LIMITS FOR TEMPORARY OVERVOLTAGES IN ENGLAND AND WALES NETWORK

PURPOSE AND SCOPE

This Technical Guidance Note presents the limits for temporary over voltages in the GB EHV network for 400kV and 275kV voltage levels.

The limits shall be used at design stages, equipment procurement and assessment of the grid performance.

Due to the nature of temporary overvoltages and their effects on equipment connected to the network, the limits are provided in two parts; the limit that applies to the changes in the instantaneous level of the voltage and the limit that applies to the changes in the root mean square (rms) of the voltage. The limit on the rms value of the voltage applies only to unplanned events.

It is required by this technical guidance note that all designs impacted or altered due to the implementation of these limits are recorded for the duration of three years from the date of publication of this document. The changes made including the parameters of TOV, i.e. magnitude and duration shall be entered in the record. System Design department, Network Engineering, ETAM is responsible for keeping the records. National Grid’s System Design department shall be informed to update the records in cases where the project is managed and study is performed by other organisations.

PART 1 –GUIDANCE

1 QUICK REFERENCE GUIDE

1.1 For assessing compliance, electromagnetic transient studies are required. EMTP-ATP programme is recommended. Other similar electromagnetic transient programmes are also acceptable.

1.2 The recommendations in TGN(E) 261 shall be followed in electromagnetic transient studies.

1.3 Both instantaneous and rms values of voltage shall be assessed against the limits. Compliance is achieved when both limits are met.

1.4 Compliance with the limit in this TGN for rms value of TOV is required for unplanned events only. Limits for rms value of voltage for planned events are included in the Grid Code CC.6.1.7. Compliance with the limit in this TGN for instantaneous value of TOV is required for planned and unplanned events.

1.5 The assessment is required for new designs, network alteration, extension and refurbishment in the Transmission Grid and distribution networks, e.g. new embedded generation connection, when there is a possibility of changes in the modal characteristic of the network at the point of connection and/or changes in protection and control systems.

1.6 Lowest fault levels usually results in the worst case TOV. However, depending on the plant in the vicinity of the point of study other fault levels may also be considered to ensure compliance.

1.7 Both three and single phase fault levels shall be considered to represent the positive and zero phase sequence impedances of the supply system.

1.8 In marginal cases when the voltage exceeds the limits, surge arresters and corona effects shall be included in the study.

1.9 If surge arresters are included in the study, energy absorption during TOV against their rating shall be assessed.

1.10 The equipment losses shall be adequately represented in the marginal cases, as prescribed in TGN(E) 261 [3].

1.11 Projects impacted or altered by the limits in this technical guidance note shall be reported to System Design department, Network Engineering, ETAM, National Grid.

2 INTRODUCTION

Temporary power frequency overvoltages, hereafter referred to as TOVs, are slow changing overvoltages of the system frequency component of voltage with a frequency or frequencies that can be lower or higher than the system frequency. The superimposed changes on the system voltage are caused by resonance conditions in the network. The main characteristic of TOVs is their long duration which can be from several cycles up to 30 seconds or even longer. CIGRE WG 33.10 [1] defines TOV as voltages above the maximum network voltage, usually 1.05% of the nominal, that last for two cycles or more. The damping presented by the network to TOVs is usually low.

This document presents limits for TOVs in the GB network that shall be used at design stages and for equipment procurement and installations. The limit for rms value of the voltage applies only to unplanned events. The criteria for planned events and switching are outlined in the Grid Code CC 6.1.7. The limit for instantaneous value of the voltage applies to both planned and unplanned events.

Due to the nature of TOVs and their effect on equipment connected to the network, the limits are provided in two parts:

a) The limit that applies to the changes in the instantaneous level of the voltage.

b) The limit that applies to the changes in the root mean square (rms) of the voltage.

Both above conditions shall be complied with.

For the purpose of clarity, examples to illustrate the instantaneous and rms levels of TOV are given in Appendix A.

The main considerations in devising the limits are ensuring the highest degree of safety, security and quality of supply and enabling efficient designs in terms of cost and reduced complexity in installation and operation.

The background and theoretical basis for the limits for TOVs are presented in [2].

3 APPLICATION AND IMPLEMENTATION

This TGN shall be used for the following purposes:

a) All equipment procured for use in the transmission network shall have, as a minimum requirement, the capability to withstand the transient voltage characteristic specified in this document.

b) The network shall be designed to ensure that any transient voltage profile conforms to the voltage characteristic specified.

c) All protection and control systems and inter-trip schemes are designed to ensure compliance with the transient voltage profile specified.

The requirements for plant withstand capabilities are given in NGTS1 [4].

In general any new installation that changes the modal characteristic of the network at the point of interest shall be assessed against the limits presented in this document.

The limits shall be complied with by all network designs, extensions and reinforcement projects including but not limited to new transformers, shunt active and passive reactive power compensators, cable and line installations, new and refurbished protection and control systems.

The compliance with this technical guidance note is normally ensured by performing electromagnetic transient studies. It is recommended that EMTP-ATP software or equivalent is used. TGN(E) 261 [3] recommendations shall be followed in such studies.

Usually the lowest fault level leads to the worst case temporary overvoltages due to the proximity of resonance frequencies to low order harmonics and lower damping presented by the network. However, depending on the installations surrounding the point of study, for example when there are large concentrations of capacitor banks, cable connections and/or transformers, maximum fault level may also need to be investigated. When applicable and at the boundary point, both three phase and single phase fault levels should be considered to represent the supply system.

Single, double and three phase fault inception and clearance, load/generation rejection, line/cable re-energisation by means of auto-reclose and parallel line resonance conditions shall be assessed.

Surge arresters and corona effects reduce the magnitude and duration of TOVs. In marginal cases, these shall be included in the model to improve accuracy of the results. Surge arresters energy absorption shall be checked against their rating to ensure damage is avoided.

Furthermore, losses in plant, such as transformers, generators, cables and lines shall be adequately represented when assessing marginal cases. For guidance see TGN(E) 261 [3].

4 LIMITS FOR TEMPORARY OVERVOLTAGES IN ENGLAND AND WALES NETWORK

Limits are given for the instantaneous level of TOV’s and their rms values.

The limit for instantaneous value of voltage applies to unplanned and planned events. The limit for rms value of voltage applies to unplanned events only.

Equipment installed in the transmission network shall withstand the voltage characteristic defined in this document. The network, protection and control systems shall be designed such that in the event of changes in the network, the voltage profile shall comply with the characteristic given below both in magnitude and duration.

It is required by this technical guidance note that all designs impacted or altered due to the implementation of these limits are recorded for the duration of three years from the date of publication of this document. The TOV magnitude and duration shall be part of the record. System Design department, Network Engineering, ETAM, National Grid is responsible for keeping the records. National Grid’s System Design department shall be informed to update the records in cases where the project is managed and study is performed by other organisations.

At the end of the three year period the appropriateness of the limits will be reviewed.

4.1 Limits for Instantaneous Value of TOV

The TOV instantaneous values shall not exceed 2.0 pu or 200% of the peak value of the phase to neutral voltage of the System continuous voltage defined in NGTS 1 [4]. For the purpose of clarity these are 420kV rms phase to phase and 300kV rms phase to phase for 400 kV and 275 kV nominal System voltages respectively.

In the cases when the instantaneous voltage exceeds the above limit more detailed studies will be needed to ensure that security of supply is not impacted. The special cases shall be referred to the Policy or System Design departments within ETAM for further guidance.

4.2 Limits for RMS Value of TOV

The limit for the change in the rms value of the TOV and its duration is shown in Fig 1.

The per unit value is on the base of System Continuous Voltage of 420kV and 300 kV rms for phase to phase nominal System voltages of 400kV and 275kV respectively. The limit applies to the phase to neutral voltages.

The rms value is calculated in accordance with Class A requirement specified in IEC 61000-4-30 for voltage dips and swells, which states that rms is calculated over one complete cycle refreshed every half a cycle.

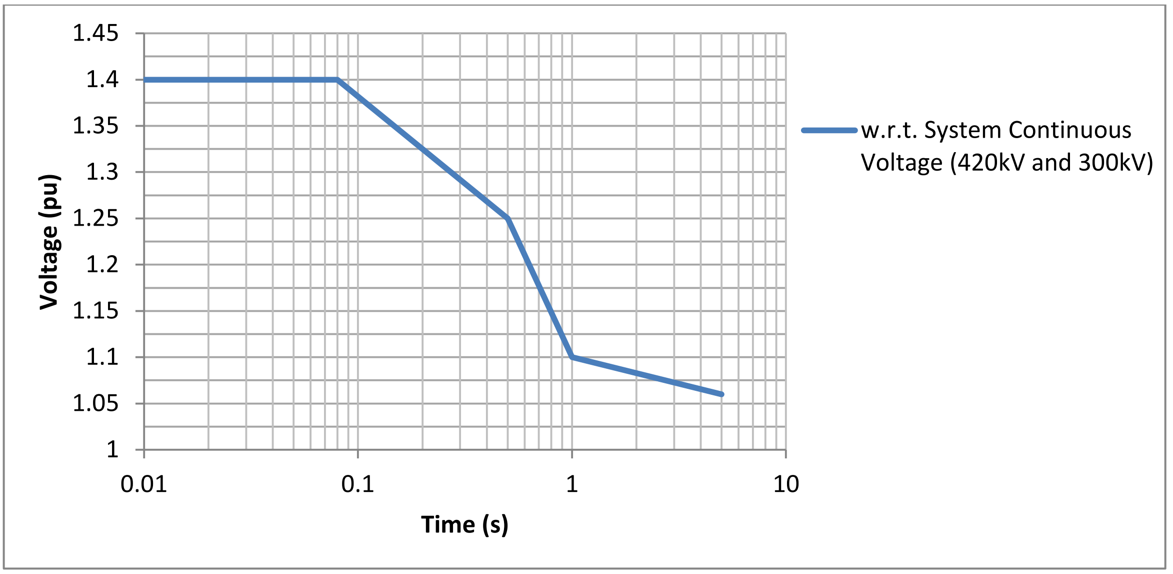

Fig 1- Limits for RMS Value of TOVs for 400kV and 275 kV in GB Network

PART 2 - DEFINITIONS AND DOCUMENT HISTORY

5 DEFINITIONS

TOV	Temporary overvoltage
RMS	root mean square, measured over one cycle and refreshed every half a cycle (IEC 61000-4-30)
England and Wales Network	Transmission network in England and Wales
EMTP-ATP	Electromagnetic Transient Programme-Alternative Transient Programme
Passive reactive power compensator	Mechanically switched reactive power compensators with no control systems
Active power compensator	Reactive power compensators with control systems, e.g. SVCs

6 AMENDMENTS RECORD

Issue	Date	Summary of Changes / Reasons	Author(s)	Approved By (Inc. Job Title)
1	May 2016	New document	Forooz Ghassemi Power System Engineer System Design Network Engineering	Mark Perry System Design Manager Network Engineering

7 IMPLEMENTATION

7.1 Audience Awareness

Audience	Purpose Compliance (C) / Awareness (A)	Notification Method Memo / letter / fax / email / team brief / other (specify)
ETAM, SO	A	Email

7.2 Training Requirements

Training Needs N/A / Informal / Workshop / Formal Course	**Training Target Date**	**Implementation Manager**
Informal	October 2016	Mark Perry

7.3 Compliance

This guidance note is to be complied with in equipment procurement, design of the network and protection and control systems.

7.4 Procedure Review Date

3 years from publication date.

PART 3 - GUIDANCE NOTES AND APPENDICES

8 REFERENCES

[1] CIGRE WG 33.10, “temporary overvoltage withstand characteristics of extra high voltage equipment”, Electra No. 179, August 1998.

[2] National Grid Report, Proposed Limits for Temporary Overvoltages in GB Grid, June 2015.

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[3] TGN(E) 261, A Guide to Electromagnetic Transient Studies, Issue 1, National Grid publication, August 2015.

[4] NGTS 1, Rating and General Requirements for Plant, Equipment and Apparatus for the National Grid System, Issue 7, National Grid publication, June 2007.

APPENDIX A - ILLUSTRATION OF INSTANTANEOUS AND RMS VALUES OF TOV

In order to illustrate typical overvoltages that can occur in a system, examples related to instantaneous values and rms values of overvoltages are presented.

Figure A1 shows a model of a HVDC converter station with all associated filter modules connected to a 400 kV system represented by its equivalent Thevenin model via 2.5 km of 400 kV cables.

Figure A2 illustrates the instantaneous voltage of the network busbar, NETW4, for a three phase fault at BPOL1 busbar. It can be seen that the voltage reaches 2.1 pu, based on the peak of the phase to ground of the System maximum continuous voltage after the fault is cleared. This can be considered as a marginal, non-compliant case. As can be seen from Fig A1, no surge arrester was included in the model. The presence of surge arresters reduces the instantaneous voltage to a level below the limit for instantaneous overvoltages and thus the design will become compliant, as shown in Fig A3. The current in the surge arrester during the transient is shown in Fig A4. The energy absorption capability of surge arresters should be checked against the device rating. Furthermore, in marginal cases such as this, more detail should be included in the supply system model by extending the model to two substations away from the point of incidence [3]. This modification alters the overall losses in the model and may affect the TOV magnitude and duration. The model can further be refined by adding the corona effect in transmission lines.

Figure A5 shows the rms value of the voltage for the same scenario as above. As can be seen the rms voltage increases and oscillates with a peak value of 1.22 pu. The voltage rms begins to reduce to the nominal voltage about 500 ms after the fault was cleared. This voltage has to be compared against the rms voltage characteristic shown in Fig 1 to assess compliance. In this case the voltage rms is compliant.

Figure A6 illustrates the voltage rms for a condition when the power transfer across the HVDC was removed. This condition may arise when there is a three phase fault at the remote end of the converter station.

As can be seen the voltage rms peaks at 1.21 pu with a steady state value of the 1.13 pu. With respect to Fig 1, action is necessary to limit the duration of the overvoltage, failing to do so would lead to a non-compliant condition.

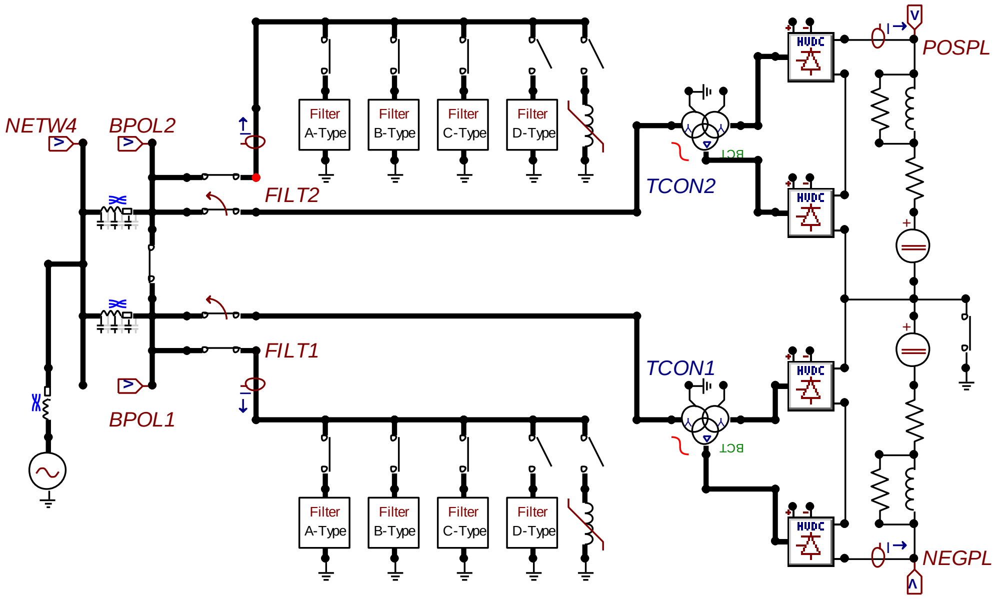

Fig A1- Model of a HVDC Converter Station

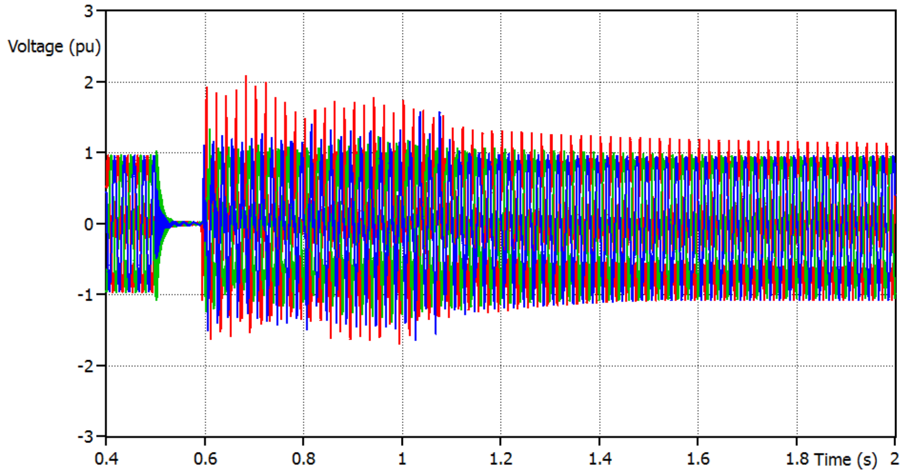

Fig A2- Instantaneous Voltage for a Three Phase Fault

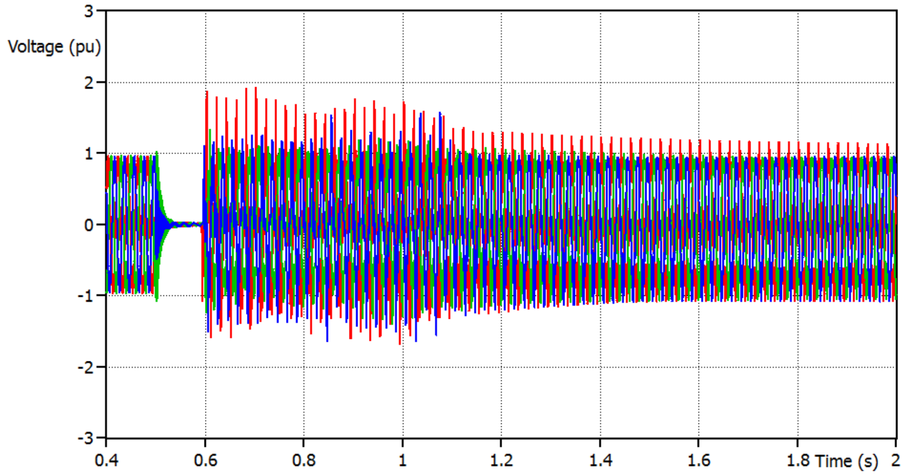

Fig A3- Instantaneous Voltage for a Three Phase Fault with Surge Arrester included

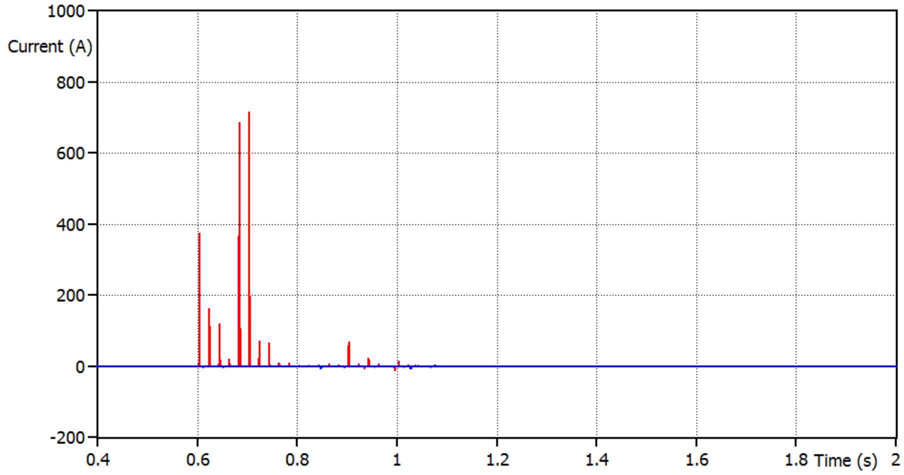

Fig A4- Current in Surge Arrester

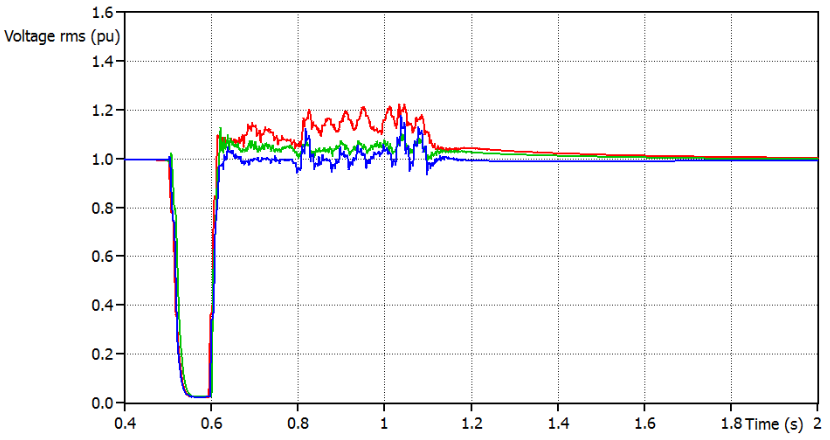

Fig A5- Voltage RMS Value for a Three Phase Fault

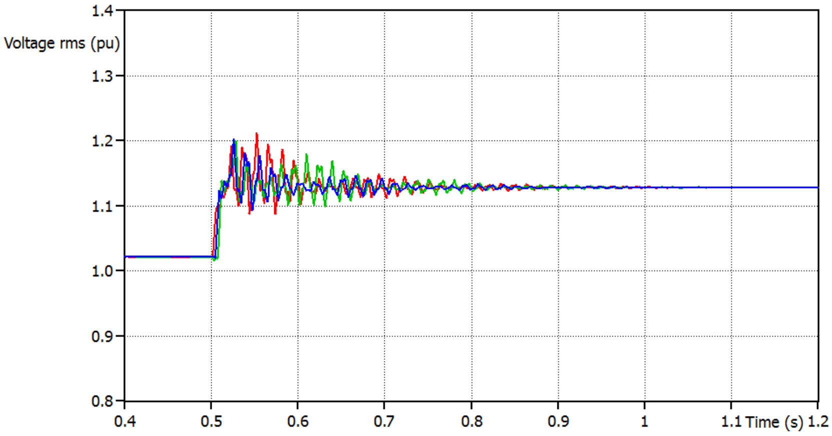

Fig A6- Voltage RMS Value for a Load/Generation Rejection Case