Celsius Solutions: Cost Benefit Analysis and Buy Order

Cost benefit analysis and buy order for the techniques and solutions developed during the Celsius project, and being recommended to Business as Usual

Report for Electricity North West

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1 Introduction

1.1 Celsius Project Summary

The Celsius project was awarded funding under Ofgem's 2016 Network Innovation Competition (NIC). It is being led by Electricity North West (ENWL). Ricardo Energy & Environment are acting as key technical consultant project partners on this project. The project started in January 2016 and will complete in March 2020.

The Celsius project has developed techniques and demonstrated solutions that can release capacity in existing secondary transformers, thereby potentially delaying the need to reinforce as the load grows. This includes:

- **A methodology for determining a more informed transformer rating**, which takes into account substation environment and monitoring data. It is noted that the nameplate rating provided on a transformer is conservative, and that under many substation environments and loading conditions, a higher rating may be able to be adopted. This rating is limited by the operating temperature of the transformer, and a more informed rating can be determined by comparing operating temperature with the transformer load, and estimating the actual load at which the maximum allowable operating temperature will be reached.
- **Cooling technologies and solutions**, which can be retrofitted into the substation or on the transformer to lower the operating temperature, and therefore release additional capacity.

The first phase of the Celsius project trials and analysis involved 520 secondary transformers. These trials developed the methodology for determining an improved rating for the transformers based on measured data and site information. This analysis was based on detailed data and information gathered and analysed through statistical methods. This analysis was reported in the 'Secondary Network Asset Temperature Behaviour Report', to be updated in early 2020. This phase concluded that it is possible to identify a more informed rating from site information and data, and that the capacity release from this varies widely between sites.

The second phase of the project and analysis involved installing retrofit cooling technologies into 100 of these trial sites, to assess their benefits and impact on the more informed rating. This analysis was reported in the 'Secondary Network Asset Temperature Behaviour with Retrofit Monitoring Report', to be updated in early 2020. This phase of the report concluded that the following technologies may be of benefit when installed into a substation:

- **Active ventilation of substations**: where air flow is increased though fans in order to cool the substation.
- **Improved passive ventilation of substations**: substations generally have established passive ventilation arrangements, but it may be possible to improve these arrangements, particularly if the existing arrangements are not optimal.
- **Protection of outdoor transformers from solar heating**: using white paint which reflects solar radiation.

Following this work, the learning from the two phases has been combined to form recommended updates to the business as usual network operations. Part of this is documented in the 'BAU Monitoring Solution Specification', delivered in September 2019, which covered the recommended process itself, and the requirements of the associated monitoring solution. This document provides the results of business case analysis for the implementation of Celsius techniques compared to traditional methods.

1.2 This Document

This document includes the following sections:

- **Section 2: Buy Order: Intervention Cost Assumptions** – A list of the various Celsius and traditional techniques, with associated costs and relative advantages and disadvantages.
- **Section 3: Cost Benefit Analysis**– Describes the methodology and results of the cost benefit analysis for the Celsius business as usual recommendations including the limitations, confidence and conclusions that can be drawn.

2 Buy Order: Intervention Cost Assumptions

The following table provides cost and benefit details for each Celsius technology, and equivalent traditional technology.

The costs information for the Celsius technologies is based on trial experience and information provided by suppliers. There is uncertainty in this cost due to the range of site characteristics, for example, substation shape and size, ease of providing any required supply points, and ease of making structural changes. For this reason, a range of costs is given in many cases. It is assumed that there is no notable increase in operational costs for Electricity North West as a result of utilising the technologies, as any minor maintenance will fall in line with usual substation inspection timescales. This has been supported by information gained from suppliers of the active cooling technologies and is part of the specification for monitoring solutions developed as part of this project. Capital costs assume that the Celsius technologies have been integrated into an established BAU process including communications, SCADA, training of personnel, and maintenance.

The traditional reinforcement approach includes replacing transformers with a larger capacity and building a new substation. The traditional options were selected with agreement from Electricity North West to reflect a likely approach to reinforcing a substation with increasing load. The costs have been supplied by Electricity North West. It is assumed that there is no notable increase in operational costs for Electricity North West.

Technology	Capital Cost	Capacity Release
Traditional: reinforcement to a 300kVA transformer	£16,243 Assumes no new plinth or generator is needed	500% Assuming existing transformer is 50kVA
Traditional: reinforcement to a 500kVA transformer	£17,408 Assumes no new plinth or generator is needed	59% - 400% Assuming existing transformer is between 100kVA and 315kVA
Traditional: reinforcement to a 800kVA transformer	£18,813 Assumes no new plinth or generator is needed	60% Assuming existing transformer is 500kVA
Traditional: reinforcement to a 1000kVA transformer	£18,813 Assumes no new plinth or generator is needed	25% to 33% Assuming existing transformer is between 750kVA and 800kVA
Traditional: installation of a new 800kVA substation	£75,000 Assumes near existing HV & LV network, land costs of £15k	80% Assuming existing transformer is 1000kVA (and remains in operation)
Celsius Intervention: monitoring and more informed rating	£800 to £1000 Includes equipment costs and installation	Depends on substation characteristics. Average release from trial: Stone/brick: 26% Glass reinforced plastic: 10% Part of larger building: 27% Fenced enclosure: 33%

Technology	Capital Cost	Capacity Release
Celsius Intervention: Active ventilation of substations	£4,300 to £5,200 Includes equipment costs, site preparation and installation	Depends on substation characteristics. Average release from trial (in addition to monitoring and improved rating alone): Stone/Brick: 15% GRP: 25%
Celsius Intervention: Improved passive ventilation of substations	£1,800 to £6,000 Includes equipment costs, and installation. Higher costs due to unusual site layouts and load bearing walls in shared buildings.	Depends on substation characteristics. Average release from trial(in addition to monitoring and improved rating alone): Stone/Brick: 9% GRP: 8%
Celsius Intervention: Protection of outdoor transformers from solar heating	£1,500 - £2,200 Includes painting transformers using white paint.	Depends on substation characteristics. Average release from trial (in addition to monitoring and improved rating alone): 7%

3 Cost Benefit Analysis

3.1 Methodology

The cost benefit analysis was carried out to determine the relative costs and benefits of the business as usual recommendations from Celsius compared to traditional methods.

The analysis focuses on meeting the load growth in the network, as this is the most straight-forward benefit case to model. The benefits to Electricity North West are in the form of reduced spending. Reinforcement in response to specific connections requests are paid for, at least in part, by the customer who is connecting, and the timescale requirements for providing that connection offer means that may not be possible to support connections requests using Celsius methods.

Cost benefit analysis involves comparing two cases:

- **Base Case:** representative of the traditional reinforcement approach used for a transformer that is becoming overloaded
- **Celsius Case:** representative of the approach that would be possible with the Celsius methods

These cases are determined and compared for ENW sites that are expected to be overloaded over the next 30 years, and the benefits are multiplied to extend to a GB scale. The sections below summarise the methodology that was used in order to carry out this cost benefit analysis.

3.1.1 Base Case Definition

The base case assumptions have been defined and agreed with Electricity North West to be representative of the approach used in traditional reinforcement of a substation with load growth.

The assumed process once a substation is overloaded is as follows. Note that as the cost benefit analysis will be for 30 years of growth, multiple interventions are often needed for the same site. Costs are assumed to be as listed in Section 2.

- **Validation:** The load is validated using data logging to ensure there is no error in reading.
- **Investigation of reconfiguration options:** it may be possible to reconfigure the network to pass some load from overloaded transformer to a nearby transformer with spare capacity.

This is a low-cost way of releasing capacity. In the business case we have modelled between 0% and 10% capacity being released in this way.

- **Traditional reinforcement – where the existing transformer is less than 1000kVA:** This includes replacing an existing transformer with a larger one, therefore providing further capacity without the need for additional substation infrastructure. The approach to transformer sizing is as follows:

Existing transformer	Replacement
50kVA, 100kVA, 200kVA	300kVA
300kVA, 315kVA	500kVA
500kVA	800kVA
750kVA, 800kVA	1000kVA

- **Traditional reinforcement – where the existing transformer is 1000kVA:** Transformers greater than 1000kVA are not commonly used at secondary substation level. Therefore, the transformer cannot be upgraded in the same way as the smaller transformers. In this case, it is assumed that it is possible to release capacity through reconfiguration (in addition to that described previously) and the reinforcement of an adjacent substation. It is assumed that an adjacent 500kVA transformer is replaced by a 1000kVA transformer, releasing 500kVA in capacity overall.

- **Additional substation:** Where the load growth continues to grow and exceeds the capacity release from reconfiguration and reinforcement options, then an additional substation is installed. It is assumed that the new substation will be 800kVA, and that on installation the load will be shared between the new substation and the overloaded transformer. If load continues to grow, then the additional transformer can be upgraded to 1000kVA.

3.1.2 Celsius Case Definition

The Celsius case is based on the BAU recommendations that have been developed by the Celsius project and are representative of the approach that could be used to support a substation with load growth.

The assumed process once a substation is overloaded is detailed below. Note that as the cost benefit analysis will be for 30 years of growth, multiple interventions are often needed for the same site. Costs are assumed to be the average of those experienced in the trial.

- **Celsius monitoring and more informed rating:** Installation of monitoring will validate the load readings and will also allow a more informed rating to be calculated. The capacity released when a more informed rating is calculated varies with site characteristic. The cost benefit analysis assumptions are based on the average capacity release from the trial of monitoring and more informed rating as provided in Section 2.
- **Colling technology:** The Celsius project trialled a number of cooling technologies. The cost benefit analysis assumes that the following technologies are used for each building type. These were selected as the most effective technologies at releasing capacity in the majority of situations, though it should be noted that the optimal solution and its effectiveness varies by site. The analysis assumes the capacity release to be the average capacity release from the successful implementations of each technology in the Celsius trials.
    - **Stone/brick:** Active cooling, releasing 16% capacity above monitoring and more informed rating alone
    - **Glass reinforced plastic:** Active cooling, releasing 25% above monitoring and more informed rating alone
    - **Part of larger building:** Improved passive ventilation, releasing 7% above monitoring and more informed rating alone
    - **Fenced enclosure:** White paint, releasing 7% above monitoring and more informed rating alone

- **Traditional reinforcement:** Where the load exceeds the capacity release achieved through monitoring, improved rating and cooling, then it is assumed that the site is reinforced using the same traditional reinforcement approach as described in Section 3.1.1.

The model assumes that the Celsius methods are ready to deploy, and any necessary integration into incumbent IT and revision of existing business processes has been carried out.

3.1.3 Electricity North West roll out scale

The assumptions used to calculate the Electricity North West roll-out scale include:

- **Overloaded sites up to 2033:** The Future Capacity Headroom (FCH) model provides detail of the transformers that will be overloaded up until 2033 and their load growth over this time. This list was filtered for ground mounted sites with ratings of 50kVA, 100kVA, 200kVA, 300kVA, 315kVA, 500kVA, 750kVA, 800kVA, and 1000kVA, and for sites that are up to 50% utilised in 2018. It was assumed that more heavily loaded sites would be dealt with using traditional reinforcement. This provided 1,256 sites.
- **Load growth beyond 2033:** The load growth assumptions beyond 2033 was assumed to be 3.5% per year, which was calculated from the average load growth of the data between 2018 and 2033. Sensitivity analysis was carried out to investigate the sensitivity of the results to this assumption.
- **Sites becoming overloaded after 2033:** The FCH data was then used to estimate the number and profile of sites that become overloaded in the years after 2033 up until 2050. It was assumed that the pattern and profiles of these sites are the same as the data up until 2033. This added an additional 1,554 sites to the model.

The resultant model included 2,710 sites.

3.1.4 GB roll out scale

In order to estimate the roll out scale over GB, the results for Electricity North West were multiplied proportionately to the number of ground mounted distribution transformers there are in GB compared to in Electricity North West. It is estimated that there are 220,000 ground mounted secondary transformers in GB, of which 17,000 are in the Electricity North West area.

3.1.5 Modelling methodology

The model is based on an NPV calculation up to 2050 using a discount rate. Results are in 2019 values.

3.2 Results

The Cost Benefit Analysis model results are shown in the table below:

Roll out scale	Benefits of Celsius methods over traditional up to 2050 (£m)
Electricity North West	33
GB	431

These results assume a 3.5% load growth in the long term forecast for each site (the short term forecast for each site is provided by the FCH model as described in Section 3.4.1) and include no assumptions for capacity released through reconfiguration before reinforcement.

Sensitivity analysis was carried out into the impact of key assumptions in the modelling. The tables below show the results of this sensitivity analysis over GB scale:

Modelling assumptions: Long term load growth of transformers	Benefits of Celsius methods over traditional up to 2050 at GB scale (£m)
2%	365

Modelling assumptions: Long term load growth of transformers	Benefits of Celsius methods over traditional up to 2050 at GB scale (£m)
3.5% (default case)	431
5%	502
The load growth assumption makes a significant difference to the benefits results. However, even at modest load growth of 2%, the Celsius methods still provide a significant benefit over time. The assumption of 3.5% is taken from the FCH model data up to 2033 for Electricity North West, and so is considered a reasonable assumption.	

Modelling assumptions: Capacity release from reconfiguration	Benefits of Celsius methods over traditional up to 2050 at GB scale (£m)
No capacity release modelled for transformers less than 1000kVA (default case)	431
10% capacity release for all sites as they first become overloaded	405
The reconfiguration capacity release assumptions have limited impact on the model results. As the potential for capacity release from reconfiguration will be site specific, and the impact on the results is limited, this is not included in the analysis.	

These results indicate the scale of benefit that the Celsius methods could achieve compared to traditional methods. It should be noted that the results do not include other innovative methods that are available, or will become available, to support management of load in distribution networks. It is intended that the Celsius methods should become part of the toolkit of methods that a DNO can use as the demands on the network change over time.

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