NIA Project Registration and PEA Document

Date of Submission

Apr 2015

Project Reference Number

NIA_UKPN0001

Project Registration

Project Title

Power Transformer Real Time Thermal Rating

Project Reference Number

NIA_UKPN0001

Project Licensee(s)

UK Power Networks

Project Start

June 2014

Project Duration

4 years and 7 months

Nominated Project Contact(s)

Hytham Emam

Project Budget

£1,820,853.00

Summary

The projects will trial Power Transformer Real Time Thermal Rating at two primary substations, 1 each in London & South Eastern licence areas of UK Power Networks. The main objectives are to:

- Conduct extended heat run tests on representative transformers in order to clarify the variance between top oil and measured winding hot spot (WHS) temperature (where fibres are fitted) and make comparison with calculations;

- Install Transformer Management System (TMS) equipment to gain access to key parameters;

- Conduct tests to establish summer/winter rating with/without evaporative cooling; and

- Develop an approved policy for implementing Power Transformer Real Time Thermal Rating

- Develop a scalable central transformer management platform.

Nominated Contact Email Address(es)

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Problem Being Solved

The project was started as a LCNF Tier 1 project and was forecast from the outset to transition to NIA.

DNOs are required to plan and develop within P2/6 guidelines and the rating of a transformer and network operation is governed by thermal considerations. Energised transformers result in losses in the core and windings which become hot, causing oil temperature to rises. Increased loading increases the losses and hence the temperature and the highest temperature in the winding must not exceed the allowable design limit. For the vast majority of the DNOs' installed fleet, it is not possible to measure this hot spot temperature directly, since fibres have only recently begun to be embedded in new transformers for particularly sensitive sites. The top oil temperature is usually measured directly and various methods have been employed to simulate or estimate the winding hot spot

(WHS) temperature. Loading guides define limits to loading based on factors such as solar radiation, ambient temperature, pre-load and the environment.

These parameters affect the real-time rating of plant and it is anticipated that up to 20% increase in ratings can be assigned, if actual operating conditions are used and additional evaporative cooling is introduced.

Under transient i.e. N-1 scenarios, the rate of rise of oil and winding temperatures depends on the difference between rate of energy generation within the transformer and dissipation, and on the thermal time constant of the transformer and its components. It therefore becomes more difficult to simulate or estimate the WHS temperature when load and environmental conditions are changing. Manufacturer's factory acceptance tests if performed will establish the thermal heat curve for the transformer and can provide a more refined approach to calculating the WHS.

Improved measurements only calculate a shortfall in capacity or the time before a shortfall will occur. As such, techniques such as pre-cooling, additional cooling, or load transfers need to be in place to relieve the transformer under N-1 scenarios.

Method(s)

The project will retrofit a suitable Transformer Management System (TMS) solution at sites where tight capacity margins prevail during RIIO-ED1, to trial Power Transformer Real Time Thermal Rating.

The main activities will be:

• Conduct extended heat run tests on at least one new transformer at factory acceptance test to validate variance between actual WHS measurements using fibres vs. calculated WHS temperatures. This transformer will be representative, but will not be identical to the transformers on site;

• Real-time monitoring of key parameters at existing transformer sites: top/bottom oil/ambient temperatures, demand shape (evening peaks/cooling cycle) & load transfers;

• Installation of additional fans (normal and/or evaporative cooling), real time loading/ageing calculations based on thermal data; and

• Create an "out of firm" condition and ensure that design limits are not exceeded.

In the event of a predicted out of firm condition arising, consideration will be given to mitigating actions. These could typically include:

• Calculating rate of winding temperature rise of the remaining transformers in the event of loss of one circuit and assessing time available at load curve prevailing; and

• Effecting load transfer where available.

Scope

The projects will trial Power Transformer Real Time Thermal Rating at two primary substations, 1 each in London & South Eastern licence areas of UK Power Networks. The main objectives are to:

• Conduct extended heat run tests on representative transformers in order to clarify the variance between top oil and measured winding hot spot (WHS) temperature (where fibres are fitted) and make comparison with calculations;

• Install Transformer Management System (TMS) equipment to gain access to key parameters;

• Conduct tests to establish summer/winter rating with/without evaporative cooling; and

• Develop an approved policy for implementing Power Transformer Real Time Thermal Rating

• Develop a scalable central transformer management platform.

• Develop a Software Platform to capture the developed thermal model and integrate the data received with UK Power Networks SCADA (PowerOn) to optimise the thermal model to enable real time monitoring and infrastructure planning.

Objective(s)

The Power Transformer Real Time Thermal Rating project intends to demonstrate how additional capacity can be made available from existing assets and defer reinforcement by three years or more. It is estimated that transformers can be loaded by up to 20% above static seasonal rating.

Changes in environmental conditions have a dramatic effect on transformer loading and in urban areas due to rise in air conditioning installations, historic conditions of load and ambient temperature may not be fully representative of the situation at particular sites. This seasonal increase in loading may lead to cautious network reinforcement decisions.

This demonstration will be achieved by retrofitting TMS onto existing assets to provide real-time monitoring of the transformer's health, and continuously calculate the transformer thermal capacity, thereby safely loading the transformer close to the maximum top oil

temperature less 2 Deg Celsius allowed by design nameplate.

An increase in capacity will be achieved by carrying out the following:

- Installation of an active TMS, monitoring ambient & top / bottom oil temperatures;
- Installation of additional fans, modification to cooling set-points and enabling pre-cooling;
- Initiate pre-cooling in the event of a loss of one transformer (N-1 scenario);
- Create an "out of firm" condition by altering network normal operational configuration; and
- Use the TMS to ensure design limits are not exceeded and calculate impact on degradation.

A greater understanding, visibility in asset performance is expected to lead to a reduction in assets replacement, facilitating the connection of additional loads and low carbon technologies.

The main remaining risks for the project will be not being able to gain network outages to install the second TMS equipment, the ability to carry out load transfers, and operating under N-1 conditions (close to transformer nameplate rating). The risks during the trial will be mitigated at primary substation by using load banks (which can be quickly disconnected) to supplement transformer loading. Actual network load will be used to load the transformer to remain within seasonal capacity, managing the operational risk and further mitigated by robust planning.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

The following will be considered when assessing whether the project has been successful:

- Tests to compare fibre measurements and calculations have been carried out;
- Transformer management systems have been installed at the trial sites and performing correctly;
- An understanding of whether an improved rating can be assigned to primary transformers has been developed.
- A thermal model has been verified and its accuracy results/future improvements documented in the project final report.

Project Partners and External Funding

The project partner will be Wilson Transformer Company for the supply, installation and commissioning of TMS equipment.

Potential for New Learning

The main learning that will be shared with other DNOs is expected to include:

- An improved understanding of transformer thermal behaviour and asset utilisation;
- What is a safe enhanced transformer rating;
- The required minimum specification for TMS equipment; and
- What policies need to be developed to implement Power Transformer Real Time Thermal Rating.

Scale of Project

The trial will be carried out at 2 Primary substations and will monitor 6 primary transformers:

- Four Transformers will be monitored at Lithos Road 66/11kV substation; and
- Two Transformers will be monitored at Weybridge Town Primary 33/11kV substation.

The second trial will be carried out at circa 12 primary substations and will monitor all connected primary transformers on those substations.

These first trial would be representative of typical primary substation installations within LPN (urban) / SPN (rural) and how the trials could be repeated at other primary sites following successful testing with minimum retrofit equipment.

The second trial would be representative of typical primary substations installations across all three license areas (LPN, SPN and EPN) and will demonstrate configuration for minimum retrofit equipment.

Some elements of remote monitoring of the equipment will be managed from the control centre at Fore Hamlet, Ipswich. In the second trial, the project will configure remote monitoring data from all sites into a central transformer management platform.

Due to the complexity, network criticality and asset health the second trial will be carried out at seven primary substations with 16 transformers in total and will monitor all connected primary transformers on those substations. These sites were selected following discussions with infrastructure planners and control engineers considering the following:
- Transformer and Assets health.
- Replacement/Deferment.
- N-1 situation (Important customers/impact in case of issues).
- Constraints by other assets (bushings, cables, circuit breakers, etc.)
- Network Arrangements (faults, other circuits).

Technology Readiness at Start

TRL7 Inactive Commissioning

Technology Readiness at End

TRL8 Active Commissioning

Geographical Area

Work has been carried out to review and select appropriate trial sites. We currently expect to proceed with the trial in the following areas, subject to detailed design and also subject to any outage restrictions:

Area 1: London Power Networks - North West London - Lithos Road 66/11kV SS.

Area 2: South Eastern Power Networks - Surrey - Weybridge Town 33/11kV SS.

This project will comprise 2 Primary substations having 6 transformers in total. 4 transformers at Lithos Road 66/11kV substation LPN area and 2 transformers at Weybridge Primary 33/11kV substation SPN area.

Revenue Allowed for the RIIO Settlement

All sites have been chosen since they present multiple constraints during the RIIO-ED1 period. Following completion of the trials, a decision will be made on whether to proceed with the deferment of the primary transformers replacement at these sites in the later part of the RIIO ED1 period.

Please note that the sites being targeted by this project are not those where UK Power Networks have committed to deliver net savings during the ED1 period. The ED1 committed sites are being targeted by UK Power Networks using findings from and in parallel to this project.

Indicative Total NIA Project Expenditure

£1,820,853 is the total expenditure which is expected to be incurred. The split of the expenditure is shown below:

LCNF Tier 1: £323,980
NIA: £1,496,873
Additional NIA Project Expenditure requested in this change request is : £298,853

The financial split has changed between LCNF and NIA due to the additional time required to resolve technical issues, contractual negotiations and order placement for the TMS equipment.
Furthermore following internal stakeholder feedback the additional software platform requirements resulted in additional system requirements. The software platform will provide (on trigger) an optimisation tool that will produce updated thermal coefficient values. The historical data will be used to derive appropriate coefficient values and this will be specific to each Transformer.
In addition due to the complexity of each site following the actual surveys there is additional installation costs compared to the initial budgeted costs to be able to connect the monitoring equipment on each specific site (scaffolding, cable pulling, ..etc)

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Following the successful demonstration of real time thermal rating, UK Power Networks has committed to deliver £15m of net savings during the ED1 period, by deferring the replacement of Primary Transformers by at least 3 years.

Please provide a calculation of the expected benefits the Solution

- Base Cost (Cost of replacing 6 primary Transformers) = £4,500,000
- Method cost (Benefits of deferring the replacement by 3 years + Cost of fitting TMS to 6 Txs) = £4,426,966
- Financial benefits = Base Cost – Method cost = £73,034

Please note that the method cost includes the present value of eventually replacing the transformer.

Please provide an estimate of how replicable the Method is across GB

Source: UK Power Networks Business Plan (2015 – 2023), Annex 9: Smart Grid Strategy

Based on the commitment made in our smart grid strategy on Dynamic Transformer Rating, it is estimated that approximately 225 primary transformers could be equipped across GB.

Please provide an outline of the costs of rolling out the Method across GB.

The average cost of each installation is estimated to be £73k per Transformer

Estimated cost of rolling out to GB = £16.5m

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☐ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify

repeating it as part of a project) equipment (including control and communications system software).

☑ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☑ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

If successful, the learning could be used by relevant Network licenses to apply real-time thermal ratings to their grid and primary transformers

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

Innovation strategy capability themes addressed:

- Understand the condition of our assets;
- Managing asset risk and improving fault performance; and
- New options to release capacity at 11kV, 33kV and 132kV.

The project is focussed on the release of capacity, but provides more information about transformer condition at the same time, hence assisting in managing asset risk.

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

No DNO (LCNF or IFI project) is currently planning to operate primary transformers close to their thermal limits whilst using a suitable TMS fitted to carry out thermal calculation and pre-cooling, to ensure design limits are not exceeded during N-1 condition, and provide enhanced real time thermal rating.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

n/a

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

n/a

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

n/a

This project has been approved by a senior member of staff

☑ Yes