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# NIA ENWL004
# Combined Online Transformer Monitoring

## Progress Report

**31 July 2018**

## VERSION HISTORY

| Version | Date | Author | Status | Comments |
|---|---|---|---|---|
| V1.0 | 1 June 2018 | Paul Marshall<br>Project Manager | Final | Final version following internal review and comment |

## REVIEW

| Name | Role | Date |
|---|---|---|
| Lucy Eyquem | Innovation PMO Manager | 19 July 2018 |
| Paul Turner | Innovation Manager | 25 July 2018 |

## APPROVAL

| Name | Role | Date |
|---|---|---|
| Steve Cox | Engineering & Technical Director | 31 July 2018 |

# CONTENTS

# GLOSSARY

| Term | Description |
|---|---|
| DGA | Dissolved gas analysis |
| DNO | Distribution network operator |
| IFI | Innovation Funding Incentive |
| IPR | Intellectual property rights |
| LCN Fund | Low Carbon Networks Fund |
| NIA | Network Innovation Allowance |
| PD | Partial discharge |
| RIIO-EDI | First electricity distribution price control to reflect the new RIIO model (Revenue = Incentives + Innovation + Outputs) |

# 1 PROJECT FUNDAMENTALS

| Title | Combined Online Transformer Monitoring |
|---|---|
| Project reference | NIA_ENWL004 |
| Funding licensee(s) | Electricity North West Limited |
| Project start date | September 2014 |
| Project duration | 8 years |
| Nominated project contact(s) | Paul Marshall (innovation@enwl.co.uk) |

# 2 PROJECT SCOPE

Previous research carried out under an Innovation Funding Incentive (IFI) project defined an oil regeneration window for transformers at or near the end of their design life which would extend it by approximately ten years. The First Tier Low Carbon Networks Fund (LCN Fund) project deployed online monitoring equipment at six sites where the oil regeneration technique will be used.

This Network Innovation Allowance (NIA) version of the First Tier project will validate the data from the monitoring equipment and use it to calibrate the previous IFI research. These results will then be fed into data visualisation software that has been developed to allow consistent comparison.

Electricity North West will work closely with an academic resource to validate the data and calibrate the life extension results once sufficient online data has been recorded for a significant time period to allow the results to be reliable and consistent.

# 3 OBJECTIVES

This project is split into two distinct phases:

**Phase 1:** the development of a dashboard/decision tool to be used by Electricity North West. This phase was completed by April 2016.

**Phase 2:** the data validation of existing research into transformer life extension by oil regeneration. This phase was due to be completed by September 2017 but has been extended to allow for further chemical ageing and degradation processes to occur and to be validated against the research results.

# 4 SUCCESS CRITERIA

- Completion of a dashboard and decision tool utilising the online results
- Validation and calibration of the actual end of life oil regeneration results against predicted values derived from academic research.

# 5 PERFORMANCE COMPARED TO THE ORIGINAL PROJECT AIMS, OBJECTIVES AND SUCCESS CRITERIA

The project is currently on target against the original aims, objectives and criteria for oil regeneration. However, due to the importance of the tap changer acoustic monitoring innovation research a separate project has been established to focus on that area and consequently it is no longer considered as part of this project. The tap changer project is NIA_ENWL012 Tap Changer Monitoring.

The project uses the online dissolved gas analysis (DGA) and partial discharge (PD) monitoring equipment previously installed under First Tier funding to continue to monitor the condition of six 132kV transformers.

The first phase of the project was the development of a dashboard/decision tool to be used by Electricity North West. This phase has been successfully completed and a monthly report is produced showing the condition of the six transformers.

One of the transformers had its oil regenerated six years ago as part of the initial IFI oil regeneration research. As this transformer was one of the first within Electricity North West to have its oil regenerated, it is considered to be valuable learning for the project to monitor its condition; although it should be acknowledged that its condition may differ as it was regenerated under research conditions and did not follow the current Electricity North West policy for oil regeneration.

Delays in implementation of oil regeneration due to the complex nature of the process have impacted on the data validation phase. Transformers at two different substations have had their oil regenerated and are currently in the data collection phase. It is planned that the other two sites will have their oil regenerated during the 2018 summer period.

The chemical degradation process within transformer oil is a very complex and slow process. The oil acts as the coolant and part of the insulation together with oil-impregnated paper and board. Both of these materials are affected by several different ageing processes, and are also affected by each other. Therefore the project's duration has been extended to six years to allow time for the chemical ageing and degradation process to occur and be validated against the research results.

The data collected will allow further academic research to be undertaken to develop an understanding of the effects of life extension on failure modes and maintenance requirements of assets. The actual data will calibrate the theoretical research data to prove that oil regeneration is a safe, reliable and cost-effective asset management technique which can be used to extend the operating life of a transformer.

The project is split into two distinct phases:

**Phase 1:** the development of a dashboard/decision tool to be used by Electricity North West.

This phase has been successfully completed and a monthly report is produced on the condition of the six transformers selected for the trial. This report consists of high level red, amber and green status management reporting. All of the transformer monitoring techniques are based on international measurement standards. The data visualisation also provides the ability to further analyse more in-depth data for dissolved gas analysis, bushing monitoring and partial discharge which is trended over a suitable time period. This monthly data visualisation and reporting now encompasses all the DGA and PD monitoring equipment that Electricity North West has installed.

The reporting covers a fleet overview, a high level short-term actions check list, a summary of fleet condition and exception reporting, and site specific details as shown below:

*Figure 5.1: Fleet overview*

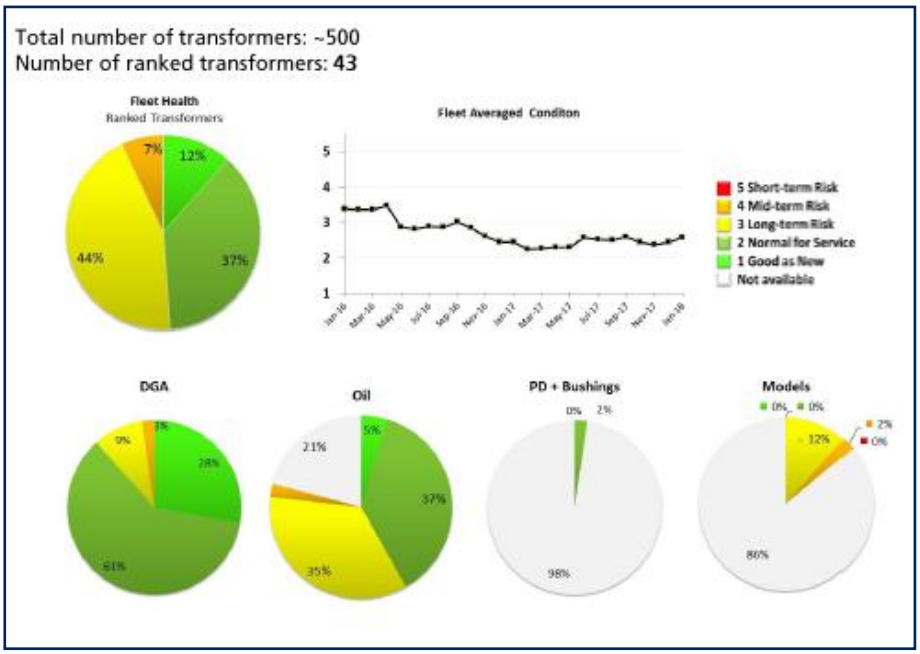



*Figure 5.2: High level short-term actions check list*

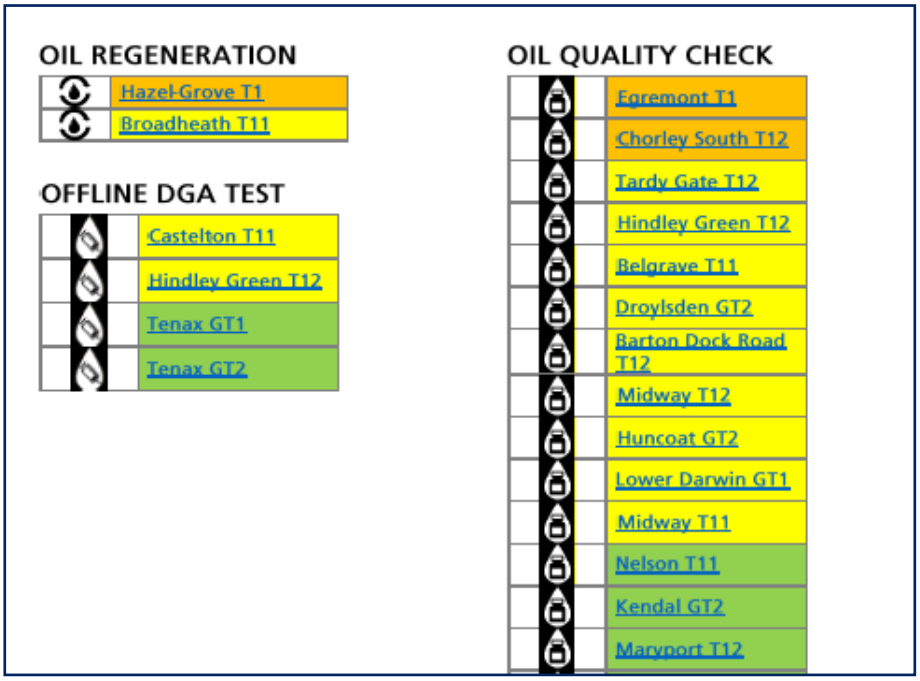
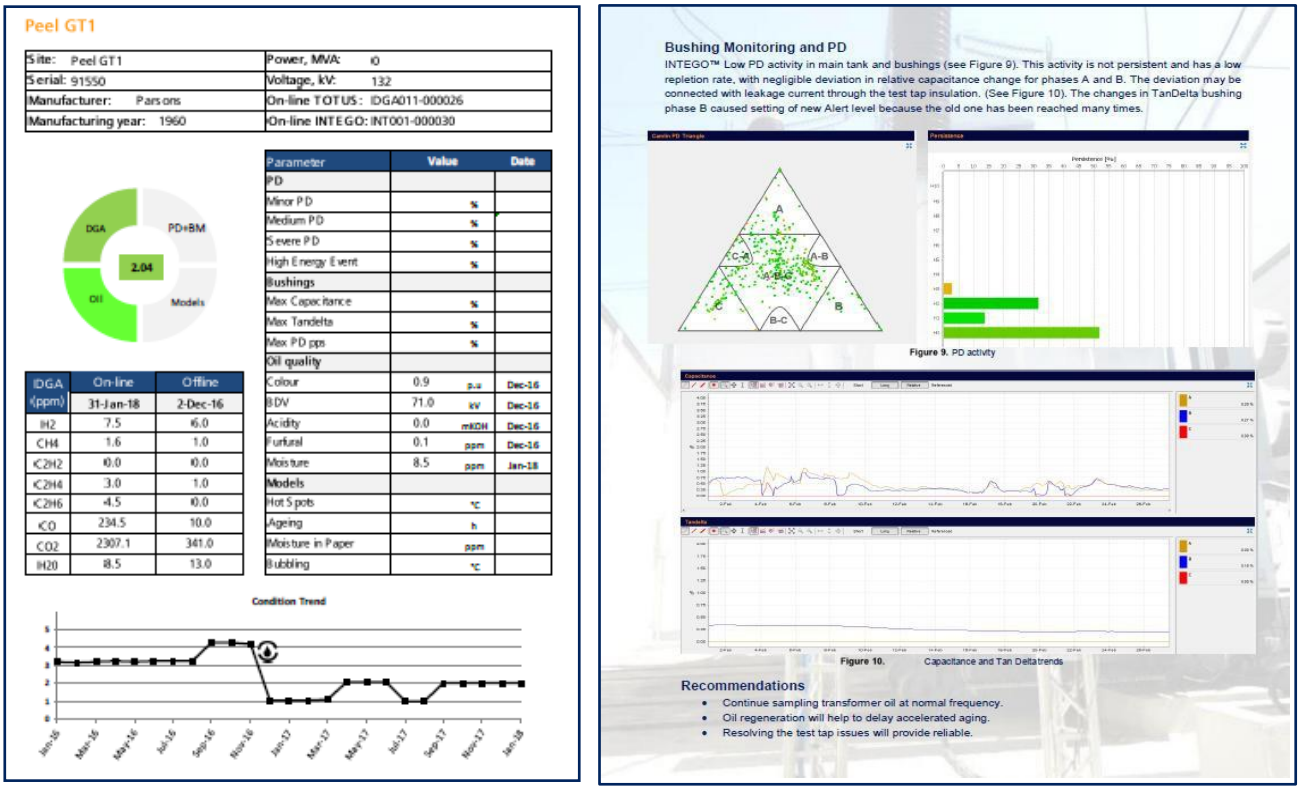


*Figure 5.3: Summary of fleet condition and exception reporting*

| Activity required | Transformer | January 2018 Condition | Previous condition | Comments | Monitoring system status |
|---|---|---|---|---|---|
| | | | | lab that affects insulation strength. Moisture from lab is different to online data. It is necessary to repeat oil sampling for moisture content and BDV. | |
| | Broadheath T11 | 3.10 | ⇩ 3.13 | Significant oil aging. Moisture from lab is different to online data. Oil quality sampling should be repeated. Oil reclamation should be planned. | |
| | Huncoat GT2 | 3.10 | ⇧ 3.07 | There is relatively low breakdown voltage obtained in lab that affects insulation strength. Moisture from lab is different to online data. It is necessary to repeat oil sampling for moisture content and BDV. | |
| | Lower Darwin GT1 | 3.08 | ⇧ 2.09 | Moderate moisture concentration in cellulose obtained by models calculation. Oil regeneration was done in 2017. Moisture from lab is different to online data. Oil quality sampling should be repeated. | |
| | Midway T11 | 3.06 | 3.06 | Moderate moisture concentration in cellulose obtained by models calculation. . Moisture from lab is different to online data. Oil quality indices should be updated. | |
| | Bispham GT1 | 2.15 | 2.15 | No additional action required. | |
| | Nelson T11 | 2.14 | ⇩ 2.16 | Moisture from lab is different to online data. Oil quality sampling should be repeated. | |
| | Tardy Gate T11 | 2.12 | 2.12 | No additional action required. | |
| | Barton Dock Road T11 | 2.11 | 2.11 | Stead increase of CO and CO2 to pre-regeneration concentration. No additional action required. | |
| | Bamber Bridge T11 | 2.11 | ⇩ 2.13 | No additional action required. | |
| | Kendal GT2 | 2.09 | 2.09 | Oil quality analysis required for initial reference. | |
| | Huncoat GT1 | 2.08 | ⇧ 2.01 | No additional action required. | |

*Figure 5.4: Site specific details*



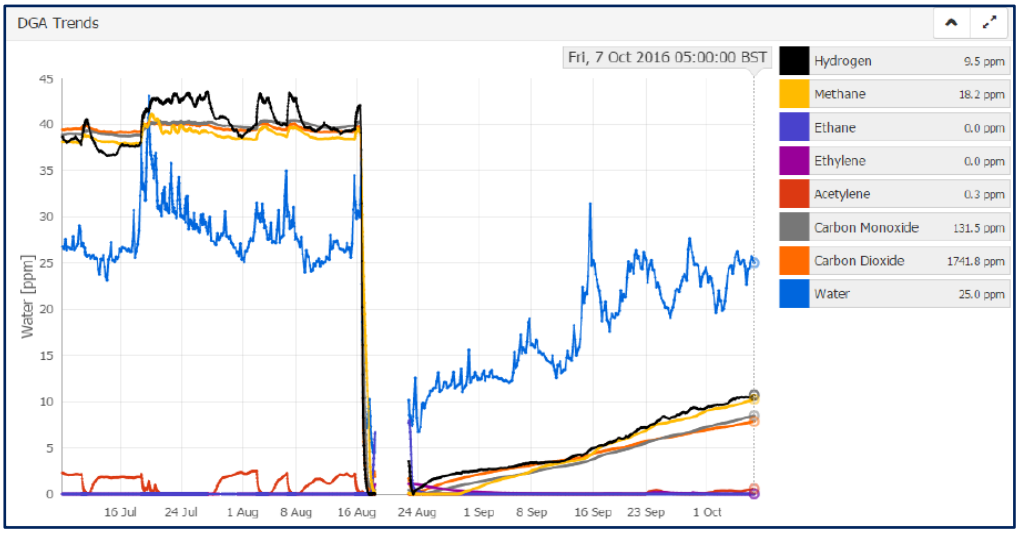
**Phase 2:** the data validation of existing research into life extension by oil regeneration.

This phase was due to be completed by September 2017 but has been extended to allow for further chemical ageing and degradation processes to occur and to be validated against the research results.

The oil regeneration process has been developed over a number of years to reach its current successful state. Early attempts revealed that where the oil regeneration process was completed too quickly, (ie in a few days) that the core of the transformer was not raised to the desired 65-85 Deg C. An example of this can be seen in the DGA graph for Barton Dock below which shows the chemical trends before and after oil regeneration in August 2016.

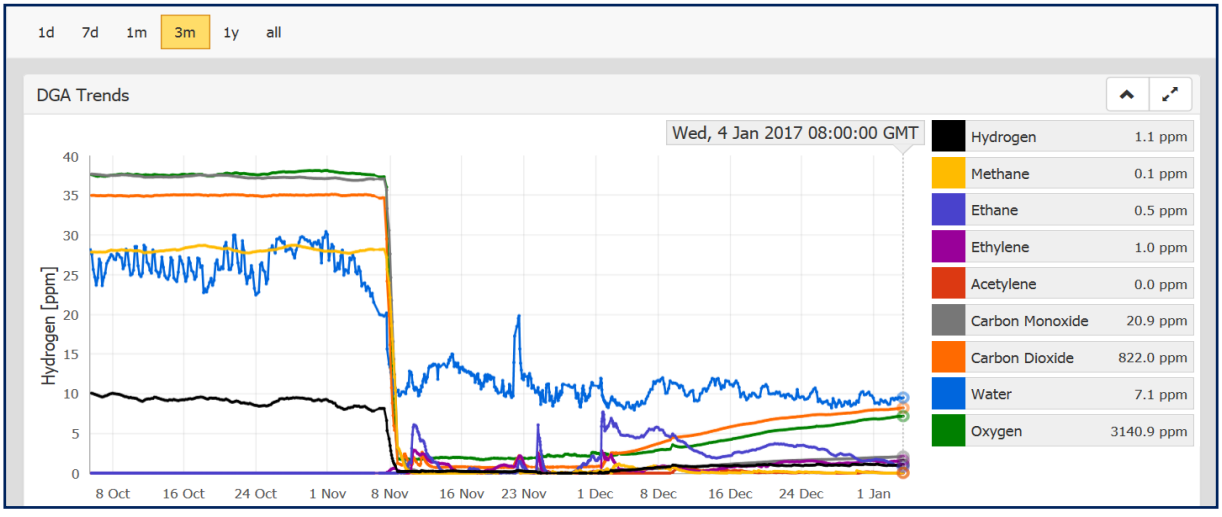
Following the transformer oil regeneration it can be seen that in the following months the oil condition returned to pre-regeneration levels leading us to conclude that the process required modification if it was to achieve its stated aims.

*Figure 5.5: Chemical trends before and after oil regeneration – Barton Dock transformer*



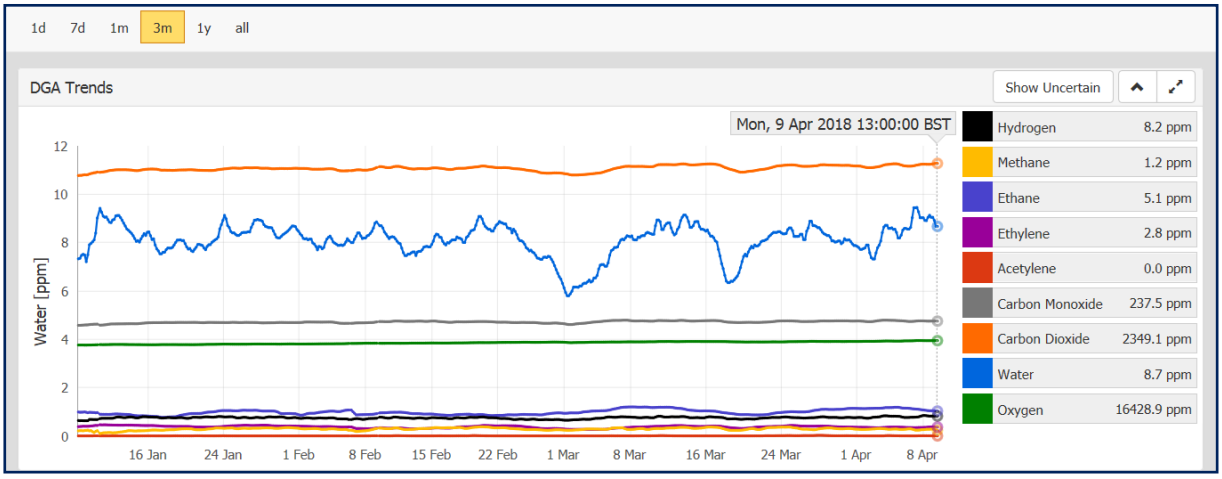

The graph below is an example of a successful oil regeneration process where the oil is cleaned in stage one of the oil regeneration process over a few days. This is followed by stage two where the core of the transformer is raised to 65-85 Deg C, which is the optimum range to heat the mineral oil to its aniline point when it becomes an effective solvent for its own decay product including sludge and water on the cellulose paper insulation. After the stage two oil regeneration process the DGA graph does not return to pre-oil regeneration levels as previously shown for the Barton Dock transformer.

*Figure 5.6: Successful oil regeneration – Peel substation, January 2017*



Continuing analysis of the transformer revealed that the DGA trends continued to remain at low levels validating that the oil regeneration process was successful.

*Figure 5.7: Successful oil regeneration – Peel substation, April 2018*




Electricity North West will work closely with an academic resource to validate the data and calibrate the life extension results once online data has been recorded for a significant time period to allow the results to be reliable and consistent

# 6 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

No modifications to the planned approach are required at this time although the selection of three alternative sites coupled with some delay in the planned oil regeneration dates will impact on the data validation and project end dates.

Due to the importance of the tap changer acoustic monitoring innovation research a separate project has been established to focus on that area in more detail across 40 sites and therefore it is no longer considered as part of this project. The tap changer project is NIA_ENWL0012 Tap Changer Monitoring.

# 7 LESSONS LEARNED FOR FUTURE PROJECTS

The oil regeneration research has been embedded as business as usual within Electricity North West as part of its RIIO-EDI strategy and could easily be adapted by other distribution network operators (DNOs).

# 8 THE OUTCOME OF THE PROJECT

Not applicable.

# 9 DATA ACCESS

Electricity North West's innovation data sharing policy can be found on our website.

# 10 FOREGROUND IPR

Not applicable.

# 11 PLANNED IMPLEMENTATION

Not applicable.

# 12 OTHER COMMENTS