearby. Lightning nearby may induce dangerous voltages in metal parts and electronic circuitry, which can damage the system seriously.
The support structures of the solar modules shall be properly earthed; the same applies for the control equipment. Both connections must be made to the existing station earthing system (if available). The earthing of the controller cabinet is done at a special earthing bolt at the bottom.
The reinforced concrete foundations could be used as an earthing system, if the anchor rods are electrically connected to the steel bars (*).

Ad 4)
Cable routing from the solar modules to the control equipment should be unobstructed.

(*) The earthing resistance must be measured in order to decide if the earthing system is sufficient enough.

7.5 Support structure

Introduction

This manual describes the mounting sequence of a stand-alone support structure.

The support structure consists of a number of uprights, each mounted on a base plate. Each base plate requires two or three (for extra securing) anchor bolts. The type of anchor bolts is chosen because of its ability to be connected to the armouring of the concrete. At least 10 cm. of the threaded ends of the anchor bolts must be above the concrete surface of the foundation blocks. For the position of the anchor bolts, refer to drawing x.

The solar arrays should be positioned in such a way that sunlight is utilised to its maximum. Situated on the Northern hemisphere the array should face South, in order to receive as much as possible insolation during the winter period. To obtain maximum generated energy throughout the year, it is calculated that the solar modules must be tilted to a certain angle from the horizontal plane.

The solar module beams, traverse beams and uprights are specially designed to be used as a cable tray.

For a complete overview and the general dimensions of the support structure, please refer to the system drawings.

The way of installation of the entire support structure is as follows in short:

- Mount the base plates on the anchor bolts
- Erect the uprights on the base plates
- Connect the tilt angle construction on the uprights
- Mount a string of solar modules upon two beams
- Connect the module interconnection cables according to the wiring diagram
- Connect the traverse beams to the solar module beams
- Connect the traverse beams with solar modules to the tilt angle construction
- Connect the supports with the coupling plates
- Connect the wind tracing
- If available connect the hanging brace with controller box, sub array junction box etc.

Assembling the support structure

Refer to drawing x for mounting details.
If the surface is flat enough for the support structure, the base-plates can be mounted directly on top of foundation. Otherwise the base plates should be mounted several cm. above the surface and after adjusting filled up with cement mixture.

1. Mount the base-plate to each upright with four hexagon screws M12x25, washer, spring washer and hexagon nuts M12. Place the uprights with the base-plates on the anchor bolts. Adjust the uprights in a vertical position and at the same level by means of the nuts on the anchor bolts. Turn the nuts hand-tight only.
2. Connect the angle construction to the uprights using the M10x25 bolt, washer, spring washer and M10 nut.

<u>Mounting and wiring of the solar modules</u>

1. Place packing material on a flat surface. (This packing material serves as a protective layer to prevent the solar modules from damaging). Place the solar modules, according to drawing x with the junction boxes facing up. Keep at least 2 mm distance between

the solar modules.

2. Place the beams over the solar modules (see picture on next page)

A string of solar modules.

3. Mount the beam to the solar module according drawing x detail D.
4. Place the traverse beams upon the module beams (in order to fixate the module beams and connect the traverse beams to the module beams loosely using the hexagon bolts M10x25, washers M10, spring washers M10 and nuts M10.
5. Make sure that the module beams lay on the modules symmetrically (so make sure that on either side the same space is left between the edge of the module and the module beam).
6. Fasten the bolts of the entire string and fasten the bolts that connect the traverse beams to the solar module beams.

The solar module beams are connected to the traverse beams

7. Lift the traverse beams together with the solar modules and connect them to the tilt angle construction using the M10x25 bolts, washer, spring washer and M10 nut.

When carrying a string of modules do not hold the frames or the junction boxes of the modules but only the beams. Otherwise the modules may be damaged! Prevent torsion.

8. Connect the wind tracings to either side of the support using the M10x25 hexagon bolts, washers, spring washer and M10 hexagon nut.
9. Assemble other support structures as described above.
10. Connect the cable trays and beams for holding the enclosures on the correct position (see drawing x.

Mounting the enclosures:

The following has to be carried out during assembling;

The enclosures must be mounted to the support with the supplied M8x40 bolts & M8 nuts (inside wooden crate installation material). First fasten the bolts (with one nut and one washer) to the beams in the correct mounting holes. When all four bolts are connected, slide the controller-, slave or battery fuse/switch box over the bolts and fasten them with a washer, spring washer and nut.

7.6 Mounting and wiring of the solar modules

Note: do not connect anything to the controller and the battery unless mentioned in these instructions. For detailed assemblies of the cables see attached drawings.

The solar modules are mounted to solar module support beams.

Preparing the strings

The mounting material set of each module is packed inside the junction box. Open the junction boxes of the modules and remove the mounting materials.

Mount the solar modules on the support structure according drawing x.

Module interconnection cabling

Before working on the electrical installation it is advisable to make sure all modules are covered with an opaque material (black plastic, canvas, etc, or turned upside down) in such a way that no light can reach the solar modules to avoid burn or sparks.

Before making the interconnection cables between the solar modules define with holes in the junction box are needed for fastening the cable glands. Punch out the circle of thinner plastic in the chosen hole with a screwdriver or similar instrument. Connect the module interconnection cables as detailed in drawings x and x. Make sure all the screws for electrical connections and the cable glands are tightened securely. After the connections coat metal parts with the delivered silicone grease. Then close the junction boxes except the ones for the array cables.

Note : If the solar modules are disposed to day light (even at low irradiances) there will be power on the terminals in the junction boxes, to prevent this the modules should be covered.

7.7 Interconnection cables between enclosures

All interconnection cables should be connected according the relevant drawings. Special attention should be taken regarding polarity and colour of the wires.

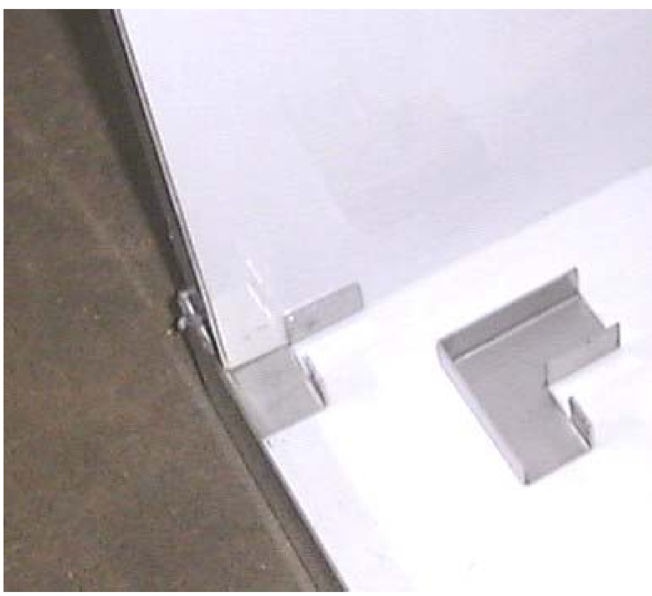
Note: The cable (Vulto mb 4x25 mm^2) between the Battery Fuse Switch Box and the Output Box should have the same length for both subsystems. For subsystem A the remaining cable should be bundled and buried into the ground.

7.8 Assembling the battery box

For a complete overview of the battery box and its components, please refer to drawing 413338.07.06.

Place the bottom panel on the correct location on a flat floor. After that place all battery-cells on this panel. All battery interconnections (and filling up the batteries) should be carried out first before further assembling the battery box.

After connecting the battery place all vertical panels on the bottom panel by sliding the panels into the bottom angle profile. Fix the side panels on the top with the top angle profiles.



Bottom & top angle profile

Mount the cable gland and the battery fuse holder on the steel plate. A not used PG9 cable gland should be closed with the delivered black stopping plug.

If all connections to the battery are fixed the battery box can be closed by putting the top panel on top of the battery box. Slide the steel-closing strip through the steel strip at the side of the top panel. The closing strip can be locked with the delivered lockers (2 per battery-box).

7.9 Battery connections

For handling the battery see the attached battery manual.

Avoid short-circuiting of the battery. Any short-circuit will blow the battery fuses or, if fuses are omitted, result in a destruction of power cables, tools, strips and the eventually the battery itself.

THE SHORT CIRCUIT CURRENT MAY BE MORE THAN 1000 AMPS.

Connect all cables on the controller-side first and afterwards to the battery. Remove the battery fuse with the supplied tool and store the fuse(s) in a safe place.

Note: the fuses must be removed before and during installation.

Fuses must be installed during start-up/commissioning.

For correct connection of all battery and sense cables to the controller see the specific drawings.

7.10 Sensor connection

The sensor is used for temperature measurement of the battery. The voltage of the battery is measured directly on the busbar in the battery fuse/switch box. Make sure that the polarities of the battery power and sense battery cables are not reversed.

The battery power and battery sense cables are always the FINAL connections to be made to the battery. After installation put silicone grease on all battery-connections/busbars.

7.11 Installation sequence

(some of the following items might be completed during installation).

1. Cover the solar modules.
2. Switch all circuit breakers in the off (= down) position. Isolate the sensor inputs (in the controller box) by lifting the 4 orange isolators on the sensor-input terminals.
3. Unscrew the cable-glands for the load, the positive and negative battery cable, the battery sense cable and if necessary for the alarms.
4. Connect the module cabling (not yet to the controller). Prepare the load cabling.
5. Pull the cable through the respective glands in the controllerbox, slave box and battery fuse/switch box and connect the cables to the terminals.
   - battery sense cable brown to terminal sense [+] brown.
   - battery sense cable white to terminal sense [-] white.
   - battery sense cable green to terminal sense [t] green.
   - battery sense cable yellow to terminal sense [t] yellow.
   - battery sense screen black to terminal sense (earth) black.
   - negative battery power cable to terminal BATTERY [-].

- positive battery power cable to terminal BATTERY [+].

6. Put the negative battery power cables to the [-] pole of the battery together with the metal part of the sensor. Screw them down firmly.
7. Put the positive battery power cable on the clamp of the positive [+] fuse.
8. Put the positive battery power cable from the fuse to the [+] pole of the battery together with the red wire + tabwasher of the sensor.
9. Connect all interconnection cables between the enclosures.
10. Connect the module cables to the control-terminals.
11. Remove the covering from the solar modules.

7.12 Putting system into operation

Starting up of the system should be preceded by an extensive check-up of all cabling connections. After this check-up the polarities of the connections should be checked with a Voltmeter before any switch is operated.

12. Check the polarity and voltage with a DC-Volt meter on the solar modules input terminals of the Charge regulator (approx. 64V - 88V) for each solar module (open circuit voltage). Replace the cover of the solar modules.
13. Check again if the output circuit breakers in both Battery Fuse/Switch boxes are in the "off" (green flag) position. Failing to do so may destroy the internal fuse of the output regulator.
14. Place the battery fuses in the fuse-holders inside the battery box. After this the yellow LED (operational indicator) on the CCU III Master control must light up. If not, check the polarities of the battery power cables.
15. If one or two of the red LED's on the CCU III Master control are on (pre-warning low Voltage or general alarm / Load disconnect), toggle the test switch upwards to high voltage test and hold it until the red LED's are off. Four green LED's will be on. Release the switch and wait at least 15 seconds. Normally only the yellow LED will stay on now, except at low or high battery voltages.
16. Close the orange isolators on the sense input terminals. If this causes (after a few seconds) the red LED's to light up, the sensor's voltage polarity is probably reversed.

    CHECK AND CORRECT THIS FIRST!

17. Remove the cover of the solar modules.
18. Switch on the "main solar switch" in the controller- and slave boxes.
19. If there is sufficient sunlight, the battery will be charged now. The charge current of each sub-array, the total array current and the battery current can be checked with the supplied DC-current clamp meter. To be checked are the total battery current (battery power cable) and the current of each solar sub-array.

17\. Toggle the test switch upward to the high voltage test position and hold it. All the green LED's on the Master control must be on and total battery current must be zero. Release the switch. After a few seconds the sub-arrays will reconnect if the battery is not fully charged.

18\. Repeat this for all slave units.

19\. Move the test switch down. After 5-15 seconds the red LED’s are on and the load relay will switch off. Release the switch.

20\. Check all connectors, cable glands, etc.

The system is ready for use after conditioning the battery. The output regulator can then be connected and switched on for TESTING.

Before taking the system into final operation, it is advised to operate the system for some days with the load disconnected, in order to be sure to start with a high state of charge of the battery.

7.13 Battery charging

The battery must be fully charged before putting system into final operation.

The State of Charge (SOC) of the battery at the time of putting the system into operation depends on the storage time and the time elapsed between delivery and installation. Also the temperature to which the battery was exposed during storage has impact on the SOC. Before any load is connected to the system, the battery should be charged up to at least 95%.

To charge the battery, proceed as follows: switch off all the loads and let the battery charged by the solar modules until the battery charge LED is on and the charge control has switched on and off the sub-arrays regularly for at least one day. Depending on the initial SOC and weather conditions, this whole procedure can last for approximately one week.

Charging may also be performed with a battery charger and a (portable) generator.

If the previous measurements were satisfactory the load can be put into operation.

7.14 Putting the cathodic protection output regulator into operation

<u>Start-up instruction output regulator.</u>

Remove the fuses in the battery box.

- Switch on the output circuit breakers in the Battery Fuse Switch boxes.

<u>Testing the output regulator.</u>

- Ensure that the output circuit breaker and switch for the timer unit are in the “off” position.
- Check if the "V" and "A" setting potmeters are in the "0" position.
- Put the switch on the CCU-R in the "ON" position in order to activate the CCU-R. The load will not be active now because the load is still switched off by the circuit breaker in the output box.
- Check if the switch on the ref. Cell control is in the "manual" position.
- Connect the supplied dummy loads to the output terminals. One board is 1000 W. Each set of two lamps is 200 W.
- Switch on the output circuit breaker.

<u>Maximum output voltage:</u>
Adjust the required maximum output voltage with the “output voltage” potentiometer of the

CCU-R, values can be observed on the V&A-meter. Use e.g. 200 W load.

Maximum output current or protection current:
Adjust the required output current with the two (course and fine) “output current” potentiometers of the CCU-R. Increase the load by "adding" lamps. Value can be observed on the V&A-meter.

Remove the dummy loads and connect the real load.

Connect the ref. cell-cable to the ref. cell input terminals. Put the switch of the ref. cell control in the “ref. cell control” position. Connect a voltmeter to the two ref. cell input terminals. Adjust the required output voltage with the “setpoint” potentiometers (coarse and fine) of the ref. cell control. The V&A meter will only show the output voltage not the ref. Cell voltage.

If the system operates satisfactory, close the enclosure.

The CP-system is now in operation.

8. MAINTENANCE

General

Although a solar generator requires little maintenance, regular inspection and maintenance will assure a satisfactory performance.

Regular records of the maintenance activities and inspection results will enable a pre-warning if something tens to go wrong, or might help to find the cause after a failure or malfunction.

The time between the maintenance operations depends on the site conditions.

Recommended overall times between maintenance schedules are:

-	Modules	:	3 - 6 months (varies at local circumstances)
-	Support structure	:	6 months
-	Batteries	:	6 months
-	Controller	:	6 months

Solar modules and support structure

Keep the modules clean. Periodically remove accumulated dirt, dust and sand. The interval between cleaning depends on the local situation. The performance of the solar array will drop (up to 30%) if the modules are left dirty.
Use a soft brush and clean water to clean the solar modules.

If the modules are not cleaned sufficiently and frequently enough, the battery will not be charged sufficient. This can cause permanent damage to the battery. The guarantee on the battery will be invalidated if the above cleaning conditions are not fulfilled.

- Check the modules on damages (glass or backside).
- Check the junction boxes for well-tightened lids and glands.
- Check if all the junction boxes are properly closed.
- Check all the interconnection and array cables for cracks and loose connections.
- Check the support structure for tightness.
- Check for proper connection of the earth wires.

The stanchions and all other parts have been hot zinc dipped (galvanised), they need no further maintenance than an annual inspection.

- Check the conditions of the zinc plating, if damaged, repair it with a zinc-rich paint (at least 92% zinc when air-dried, at least 50-micron thickness). Check the completeness and tightness of all bolts, nuts, screws and washers.

Checking the solar modules electrically

To check the solar modules electrically you need to measure the output voltage (when it's bright weather) of the solar modules when they are disconnect (by the controller). Therefor measure the voltage on the solar modules input terminals inside the controller box. Put the test switch on the controller in the high voltage mode. The solar modules will be disconnected and the voltage must be between 16-22 V (system voltage 12 V), 32-44 V (system voltage 24 V), 64 - 88 V (system voltage 48 V).

Controller CCU III

- Check all the connections of the terminals in the CCU III for proper connections. Keep the door of the CCU III closed tightly to prevent the ingress of moisture and dirt.
- Check the closing strip in the door for cracks and holes.
- Check that cable-glands on the CCU III are well tightened.
- Check the blanking plates in the unused cable-glands.

Battery

It is important to keep the batteries dry and clean. This will contribute to top performance and maximum service life. Do not use a wire brush or solvents of any kind such as petrol, thinner, acetone, paraffin, etc.

- Check at least once every 6 months that all electrical connections from battery to controller are tight. The connectors and pole screws should be corrosion protected by coating with thin grease.

Checking the battery voltage.

- Disconnect the solar array by disconnecting the solar input wires or cover the solar modules with an opaque material.

- Wait for 5 minutes for the battery to recover.

- Switch off the load(s).

- Measure the battery voltage.

- The voltage should be between fully charged and low on charge.

System voltage	fully charged	low on charge
12 V	14.2 V *)	12.0 V
24 V	28.4 V *)	24.0 V
48 V	56.8 V *)	48.0 V

*) values at 20°C, for other temperatures these values has to be corrected with the temperature coefficient.

- Reconnect the load and switch these on.

- Measure the battery voltage.

- If the battery voltage drops dramatically (2V or more for a 12V battery and 4V or more for a 24V/48V battery), compared to the voltage measured with the load disconnected, the battery is in a bad condition and should be replaced.

- If it is not possible to activate the load.
- Connect the solar modules and disconnect the loads.
- Wait for a sunny moment, the batteries are now charged by the solar modules.
- Measure the total battery voltage.
  If the battery voltage is much higher (2.0 V or more than the voltage measured when the modules were disconnected), the battery is in a bad condition and should be replaced.
- When a battery is in a bad condition you can try to recondition the battery (see reconditioning the battery).
- Normally when a battery is in a bad condition, the battery has to be replaced.

Reconditioning the battery.

- Reconditioning is the charging of the battery to a somewhat higher level as normal (boost charge), in order to guarantee that all individual cells are charged equal and completely. Switching off the load switch for one or more days can do this.
- Also reconditioning can be done with a battery-charger and a portable generator.

In case a battery has to be replaced, proceed as follows.

IMPORTANT:

Disconnect the solar array by disconnect the solar input wires or cover the solar modules with an opaque material. Switch off the battery and load.

First disconnect one cable of one battery terminal. Cover the cable ends with proper insulation tape in such a way that short-circuiting is not possible. Then disconnect the other cable and tape the cable end also. Remove the battery out of the battery box.

Insert the battery in the proper position in the battery box and connect the cables in the same way as disconnect (as described above).

By following this procedure, it is not possible to damage anything by accidental short-circuiting of poles or cable ends.

For more detailed information refer to the manual of the battery manufacturer.

9. TROUBLE SHOOTING

Most relevant test and check of functions can be done with the controller's display and test switch. A multi-meter and a DC-current clamp meter will be required when trouble shooting.
The solar system size is calculated for the defined load and based upon the expected insulation with sufficient safety margins. However special unforeseen/unknown local circumstances may cause improper functioning.

Although all generator components are designed and produced for fault-free operation for a long time under normal conditions, problems might occur due to incidental external unforeseen events.
If anything is outside normal operation conditions, the generator may react differently and display one or more malfunctions. With the help of the fault diagnosis below, the reason for malfunction can be found. A possible remedy is advised.

A] Diagnosis: Battery voltage is too low.

Possible causes:

1. Too much load current.
2. Too many consecutive days of low insulation.
3. (Partial) shading of the modules.
4. Dirty modules.
5. Loose cabling.
6. Defective temp/volt. sensor
7. Defective CCU III.

1. Check the daily load of the generator in Ah and compare this with the design value
2. Check whether the insulation has been very low over a longer period than average.
3. Check that no shading of modules can occur. Even partial shading of modules (e.g. leaves or bird droppings) will reduce the output considerably.
4. Check whether the modules are not dirty. Accumulated dust and dirt will decrease the module output considerably.
5. Check all cabling of the solar modules, the junction boxes, the CCU III and the battery.

6.a Measure at the voltage sense terminals (sense, brown/white) whether the battery voltage is present. If not, replace the sensor. To protect the wiring of the temp/volt. sensor against overload, which could happen when accidentally short circuiting the voltage sense wires; the sensor is internally provided with a very thin PCB-track which will be destroyed. When this has occurred the sensor has to be replaced. Measure the resistance of the temperature sensor by removing the wiring to the controller (sense terminals t-t) and measure with an Ohmmeter. If the sensor is defect (normally either short-circuit or open-circuit) it should be replaced.

Temperature of sensor (°C)	Resistance of sensor (Ohm)
40 °C	2250 Ohm
30 °C	2080 Ohm

20 °C	1920 Ohm
10 °C	1775 Ohm
0 °C	1635 Ohm
-10 °C	1500 Ohm

Table: Temperature dependence of resistance of temperature sensor (values ± 10%).

6.b With the CCU connected and the battery connected, measurement at the temperature sense terminals should show a voltage over the sensor of less than 1 Volt (approx. 0.7V, but not zero). Approx. 2.5 Volt indicates a bad or loose contact or a defective sensor. Refer to resistance measurement. 0V indicates a bad contact to the CCU or a defective CCU III, locate the fault and repair, if necessary replace the CCU III.

7. Check whether current from the array is flowing into the battery. If not, by-pass minus module inputs to minus battery. If current is flowing now, the CCU is suspected to be defect, replace CCU.

B] Diagnosis: Battery Voltage is too high

Possible causes:

1. Loose or defective battery voltage and temperature sensor.
2. Defective CCU III.

1. Check the connections of the battery voltage and temperature sensor.

2. At boost charge level (+ 1V), (see specifications and take the temperature compensation into effect) all module inputs should be switched off. If this is not the case and still current from module to battery is flowing, the CCU III should be replaced.

C] Overload

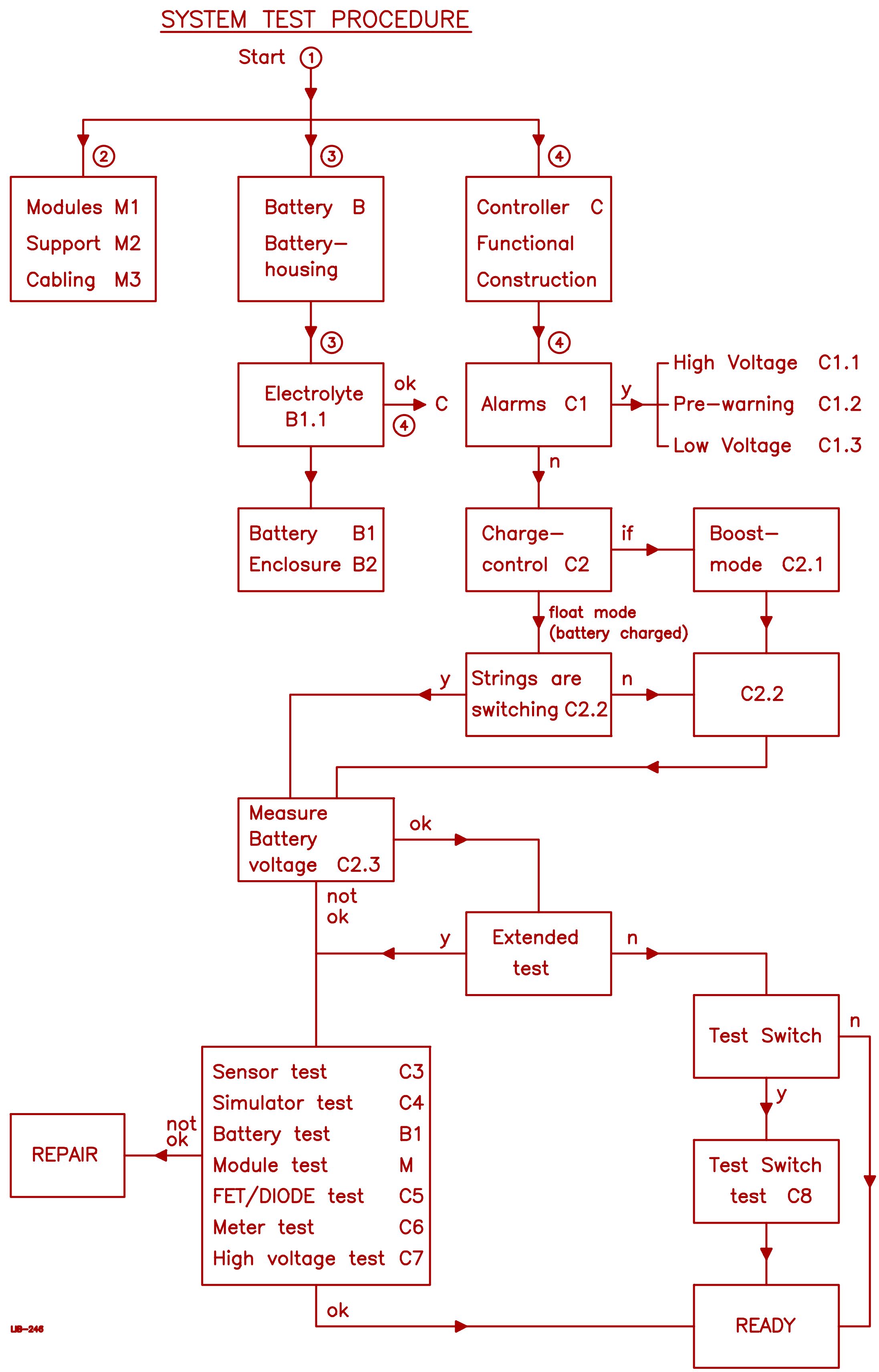
Indications: Circuitbreaker off

One or more outputs of the CCU have been overloaded. For reset disconnect the load which causes the overload. Check and repair load. Reconnect the load with the circuitbreaker.

D] Short-circuit

Indications: Fuses blown

One or more outputs of the controller have been overloaded. Check and repair the short-circuit. Replace the blown fuses.



Flow diagram system test procedure

9.1 System test procedure

General

This description belongs to the flow diagram but can be used separately. Single numbers indicate a preferred check order.

There are three groups, indicated by a preceding character:

S - Solar module, support and related cabling.
B - Battery, battery enclosure and related cabling.
C - Controller and related items.

Some items are controller and/or controller dependent. Action to be taken after a test are indicated by [→] If cables are to be disconnected, take safety precautions, avoid short circuits and reconnect when tests completed.

Minimum tests during normal maintenance.

Solar modules:	M1.1, M2
Battery:	B1.1, B1.11, B1.3.1, B2, B3
Controller:	C1, C2, C8

S Solar module and support construction.

S1 Solar module and array

S1.1 Visual inspection.

S1.1.1 Accumulated dust → clean modules and decrease maintenance interval.
The solar modules must be cleaned regularly in order to ensure that current output of the solar modules is not reduced more than 2.5%. If the modules are strongly polluted, the energy output of the solar module can be reduced up to 30%.
Cleaning of the solar modules is required at least once per half year. Use a soft brush and clean water to rinse the solar modules. Depending on local circumstances, a higher cleaning frequency may be necessary.
If the modules are not cleaned sufficiently and frequently enough, the battery will not be charged enough. This can cause permanent damage to the battery. The guarantee on the battery will be invalidated if the above cleaning conditions are not fulfilled.

S1.1.2 Shading:
If during a part of the day a part of the array is shaded by one or more objects (trees, buildings etc.), output will be reduced. → If more output is needed either remove objects or move array or increase number of modules.

S1.1.3 Mechanical solar module defects:
Glass broken, cell broken, internal corrosion, moisture ingress, major frame damage, loose junction box, back protection damage → Replace solar module.

S1.1.4 Other mechanical:

Cable mounting, cracks in cable isolation. Check the junction boxes for well-tightened lids and glands (do not open the junction box).

S1.2 Electrical tests on sub arrays or strings.

S1.2.1 Output current and Voc with cables connected.
Measure current of the sub-array with the controller meter or DC current clamp meter when the controller is charging, see reasonable values.
If not possible or not OK → S1.2.2, S1.2.3 and S1.2.4 until OK or solved.
Measure the voltage V over + and - array cables.
When controller is charging, V = approx. battery voltage.
When the controller is not charging, V = open array voltage.
See reasonable values.
If not OK → S1.2.3 and 1.2.4

S1.2.2 Output current and Voc with cables disconnected.
Disconnect the sub-array cable from the controller. Measure short-circuit current of the sub-array with an A-meter or DC current clamp meter. See reasonable values. If not OK → S1.2.3 and S1.2.4.
Measure the voltage V over + and - array cables, V = open array voltage.
See reasonable values.
If not OK → S1.2.3 and 1.2.4

S1.2.3 Cables, general.
Check all solar module interconnection cables on tightness of the electrical connections, polarity, short-circuit and damage.
If not OK → repair or replace.

S1.2.4 Performance of single solar modules.
For each solar module: Disconnect the solar module cable and measure short circuit current and open circuit voltage.
See reasonable values.
If not OK → Replace module.

S2 Solar module support

S2.1 Check on corrosion, completeness, orientation etc.

S2.2 Tightness of bolts, nuts, etc.
The steel structure is to be checked on the following points :
- Check that all the bolts and nuts are sufficiently tightened.
- Check also the nuts of the solar module T-bolts.
- Check the steel structure for damage, hair cracks or corrosion (if necessary replace or repair these parts).

S2.3 Check on damage, bent parts, torsion.

S2.4 Check earthing set.

S3 Check Cabling

B Battery, see also separate instructions if available.

B1 Electrical, SOC, Electrolyte (not applicable for closed batteries).

B1.1 Check the electrolyte level.
If too high → B1.3. Find cause
If between min-max. marks → B1.1.1, top up.
If below min → B1.11, B2, C2, top up and find cause.

B1.1.1 Check the water consumption with system log-book and normal usage.
If the normal water consumption is not mentioned in the system documentation use the following: a normal usage is the volume between max. and min marks on the battery during a year.
If normal → top up if necessary.
If too high → C2 and reduce float charge setting.
If too low, → B1.2, and increase float charge setting if necessary.

B1.2 Measure electrolyte density in each cell, calculate the average and compare the difference.
Normal average: see 'reasonable values'. Normal difference: less than 0.01.
If difference approx. 0.01, → recondition of the battery is recommended.
If difference more than 0.01, → B1.4 recondition the battery and B1.1.1.
If difference more than 0.02, bad battery or insufficient charge factor. → B1.4 recondition the battery and B1.1.1, increase charge factor. If no improvement, replace cell or battery.

B1.3 Measure the temperature of the battery banks.
Measure the voltage of each battery and record the readings in the maintenance sheet.

B1.3.1 Measure total battery voltage and record the readings in the maintenance sheet.

B1.3.2 Measure each cell voltage and record the readings in the maintenance sheet.

B1.4 Reconditioning the batteries.
Reconditioning is the charging of the batteries to a higher level as normal, in order to guarantee that all-individual cells are charged completely. This can be done by switching off all the loads for some days until the green 'battery charged' LED is "on". Also reconditioning can be done with a battery-charger and a portable generator.

B2 Mechanical battery matters.

B2.1 Cleaning, corrosion (protection).
Keep the top of the batteries clean from dust and salt deposits (clean with water or caustic soda solution in water). If mounted, check and clean flame retarding vents. Grease poles and unprotected metal with Vaseline if necessary.

B2.2 Check the connections of each battery.

If necessary fasten the bolts. Check cables on damage and isolation. Replace if necessary. Check the connection of the voltage sensor on the battery pole. If necessary fasten the bolts.

B2.3 Check on mechanical damage.

B3 Battery enclosure (if applicable).

B3.1 Check the battery enclosure for cleanness.
If dust or dirt has accumulated, clean this out of the battery enclosures. Pay special attention to ventilation provisions.

B3.2 Check on mechanical damage.

C Controller

C1 Alarms
If the controller has an alarm -unit, -relay(s) and/or -indication, check it's status.
If not → C1.4.
If High voltage alarm. → C1.1
If Low voltage pre-warning alarm. → C1.2
If General alarm / Low voltage alarm. → C1.3

C1.1 High voltage alarm.
Check if sub-array disconnect LED's are "on".
If C1.5 OK. → If C3 OK → C1.1.1.

C1.11 Check if sub-array disconnect LED's are "on".
Measure open voltage Voc of array (M1.22). Measure the voltage between V+ and V- module input of each input. If V < (Voc - 1) for an input, the input or controller is probably defective → Disconnect the array cable from each defective input. If Vbat drops after some time → replace controller. (C2)

C1.2 Pre-warning low voltage alarm.
Possible causes:

1. Too much load current.
   Check the daily load of the system in Ah and compare this with the design values.
2. Too much consecutive days of low insulation.
   Check whether the insulation has been very low over a longer period than average.
3. (Partial) shading of the solar modules. → M1.12
4. Dirty solar modules. → M1.11
5. Loose cabling or wiring. → M1.2
6. Battery has reduced capacity or defective.
   A reduced capacity is possible during extreme low temperatures (below -10°C or 14°F; at this temperature only approx. 60% of the rated capacity is available).
7. Defective voltage/temperature sensor. → C1.2.7

8 Defective charge controller. → C3 (temp sense test may be skipped).
If OK → C5

C1.3 General alarm/Low voltage alarm. → C1.2

C1.4 Measure the Battery Voltage Vbat and compare with nominal controller setting or

High voltage alarm:	if Vbat > (Vhigh-hyst) see 'reasonable values'
Pre-warning Low voltage:	if Vpre-warn > Vbat > Vlow-volt.
Low voltage:	if Vbat < Vlow-volt.

C1.5 Check if alarms are valid (no malfunction on alarm detection). → C1.4 (If not yet done).
OK if valid.
If not OK → replace alarm unit or controller.

C2 Charge control function.
Possible modes:

C2.1 *Boost Charge mode*:
After discharging during the night the battery will be charged to a some what higher voltage, the green 'battery charged' LED is off. This is the normal situation early in the morning and may last the whole day on dark cloudy and rainy days or if previous days had very low solar insulation.

C2.2 *Float Charge mode*:
The green 'battery charged' LED is on. During bright days this is a normal situation after some hours. One or more sub-arrays are disconnected or periodically switch on and off. This is indicated by green LED's. *Charge mode without sub-array switching*. At the end of the day or during temporally dark period, the battery charged LED may be on with all sub arrays connected.

C2.3 Check relation between charge mode and battery voltage.

C2.4 Check calibration

C3 Battery voltage/temperature sensor test.
Check the sensor fuses when available.

C3.1 Voltage sense.
Measure the voltage between + voltage sense input terminal and + battery input of the controller. When current is flowing through the battery cable (charging or discharging) a current dependant voltage of 5mV to 500mV can be measured. Repeat for - terminals.

C3.1.1 Voltage sense open circuit detect.
Disconnect the + voltage sense cable from the controller (beware of short circuit) or open the circuit breaker when available. Measure the voltage between cable and - battery input. The battery voltage (± 500mV due to voltage drop battery cable) should be measured. Reconnect the sensor cable. Repeat for the - sensor cable

(but measure between cable and + battery input). If one of the tests fails → Check the sensor connections on the battery it self. If OK → the voltage/temperature sensor is damaged (probably the internal non-replaceable fuse). Replace the sensor.

C3.2 Temperature sense.

C3.2.1 With connected cables, measure the voltage at the temperature sensor terminals. A voltage of between 0.5V and 1V is normal. Approx. 2.5 V indicates a bad or loose contact or a defective sensor, → C3.22 resistance measurement.
A voltage of 0 V indicates a short circuit in the sensor → C3.22 or a bad contact in the controller terminals, connector or electronics. Locate the trouble and replace the sensor or controller if necessary.

C3.2.2 Measure the resistance of the temperature sensor at the terminals in the controller. Refer to the next table.

Temperature of the sensor.	Resistance of the sensor.
40 °C	2250 Ohm
30 °C	2080 Ohm
20 °C	1920 Ohm
10 °C	1775 Ohm
0 °C	1635 Ohm
-10 °C	1500 Ohm

Table: The resistance of the sensor as a function of the temperature.

If there is a short circuit or an open circuit, check the cable.
If OK → replace the sensor.

C4 Simulate or force high and low voltages with battery connected.

C4.1 High voltage.
Controllers with test switch: Push the switch to high voltage position (standard the switch will return automatically to neutral position when released).

C4.2 Low voltage.
Controllers with test switch: Push the switch to low voltage position (standard the switch will return automatically to neutral position when released).

C5 Solar module input circuit test.

C5.1 Blocking function.
Disconnect the - sub-array cable of each controller solar module input and short circuit the module input using a 1A amp meter in series with a 2A fuse. The current reading should be less than 50 mA. Reconnect the cable.

C5.2 Voltage drop (when sub-arrays are connected) during charging.
If not all sub-arrays are connected, force the controller in boost or charge mode (C4.2). Measure voltage V between each - solar module input and - battery input. If V < 1 V (V < 1.4V for 48V and 60V CCU III versions) then OK. If not → check internal controller cabling. Repeat test by measuring - solar module input voltage as close as possible to the PCB (power connector). → replace the controller.

C5.2 Current leakage (during sub-array disconnected).
Force all sub-array inputs in disconnected (C4.1). (check if sub-array disconnect LED's are on). Measure open voltage Voc of array (M1.22). Measure the voltage V between + and - solar module input of each input. If V < (Voc - 1) for an input, the input or controller is probably defective (→ check internal cabling on short circuit). → replace controller. (C2)

C5.3 Equality of sub-array currents.
Under the same solar radiation and (battery) voltage conditions, each string of solar modules should produce approx. the same current (± 15%). If one or more strings are connected in parallel (i.e. a sub array), correct the observed current values. Before measuring, be sure no sub array is disconnected by the controller (C4.2).

C5.4 Test during float charge switching.
Measure the battery voltage. The voltage will be varying between the float charge voltage setting (compensated for temperature) and the float charge reconnect voltage setting. Sub arrays must switch on and off to maintain this voltage. If all sub arrays are connected and the solar radiation is low, the voltage will drop below the float charge reconnect setting.

C6 Metering.
If the controller is equipped with (optional) metering facilities, like V- and A-meter, the values may be checked by using an appropriate hand held multimeter and clamp on DC A-meter.

C7 System high voltage.
It is difficult to test the system high voltage behaviour in the field as the controller measures the system voltage on the power terminals of the battery (not the sense terminals). If the controller passes test C5.2 and C5.4 a system high voltage will not occur. If a system high voltage is observed → check controller calibration → if ok → replace the controller.

10. ATTACHMENTS

10.1 Drawings/partslists

Survey of documents x	A4

10.2 Product information sheets

Solar module	A4
Battery data sheet	A4
Battery, installation, commissioning and operation manual	A4