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AC RESISTORS AND RESISTOR BANKS

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PURPOSE AND SCOPE

This document forms part of a suite of documents which define National Grid's functional and performance requirements for new plant and equipment.

This Specification states the functional and performance requirements for naturally air cooled resistors that will form an intrinsic part of a 'Subsystem' (see Section 5 for definitions) to be connected to the National Grid Transmission System (Electricity) or Third Party Networks, but excludes earthing resistors.

Note, the resistor rating methodology is specified in the National Grid Technical Specification(s) that relate(s) to the specific Subsystem into which the resistor is to be incorporated.

Reference is made to TS1 in respect of the general applicability of the requirements of this and other (NG)TS specifications to non National Grid connected Users of the Transmission System.

PART 1 – PROCEDURAL

1 GENERAL REQUIREMENTS

1.1 Overall

Resistors, including all of their component parts, shall be designed for a minimum operating life of 40 years. Where maintenance is required to meet the lifetime requirement, details (including spares requirements) shall be declared in Appendix D. The equipment shall also comply with the relevant requirements specified in TS 1, TS 2.1, NGTS 2.2, and the additional requirements herein.

1.2 Physical Arrangement and Construction

The resistor bank shall be free-standing and calculations shall be provided in accordance with TS 2.1 to demonstrate the mechanical adequacy of the resistor together with its support structure/insulators for at least the following loading effects (electrical and mechanical) :-

- mechanical loads during operation and installation

- electromagnetic forces including those arising from any fault / short time loading conditions
- wind, ice and seismic loading
- forces due to expansion and contraction due to both ambient temperature and load variation

A report demonstrating the resistor bank capability shall be provided within the time stated in Appendix C Item 19, after contract placement.

Unless otherwise stated in the Enquiry Document, all plant shall be suitable for outdoor use. The resistor enclosure(s) shall provide a degree of environmental protection conforming to at least classification IP23, or higher, in BS EN 60529 (it is acknowledged in this respect that the enclosure may be live).

No metallic parts used in the construction of the resistor shall be electrically isolated. All such parts within the resistor shall be electrically bonded to the enclosure (where this is metallic).

The arrangement of external connections shall facilitate simple interface connections with other plant and equipment, including any separate current transformers provided for protection purposes.

1.3 Connections

BS EN 60694, Section 4.4.2, on Temperature Rise, in Table 3, states the maximum safe temperature rise allowable for various materials and methods of connection whilst in service. These limits shall apply to the internal and external connections of the resistors. It is to be noted that welded or brazed connections are not temperature restricted by that Table.

1.4 Maintenance and Erection Facilities

The layout and design of resistor banks shall be such as to allow suitable access for maintenance and for replacement of any failed resistor element(s), e.g. by the provision of resistor unit enclosure access doors / covers (where appropriate). The design of resistor units shall nonetheless allow the installation or removal of base insulators and insulators between individual resistor units (where applicable) without the need to remove the resistor unit enclosure covers. To permit ease of installation and replacement, the units shall be provided with lifting eyes.

The incoming and outgoing terminal bushings for each bank and units (where applicable), and unit position within a bank (where applicable) shall be clearly labelled in a permanent manner.

1.5 Bushings and Insulators

All insulation within the resistor bank shall comply with the following performance requirements:-

- 1.5.1 It shall satisfy the minimum lightning impulse levels, both HV to LV terminals, HV terminal to earth and LV terminal to earth as specified by the Principal Contractor (where applicable), or in other associated Level 2 (NG)TS, with the resistor at a temperature arising from operation at rated continuous maximum current in an ambient of 20°C.
- 1.5.2 In respect of all external insulation and unless otherwise specified by the Principal Contractor (where applicable), in other associated Level 2 (NG)TS or in the Enquiry Document, the **minimum** creepage insulation distance shall also comply with the following performance requirements:

- a) For equipment mounted in the vertical/upright position, 25mm/kV based on the voltage across that insulation (derived from resistor rated voltage).
- b) For equipment mounted in any other spatial orientation, 31mm/kV based on the voltage across that insulation (derived from resistor rated voltage).
- c) However, where necessary this creepage distance shall be increased to take into account the allowances for the factor k_d in accordance with IEC 60815-2 clause 10.3.

The requirements of NGTS 3.2.7, Bushings, shall also be met. All the relevant parts of Appendix A of NGTS 3.2.7 shall be completed for each different bushing used. Where items are not relevant to the units, then the schedule shall be marked 'Not relevant', and a description attached. This description, which may be in the form of a manufacturer's pamphlet, shall indicate why the information cannot be provided for the bushing offered.

The requirements of NGTS 3.2.9, Solid Core Post Insulators, shall be met. All the relevant parts of Appendix A of NGTS 3.2.9 shall be completed for each different insulator used. Where items are not relevant to the units, then the schedule shall be marked 'Not relevant', and a description attached. This description, which may be in the form of a manufacturer's pamphlet, shall indicate why the information cannot be provided for the insulator offered.

Where the insulator used is not 'standard', and for which such information is not available, the Tenderer shall provide a description of the insulator offered.

1.6 Protection

The design of the resistor bank shall comprise two parallel current paths each with separately brought out connections to enable a current differential system for detecting resistor 'open circuit / high resistance' faults.

The protection arrangements shall also monitor for thermal overload of the resistor. To facilitate the calculation of appropriate protection settings, the contractor shall provide over-current/time characteristics showing the thermal withstand capability of the installed resistor.

In the case of SVC and MSC applications, the resistor protection system(s) shall accord with NGTS 3.6.6 and TS 3.24.11 respectively.

2 PERFORMANCE REQUIREMENTS

2.1 General

The resistor bank shall be naturally air cooled, and the maximum temperature of any resistor element and any insulation shall not exceed the maximum safe working temperature of the material, under all rated operating conditions, both continuous and transient.

When neither side of the resistor is connected to earth, the resistor shall be designed and manufactured so as to withstand the thermal and mechanical effects of a short circuit between any resistor terminal and earth. The fault impedance shall be taken into account, and the fault duration shall be taken as one second. The maximum system short circuit levels are those specified in TS 1 and the fault current shall be defined by the Tenderer for the specific Subsystem concerned, and agreed before contract placement. No permanent deformation of, or change in element material physical properties shall occur under such conditions.

Where a resistor bank comprises multiple units, the design shall allow for the non linear transient voltage distribution that can occur for that arrangement.

2.2 Current Rating of the Resistor

The resistor will normally be installed as part of a harmonic filter, either as part of a Mechanically Switched Capacitor, or as part of a power electronic system, e.g. Static Var Compensation equipment. Where this is so, the harmonic currents shall be calculated by the method stated in the relevant level 2 NGTS for the specific Subsystem concerned. The resistor shall be rated to carry continuously the fundamental current and the specified harmonic currents. The rated current of the resistor shall be defined as the 50 Hz current causing equivalent heating of the resistor.

Where the resistor is not installed as part of a filter, and the loading is steady, then the current rating shall be defined by the current that would flow in the resistor at its minimum tolerance and with its resistance at an ambient temperature of 20°C.

For all other applications, the current rating shall be defined by the Tenderer, and agreed before contract placement.

2.3 Voltage Rating of the Resistor

When the resistor is part of a harmonic filter, its voltage rating shall be defined by the arithmetic sum of the peak voltages corresponding to the fundamental and harmonic currents used to define the current rating.

When it is not part of a filter, the voltage rating shall be defined by the peak voltage that occurs across the resistor in normal service.

2.4 Maximum Change in Resistance

The change in the nominal resistance value of the resistor from minimum specified ambient temperature, resistor unenergised, to maximum specified ambient temperature, resistor energised under rated current (continuous maximum) conditions shall not exceed 20% unless the Enquiry Document states otherwise.

2.5 Availability

The resistor shall be designed to have an availability of greater than 98%, including planned maintenance outages unless the Enquiry Document states otherwise.

2.6 Multiple Resistors

In some applications, it may be convenient to mount more than one, or parts of more than one, resistor type in a common enclosure. In such instances the design shall allow for the resistance of each separate resistor to be measured by applying measurement leads to its terminals, and without the need to make any disconnections inside the enclosure.

3 TEST REQUIREMENTS

3.1 General

The following tests shall be performed as a minimum, and the results recorded in the test certificates. The measurements will be compared with those made both during site commissioning of the equipment and maintenance activities during the life of the plant.

Accuracy tests shall be performed in a laboratory with equipment, methods, and processes that are traceable to National/International standards.

3.2 Routine Tests

For each resistor bank, Routine test reports shall include details of all Routine measurements made in accordance with this specification. Routine testing may be implemented in any order.

3.2.1 Resistance Measurements

Resistance measurements for the following components shall be performed at d.c. and to an accuracy of 0.5%. This shall be compensated, where necessary, for an ambient temperature of 20°C.

- a) The resistance of each resistor within a unit enclosure
- b) The resistance of each resistor sub-assembly
- c) The resistance of each terminal of a sub-assembly to its frame.

3.2.2 Insulation Tests

The voltage appearing across each insulator shall be calculated from the resistor voltage rating, with the nominal value increased to allow for the manufacturing design, the manufacturing tolerance allowed by the design, and the temperature rises of the various parts when operating at rated current.

- a) The voltage withstand of all stages of the insulation, e.g. the elements to the sub-frame, between sub-frames, all stand-off and support insulators, shall withstand a 10 second test of either 1.1 times the corresponding rms voltage appearing across the insulation, or a d.c. test equal to the peak of that voltage (Note these tests may need to be done before connections to frame work are finally made).
- b) A final insulation test shall be done by removing the tie between the resistor and the unit enclosure. The insulation of the resistor from the enclosure shall be demonstrated by utilising an appropriate insulation resistance test device.

3.3 Type Tests

Unless otherwise agreed, the resistor bank shall first have withstood a complete set of Routine tests. Subsequently, the following Type tests shall be performed, followed by a further complete set of Routine tests: -

3.3.1 Temperature Rise Test

The complete resistor bank, or those sets of unit enclosures that are mounted vertically in service, shall be mounted in still air. Ideally, this will be inside a building of suitable size so that the ambient air temperature does not rise. Otherwise, the test may be completed outside, if protected from the wind by a 'chimney' that starts at or below the lowest level of the lowest resistor unit enclosure(s), and ends at or above the top of the highest resistor enclosure(s). If such a chimney cannot be provided, then the test shall be performed with outdoor wind speed not exceeding 2 metres/sec.

The temperature of at least the following points shall be measured:-

- a) The highest temperature of the hottest element.
- b) The ambient temperature.
- c) The exit air temperature.
- d) The inlet air temperature.

It is recommended that the following points are also measured:-

- e) The air temperature at a point vertically above and not greater than half the minimum vertical clearance to the unit enclosure top, measured from the element hot spot.