# Installation, Commissioning and Operating Instructions for Renewable Energy Storage applications

**RES SOPzV 2V cells - Valve Regulated Lead Acid Batteries**

| | | | |
|---|---|---|---|
| Assembly and CE-marking by: | ________________ | Date: | ___ /_______/__ |
| Commissioning by: | ________________ | Date: | ___ /_______/__ |
| Number of cells: | ________________ | Type: | ___ |

## Safety Instructions

Read the instructions carefully and place them close to the battery.

Work on batteries to be carried out by skilled personnel only!

While working on batteries wear safety glasses, goggles and protective clothing! Comply with accident prevention rules as well as with EN 50 272-2, VDE 0105 part 1!

No smoking!

Do not expose batteries to naked flames, glowing embers or sparks, as it may cause an explosion.

Acid splashes in the eyes or on the skin must be washed with water. In case of accident consult a doctor immediately!

Clothing contaminated by acid should be washed in water.

Risk of explosion and fire.
Caution: Metal parts of the battery are always under voltage. Do not place tools or other metal objects on the battery!
Avoid short circuits!

Electrolyte is highly corrosive.

Batteries and cells are heavy.
Ensure secure installation!
Use only suitable handling equipment e.g. lifting gear in accordance with VDI 3616.

Dangerous voltage!

Batteries with this symbol can be recycled.

Pb

Treat batteries as special waste.
Do not mix them with other industrial or household waste.
Recycling can be achieved through a recognized company for battery recycling or by returning them to the manufacturer, depending on the agreement you have made.

Usage of the battery which does not comply with the OPERATING INSTRUCTIONS, repairs carried out with non-approved spare parts or unauthorized interference with the battery will invalidate any claim for warranty.

## 1. Delivery and Storage

### 1.1. Receiving inspection

Inspect for missing components. Check against the packing documents. Inspect each package or pallet for integrity and electrolyte leakage.
Record receipt date and inspection data results, notify manufacturer of any damage and take photographs if necessary.

### 1.2. Storage

Store the battery in a dry, clean, ventilated and preferably cool and frost-free location. Do not expose the cells to direct sunlight as damage to the container and cover may occur.

Do not stack one pallet above the other. Avoid storing unpacked cells on sharp-edged supports. Storage on a pallet wrapped in plastic material is permitted except in rooms where the temperature fluctuates significantly, or if high relative humidity can cause condensation under the plastic cover. With time, this condensation can cause a whitish hydration on the poles and lead to high self-discharge by leakage current.

Protect the batteries from any risk of electric shock resulting from short-circuiting by a conductive object or from a building up of conductive dust.
It is recommended to have the same storage conditions within a batch, pallet or room.

Since the batteries are supplied charged, storage time is limited. In order to easily charge the batteries after prolonged storage, it is advised not to store them more than 6 months at 20°C, 4 months at 30°C, 2 months at 40°C. A refreshing charge shall be performed after this period as a full charge (see p.3.2.1). Failure to observe these conditions may result in significantly reduced capacity and service life.

Record dates and conditions for all charges during storage.

### 1.3. Unpacking and Handling

Lifting heavy cells can be made from the cell poles. Both poles have to be used. The lifting force shall be applied vertically up and equally on each of the poles.
Never drag or roll the battery since damage will be caused.
Do not apply force to the safety valve during handling.
The batteries are fully charged before shipment. Do not short circuit.
Check for evidence of leakage. All cells with visible defects such as cracked jars, loose terminal posts, or other unrecoverable problems shall be rejected.

## 2. Installation and commissioning charge

### 2.1. Room and Installation design

The electrical protective measures or devices and the accommodation and ventilation of the battery installation must be in accordance with the applicable rules and governmental regulations. Specifically EN 50272-2 applies.

The battery should be installed in a clean, dry area. Avoid placing the battery in a warm place or in direct sunlight. The location or arrangement of cells should result in no greater than a 3°C temperature differential between cells within a series-connected string at a given time. Avoid conditions that result in spot heating or cooling, as temperature variations will cause the battery to become electrically unbalanced.

Ensure the installation allows adequate air flow around the battery assembly for better cooling.

The layout of the room must allow easy access to the batteries. Provide adequate space and illumination for inspection, maintenance, testing, and cell/battery replacement. Space should also be provided to allow for operation of lifting equipment and taking measurements (cell voltage and temperature).

### 2.2. Racks and mechanical stability

Calculations should be performed to ensure that floor loading capabilities are not exceeded. Seismic forces shall be considered when applicable.
Approved, insulated battery racks or trays with lateral force on the sidewalls in order to avoid an excessive bulging of the battery cell containers are recommended for proper installation.

**The installation should provide adequate structural support and be as free of vibration as practical.**

### 2.3. Cells in parallel strings

Valve-regulated cells may be connected in parallel to give higher current capability. In the case of parallel connected strings, use batteries of the same capacity, design and age only with a maximum of 4 parallel strings. If more than 4 strings are required, consult SYSTEMS SUNLIGHT S.A. The resistance of the cables in each string must be the same, e.g. same cross-section, same length. In addition, each string should be equipped with disconnect capabilities for maintenance and safety purposes.

### 2.4. Preliminary control

Check for evidence of leakage. All cells with visible defects such as cracked jars, loose terminal posts, or other unrecoverable problems shall be rejected.
In case the surface of battery container is dirty before installation wash with soapy water only.

Carry out OCV (open circuit voltage) measurements on each individual cell battery to check their compliance against the variation and absolute voltage criteria:

- The cells' OCV must not deviate from average more than ± 0.025 V.
- The cells' OCV must not be lower than 2.07 V.

Should not compliance noticed, consult SYSTEMS SUNLIGHT S.A..
Note: OCV of a fully charge cell is ~2,13 V. Per 10% Depth of Discharge (DOD) the voltage is reduced by ~0,025 V, for example, OCV of 2,08 V corresponds to 20% discharged cell.

### 2.5. Electrical connections

Ensure that the cells are installed in the correct polarity. Check that all contact surfaces are clean. If required, clean with a brass brush/pad. You may lubricate slightly the inserts and connections with silicone grease. Petroleum-based lubricant is not recommended.

Tighten the terminal screws, using the correct torque loading of 22 Nm.

Electrical connections to the battery and between cells on separate levels or racks should be made to minimize mechanical strain on battery terminal posts.

For systems where the total battery voltage is measured at the controller, use oversized cables to the battery in order to minimize the voltage drop.

Check the battery's total voltage. It should match the number of cells connected in series. If the measurement is not as expected, recheck the connections for proper polarity.

Batteries with a nominal voltage > 75 V require an EC conformity declaration in acc. with the low voltage directive (73/23/EEC), which confirms that the CE marking is applied to the battery. The company installing the battery is responsible for the declaration and applying the CE marking.

For future identification, apply individual cell/unit numbers in sequence starting from one end of the battery. Also apply identification numbers for the parallel strings.

Connect the battery to the DC power supply, with the charger switched off, battery fuses removed and the load disconnected, ensuring that the polarity is correct.

### 2.6. Instrumentation

For large installations consider the instrumentation for measurements and alarm. These include Voltmeter, Ammeter, Ah counter, High- and low-voltage indicators, Ground fault detector(s) and
Temperature sensor(s) for the battery and the ambient air. For smaller installations use portable test equipment.

The temperature sensors shall be fixed on the cell units (side wall or negative pole).

The use of monitoring and recording systems is mandatory in "Hybrid" systems.

### 2.7. Commissioning charge

The initial charge is very important for the future battery operation and the battery's service life. It is performed as a full charge in paragraph 3.2.1. Keep the records in the battery's logbook.

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## 3. Operation in respect to the RES design

**In "Stand-alone" systems**, the renewable source – basically PV arrays - is the only charging source available for the battery. In some systems, an external source - like diesel - can be used but this is not within the basic design principle, e.g. the source is engaged only intermittently and manually by the user, to serve excessive loads or to maintain the batteries with equalizing charges.
Two types of charge controllers can be used:

- On-Off PV controllers. The controller interrupts the charging current from the PV array (off state) when the battery voltage reaches the high regulation point (e.g 2.45Vpc) to connect it back (on state) when the voltage drops to the low regulation point (e.g. 2.35Vpc). This type is not recommended for VRLA batteries.
- Constant Voltage type (PWM method is also included here). Once the battery voltage reaches the regulation point, the controller limits the charging current to keep the voltage constant at this level, given that enough power is available from the renewable source. Two sub types may be defined here:
  - One voltage step controller: There is only one regulation point.
  - Two voltage step controller: There are two regulation points. Initially the controller maintains an elevated voltage to recharge the battery fast (absorption stage) then, after certain time or other criteria, it steps back to a lower voltage to prevent unnecessary overcharging (floating stage)

**In "Hybrid" systems**, the renewable source size is smaller than the application load. There is always an independent source available - diesel or grid – to recharge the battery in every cycle, once a minimum state of charge has been reached. The same source can be also engaged, either automatically at regular intervals or manually when required, to maintain the battery with equalizing charges. Only Constant Voltage controllers (usually with two voltage steps) shall be used here.

### 3.1. Discharging

No restriction on the discharge current is required, as far as the connections are properly sized and the battery temperature stays within the allowable limits.

The maximum allowable discharge per cycle (Max Daily DoD - MDDOD) is

- 20% for Stand-alone and
- 60% for Hybrid systems

For discharge currents lower than 0.1*C10, the MDDOD is expressed in % of the C10 value. For example, the cell "RES 6 SOPzV 850" has C10=687Ah therefore a 60% MDDoD means 413 Ah extractable per day.

The maximum allowable DoD (MDOD) is 80% of the maximum available capacity, unless otherwise has been approved by Systems Sunlight.

*Overdischarge Protection*
The MDOD limit control should not be implemented solely through control systems based on Ah-counters (integrating the ampere-hours into and out of the battery). Monitoring the battery voltage against the low-voltage disconnect setting (LVD) should always be included.

The MDDOD limit control - for hybrid applications - can be realized either by Ah-counters control units or/and by battery voltage monitoring. For Stand-alone systems see the note below for the Array to Load ratio.
The graphs at the end of this document give the battery voltage to DoD relation as a guidance for the initial LVD settings (first-try settings). The system designer or installer shall adjust and confirm them upon the actual conditions of the system. For systems where the voltage is measured at the controller and not on the battery, the voltage drop on the connections to the battery shall be considered.
For critical systems with the load directly connected on the battery, an alarm or other method of user feedback must be included to give information on the battery status when DoD exceeds 60 to 80%.

*Array to Load ratio for Stand-alone systems*
In Stand-alone systems, the renewable source shall be sufficiently oversized against the application load in order to avoid excessive cycling near the MDOD which limits dramatically the battery's life expectancy. The ampere hour output of the PV array (or other renewable source) over the load ampere hours for the minimum design month (month with minimum PV output) should be at least 1.3 (acc. to IEEE1013) to recharge the battery while the daily load is supplied.

<u>Low-voltage reconnect (LVR) for Stand-alone systems</u>
The battery voltage at which the load is reconnected after a low-voltage disconnect shall be above 2.2 Vpc

## 3.2. Charging

### 3.2.1. Full charge

The full charge is a prolonged charge at an elevated voltage, performed under the supervision of the user. It lasts until certain full charge criteria are fulfilled but not outside certain minimum and maximum duration limits. It is used mainly

- as Commissioning charge after installation in paragraph 2.7
- as Corrective Equalizing charge in paragraph 3.2.2.2
- as preparation charge before a capacity test in paragraph 6
- as refresh charge during long storage period (in paragraphs 1.2, 7)

During charge, the battery temperature shall be continuously monitored. It should never exceed 45°C, otherwise the charge shall be interrupted for sufficient time to cool down the battery.

*Case 1) With external charger of IU - characteristic.*
For the commissioning charge the current shall be limited to 0.1*C10 Amps.

| Battery temperature | Voltage settings | Minimum and maximum charging times | Full charge criteria. |
|---|---|---|---|
| 15-30°C | 2.35 – 2.40 V | 36h – 72h | when the individual cell voltages have not risen for a period of 4 hours. |
| 30-40°C | 2.32 – 2.35 V | 24h - 48h | |
| 0-10°C | 2.38 – 2.45 V | 48h - 72h | |

*Case 2) With external charger of IUI or I - characteristic.*
Using an IUI or I charger that can charge the battery with constant current at an elevated voltage, higher than 2.60 Vpc up to 2.80 Vpc.

| Bulk charge current limitation | Voltage settings for U phase | gassing charge current limitation | Minimum and maximum charging times at gassing phase | Full charge criteria |
|---|---|---|---|---|
| 0.2*C10 | 2.33 – 2.40 V | 0.012*C10 (1.2 A per 100Ah nominal capacity) | 5h – 8h | when the individual cell voltages have not risen for a period of 1 hour. |

*Case 3) Using the solar controller.*
Connect the battery to the controller and leave it for 1-2 weeks while the application load is disconnected. Full charge criteria are not applicable here. Use the following voltage settings:

| On-off controllers | -20 to 0°C | 0 to 35°C | >35°C |
|---|---|---|---|
| High disconnect voltage (Vr) | 2,55V | 2,45V | 2,40V |
| Low restart voltage (Vrr) | 2,35V | 2,30V | 2,25V |

| Constant Voltage controllers | -20 to 0°C | 0 to 35°C | >35°C |
|---|---|---|---|
| Regulation voltage (Vr) | 2,45V | 2,37V | 2,33V |

### 3.2.2. Equalizing

*3.2.2.1. Functional Equalizing*

During a cycling operation, the target is to achieve an almost complete recharge (100% SOC) after every discharge cycle otherwise a permanent capacity decrease will threaten the battery's state of health. This is not always possible in Stand-alone applications where the RES source depends on the weather conditions and the load is possible to exceed the expected level. Here, a proper "Array to Load ratio" as given in paragraph 3.1, is critical for the life expectancy of the battery. For Hybrid systems with diesel generator (e.g. mainly telecom hybrid systems), the charging source is always available but the boost charging time is restricted to achieve a more efficient utilization of the diesel. In both cases, a scheduled (functional) equalizing charge shall be given at regular intervals (see next) to protect the battery from sulphation and lagging cells.

- Equalizing frequency is adjusted according to the charge deficit. The less complete the daily recharge is, the more frequent the equalizing is required.
- The charging duration is fixed.
- The voltage settings are the same values used for a normal recharge.

*3.2.2.2. Corrective Equalizing*

Equalizing charges are also required after incidents of excessive stress for the battery (deep discharges with inadequate charges) or when the individual cell voltages show excessive deviation from the average (lagging cells

and sulphation problems).
Should the voltage in individual cells deviate from the average value more than the following limits, perform an equalizing charge:

| Battery state | 2V cells |
|---|---|
| at floating, after the first 6 months of operation | -0.1V / +0.2V |
| at the end of the normal charge, while current is stable, after the first 6 months of operation | -0.2V / +0.35V |
| during discharge, while DoD is between 5 and 20% | ± 0.04V |
| during discharge, while DoD is between 20 and 60% | ± 0.06V |
| at rest, 24h after a Functional Equalizing charge | ± 0.025V |

Corrective Equalizing is performed as a Full Charge in paragraph 3.2.1.

If the voltages are still out of the limits, Systems Sunlight Customer Service should be called.
A service contract with Systems Sunlight S.A. is recommended.

### 3.2.3. Normal operation charging

The following charging voltage settings are optimum values, so the battery is not heavily undercharged or overcharged. A good indicator to check this is the percentage of overcharge per cycle (charging factor) within a long period of operation (a month to a year). Deviations from the charging factors given here, prompt to check the charging settings and the overall system operation again:

- >107% for Stand-alone systems with Maximum Daily DOD less than 5%
- 105% to 110% for Stand-alone systems with MDDOD more than 5%
- 104% to 107% for Hybrid systems.

*3.2.3.1. Settings for Stand-alone systems*

The settings shall be adjusted according to battery temperature. Temperatures are averaged over one month:

| Controller type | Setting | -20 to 0°C | 0 to 15°C | 15 to 35°C | >35°C |
|---|---|---|---|---|---|
| Constant Voltage – one step | Vr | 2,50V | 2,45V | 2,40V | 2,35V |
| Constant Voltage – two steps | absorption maximum 2 h per day | 2,55V | 2,50V | 2,45V | 2,40V |
| | float | 2,45V | 2,40V | 2,35V | 2,30V |
| On-off | High voltage (Vr) | 2,55V | 2,50V | 2,45V | 2,40V |
| | Low voltage (Vrr) | 2,35V | 2,30V | 2,30V | 2,25V |

For systems with oversized PV array and low MDDOD (<5%), use lower settings (see paragraph 3.3).

Functional equalizing charges are required in periods with marginal "Array to Load ratio", less than 1.3. Typical frequency is 1 to 6 times per year.

*3.2.3.2. Settings for Hybrid systems*

The settings shall be adjusted according to the battery temperature. Temperatures are averaged over one month.
The duration for the absorption phase per cycle can be within 4 to 12 hours. The frequency of the Functional Equalizing charges is adjusted accordingly.

| Controller type | Setting | -20 to 0°C | 0 to 15°C | 15 to 35°C | >35°C |
|---|---|---|---|---|---|
| Constant Voltage | Absorption voltage | 2,50V | 2,45V | 2,40V | 2,35V |

Functional equalizing frequency

| Absorption time | 4-6h | 6-8h | 8-10h | 10-12h |
|---|---|---|---|---|
| Equalizing every | 7 cycles | 14 cycles | 21 cycles | 28 cycles |
| if one cycle is one day | one week | two weeks | three weeks | four weeks |

A functional equalizing lasts 24 hours with voltage settings the same as above.

## 3.3. Operation at no or very low load

When there is little or no load connected to the system for long periods (more than 1 month) while the battery remains connected, the normal charging settings in paragraph 3.2 are too high and result in unwanted overcharging. The same is true for Stand-alone systems with oversized PV array and very low MDDOD (<5%) like in remote Telecom transmitters.

Use the following settings. Temperatures are averaged over one month:

For Stand-alone systems:

| Controller type | Setting | -20 to 0°C | 0 to 15°C | 15 to 35°C | >35°C |
|---|---|---|---|---|---|
| Constant Voltage – one step | Vr | 2,37V | 2,35V | 2,30V | 2,27V |
| Constant Voltage – two steps | absorption maximum 2 h per day | 2,40V | 2,40V | 2,35V | 2,30V |
| | float | 2,35V | 2,30V | 2,25V | 2,25V |
| On-off | High voltage (Vr) | 2,40V | 2,35V | 2,30V | 2,30V |
| | Low voltage (Vrr) | 2,20V | 2,20V | 2,20V | 2,20V |

For hybrid systems:

- when only PV is engaged: use settings as in "Constant Voltage – one step" case above
- when only diesel is engaged (continuously): reduce the previous settings by 0.05V each.

### 3.4. Temperature limits

All technical data apply for the nominal temperature of 20°C. The ideal operating temperature range is 20°C to 25°C. The recommended operating temperature range is 15°C to 35°C. Higher temperatures reduce the working life. A maximum temperature of 45°C must not be exceeded. In hybrid applications the yearly average of battery temperature should be less than 30°C.
Subzero temperatures may cause electrolyte freezing and irreversible damage when the battery's state of charge (SoC) is low. The minimum safe temperature Vs SoC is given below:

| SoC (% to C10 – DIN value) | 0% – 40% | 40% – 60% | 60% – 80% |
|---|---|---|---|
| Freezing point | -30 °C | -20 °C | -15 °C |

The system designer/installer shall consider countermeasures like thermal insulation, increasing the battery capacity or increasing the minimum system voltage. In Stand-alone systems it is recommended to use controllers with adjustable LVD setting to the battery temperature (higher LVD for lower temperature).

During operation, the temperature difference between individual battery cells should be below 3°K.

### 3.5. Current limits

The maximum charging current during the bulk charging is 0.2 x C10, while the battery voltage is below the gassing voltage of 2,40V x number of cells.

### 3.6. Ripple currents

During recharging up to 2.40 V/cell, the effective value of the AC ripple current may reach temporarily at maximum 10 A /100 Ah C10 nominal capacity. After recharging and at float charge in stand-by or buffer operation, the effective value of the AC ripple current must not exceed 5 A /100 Ah C10 nominal capacity.

## 4. Battery Maintenance

To avoid leakage currents and the associated risk of fire, keep the battery dry and clean. Clean with clear water and do not use any solvents and detergents as they can cause permanent damage to container or lid. Avoid electrostatic charges.

To be checked and listed every 6 months:

- battery voltage
- voltage of some cells (pilot cells)
- temperature of the container in some cells (pilot cells)
- confirm daily DoD per cell
- confirm max DoD per cell does not exceed the allowed limit
- confirm charging factor is within acceptable limits
- confirm that charge settings correspond to the recommended ones
- finally check if corrective equalizing is applied according to 3.2.2.2

Check and list every 12 months:

- The voltages and temperatures in all cells.
- Connectors, racks and ventilation.

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## 5. Faults

Should faults be detected in the battery or the charging device, Systems Sunlight Customer Service should be contacted immediately. Measured data simplify fault detection and elimination. A service contract with Systems Sunlight S.A. will detect faults in time.

## 6. Testing

Tests must be conducted according to IEC 60 896 - 21. Check that the battery is fully charged. Before testing new batteries it must be ensured that a sufficient commissioning charge has been applied and the battery is fully charged.

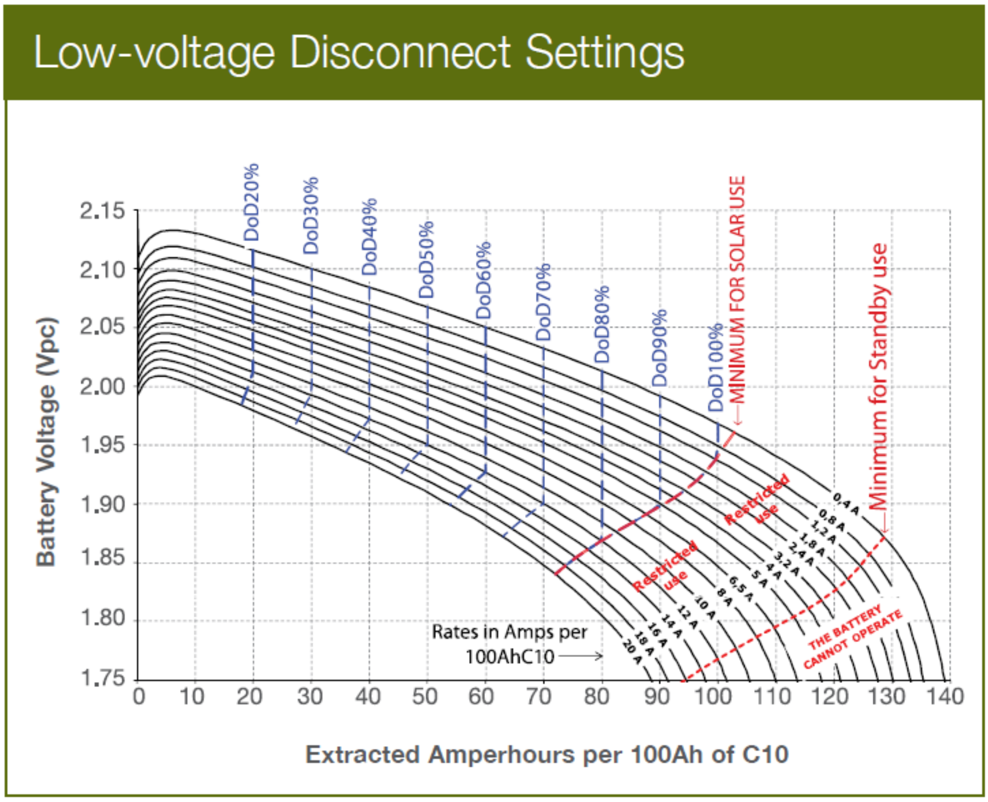
## 7. Storage and taking out of operation

If filled lead acid accumulators are to be taken out of operation for a long period of time, they must be placed fully charged in a dry, frost-free room. To avoid damage, periodical equalizing charging (see 3.2.1) or permanent float charging has to be made.

## 8. Transport

RES SOPzV cells are protected against short-circuit. If properly packed, batteries are no dangerous goods according to the international regulations for dangerous goods on road and on rail (ADR and RID).

## Battery Voltage in relation to DoD as a guidance for the initial LVD settings (first-try settings) - 20ºC reference temperature




**Notes:**

- The minimum voltage, for standby use, represents the maximum available capacity.
- The minimum voltage, for solar use, represents the 80% of the maximum available capacity. It is the lower LVD setting except in special applications and after Sunlight's approval.
- The DoD 60% line, represents the minimum voltage setting to control the end voltage of each discharge in hybrid applications. It's always recommended to implement a supplementary control by Ah counter.