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INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

Electric double-layer capacitors for use in hybrid electric vehicles – Test methods for electrical characteristics

Condensateurs électriques à double couche pour véhicules électriques hybrides – Méthodes d'essai des caractéristiques électriques

IEC 62576:2009

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN HYBRID ELECTRIC VEHICLES – TEST METHODS FOR ELECTRICAL CHARACTERISTICS

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The text of this standard is based on the following documents:

CDV	Report on voting
69/158/CDV	69/162/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

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INTRODUCTION

The Electric double-layer capacitor (EDLC) is a promising energy storage system for hybrid electric vehicles (HEVs), and EDLC-installed HEVs have begun to be commercialized with an eye to improving fuel economy by recovering regenerative energy. Although a standards series (IEC 62391 series) for EDLC already exists, those for HEVs involve patterns of use, usage environment, and values of current that are quite different from those assumed in the existing standards. Standard evaluation and test methods will be useful for both the auto manufacturers and capacitor suppliers to speed up the development and lower the costs of such EDLCs. With these points in mind, this standard aims to provide basic and minimum specifications in terms of the methods for testing electrical characteristics, and to create an environment that supports expanding market of HEVs and large capacity EDLCs. Additional practical test items to be standardized should be reconsidered after technology and market stabilization of EDLCs for HEVs. In terms of endurance that is important in practical use, just basic concept is set forth in the informative annexes.

ELECTRIC DOUBLE-LAYER CAPACITORS FOR USE IN HYBRID ELECTRIC VEHICLES – TEST METHODS FOR ELECTRICAL CHARACTERISTICS

1 Scope

This standard describes the methods for testing electrical characteristics of electric double-layer capacitor cells (hereinafter referred to as capacitor) to be used for peak power assistance in hybrid electric vehicles.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60068-1:1988, *Environmental testing – Part 1: General and guidance*

Amendment 1(1992)

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
reference temperature
reference temperature (°C) to be used in the test

3.2
ambient temperature
ambient temperature of the surrounding space in which a capacitor is placed

3.3
upper category temperature
highest ambient temperature that a capacitor is designed to operate continuously

3.4
lower category temperature
lowest ambient temperature that a capacitor is designed to operate continuously

3.5
applied voltage
voltage (V) applied between the terminals of a capacitor

3.6
rated voltage
U_R
maximum d.c. voltage (V) that may be applied continuously for a certain time under the upper category temperature to a capacitor so that a capacitor can exhibit specified demand characteristics. This voltage is the setting voltage in capacitor design

NOTE The endurance test using the rated voltage is described in Annex A.

3.7
charge current
I_c
current (A) required to charge a capacitor

3.8
discharge current
I_d
current (A) required to discharge a capacitor

3.9
stored energy
energy (J) stored in a capacitor

3.10
charge accumulated electrical energy
amount of charged energy (J) accumulated from the beginning to the end of charging

3.11
discharge accumulated electrical energy
amount of discharged energy (J) accumulated from the beginning to the end of discharging

3.12
calculation start voltage
voltage (V) at a selected start point for calculating the characteristics including capacitance under a state of voltage decrease during discharge

3.13
calculation end voltage
voltage (V) at a selected end point for calculating the characteristics including capacitance under a state of voltage decrease during discharge

3.14
capacitance
ability of a capacitor to store electrical charge (*F*)

3.15
nominal capacitance
C_N
nominal capacitance value (C_N) to be used in design and measurement condition setting (*F*), generally, at the reference temperature

3.16
internal resistance
combined resistance (Ω) of constituent material specific resistance and inside connection resistance of a capacitor

3.17
nominal internal resistance
R_N
nominal value of the internal resistance (R_N) to be used in design and measurement condition setting (Ω), generally at the reference temperature

3.18
constant voltage charging
method of charging a capacitor at specified voltage continuously

3.19
pre-conditioning
discharging and storage of a capacitor under specified ambient conditions (temperature, humidity, and pressure) before testing

NOTE Generally, pre-conditioning implies that a capacitor is discharged and stored until its inner temperature attains thermal equilibrium with the surrounding temperature, before its electrical characteristics are measured.

3.20
voltage treatment
voltage application before measurement of a capacitor's electrical characteristics

NOTE Generally, this treatment is applied to a capacitor that has been stored for a long time or to a capacitor whose history is not clear.

3.21
post-treatment (recovery)
discharging and storage of a capacitor under specified ambient conditions (temperature, humidity, and pressure) after tests

NOTE Generally, post-treatment implies that a capacitor is discharged and stored until its inner temperature attains thermal equilibrium with the surrounding temperature before its electrical characteristics are measured.

3.22
charging efficiency
efficiency under specified charging conditions, and ratio (%) of stored energy to charge accumulated electrical energy. This value is calculated from the internal resistance of a capacitor

NOTE Refer to Equation C.8 in Annex C.

3.23
discharging efficiency
efficiency under specified discharging conditions, and ratio (%) of discharge accumulated electrical energy to stored energy. This value is calculated from the internal resistance of a capacitor

NOTE Refer to Equation C.10 in Annex C.

3.24
energy efficiency
E_f
ratio (%) of discharge accumulated electrical energy to charge accumulated electrical energy under specified charging and discharging conditions

3.25
voltage maintenance characteristics
voltage maintenance characteristics of a capacitor when its terminals are open after charging

3.26
voltage maintenance rate
ratio of voltage maintenance
ratio of the voltage at the open-ended terminals to the charge voltage after a specified time period subsequent to the charging of a capacitor

3.27
power density
electrical power per unit mass (W/kg) or per unit volume (W/l) that can be recovered from a charged capacitor

3.28
rated power density
specified maximum power density (W/kg or W/l). Generally, it is calculated by using the nominal internal resistance and the rated voltage

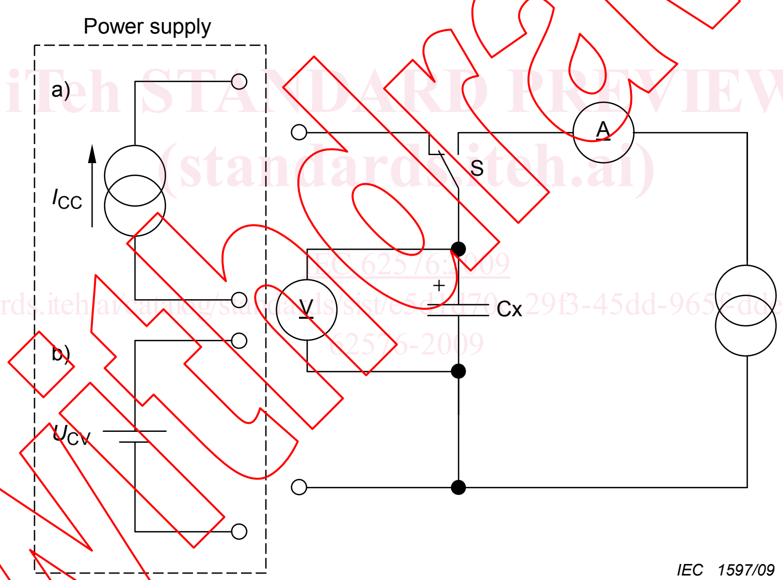
3.29
maximum power density
***P*dm**
maximum power density (W/kg or W/l) that can be recovered from a charged capacitor. Generally, it is calculated by using the internal resistance and the rated voltage

4 Tests and measurement procedures

4.1 Capacitance, internal resistance, and maximum power density

4.1.1 Circuit for measurement

The capacitance and the internal resistance shall be measured by using the constant current charging and discharging methods. Figure 1 shows the basic circuit to be used for the measurement.



Key

I_{CC} constant-current

U_{CV} constant-voltage

Ⓐ d.c. ammeter

Ⓥ d.c. voltage recorder

S changeover switch

Cx capacitor under test

constant current discharger

a) constant current charging

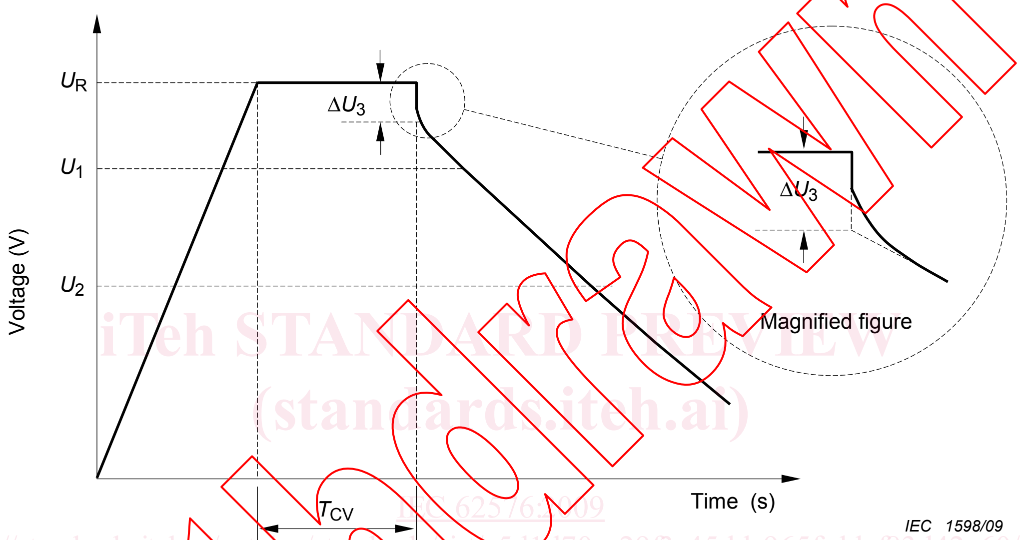
b) constant voltage charging

Figure 1 – Basic circuit for measuring capacitance, internal resistance and maximum power density

4.1.2 Test equipment

The test equipment shall be capable of constant current charging, constant voltage charging, constant current discharging, and continuous measurement of the current and the voltage between the capacitor terminals in time-series as shown in Figure 2. The test equipment shall be able to set and measure the current and the voltage with the accuracy equal to ± 1 % or less.

The power supply shall provide the constant charge current for the capacitor charge with 95 % efficiency, set the duration of constant voltage charge, and provide a discharge current corresponding to the specified-discharge efficiency. The d.c. voltage recorder shall be capable of conducting measurements and recording with a 5 mV resolution and sampling interval of 100 ms or less.



Key

U_R rated voltage (V)

U_1 calculation start voltage (V)

U_2 calculation end voltage (V)

ΔU_3 voltage drop (V)

T_{CV} constant voltage charging duration (s)

Figure 2 – Voltage-time characteristics between capacitor terminals in capacitance and internal resistance measurement

4.1.3 Measurement procedure

Measurements shall be carried out in accordance with the following procedures using the test equipment specified in 4.1.2.

a) Pre-conditioning

Before measurement, the capacitors shall be fully discharged and then incubated for 2 h to 6 h under the reference temperature, set at 25 °C ± 2 °C, as specified in 5.2 in IEC 60068-1, or that specified by the related standards.

NOTE 1 The heat equilibrium time which provides a reference for the soaking time is described in Annex B.

b) Sample setting

Fit the sample capacitors with the test equipment.

c) Test equipment set-up

Unless specified otherwise by related standards, the test equipment shall be set-up in the following manner.

1) Set the constant current I_c for charging. At this current, the capacitors shall be able to charge with 95 % charging efficiency based on their nominal internal resistance R_N. The current value is calculated by $I_c = U_R / 38 R_N$.

   NOTE 2 The general concept for 95 % charging or discharging efficiency is described in Annex C. When the rated value of internal resistance of a capacitor is uncertain, the current for the measurement can be set according to the advisable procedures described in Annex D.

2) Set the maximum voltage for constant current charging as the rated voltage U_R.
3) Set the duration of constant voltage charging T_{CV} to 300 s.
4) Set the constant current discharge value. This value shall allow for a 95 % discharging efficiency based on the capacitor's nominal internal resistance R_N , and is calculated by $I_d = U_R / 40 R_N$.
5) Set the sampling interval to 100 ms or less, and set the test-equipment so as to measure the voltage drop characteristics up to 0,5 U_R.

4.1.4 Measurement

After the setting as specified above, the voltage-time characteristics between capacitor terminals as shown in Figure 2 shall be measured.

4.1.5 Calculation method for capacitance

The capacitance C shall be calculated using Equation (1) based on the voltage-time characteristics between capacitor terminals obtained in 4.1.4.

NOTE This calculation method is called “energy conversion capacitance method.”

$$C = \frac{2W}{(0{,}9\,U_R)^2 - (0{,}7\,U_R)^2} \tag{1}$$

where

C is the capacitance (F) of capacitor;

W is the measured discharged energy (J) from calculation start voltage (0,9 U_R) to calculation end voltage (0,7 U_R);

U_R is the rated voltage (V).

4.1.6 Calculation method for internal resistance

The internal resistance R shall be calculated using Equation (2) based on the voltage-time characteristics between capacitor terminals obtained in 4.1.4.

$$R = \frac{\Delta U_3}{I_d} \tag{2}$$

where

R is the internal resistance (Ω) of capacitor;

I_d is the discharge current (A).

ΔU_3 Apply the straight-line approximation to the voltage drop characteristics from the calculation start voltage (0,9 U_R) to the calculation end voltage (0,7 U_R) by using the least squares method. Obtain the intercept (voltage value) of the straight line at the discharge start time. ΔU_3 is the difference of voltages (V) between the intercept voltage value and the set value of constant voltage charging.

NOTE This calculation method is called "least squares internal resistance method."

4.1.7 Calculation method for maximum power density

The maximum power density P_{dm} is calculated by using the internal resistance value calculated in 4.1.6 and Equation (3).

NOTE This calculation method is called "matched impedance power density method."

$$P_{dm} = \frac{0{,}25\, U_R{}^2}{RM} \qquad (3)$$

where

P_{dm} is the maximum power density of capacitor (W/kg or W/l) ;

U_R is the rated voltage (V);

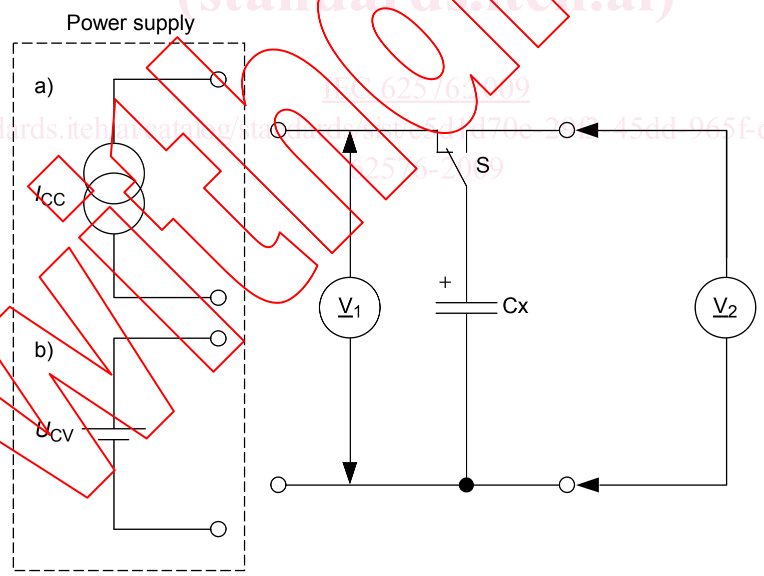
R is the calculated internal resistance (Ω);

M is the mass or volume of capacitor (kg or l).

4.2 Voltage maintenance characteristics

4.2.1 Circuit for measurement

Figure 3 shows the basic circuit for measuring the voltage maintenance characteristics.



Key

I_{CC} constant-current

U_{CV} constant-voltage

V_1 V_2 d.c. voltmeter

S changeover switch

Cx capacitor under test

a) constant current charging

b) constant voltage charging

Figure 3 – Basic circuit for measuring the voltage maintenance characteristics