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National Grid
Technical
Specification

NGTS 3.11.1
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Capacitors and Capacitor Banks

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CAPACITORS AND CAPACITOR BANKS

FOREWORD

This document forms part of a suite of documents which define National Grid Company plc (NGC) functional and performance requirements for new plant.

1 SCOPE

This Specification outlines the functional and performance requirements for capacitors and capacitor banks for use within items of plant to be connected to NGC's supergrid network. It does not include bank protection schemes or switchgear connections to the HV system, which can be found in the National Grid Technical Specifications listed in Section 2. The rating requirements shall be specified in the inquiry document.

2 REFERENCES

This Specification makes reference to, and must be read in conjunction with the documents listed below.

IEC 549:1976	High-voltage fuses for the external protection of shunt power capacitors
IEC 593:1977	Internal fuses and internal overpressure disconnectors for shunt capacitors
IEC 871:1987	Shunt capacitors for a.c. power systems having a rated voltage above 660 V
IEC 871-1	Part 1 - General
IEC 871-2	Part 2 - Endurance testing
BS 1650	Specification for capacitors for connection to power-frequency systems
NGTS 1	Overview National Grid System
NGTS 2.1	Substations
NGTS 2.2	Switchgear
NGTS 2.6	Protection
NGTS 3.1.1	Busbars
NGTS 3.1.2	Earthing for NGC Substations
NGTS 3.2.7	Bushings
NGTS 3.3.2	Dry-type Reactors
NGTS 3.6.6	Protection of SVC and MSC

3 GENERAL REQUIREMENTS

3.1 Overall

The capacitors, including all their component parts, shall be designed for a minimum operating life of 20 years. Where maintenance is required to meet the lifetime requirement, details shall be declared. The equipment shall conform to NGTS 2.1.

3.2 Racking

The racking shall be designed to carry safely all the required capacitor units, conductors, insulators and other fittings. Allowance for additional loading during erection, equipment maintenance and access shall be made.

Where metal racking is used, all metal mechanically fixed to the racking and all joints within the racking, shall be connected as specified in NGTS 2.1.

Each rack shall be uniquely numbered in a secure and permanent manner and in a way that is

readable from a point on the ground to which access is permitted with the bank energised.

Each rack shall be supplied with the position of each capacitor unit numbered in a permanent manner which shall be readable from a point on the ground, to which access is permitted with the bank energised.

Each rack shall have a boss to which NGC approved drain earths can be connected.

3.3 Transient Currents

The transient current that flows on energisation shall not exceed the rating of the associated circuit breaker or switch controlling the capacitor bank, with due allowance for the system to which it is connected - see NGTS 2.2.

If damping reactors are used they shall comply with the requirements of NGTS 3.3.2 Dry Type Reactors.

The reactors shall be maintenance free, suitable for outdoor installation, naturally (self) air cooled and shall be capable of withstanding the full lightning and switching impulse voltages of the system, as specified in NGTS 1.

3.4 Maintenance Facilities

3.4.1 Layout

The layout of the banks shall be such as to allow suitable access for maintenance and for replacement of any failed unit.

3.4.2 Shorting Switches

Each rack shall be equipped with capacitance maintenance shorting switches.

When closed, each capacitor unit on the rack shall be short circuited and connected to the rack.

The switch shall be able to be locked in the open and the closed positions.

The 'locking' shall be by a mechanical interlock, which allows the shorting equipment to be part of a mechanical interlock chain as specified in the tender document - see NGTS 3.1.1.

The Switches shall be able to be opened and closed from a safe position at ground level and shall be able to be locked into either position without infringing the safety clearance - see NGTS 2.1.

Several shorting switches in a bank may be operated together.

The manual effort to operate the equipment under all the conditions arising in service shall not exceed a force of 400 Newtons applied on a lever of no more than one metre in length.

When the shorting switches for a bank are closed, the bank shall be clearly and visibly connected to earth.

3.4.3 Removal Equipment

Equipment approved by NGC shall be provided to assist in the removal of failed units. This equipment shall include:

Two purpose-built and insulated leads, or Continuity Bond Leads, designed to ensure that the circuit shorting out the capacitor units on the rack by the maintenance switch can not be broken, whilst allowing the complete disconnection and removal of any capacitor unit.

Four purpose-built and insulated leads, or Temporary Short Circuit Leads, to apply a temporary short to a unit while its connections are being broken.

Nine purpose-built and insulated leads, or Bolted Short Circuit Leads, that can be applied securely to an isolated unit, short circuited by a Temporary Short Circuit Lead, to allow safe movement.

Where the Capacitor Bank is externally fused, two Discharge Sticks shall be provided that are suitable to short circuit a unit safely, in the event of an operated fuse. For design purposes, the unit shall be assumed to be charged to the voltage specified for the unit short circuit discharge type test.

Sufficient purpose-built and insulated leads, or Shorting Switch Maintenance Leads, to allow all the shorting switches that may be operated together from any one operating handle to be maintained safely. 10% spares, rounded up to the next whole number, with a minimum of one, shall also be provided.

Equipment to assist the manoeuvring of a capacitor unit into and out of the rack. One type of this equipment will be suitable for all capacitor units. If no equipment can be offered for this function, then the weight of the capacitor unit is restricted to 76 kg if the unit is mounted with the bushings horizontal, or 40 kg if the unit is mounted with the bushings vertical.

(The insulation of the cable included in these leads shall be coloured a bright red.)

3.4.4 Spares

The tenderer shall state the recommended spares holding to achieve a life of 20 years (the specified life) and a life of 10 years, see part 6 of this Specification.

3.5 Busbars and Clearances

A fully rated set of conductors and connections shall be supplied, to connect all the capacitor equipment. Busbars shall conform to NGTS 2.1. Safety clearances shall conform with the requirements of NGTS 2.1 unless the equipment concerned is fenced off and access prevented (by an interlocking scheme to the approval of NGC) whenever the equipment is unearthed.

3.6 Bushings and Outdoor Insulators

Bushings, including wall bushings and outdoor insulators shall conform to NGTS 3.2.7. All the relevant parts of Appendix A of NGTS 3.2.7 shall be completed for each different bushing or insulator used.

3.7 Protection

The protection of the capacitors and the capacitor bank shall be as specified in NGTS 3.6.6.

3.8 Technical Data

The Tenderer's attention is drawn to the information requested in Part 6 of this Specification. This information shall be provided at the time of tender.

4 PERFORMANCE REQUIREMENTS

4.1 Main Requirements

The following Clauses of IEC 871-1:1987 are relevant and shall apply.

Definitions. Clause 3 and its sub-clauses.

Service conditions. Clause 4.1. The ambient air category will be a standard range that encompasses the range defined in the site conditions, see Tender Document.

Insulation Levels. Section 3 Table 4 gives the standard insulation levels for 52 kV<Um<300 kV. NGTS 1 supplies the system insulation levels.

Maximum Permissible Voltages. Clause 19 gives the long duration voltages and the switching voltages that the capacitor installation shall withstand.

Maximum Permissible Current. Clause 20 gives the long duration currents that the capacitor installation shall withstand.

Discharge Devices. Clause 21 defines the requirements for each unit, but the discharge time requirement shall be 150 ms.

Container Connections. Clause 22 gives the requirement.

Markings of the Unit. Clause 25 defines the requirements for the markings on the units.

Markings of the bank. Clause 26 defines the markings of the bank that shall be provided on a rating plate.

4.2 Additional Requirements

The capacitor bank and its units shall additionally meet these requirements.

If capacitor bank is star connected, the star point shall be connected to earth.

The capacitor bank and its units shall be suitable for operation over the temperature range of -25°C and +40°C.

The impregnant shall be bio-degradable, to the approval of NGC.

The required tests on the capacitors are defined in Part 5 of this Specification.

4.3 Unit Fusing Requirements

4.3.1 General

The fuse shall operate only when the capacitor unit/element it is protecting fails. The fuse shall not operate when the protected unit/element discharges into a parallel connected and faulted unit/element. The fuse shall not operate due to the inrush or outrush currents when the bank is energised or de-energised, or when a parallel connected bank is energised or de-energised.

The fuse shall be able to operate on the 50 Hz current that flows in the event of a unit/element failure at a voltage zero.

4.3.2 Internal Fusing Requirements

The following clauses of IEC 593:1977 and of its amendments 1 (of 1980) and 2 (of 1986) are rlevant and shall apply.

General requirements. Clause 4.1.

Disconnecting Requirements. Clause 5.1, but the voltage limits shall be as defined here.

When a Minimum Normal Operating Voltage, U_α, is defined, the lower limit, u_1, as defined in table 1 of clause 5.1, shall be the lower of:-

$$0.98 \times \sqrt{2} \times U_\alpha \text{ and } 0.9 \times \sqrt{2} \times U_N .$$

If the Minimum Normal Operating Voltage is not defined, the lower limit shall be:-

$0.9 \times \sqrt{2} \times U_N$, as defined in table 1 of clause 5.1.

The upper limit, U_2, shall be as defined in table 1 of clause 5.1.

Withstand requirements. Clause 6.

4.3.3 External Fusing Requirements

The following clauses of chapter 2 Performance Requirements of IEC 549:1976 are relevant and shall apply.

General requirements. Clause 3.1.

Breaking Requirements. Clause 3.2, however the Rated Capacitive Breaking Current shall never be less than the actual maximum current during transients that the fuse may experience.

Withstand Requirements. Clause 3.3.

Additionally, the external fuse tail shall be protected to ensure that no damage shall occur due to corrosion or removal of the fuse. This protection shall be defined in the Maintenance procedure.

4.4 Reliability and Availability

The Capacitors and/or Capacitor Banks shall be designed to have an availability of greater than 98%, including planned maintenance outages.

Routine maintenance shall not be required more than annually. All plant items which require regular inspection shall be listed in the tender, together with the recommended time between inspections.

5 TEST REQUIREMENTS

5.1 General

Routine tests which shall be carried out on each unit, but documentary proof of type tests may be accepted.

The tests shall normally be carried out at 50 Hz, except where otherwise stated. If testing is performed at a higher frequency, then the tests shall be carried out at the same voltage as would have been used had the testing been carried out at 50 Hz.

The routine test results, presented in sub-tables that are based on the position where the unit is mounted in the bank, shall be provided.

The type test reports shall be provided. The reports shall also include the data of the Main Plant Performance for the units tested.

5.2 Routine Tests

These tests shall be carried out on each unit in the order listed below and to the relevant specification.

(a) Sealing test. See IEC 871-1, clause 12
The un-energised capacitor units shall be heated throughout so that, for at least 2 hours, all parts reach a temperature of at least 75°C. No leakage shall occur. The leakage indicator used shall be stated.

(b) Capacitance and loss tangent measurement. See IEC 871-1, clause 7 and 8.
The preliminary capacitance measurement, and the voltage at which it is made, shall be recorded. The unit loss tangent (tan δ) shall be less than that specified in the Main Plant Performance data. The actual figure used shall be given in Part 6, Section 1 Item 16.

(c) Voltage test between terminals. See IEC 871-1, clause 9.
The a.c. test is the preferred method. The method used in routine tests shall be included in the data on the Main Plant Performance.

(d) A.C. voltage test between terminals and container. See IEC 871-1, clause 10.

(e) Test of internal discharge device. See IEC 871-1, clause 11.
The resistance of the discharge device, and its method of measurement, shall be recorded in the routine test report.

5.3 Type Tests

Each of these tests shall be applied to two samples of the unit which will first have been routine tested as required in section 5.2.

(a) Thermal Stability. See IEC 871-1, clause 13.

(b) Capacitance loss tangent (tan δ) measurement at elevated temperature. See IEC 871-1, clause 14.

(c) A.C. voltage test between terminals and container. See IEC 871-1, clause 15.

(d) Lightning impulse test between terminals and container. See IEC 871-1, clause 16. Fifteen impulses of positive polarity and fifteen pulses of negative polarity shall be applied.

(e) Short-circuit discharge test. See IEC 871-1, clause 17.

Each of the units shall then be tested to destruction in the following manner. The Short circuit discharge test shall be repeated, but with the voltage from which it is discharged being raised successively by 0.5 x U_N, and the number of discharges increased to 10. The voltage used in the voltage test (clause 9) shall be kept constant. The discharge voltage shall be increased until the unit's capacitance changes by more than 10%, or until the witnessing engineer is satisfied that some failure has occurred. The unit shall then be opened , and the failure modes inspected.

(f) Shorting Switch Test.
The shorting switch shall be assembled as installed in the field. The initial contact resistance and the contact pressure of each contact finger shall be measured. The initial contact resistance shall be less than 100μΩ. The switch shall be operated 500 times. At the end of the 500 operations the contact resistance and pressure shall be re-measured. The contact resistance shall not have increased by more than 50% of its initial value. The contact pressure of the fingers shall not have reduced by more than 50% of its initial value.

(g) Endurance Testing.
See IEC 871-2: 1987. The endurance test report will have reference to all the parameters of the unit tested that are required to define 'similar' (according to IEC 871-2) units.

5.4 Internal Fusing

The testing of the fusing shall be generally in accordance with section 3 of IEC 593:1977, including amendments 1 of 1980, and 2 of 1986.2.

5.4.1 Type Tests

The disconnecting test for fuses shall be as specified in clause 10 of IEC 593, except the lower test voltage shall be the lower of 0.9 U_N and 0.98 U_α, where U_α is the Minimum Normal Operating Voltage of the capacitor.

The disconnecting test on disconnector, detailed in clause 11 of IEC 593, shall be applied.

5.5 External Fusing

The testing of the fusing shall be generally in accordance with chapter 3 of IEC 549:1976.

6 TECHNICAL DATA OF EQUIPMENT SUBMITTED FOR APPROVAL

PART 1 MAIN PLANT PERFORMANCE

Item No	Description		Units
1	Rated voltage (a) Per bank (b) of Each capacitor unit		 kVrms kVrms
2	Rated 50Hz current (a) Per bank (b) of Each capacitor unit		 A A
3	Rated output of (a) Each bank (b) Each capacitor unit		 kvar kvar
4	Nominal capacitance and tolerance of (a) Each bank tolerance (b) Each capacitor unit tolerance		 μF % μF %
5	Weight of (a) Each assembled single stack (b) Each capacitor unit		 kg kg
6	Capacitor units in a single phase Number connected in parallel Number in series		
7	Capacitor elements in a single unit Number connected in parallel groups Number of groups connected in series		
8	Nominal rated voltage of each element		kV
9	Minimum breakdown voltage of each element		kV
10	Impregnant Details (a) General (b) Dielectric constant		
11	Element Foils (a) Material (b) Thickness (c) Is start folded? (d) Is end folded? (e) Is side edge folded? (f) How is electrical connection made?		

12	Element Dielectric (a) Film material (b) Number per element (c) Thickness per film (d) Density (e) Dielectric Constant		 μm gm/cc
13	Fusing Arrangement <u>External Fuse</u> Type, Manufacturer's designation, Rating Characteristics - See IEC 549 <u>Internal Fuse</u> Diameter, Material, Maximum 50 Hz Current Rating, Length		 A mm A mm
14	<u>Internally fused capacitors only</u> Number of fuses to fail for alarm setting - see NGTS 3.6.6 Number of fuses to fail for trip setting - see NGTS 3.6.6 Protection that operates for bushing flashover		
15	Value of discharge resistance		Ohms
16	Maximum tanδ for routine test measurement Total losses determined as described in BS 1650 (a) For each unit (b) For each bank		 kW kW
17	Routine Voltage test method, (see IEC 871-1, clause 9). A.C. method preferred		
18	Maximum variation of losses of (a) each unit (b) a bank due to specified temperature range		
19	Maximum variation of capacitance due to specified temperature range		
20	Total weight of complete impregnated capacitor unit including all fittings		kg
21	Total weight of complete single phase bank including all fittings		kg
22	Type of connector provided at terminals of bank		
23	Case material, thickness, and overall finish		

24	Minimum ambient temperature at which the capacitor bank may be energised on the system without damage to the equipment		°C
25	<u>Capacitor unit short time performance</u> Overvoltage/time limits for capacitor units and their fuses. Assuming a 50 Hz power frequency voltage, without superimposed high frequency transients and with a crest value not exceeding √2 times the rms value, and the overvoltage being applied during emergency or infrequent conditions, the overvoltages being preceded by and followed by operation at rated voltage without interruption.	<u>duration</u> 1 cycle 15 cycle 1 second 15 secs 1 minute 5 mins 30 mins	<u>times rated volts</u>
26	<u>Capacitor unit transient performance</u> Transient voltage and current limits for capacitor units and their fuses Assuming that the transient is followed by prolonged energisation at rated voltage without interruption.	Probable number of switch operations per year	Peak transient values (times rated rms value) volt / amps
		4 40 400 4000	
27	<u>Capacitor unit overload performance</u> Number of hours per day (out of 24 hours) at 110% rated voltage during the designed life of 25 years.		Hours/day
28	Details of secondary (internal) insulation. Part 1 The pack (a) Material (b) Number of layers (c) Dielectric constant (d) Thickness per layer Part 2 The leads (a) Material (b) Number of layers (c) Dielectric constant (d) Thickness per layer		 µm µm
29	Number of weeks after contract is placed before the evidence will be supplied that the equipment will meet the mechanical loading requirements of NGTS 2.1.		Weeks

30	Shorting Switch Performance (after correct assembly) (a) Minimum contact resistance (b) Maximum contact resistance (c) Minimum contact pressure per finger (d) Maximum contact pressure per finger		 $\mu\Omega$ $\mu\Omega$ Pa Pa
	The following additional details are required only when the capacitor unit does not have one terminal connected to case.		
31	Nominal capacitance of secondary (internal) insulation. (Measured between case and terminals, with terminals connected together)		μF
32	Details of secondary (internal) insulation. (a) Rated insulation level		 kV

PART 2 CAPACITOR BANK PROTECTION

1	Type of fusing used in the bank (Internal/External/other)	
2	If internally fused Minimum number of fuses failed at alarm setting. (Further 14 days continuous operation allowed) Maximum number of fuses failed at trip setting. (Further 2 hours operation allowed before tripping) Method of detecting both further fuse operations within the failing unit, and unit bushing flashover.	
3	Circuit arrangement for detecting fuse operations.	
4	Number of transducers required for the protection. (a) VTs Ratio Burden (b) CTs Ratio Burden Insulation class to ground (c) Others	
4	Number of weeks after contract when the protection system calculations will be provided.	
5	Number of weeks after contract when the specification for the 'free issue' protection relays will be provided.	
6	Number of weeks after contract when the protection relays will be available for 'free issue'.	
7	Number of weeks after contract when the specifications for power circuit transducers required for the protection will be provided.	

PART 3 RECOMMENDED SPARES HOLDING

Item	Manufacturers Part Number	Recommended holding for life of		Cost/Unit (if ordered at time of contract placing)
		20 Years	10 Years	
1				
2				
3				
4				
5				
6				

This form may be copied for recommending further spares.