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**Reliability evaluation methods for vanadium flow batteries**

全钒液流电池可靠性评价方法

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### 1 Scope

China's national reliability evaluation methods for vanadium flow batteries. A flow battery stores its energy in liquid electrolyte held in external tanks and pumped through a stack of cells, which separates the energy capacity from the power rating - more tanks means more hours, a bigger stack means more kilowatts. That makes it the technology suited to long-duration grid storage, where lithium becomes uneconomic beyond a few hours. Vanadium is used because the same element in different oxidation states serves both half-cells, so cross-contamination through the membrane does not permanently degrade the electrolyte, which in principle lasts indefinitely. Reliability evaluation for such a system is unlike that for a battery: the failure modes are those of a chemical plant - pumps, seals, membranes, stack leaks and electrolyte imbalance - and the evaluation has to address the system rather than the cell.

This document specifies the overall requirements, evaluation indicators and calculation methods, test requirements and methods, reliability determination, and evaluation result for the reliability evaluation of the vanadium flow battery systems. This document is applicable to the evaluation of all types of vanadium flow battery systems for indoor or outdoor use.

### 2 Normative References

The contents of the following documents constitute indispensable clauses of this document through the normative references in the text. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB/T 2828.1-2012 Sampling Procedures for Inspection by Attributes - Part 1: Sampling Schemes Indexed by Acceptance Quality Limit (AQL) for Lot-by-lot Inspection

GB/T 29840 Vanadium Flow Battery - Terminology

GB/T 32509-2016 General Specification for Vanadium Flow Battery

GB/T 33339-2016 Vanadium Flow Battery System - Test Method

GB/T 34866 Vanadium Flow Battery - Safety Requirements ISO/IEC Guide 98-

3 Uncertainty of Measurement - Part 3: Guide to the Expression of Uncertainty in Measurement

### 3 Terms and Definitions

The terms and definitions defined in GB/T 29840 and the following are applicable to this document.

3.1 reliability The ability of a product to complete specified functions under specified conditions and within a specified time.

3.2 fault A state, in which, a product is unable to perform its specified functions. NOTE: this does not apply if the specified functions cannot be performed due to preventive maintenance or other planned actions or lack of external resources.

### 4 Overall Requirements

4.1 Reliability evaluation indicators shall include rated energy efficiency, capacity retention rate and utilization factor.

4.2 The reliability evaluation method shall adopt sampling test, and after the rated energy efficiency test, capacity retention rate test and utilization factor test, the corresponding indicators can be calculated.

4.3 The evaluation result shall be output in a test report.

### 5 Evaluation Indicators and Calculation Methods

5.1 Rated Energy Efficiency The rated energy efficiency of the vanadium flow battery systems shall be the ratio of the net discharge capacity to the sum of the charge capacity plus the auxiliary energy consumption of the charging process in a constant power charge

and discharge cycle within the evaluation period. It is calculated in accordance with Formula (1). Where,

---the rated energy efficiency of the battery system;  $E_{sd}$

---the discharge watt-hour capacity of the battery system recorded by the measurement instrument, expressed in (W h);  $W_{sd}$

---the auxiliary energy consumption of the battery system during the discharging process recorded by the measurement instrument, expressed in (W h);  $E_{sc}$

---the charge watt-hour capacity of the battery system recorded by the measurement instrument, expressed in (W h);  $W_{sc}$

---the auxiliary energy consumption of the battery system during the charging process recorded by the measurement instrument, expressed in (W h).

**5.2 Capacity Retention Rate** The ratio of the  $n$ th net discharge watt-hour capacity of the vanadium flow battery systems within the statistical period to the rated watt-hour capacity, which is calculated in accordance satisfy the requirements of the converter equipment.

**6.5.3** In addition to the tests conducted in accordance with GB/T 33339-2016, other tests may simulate actual operating conditions or use full state-of-charge (SOC) charge and discharge cycles. After each charge / discharge, stop and let it stand. The standing time shall be greater than 10 minutes.

## 6.6 Measurement Instruments

**6.6.1 Voltage measurement** The voltage measurement instrument shall have an accuracy of not lower than Class

0.5 and its internal resistance shall be at least 1 k/V. Other measurement instruments with equivalent accuracy may also be used.

**6.6.2 Current measurement** The current measurement instrument shall have an accuracy of not lower than Class 0.5. Other measurement instruments with equivalent accuracy may also be used.

**6.6.3 Electric energy measurement** The electric energy measurement instrument shall have an accuracy of not lower than Class 0.5.

**6.6.4 Temperature measurement** The division value of the thermometer for temperature measurement shall be not greater than 1 °C, and the calibration accuracy shall be not lower than 0.5 C.

## 6.7 Test of Rated Energy Efficiency

**6.7.1** A rated energy efficiency test shall be respectively conducted at the beginning of the

test period and before the end of the test period. If the test period is relatively long, a rated energy efficiency test shall be conducted once in the middle of the test.

#### **6.7.2 In accordance with the provisions of**

8.1.7 in GB/T 33339-2016, carry out the rated energy efficiency test. In addition, in accordance with 5.1, calculate the rated energy efficiency.

#### **6.8 Test of Capacity Retention Rate**

6.8.1 A capacity retention rate test shall be respectively conducted at the beginning of the test period and before the end of the test period. If the test period is relatively long, a capacity retention rate test shall be conducted once in the middle of the test.

#### **6.8.2 In accordance with the provisions of**

5.7 in GB/T 32509-2016, carry out the capacity retention rate test. In addition, in accordance with 5.2, calculate the capacity retention rate.

#### **6.9 Test of Utilization Factor**

6.9.1 The battery systems shall be charged and discharged in accordance with the operating mode agreed upon between the customer and the manufacturer.

6.9.2 Record the duration of the fault state within the test period, calculate the number of fault-free operating hours; in accordance with 5.3, calculate the utilization factor.

### **7 Reliability Determination**

7.1 Reliability Determination of Rated Energy Efficiency During the evaluation period, the rated energy efficiency of the vanadium flow battery systems shall be not lower than 90% of the nominal value.

7.2 Reliability Determination of Capacity Retention Rate During the evaluation period, the capacity retention rate of the vanadium flow battery systems shall be not lower than 80% of the nominal value. If necessary, capacity restoration can be performed before the capacity test.

7.3 Reliability Determination of Utilization Factor The determination is carried out in accordance with the value agreed upon by the customer and the manufacturer.

### **8 Evaluation Result**

The evaluation result is a test report, which shall at least include the following contents.

a) Foreword, explaining the origin of the test task.