# DESCRIPTION OF CHARGE MODE FOR LOW MAINTENANCE STM MODULES

# STM 5-100 MRE

## 1) GENERAL FEATURES

### 1.1) Introduction

Due to the characteristic of low maintenance modules (designed for topping up only during regular maintenance of the vehicle), their electrochemical behaviour does not allow the detection of a voltage threshold at the end of the first phase of charging at constant current or power, especially for temperatures above 30°C.

In addition, although more pronounced than for flooded STM modules, the temperature variation at end of the first phase of charging at constant current or power is not high enough to optimise charge management.

With this in mind, a charge mode that integrates a temperature-compensated voltage switch threshold, a specific Ah meter (pilot meter) and a module temperature measurement, has therefore been developed.

### 1.2) Description of different types of charge

Five different types of charge are used:

Initialisation charge

This is carried out during battery commissioning by the garage technician using an external command non accessible to the users.

Normal charge

This allows users to charge their batteries at home.

Equalisation charge

This is used to balance the battery to reduce capacity and voltage dispersion.
This charge offers a higher recharge coefficient than a normal charge. It is carried out periodically and automatically according to vehicle specific criteria.

Maintenance charge

This is carried out during maintenance operations. The battery is fully charged and the electrolyte is topped up. It is carried out by the garage technician using an external command non accessible to the users.

Fast charge

This is carried out at a fast charge station, allowing a completely discharged battery to be 75% charged in 30 minutes. This is not a full charging operation.

Precharge (for normal equalisation and maintenance charge types)

The beginning of a charge on a fully or deep discharged stored battery causes a voltage increase that may exceed the voltage switch threshold which occurs at the end of constant current or power phase for the overcharge phase and will therefore stop the charge prematurely. To avoid this problem, a precharge operates automatically on low current, time limited criterion before effectively starting the charging. If necessary, this precharge is carried out before a normal, equalisation or maintenance charge.

## 2) Description of method of charging

### 2.1) End of charge criteria

Different charge management methods are deployed:

1) the detection of a temperature-compensated voltage threshold in the form of a bilinear function.

2) a charged and discharged amperehour meter which takes into account the battery self discharge (pilot meter) and simulates voltage threshold detection to allow charge management at any temperature.

The criteria apply to the different types of charge used.

A specific amperehour meter is also used in which the overcharged capacity is cumulated to determine when the electrolyte in the modules needs to be topped up. This amperehour meter must be reset to zero when all the modules of the battery are topped up.

### 2.2) Operating the pilot meter

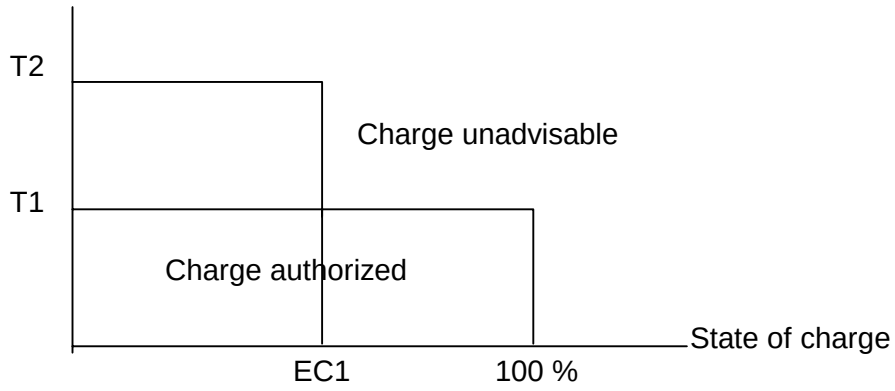
- The meter is reset to zero for a charged module.
- When the battery is inactive, the pilot meter increments the self discharge capacity (calculated from a parametric model).
- During discharge, the pilot meter increments the measured discharged capacity.
- During charge, the pilot meter decrements the measured capacity charged. The meter does not count down below zero.
- The meter is set to zero at the end of a constant current or power charge when one of the end of charge criteria (voltage threshold or pilot meter value) is reached.

## 2.3) Temperature Management during charge

### 2.3.1) Normal, maintenance and equalisation charges

The charge must only be used for the cases given in the following graphs.

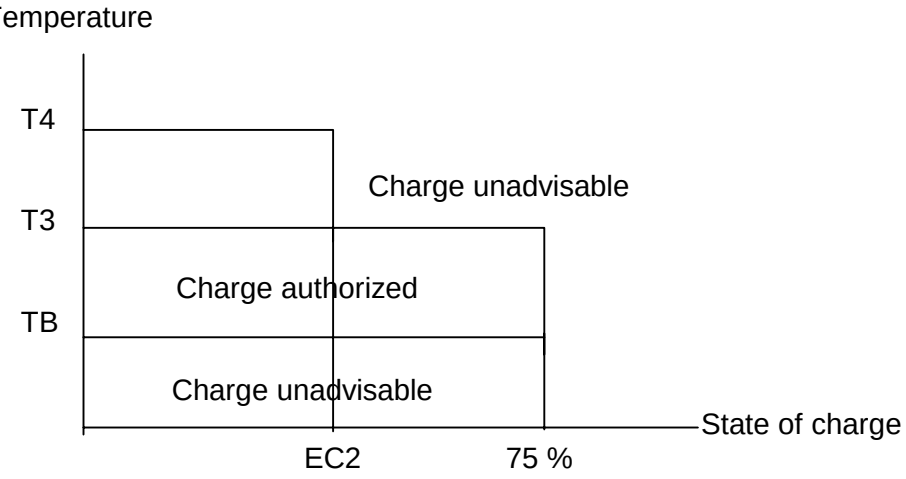
N.B. The state of charge is given by the gauge.




The authorised T1 temperature value of +40°C must not be considered as a value to start the charge systematically. Actual module temperature around +30°C is strongly recommended in order to guarantee the life time and the performance of the battery.

### 2.3.2) Fast charge

The charge must only be utilised in the cases given in the following graph:




If the temperature exceeds these limits during charging, the charge must be interrupted and restarted only when the temperature has dropped to the authorised fast charge temperature.

## 2.4) Detailed description of different types of charge

### 2.4.1) Precharge

For a fully discharged battery that has been stored for some time, the beginning of the charge causes a voltage increase that may exceed the voltage switch threshold of the constant current or power phase to the overcharge phase and hence stop the charge prematurely without restoring the full capacity of the battery . The precharge is automatically triggered at a low current and limited time before charging to avoid this problem.

Before carrying out a normal, equalisation or maintenance charge, the battery voltage should be checked. If it is lower than the UP threshold, carry out a precharge at I2 during DP, then begin the desired charging.

If the voltage remains lower than UP after precharge a battery defect indication must be displayed.

### 2.4.2) Initialisation charge

This charge is carried out to initialize the pilot meter and the battery when the vehicle is commissioned. After this charge, the pilot meter must be reset to zero and the electrolyte in the battery should be topped up.

This is a constant current charge.

#### 2.4.2.1) Constant current Phase (I)

This is a I2 charge of duration DI with:

maximum initial module temperature T5
maximum module temperature during charging is T6.

#### 2.4.2.2) Electrolyte topping-up phase

This second phase allows the topping up of modules to be optimised. It comprises current pulses of I2 (lasting DM minutes every DR minutes applicable for a maximum of 72 hours). The pulse charging can be stopped at any time, at least 30 minutes after the overcharge phase is ended, to carry out topping up in a 30 minute period. After the topping up the pulse charging is not restarted.

Status of meters at end of charge

At the end of this phase, the pilot meter is reset to zero.
The amperehour meter dedicated to cumulate overcharged capacity is reset to zero after the electrolyte has been topped up.

### 2.4.3) Normal and equalisation charge

The charge profile is (I or P) - I1.

#### 2.4.3.1) Constant current (I) or Constant power phase (P)

Detection of end of phase

- using a temperature compensated threshold voltage

threshold Ue = f(T, L1, L2) as a bilinear function

for T > TR: Ue = Uo + L1 * (T-TR)

where T is the actual module temperature

for T < TR: Ue = Uo + L2 * (T-TR)

or

- using the pilot meter value (VP1)

the first of the two conditions reached ends phase I or P.

Pilot meter status at end of Phase I or P

The pilot meter is reset to zero at the end of Phase I or P.

Safety

maximum time (t1)

If this criterion is met, the charge is stopped, the pilot meter is reset to zero and the maintenance meter increments by one set overcharged capacity (VS1)
In this case, a «defective system» indication must be displayed.

#### 2.4.3.2) Constant Current overcharge phase (Phase I1)

##### 2.4.3.2.1) Normal charge

This is a I1 constant current overcharge phase. Its duration is a function of the constant current or power phase charged capacity and must respect the value of the K1 overcharge coefficient:

$$K1 = \frac{\text{Phase I1 charged capacity}}{\text{Phase I or P charged capacity}} \times 100$$

Status of meters at end of charge:

During this phase, the pilot meter is reset to zero.

The amperehour meter dedicated to cumulate overcharged capacity is incremented by the measured overcharged capacity.

Safety:

Maximum time (t2)

If the maximum time (t2) is reached, the charge is stopped. In this case, a « defective system » indication must be displayed.

#### 2.4.3.2.2) Equalisation charge

This is an I1 constant current phase with a set DE duration irrespective of the Phase I or P charged capacity.

Status of meters at end of phase:

During this phase, the pilot meter remains at zero.
The amperehour meter dedicated to cumulate overcharged capacity is incremented by the measured overcharged capacity.

### 2.4.4) Maintenance charge

The charge profile is (I or P) - I2 type.
The electrolyte should be topped up after this charge.

#### 2.4.4.1) Constant current (I) or constant power (P) phase

Detection of end of charge

- using a temperature compensated threshold voltage

threshold Ue = f(T, L1, L2) as a bilinear function

or

- using the pilot meter value (VP1)

Meeting any of these two conditions will end Phase I or P.

Pilot meter status at end of Phase P

The pilot meter is reset to zero at the end of Phase I or P.

Safety

maximum charge time (t1)

If maximum charge time (t1) is reached, the charge is stopped, the pilot meter is reset to zero and the maintenance meter increments by one set overcharged capacity (VS1)
In this case, a « defective system » indication must be displayed.

### 2.4.4.2) Constant current overcharge phase (I2)

This is an I2 constant current phase with a set DEN duration irrespective of the Phase I or P charged capacity.

### 2.4.4.3) Electrolyte topping-up phase

This second phase allows the topping up of modules to be optimised. It comprises of current pulses of I2 (lasting DM minutes every DR minutes applicable for a maximum of 72 hours). The pulse charging can be stopped at any time, at least 30 minutes after the overcharge phase is ended, to carry out topping up in a 30 minute period. After the topping up the pulse charging is not restarted.

Status of meters at end of phase:

At the end of this phase, the pilot meter is reset to zero.
The amperehour meter dedicated to cumulate overcharged capacity is reset to zero after the electrolyte has been topped up.

### 2.4.5) Fast charge

Charge phase: IMCR maximum current

Detection of end of charge

- using a threshold voltage Ucr corrected according to the temperature and value of the intensity of the charge (ICR)

  Ucr = f(T, L3, L4, I) (linear function)

  Ucr = U1 + L3 * (T-TCR) + L4 * (I-ICR)

  where T is the actual module temperature and I is the selected fast charge current

or

- using a pilot meter value (VP2)

Safety

maximum charge time (t3)

If this criterion is met, the charge is stopped. In this case, a « defective system » indication must be displayed.

Pilot meter status at end of charge

The pilot meter is not reset to zero at end of charge.

## 2.5) Special cases

### 2.5.1) Prolonged inactivity of vehicle

If the vehicle is inactive for a long period (more than one month), self-discharge will cause a battery modelling mismatch. It will then be difficult to handle vehicle charging.

Because of this, the first recharge after the period of inactivity must be an equalisation charge to correct any mismatch between the pilot meter and the real state of charge of the battery.

### 2.5.2) Operations on the vehicle (changing the calculator or module)

In this case, information about pilot meter values becomes erroneous. An initialisation charge must be carried out to re-commission the battery and at the end of charge the pilot meter must be reset to zero.

# CHARGE PARAMETERS FOR LOW MAINTENANCE STM MODULES

## STM 5-100 MRE

All charge parameters must be configurable

| PARAMETERS | CODE | UNIT | Value |
|---|---|---|---|
| PRECHARGE | | | |
| Triggering conditions U < UP | UP | V/module | 6 |
| Charge current | I2 | A | 10 |
| Duration of charge at constant current | DP | min | 10 |
| INITIALISATION CHARGE | | | |
| Max temp at start of charge | T5 | °C | 35 |
| Max temp during charge | T6 | °C | 50 |
| Charge current | I2 | A | 10 |
| Duration of charge at constant current | DI | h | 15 |
| NORMAL, EQUALISATION AND MAINTENANCE CHARGES | | | |
| Max temperature during charge<br>if State of Charge < EC1<br>if State of Charge > EC1 | <br>T2<br>T1 | <br>°C<br>°C | <br>50<br>40 |
| State of charge | EC1 | % | 40 |
| Discharged capacity before equalisation | CDEG | Ah | 2000 |
| Overcharged capacity before maintenance | CSE | Ah | 1000 |
| CONSTANT CURRENT OR POWER PHASE | | | |
| Current of constant current phase | I | A | 20 |
| Power of constant power phase | P | W/module | 140 |
| End of constant current or power charge criteria<br>Voltage threshold at TR = 10°C<br>Voltage threshold compensation<br>- for T > TR<br>- for T < TR<br>Pilot meter value at end of phase | <br>U0<br><br>L1<br>L2<br>VP1 | <br>V/module<br><br>V/°C<br>V/°C<br>Ah | <br>8.15<br><br>- 0.015<br>- 0.030<br>0 |
| Safety | | | |
| Max. constant current or power charge duration | t1 | h | 6.5 |
| Set overcharged capacity | VS1 | Ah | 40 |

| PARAMETERS | CODE | UNIT | Value |
|---|---|---|---|
| CONSTANT CURRENT OVERCHARGE PHASE | | | |
| NORMAL CHARGE | | | |
| Overcharge current | I1 | A | 5 |
| Normal charge overcharge coefficient | K1 | % | 15 |
| Safety | | | |
| Max duration of constant current charge I1 | t2 | h | 8 |
| EQUALISATION CHARGE | | | |
| Overcharge current | I1 | A | 5 |
| Duration of constant current I1 charge | DE | h | 5 |
| MAINTENANCE CHARGE | | | |
| Overcharge current | I2 | A | 10 |
| Duration of constant current I2 charge | DEN | h | 5 |
| Electrolyte topping up phase | | | |
| Duration of peaks at I2 | DM | min | 2 |
| Rest between peaks at I2 | DR | min | 30 |
| FAST CHARGE | | | |
| Minimum temperature of fast charge | TB | °C | - 10 |
| Max temp during fast charging<br>if State of charge < EC2 | T4 | °C | 60 |
| if State of charge > EC2 | T3 | °C | 50 |
| State of charge | EC2 | % | 40 |
| Max. current of fast charge | IMCR | A | 150 |
| End of fast charge criteria<br>End of fast charge voltage at TCR and ICR<br>Reference temperature<br>Reference current<br>Compensation according to temperature<br>Compensation according to current<br>Pilot meter value at end of phase | <br>U1<br>TCR<br>ICR<br>L3<br>L4<br>VP2 | <br>V/module<br>°C<br>A<br>V/°C/module<br>V/A/module<br>Ah | <br>8.00<br>20<br>150<br>- 0.010<br>0.005<br>* 75 |
| Safety | | | |
| Max. duration of fast charge | t3 | min | 40 |

* measured capacity