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01	2021-08-02	Updated in line with SAT report document	JvV	JWL
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Contents

1 Safety

Take the required safety precautions before staring the test.

2 General Information

This document elaborates the activities that are carried out during the Factory Acceptance Test (FAT). It is also intended to register the outcomes of the activities and validate the functional requirements of the Solar Energy System (SES).

Visual inspection will be carried out on all the enclosures as per approved Inspection & Test Plan (ITP). Functional and performance checks of the SES will be performed as per approved ITP on all the control equipment of **one (typical) SES**.

Note: Mechanical structures or a complete SES will not be assembled for the FAT.
Solar array (series of PV modules) and battery are simulated by DC power supplies.

2.1 Reference documents

Reference documents must be approved without comments by client before performing FAT.

The reference documents used during FAT are:

Document No.	Rev.	Document title
		Inspection & Test Plan (ITP)
		Component data sheets
		Single line diagram
		Circuit diagram array junction box
		Circuit diagram array combiner box
		Circuit diagram control box
		Circuit diagram battery circuit breaker box
		Circuit diagram distribution box

2.2 Test and measuring equipment for FAT

The equipment that will be used during FAT consists of:

- 2 pcs. DC power supply 0-24A dc/0-70V dc
- 2 pcs. Digital multimeter (CAT IV 600 V) including test leads/cables
- 1 pc. Current camp meter (with minimum 0-300A dc range)
- 1 pc. Insulation tester with 50Vdc and 1000Vdc range (for 24V and 48V systems)
- 1 pc. Load bank (with resistors of 300W @ 30Vdc)
- 1 pc. Temperature sensor simulation device 10°C - 50°C
- 1 set Cables and accessories (for testing control equipment)
- 1 pc. 560Ω resistor (for earth fault simulation)
- 1 pc. Toolkit (spanners, screwdriver, measure lint, etc.)

2.3 Calibration certificates

Summary of valid calibration certificates for all measuring instruments:

Measuring instrument	Type	Serial No.	Date	
			Calibration	Expiry
Digital multimeter				
Digital multimeter				
Current clamp meter (0-300A DC)				
Insulation tester				

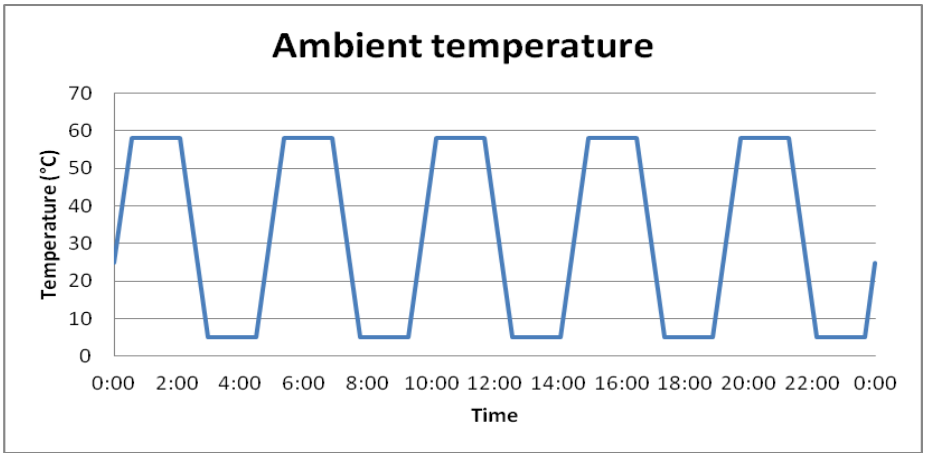
3 Heat Soak Test

3.1 Scope

In order to check if the Control box (regulation unit) is able to operate at all times, a heat soak test will be performed. The system must continue to operate with environmental temperatures from 4°C to 55°C while delivering the nominal output power. This section describes the test procedure and set-up for the heat soak test.

3.2 Test description

The Control box of one solar energy system will be placed in a climate chamber for 24 hours. During the test, the temperature will complete five cycles between 4°C and 55°C. This means each cycle will take just under five hours. The temperature will rise and fall at a rate of one degree a minute. The graph below shows the temperature change in the climate chamber during the test.



During the test the input current will be the nominal load current multiplied by the achieved array to load ratio (1.148). The remaining input power will be transferred to the (simulated) battery.

3.3 Test set-up

The Control box will be installed and tested in the climate chamber.

PV modules and batteries will be simulated by DC power supplies.
The system load will be simulated by connecting resistor banks on the output.

The table below shows the minimum tested input currents, input voltage, battery current and load voltage for the tested system during the heat soak test for 24 hours.

In/Output Control box 1	Nominal system values	Minimum values during test	Remarks	Check OK
System load	-	-		☐
System voltage	24V/48V	-		☐
System output current	-	-		☐
Achieved array to load ratio	-	-		☐
Input current (simulated solar modules)	-	-		☐
Input voltage (simulated batteries)	26V/52V	±2V/±4V		☐
Current to battery	-	-		☐

3.4 Test schedule

The table below shows the schedule for the heat soak testing of the system. The duration of the complete heat soak test for the system, including set-up and clean-up, will be two days.

Task	Duration	Begin	End
Set-up of the test	3 hrs	Day 1, 8:00	Day 1, 11:00
Heat soak test	24 hrs	Day 1, 11:00	Day 2, 11:00
Removing test set-up	1 hr	Day 2, 11:00	Day 2, 12:00

3.5 Test criteria

The Control box passes the test if at the end of the test the following criteria are met:

- Input and output currents are not changed.
- Arrays are switched on and off.
- Load output is switched on and off.

Enclosure	Tag No. / Article No. / Serial No.	Passed test
Control box	-	☐

4 Visual Inspection

In order to assess the quality of the manufactured control equipment/enclosure a visual inspection will be carried out. Each control equipment/enclosure used in the solar energy system is subjected to inspection.

4.1 Control Box (CB)

#	Description	Remarks	Action Y/N, by	Check OK
1	Check identification plate(s), general appearance and condition (undamaged).			☐
2	Check if identification numbers on components, terminals and wires are according the respective drawings.			☐
3	Check if enclosure window is properly installed.			
4	Check if all wires are terminated properly and that there are no loose connections.			☐
5	Check if enclosure and internal components are well accessible for operation and maintenance.			☐
6	Check if circuit breakers are pad-lockable in off position (if applicable).			☐
7	Check if enclosure grounding/internal earthing is properly installed.			☐

8	Check if cable gland/stopper plug sizes are according the respective drawings.			☐
9	Check if sufficient space is available for termination of external cable(s) and that terminals are suitable for the cable size(s).			☐

4.2 Distribution Box (DB)

#	Description	Remarks	Action Y/N, by	Check OK
1	Check identification plate(s), general appearance and condition (undamaged).			☐
2	Check if identification numbers on components, terminals and wires are according the respective drawings.			☐
3	Check if all wires are terminated properly and that there are no loose connections.			☐
4	Check if enclosure and internal components are well accessible for operation and maintenance.			☐
5	Check if circuit breakers are pad-lockable in off position (if applicable).			☐
6	Check if enclosure grounding/internal earthing is properly installed.			☐
7	Check if cable gland/stopper plug sizes are according the respective drawings.			☐
8	Check if sufficient space is available for termination of external cable(s) and that terminals are suitable for the cable size(s).			☐

4.3 Battery Circuit breaker Box (BCB)

#	Description	Remarks	Action Y/N, by	Check OK
1	Check identification plate(s), general appearance and condition (undamaged).			☐
2	Check if identification numbers on components, terminals and wires are according the respective drawings.			☐
3	Check if all wires are terminated properly and that there are no loose connections.			☐
4	Check if enclosure and internal components are well accessible for operation and maintenance.			☐
5	Check if circuit breakers are pad-lockable in off position (if applicable).			☐
6	Check if enclosure grounding/internal earthing is properly installed.			☐
7	Check if cable gland/stopper plug sizes are according the respective drawings.			☐
8	Check if sufficient space is available for termination of external cable(s) and that terminals are suitable for the cable size(s).			☐

4.4 Array Combiner Box (ACB) / Sub Array Junction Box (SAJB)

#	Description	Remarks	Action Y/N, by	Check OK
1	Check identification plate(s), general appearance and condition (undamaged).			☐
2	Check if identification numbers on components, terminals and wires are according the respective drawings.			☐
3	Check if all wires are terminated properly and that there are no loose connections.			☐
4	Check if enclosure and internal components are well accessible for operation and maintenance.			☐
5	Check if circuit breakers are pad-lockable in off position (if applicable).			☐
6	Check if enclosure grounding/internal earthing is properly installed.			☐
7	Check if cable gland/stopper plug sizes are according the respective drawings.			☐
8	Check if sufficient space is available for termination of external cable(s) and that terminals are suitable for the cable size(s).			☐

5 Main Functional Checks

In order to verify the functionalities of the solar energy system a functional check is performed on the main components. For this the solar modules, the batteries, the battery temperature sensor and the load will be simulated.

The solar array and the battery bank are simulated by making use of two power supplies connected to the respective input terminal of the Σ-Ahr Controller.

The battery temperature is simulated by making use of a temperature sensor simulation device directly connected to the input terminal of the temperature sensor.

The load is simulated by making use of a resistor bank connected to the solar energy system output.

The functional checks will be performed on the following enclosures.

Description	Serial No.
Control Box (CB)	
Battery Circuit Breaker Box (BCB)	
Distribution Box (DB)	
Sub Array Junction Box (SAJB) / Array Combiner Box (ACB)	

5.1 Battery temperature/voltage sensor functional check

Check the temperature sensor voltage on the voltage/temperature sensor input terminals where the temperature sensor simulation device is connected set at 25°C. Set the power supply that simulates the battery at approximately 26V/52V.

Voltage (Isolators closed)		Displayed (Isolators closed) (if applicable)		Check OK
	2.00V ±0.1V		25°C ±3°C	☐

Check battery voltage when connected to Σ-Ahr Controller (simulated battery voltage)		Check OK
Voltage sensor [V]		☐
Displayed [V] (if applicable)		☐

5.2 Σ-Ahr Controller(s) calibration check

Perform the Σ-Ahr Controller calibration check. Use the power supply that simulates the battery to check the switching of all set points. Modulate the voltage to reach each of the set points.

#	Σ-Ahr Controller calibration				Check OK
	Description	Value [V]	Limits		
			NiCd	Tolerance	
1	Load disconnected alarm (System high voltage)		31.50 V	±200 mV	☐
2	Battery charged (Boost charge voltage)		28.50 V		☐
3	Sub array disconnected (Float/equalisation charge voltage)				☐
4	Low battery voltage alarm* (Pre-warning alarm)		23.00 V		☐
5	Load disconnected alarm* (System low voltage alarm)		21.85 V		☐

** Time delay for load disconnected alarm and low battery voltage alarm is approximately 10 sec.*

#	Σ-Ahr Controller calibration				Check OK
	Description	Value [V]	Limits		
			NiCd	Tolerance	
1	Load disconnected alarm (System high voltage)		63.00 V	±400 mV	☐
2	Battery charged (Boost charge voltage)		57.00 V		☐
3	Sub array disconnected (Float/equalisation charge voltage)				☐
4	Low battery voltage alarm* (Pre-warning alarm)		46.00 V		☐
5	Load disconnected alarm* (System low voltage alarm)		43.70 V		☐

** Time delay for load disconnected alarm and low battery voltage alarm is approximately 10 sec.*

#	Σ-Ahr Controller calibration				Check OK
	Description	Value [V]	Limits		
			Lead-Acid	Tolerance	
1	Load disconnected alarm (System high voltage)		30.50 V	±200 mV	☐
2	Battery charged (Boost charge voltage)		28.80 V**		☐
3	Sub array 1 disconnected (Float/equalisation charge voltage)		28.20 V**		☐
4	Low battery voltage alarm* (Pre-warning alarm)		23.60 V		☐
5	Load disconnected alarm* (System low voltage alarm)		23.00 V		☐

** Time delay for load disconnected alarm and low battery voltage alarm is approximately 10 sec.*

** Calibration voltage level at 25°C.

#	Σ-Ahr Controller calibration				Check OK
	Description	Value [V]	Limits		
			Lead-Acid	Tolerance	
1	Load disconnected alarm (System high voltage)		61.00 V	±400 mV	☐
2	Battery charged (Boost charge voltage)		57.60 V**		☐
3	Sub array 1 disconnected (Float/equalisation charge voltage)		56.40 V**		☐
4	Low battery voltage alarm* (Pre-warning alarm)		47.20 V		☐
5	Load disconnected alarm* (System low voltage alarm)		46.00 V		☐

** Time delay for load disconnected alarm and low battery voltage alarm is approximately 10 sec.*

** Calibration voltage level at 25°C.

For Lead-Acid only

#	Σ-Ahr Controller temperature compensation					Check OK
	Description	Value		Limits*	Tolerance	
		°C	V			
1	Simulated temperature for boost charge voltage			10°C = 29.34V 20°C = 28.98V 30°C = 28.62V 40°C = 28.26V 50°C = 27.90V	± 200 mV	☐
2	Simulated temperature for float voltage			10°C = 28.74V 20°C = 28.38V 30°C = 28.02V 40°C = 27.66V 50°C = 27.30V		☐

** Temperature compensation is -36mV/°C.*

#	Σ-Ahr Controller temperature compensation					Check OK
	Description	Value		Limits*	Tolerance	
		°C	V			
1	Simulated temperature for boost charge voltage			10°C = 58.68V 20°C = 57.96V 30°C = 57.24V 40°C = 56.52V 50°C = 55.80V	± 400 mV	☐
2	Simulated temperature for float voltage			10°C = 57.48V 20°C = 56.76V 30°C = 56.04V 40°C = 55.32V 50°C = 54.60V		☐

** Temperature compensation is -72mV/°C.*

5.3 Σ-Ahr Controller(s) functional check

Perform the battery charged/discharge simulation check on the Σ-Ahr Controller(s) as described below.

Set the battery power supply to 26V/52V.

1&2: Press the test button "Simulation battery charged" on the Σ-Ahr Controller and check the switching of sub arrays.
Make use of a clamp meter to check the switching of sub arrays.

2&3: Press the test button "Simulation battery discharged" on the Σ-Ahr Controller and check the disconnection of the load. The load shall disconnect when the "Load disconnected" alarm is activated LED "ON".
Connect the resistor bank to the load output terminals and check the status of the LED indicator.

#	Σ-Ahr Controller(s) test buttons/connections		Check OK
	Description	**Limits/conditions/remarks**	
1	Test button "Simulation battery charged"	All sub arrays disconnected LED's "ON" (e.g. no current from sub arrays to system)	☐
2	Test button release	All sub arrays disconnected LED's "OFF" (e.g. current from sub arrays to system)	☐
3	Test button "Simulation battery discharged"	After 10 sec. "Low battery voltage" and "Load disconnected" LED "ON" (load should be disconnected).	☐
4	Test button release	"Low battery voltage" and "Load disconnected" LED "OFF" (load is automatically reconnected).	☐

Perform the switching of the controller/extension(s) as described below.

Make use of a clamp meter to check the individual switching of sub arrays input and load output. For this test, set the power supply that simulates the solar modules at approximately 35V - 5A/70V - 2.5A.
Connect the load bank to simulate the load, approximately 10A.
Make use of the power supply that simulates the battery for controlling the switching of sub arrays and load by Σ-Ahr Controller(s).

The following conditions shall be met:

- Sub array disconnected (LED "ON") then sub array current = 0A
- Sub array connected (LED "OFF") then sub array current = simulated current
- Low battery voltage (LED "ON") then non-essential load disconnected (if applicable), load current = 0A
- Load disconnected (LED "ON") then essential load disconnected, load current = 0A
- Low battery & Load disconnected (LED's "ON") then load current = simulated current

#	Input/output	Controller	Extension 1	Extension 2	Check OK
1	Sub array 1 [A]				☐
2	Sub array 2 [A]				☐
3	Sub array 3 [A]				☐
4	Load non-essential [A]				☐
5	Load essential [A]				☐

5.4 Circuit breaker and switch functional check

Perform the following functional checks for circuit breakers as described below.

#	Description	Limits/conditions/remarks	Check OK
1	Battery circuit breaker	Operational LED's on Σ-Ahr Controller(s) should be "ON"/"OFF" when battery circuit breaker is ON/OFF.	☐
2	Main outgoing circuit breaker	Check proper operation, power switching and polarity.	☐
3	Individual load circuit breakers	Check proper operation, power switching and polarity.	☐
4	Array switch(es)	Sub array current is interrupted when sub arrays are disconnected manually by operating array switch(es).	☐

6 Ancillary Functional Checks

In order to verify the functionalities of the ancillary components of the solar energy system a functional check will be performed.

6.1 Transducer functional check

Measure the load voltage transducer and load current transducer output current (4-20mA) in the control box and compare with the simulated battery voltage and simulated battery current. For passive transducer, connect a power supply set at 24V with multi-meter in series to the transducer output terminals.

Check battery voltage transducer (4-20mA) against simulated battery voltage (0-30V)		**Remarks**	**Tolerance**	**Check OK**
Battery voltage [V]		23.0V = 16.27mA 25.5V = 17.60mA 29.0V = 19.47mA	±0.50 mA	☐
Battery voltage transducer [mA]				

Check load current transducer (4-20mA) against simulated load current		**Remarks**	**Tolerance**	**Check OK**
Load current [A]		*Battery current range is project dependent*	±0.50 mA	☐
Load current transducer [mA]				

6.2 Nanodac functional check

Compare the Nanodac data logger data as displayed to the simulated values.

#	Description	Limits/conditions/remarks	Check OK
1	Battery voltage [V]	0 – 30V/0 – 60V	☐
2	Battery current [A]	-90 - +130A per Σ-Ahr	☐
3	Battery State of Charge [%]	0-100%	☐
4	Battery temperature [˚C]	-20˚C up to +70˚C	☐
5	Total array current [A]	0 - 130A per Σ-Ahr	☐
6	System output current [A]	0 - 90A per Σ-Ahr	☐

6.3 Alarm relay signals functional check

Modulate the voltage output of the power supply to simulate the battery voltage and check the operation of the alarm relays.
Check the operation on outgoing terminals.

#	Description	Limits/conditions/remarks	Check OK
1	Low battery voltage alarm (pre-warning) (<23.00V/<46.00V for NiCd)	Low battery voltage alarm relay LED must be "ON".	☐
1	Low battery voltage alarm (pre-warning) (<23.60V/<47.20V for Lead-Acid)	Low battery voltage alarm relay LED must be "ON".	☐
2	Load disconnected alarm (System low voltage) (<21.85V/<43.70V for NiCd)	Low battery voltage and load disconnected alarm relay LED's must be "ON".	☐
2	Load disconnected alarm (System low voltage) (<23.00V/<46.00V for Lead-Acid)	Low battery voltage and load disconnected alarm relay LED's must be "ON".	☐
3	Load disconnected alarm (System high voltage) (>31.50V/>63.00V for NiCd)	Load disconnected LED must be "ON".	☐
3	Load disconnected alarm (System high voltage) (>30.50V/>61.00V for Lead-Acid)	Load disconnected LED must be "ON".	☐
4	Earth fault alarm	Earth fault alarm relay LED must be "ON". Connect a 560Ω resistance between the positive connection and earth to simulate system earth fault.	☐
5	CPU failure alarm	CPU failure alarm relay LED must be "ON". Switch pos. 6 on the DIP switch towards the PCB and back to simulate the CPU failure alarm. Power cycle the Σ-Ahr Controller to clear the CPU failure alarm.	☐

Note: Time delay for load disconnected alarm and low battery voltage alarm is approximately 10 sec.

6.4 Other functional check

Check the output voltage of the Distribution Box (DB) by simulating the battery voltage level with a power supply.
Check the output voltage of the External Battery Charger (EBC), for this connect the input to a suitable AC supply.

#	Description	Limits/conditions/remarks	Check OK
1	Check DB output voltage	Check DB output voltage range …V ±…%	☐
2	Check EBC output voltage	Force Float (DIP switch 1) 26.5V (24V charger)/53V (48V Charger)	☐

6.5 Dielectric voltage withstand test

The Dielectric Voltage Withstand Test is performed between positive and ground and between negative and ground.
Components connected to earth must be disconnected before starting the test and reconnected again after finishing the test.

#	Enclosures	Limits (insulation resistance)	Value [MΩ]		Check OK
			+/gnd	-/gnd	
1	Sub Array Junction Box (SAJB)	R > 1MΩ			☐
2	Array Combiner Box (ACB)	R > 1MΩ			☐
3	Control Enclosure (CE)	R > 1MΩ			☐
4	Distribution Enclosure (DE)	R > 1MΩ			☐
5	Battery Circuit Breaker Enclosure (BCBE)	R > 1MΩ			☐

Note:
*For **24V** system (approx. 28V at busbar) test voltage = **50V DC***
*For **48V** system (approx. 56V at busbar) test voltage = **100V DC***

7 Outstanding Items/Punch List

Deviation related to tested and/or checked items.

Item No.	Description	Owner	Committed date	Status

8 FAT Approval Summary

The FAT of Solar Energy System control equipment/enclosures has been performed and all parties agreed herewith upon the results.

Description	Tag No. / Article No. / Serial No.	Test results	
		Pass	Fail
Heat Soak Test (CB)		☐	☐
Control Box (CB)		☐	☐
Battery Circuit Breaker Box (BCB)		☐	☐
Distribution Box (DB)		☐	☐
Array Combiner Box (ACB)/ Sub Array Junction Box (SAJB)		☐	☐

Witnessed by TSS	Witnessed by	Witnessed by
Name:	Name:	Name:
Date:	Date:	Date:
Signature:	Signature:	Signature: