Celsius
Engineering Recommendations initial review

1 Introduction

Celsius is a project which was awarded funding under Ofgem's 2016 Network Innovation Competition (NIC). It is being led by Electricity North West (ENW). Ricardo Energy & Environment are acting as key technical consultant project partners on this project.

Celsius aims to develop learning and deliverables which can be used across the industry to improve the operation and management of distribution networks. Therefore there is a need to review existing industry-wide engineering recommendations in order to understand in what way they need to be updated to reflect this learning.

Two recommendations have been identified for review; ER15: Transformer Loading Guide, and ER17: Current Rating Guide for Distribution Cables. Both of these comments were written in the 1970s, and are therefore dated in some aspects. A Review of Engineering Recommendations P15, P17 (Transformers) was undertaken by the "Customer-Led Network Revolution" project by Northern PowerGrid in 2015 and concluded

> *In P15, P17 (and P27) there is currently no explicit coverage for the use of localised site specific data (e.g. wind and load profiles) to calculate bespoke ratings or for the application of RTTR. We recommend that a separate application guide covering the rating of all distribution network asset types is produced, to assist engineers in deriving safe yet economical bespoke ratings and in using RTTR systems within control schemes.*

Note that this will not be a thorough review of the recommendations themselves, but an identification of the specific impact of Celsius on their content.

The approach taken will be to carry out an initial review early in the project, and to discuss this within a workshop with the wider group of GB DNOs. The conclusions of this initial process will then be reviewed and updated as the project goes on, and the DNO group consulted again before the project is concluded.

This document summarises the findings from the initial review.

2 Review of ER P15 – Transformer Loading Guide (1971)

2.1 General Comments

ER P15, Transformer Loading Guide, being based on the draft IEC 1969 Loading guide for oil immersed transformers, is now very aged and has been updated many times since. It appears to be in need of complete industry review to incorporate both current international standards and the learning from Celsius as well as other learning regarding changing load profiles from other Low Carbon Technology projects. This review is outside of the scope of Celsius, and therefore this document.

The "Customer-Led Network Revolution" project by Northern PowerGrid in 2015 concluded:

> *P15 references the thermal models of transformers in IEC 354 (now superseded by IEC 60076-7:2005), describes the thermal limits under which premature aging is unlikely to occur and provides limits for emergency ratings. Equations are provided to allow estimation of transformer winding temperature given a range of fixed parameters, ambient temperature and a load profile.*

and recommended:

- That P15 is extended in scope to include EHV/HV and HV/LV transformers.
- That on-site tests in accordance with IEC60076-2:2005 be carried out to establish transformer specific parameters in P15 to reflect their variation according to size and design of the transformer, unless equivalent data is available from manufacturers

- 3.3. That only load current, tap position and cooling air temperature need be measured to derive a satisfactorily accurate estimated winding temperature.

More recent recommendations include:

- ANSI "Guide for Loading Mineral-Oil-Immersed Overhead and Pad-Mounted Distribution Transformers (rated 500 kVA and less with 65°C or 55°C average winding rise)" – 1981
- IEC 354, "Loading guide for transformers"1991.
- IEC 354, Loading guide for oil immersed power transformers, incorporating IEC Corrigendum issued in 1992
- IEC 60354 implemented in 1999, introduced considerable changes to the principles of assessing thermal effects of transformers overloading under various types of load. An essential advantage of the recommended methods of verification of overloading capacity of transformers is that the size and cooling modes of transformers are considered.
- Present International standard – IEC 60076-7 : 2005 'Power transformers - Part 7:Loading guide for oil-immersed power transformers' (Standard Number BS IEC 60076-7:2005) Publication Date: 31 December 2010

2.2 Potential changes relevant to Celsius

The following high level aspects of the ER P15 recommendation may be impacted by the results of the Celsius Project.

Location in Document	Subject	Comment
Page 3, Sections 1 and 2	Introduction & Scope	This will need to be updated with our findings for distribution transformers – noting that the scope for P15 is much wider including system transformers
Page 3, Section 3	"The winding hotspot temperature, in turn, is determined by…"	This will need to be updated with our findings – Celsius will aim to identify key influencers on asset temperature, and so there may be additional factors to add beyond those already listed.
Page 3, Section 3	Basis of the recommendation	If changes are made, we should add in an explanation of where this learning has come from here.
Page 4, section 4	Recommendations	These will need to be updated with the findings of Celsius. Specifically, the rule of loading to 150% may be replaced with a dynamic factors depending on the transformer environment and updated standards Note that the temperature of the hotspot will still be maintained below 150 degrees for equipment conforming to the standards referred in P15, with a recommendation for a margin of safety and consideration of equivalents for transformers built to later international standards
Page 4 and Appendix A	Calculation of hotspot temperature	The calculation of hotspot temperature may be updated based on the findings of Celsius. An additional set of calculations will be developed for the calculation of additional capacity headroom, may also be included. Recommendations for the margin of error will also be included Note that Changes to the rate of use of life from the environmental conditions may also be impacted by Celsius findings, but calculations of the rate of use of life are not directly part of the Celsius scope.

Location in Document	Subject	Comment
Page 5, Section 6	Operational Considerations	Some references to the 150% limit which would need to be revised.
Appendix B	Example of assessment of overload capability	This may have to be re-written.

3 Review of ER P17 – Current Rating Guide for Distribution Cables (1976)

3.1 General Comments

The "Customer-Led Network Revolution" project by Northern PowerGrid in 2015 concluded

> *Based on the measurements taken during the CLNR project, the standard cable installation environmental conditions used in P17 were reviewed. For example, measurements for both soil thermal resistivity and soil ambient temperature significantly differ from the default values assumed in P17. Use of a standard model (perhaps based on CRATER which is available to all GB DNOs) for calculating bespoke ratings. (note CRATER is for 11kV & above)*

3.2 Potential changes relevant to Celsius

This engineering recommendation comes in several parts: Cables for 11kV, Solid type cables for 33kV, and ratings for 11kV and 33kV cables having extruded insulation. This does not cover the LV distribution cables that will be specifically addressed in the Celsius project.

However, there are a number of key aspects which can be taken on board during the Celsius project, such as the maximum conductor temperatures, depth, soil resistivity, ducts and proximity to other loaded circuits and the impact of different environments on the thermal performance of cables.

It may be deemed useful, as a result of the learnings from Celsius, to develop a new part of this engineering recommendations which deals directly with low voltage cables.