

SPECIFICATION AND STANDARD RATINGS FOR TRANSFORMERS, REACTORS AND QUADRATURE BOOSTERS

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PURPOSE AND SCOPE

The purpose of this document is to set out the policy to be applied when selecting the ratings (values of key technical parameters) of transformers, reactors and quadrature boosters (including phase shifting transformers) to be used on the National Grid Electricity Transmission System. The scope covers new transformers, series and shunt reactors, quadrature boosters and phase shifters for connection at 400kV and 275kV. The policy is to be applied under all circumstances whether NG, consultants or suppliers carry out the system and application design. The policy should be applied, where possible, to plant connected to the transmission system but not owned or supported by NG, however this is not mandatory. The policy does not cover generator transformers.

PART 1 – POLICY

1 CHOICE OF VALUES FOR KEY TECHNICAL PARAMETERS

1.1 General principle

The general principle to be applied to the choice of values for key technical parameters is to make new installed plant functionally compatible with existing units. This approach allows the following advantages to be gained

- 1) The minimum number of spare units is required to provide effective spares cover.
- 2) Units can be relocated or reallocated between schemes enhancing system and scheme delivery flexibility.
- 3) Procurement savings can be made and project risks reduced if transformers can be bought in larger numbers of a single design.

The application of this principle will, in general, mean that for a given scheme, the transformer is assigned key parameters that exceed the requirements. However where the standard parameters set out in Appendix A do not meet the technical requirements of the scheme, or if it is not reasonable to use the standard parameters for any other reason, then

Asset Policy must be consulted. Unless a new functional family is to be created, then as a minimum, the proposed unit must be capable of being replaced with a spare transformer, which also covers other members of the same functional family however relocatability should be maintained where possible.

1.2 Specification

Transformers reactors and quadrature boosters shall be specified to comply with the requirements of NGTS 2.03.

NGTS 2.03 sets out the normal overload and other requirements for transformers and reactors. In addition, the appropriate key technical parameters set out in section 1.4 must be quoted in the specification to the transformer manufacturer. There are also some site specific considerations that need to be taken into account when preparing the specification for a particular scheme (see Section 1.8).

1.3 Standards

NGTS 2.03 shall be based on and reference IEC 60076 Power Transformers.

1.4 Key Technical Parameters

1.4.1 Transformers

The following are the key technical parameters for transformers

- a) Higher voltage
- b) Lower voltage
- c) Whether a tertiary winding is required
- d) Winding connection
- e) Tapping range
- f) Number of tap positions
- g) Maximum and minimum Impedance voltage on each tap (referred to 100MVA see Section 1.5.6)
- h) Rated power

1.4.2 Shunt reactors

The following are the key technical parameters for shunt reactors

- a) Voltage
- b) Rated power

Series reactors

The following are the key technical parameters for series reactors

- a) Voltage
- b) Minimum short circuit impedance (referred to 100MVA)

- c) Rated throughput power

1.4.4 Quadrature boosters and phase shifting transformers

The following are the key technical parameters for quadrature boosters and phase shifting transformers

- a) Voltage
- b) Rated throughput power
- c) Minimum impedance on neutral tap
- d) Minimum advance phase angle when boosting at rated power or minimum no-load advance phase angle and maximum impedance on the tap for maximum advance phase angle.
- e) Minimum retard phase angle when bucking at rated power or minimum no-load retard phase angle and minimum impedance on the tap for maximum retard phase angle
- f) Minimum number of tap positions
- g) Whether quadrature booster or phase shifter connection is required

1.5 Values for Key Parameters

1.5.1 Standard values

The standard values for the key technical parameters are set out below and in Appendix A. These values shall be used unless they are inadequate for the purpose of the scheme or it is not reasonable to do so, for example if an excessive additional cost would be incurred. In these cases Asset Policy must be consulted.

1.5.2 Voltage

This shall be the nominal voltage for the system. Standard values are 400kV and 275kV for the higher voltage of transformers and 275kV, 132kV, 66kV, 33kV, 25kV and 11kV for the lower voltage. Note that the nominal voltage is the basis for calculating full load current from rated power on nominal tap.

NGTS 2.03 specifies the maximum and minimum voltages for operation of the equipment.

1.5.3 Tertiary windings

A 13kV 60MVA delta connected tertiary winding shall be specified on all three phase transformers which do not have a delta secondary winding. Transformers with a rated power of less 180MVA may have a delta tertiary winding with a reduced rating. Transformers with tap-changers will be arranged so that the HV to tertiary ratio is independent of tap-position.

1.5.4 Winding Connection

All transformers with a lower voltage of 132kV or higher shall be autotransformers. Transformers with a lower voltage of 66kV or lower shall be double wound. The vector group of the transformer shall be chosen from the table in Appendix A to suit the existing system. Transformers with a secondary delta connection at 33kV shall have links to allow d1 or d11 connection.

1.5.5 Tapping range, number of tap-positions and tap numbering.

400/275kV transformers will be specified without taps. The standard tapping range and number of taps for other transformers is set out in Appendix A. The standard tapping ranges have been set with the expectation that the normal power flow is from HV to LV. Where this is not the case, and the tapping range is not adequate for the requirements, then a special specification will be required, and Asset Policy will need to be consulted.

It is important to specify whether the variation of tap-position affects the no-load voltage of the HV or the LV. For autotransformers the variation shall be on the LV, for double wound transformers the variation shall be on the HV. The rated current and impedance is referred to the particular tapping voltage, so a transformer with an LV tapping at +15% will have a rated LV current at this tap of 15% less than at the normal tap.

Standard tap numbers are included in the table and this shall be included in the specification.

1.5.6 Impedance and rated power for transformers and series reactors

In accordance with industry practice, the impedance of a transformer or series reactor shall be quoted to the manufacturer as the impedance on rating.

A transformer with a higher rating may be functionally compatible with (able to replace) a transformer with a lower rating if they both have the same impedance on a base of 100MVA, for this reason the functional types in Appendix A have impedances quoted in % on 100MVA. It is essential that these impedances are converted to impedance on rating before being included in the specification.

The following formulas apply:

$$Z_{100} = \frac{Z_r}{r} \times 100$$

$$Z_r = \frac{Z_{100}}{100} \times r$$

Where

Z_r = Impedance on rating in %

Z_{100} = Impedance on 100MVA in %

r = rated power in MVA

The table in Appendix A gives the highest rated power within the existing functional families that may be specified for a given impedance on 100MVA. Normally this is the power that should be specified, but in circumstances where this is unreasonable, lower power units may be specified, according to the preferred lower values set out in the table.

Higher power units may be specified with the standard impedance on 100MVA only where the implications for spares provision has been considered and agreed with Asset Integrity.

The standard range of impedance variation (on highest rated power) is given in the table in Appendix A. In general impedance variation due to changes in tap position and manufacturing tolerance can be kept within 10% of the nominal values but tighter tolerances may be difficult for manufacturers to meet especially on transformers with wide tapping ranges.

The impedance of a series reactor will reduce slightly with current between the full load current and the short circuit current. The specification to the manufacturer shall give the minimum impedance at short circuit current and the maximum impedance at full load current.

1.5.7 Maximum buck/boost capability of quadrature boosters (QB) and phase shifting transformers (PST)

The buck/boost capability of a QB or PST at full load is determined by the no-load phase angle and impedance of the unit at the extreme tap-positions. If there is a particular system need to specify these parameters separately than this can be done, but it may be more economical for the supplier to determine these parameters from the required full load boost and buck phase angles.

1.5.8 Impedance on neutral tap for QBs and PSTs

The impedance of a QB or PST on the tap for zero no-load phase shift (neutral tap) can be zero for some (cheaper) designs. If a minimum impedance is required for system reasons then this must be specified.

1.5.9 Rating of QBs and PSTs on the extreme buck tap-position

The rating of a QB or PST on the extreme buck tap-position is restricted by overfluxing as well as by thermal considerations. To provide an economic design, the overload ratings on the extreme buck tap-position will be restricted to operation at frequencies above 49.5Hz and voltages below the continuous maximum system voltage. A system shall be provided to prevent tapping beyond the capability of the plant at each value of load, voltage and frequency.

1.5.10 Number of tap-positions for QBs and PSTs

The number of tap positions shall be given as a minimum value required to provide acceptable steps in power flow. The manufacturer may need additional tap positions to limit the MVA switched by the tap-changer. The maximum time allowed to tap from mid position to extreme tap should also be specified. 39 tap positions is the maximum that is compatible with existing control systems.

1.6 Overload Ratings

Transformers, quadrature boosters, phase shifting transformers and series reactors shall have a continuous post fault overload rating at an ambient temperature of 20 degrees C of 1.2 per unit without exceeding a winding hotspot temperature of 125 degrees C (the winding temperature indicator (WTI) trip temperature). Since the time constant of most designs is less than 3 hours this overload rating is effectively equivalent to a 1.2PU cyclic rating.

The plant shall have a 10 minute rating (following a 0.75PU pre-load) of 1.5PU current at an ambient temperature of 20 degrees C without exceeding the WTI trip temperature. The transformer and all its components shall operate at 1.5PU for 30 minutes without damage.

These standard overload requirements shall be included in NGTS 2.03.

Plant of this type should not be expected to operate at currents above 1.5PU.

1.7 Operating Conditions

Where practicable transformers shall be specified, designed and manufactured to withstand the operating conditions that may be experienced anywhere on the NG electricity transmission system. Standard parameters for voltage, frequency variation, system short circuit impedance and geomagnetic currents shall be given in NGTS 2.03.