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NIA ENWL014

Optimising Oil Regeneration for Transformers

Closedown Report

31 July 2023

VERSION HISTORY

Version	Date	Author	Status	Comments
V1	21/07/23	A Howard	Draft	
V2.0	26/07/23	A Howard	Final	

REVIEW

Name	Role	Date
Ben Ingham	Innovation Technical Manager	26/07/23
Geraldine Paterson	Innovation Manager	26/07/23

APPROVAL

Name	Role	Date
Victoria Turnham	Head of Innovation	30/07/23

CONTENTS

GLOSSARY

Term	Description
DGA	Dissolved Gas Analysis
HV	High Voltage
IFT	Interfacial Tension
mg KOH/g	milligrams of potassium hydroxide (KOH) equivalent to one gram of epoxy hardener resin. (A measure of nitrogen content)

1 EXECUTIVE SUMMARY

1.1 Aims

This project built on our previous innovation work in transformer oil regeneration and transformer oil monitoring. It analysed transformers over a 6-year period to identify the optimum period in a transformers life to carry out oil regeneration to deliver the best benefit.

1.2 Methodology

The project carried out oil regeneration at 13 sites where the transformers were considered to be at midlife. A monitoring regime was put in place with sampling, both online and offline, to track any changes in the oil condition over a period of time.

Our project partner provided the on-line monitoring equipment and analysed the data collected remotely from this instrumentation, along with results obtained from physical oil samples taken on site. Combining this analysis with asset data provided by ENWL, including details of the oil regeneration they were able to track the oil condition over the 6 years of the project.

1.3 Outcomes

The project met all objectives and success criteria, producing expected learning on the degradation of transformer oil over a period and identifying optimum points for oil regeneration.

1.4 Key learning

The project reconfirmed the benefits of oil regeneration across a number of asset types and ages.

It identified a small number of key metrics and values at which oil regeneration can be optimised.

It reconfirmed that a major driver to transformer asset life is its electrical loading (heating effect) which can make predictions of future life measured in years difficult.

1.5 Conclusions

The analysis has concluded that there is an optimum time for oil regeneration in 132kV/33kV and 33kV/HV transformers.

The optimum time is during the assets mid-life (30-45 years from installation) where:

Oil Acidity is in the 0.05 – 0.18 mg KOH/g range.

Oil Colour is in the 2-3 range.

1.6 Closedown reporting

This project was compliant with Network Innovation Allowance (NIA) governance and this report has been structured in accordance with those requirements.

This report and the associated documents are available via the Energy Networks Association's Smarter Networks learning portal at www.smarternetworks.org or via the Electricity North West website.

1 PROJECT FUNDAMENTALS

Title	Optimising Oil Regeneration
Project reference	NIA_ENWL014
Funding licensee(s)	Electricity North West Limited
Project start date	February 2016
Project duration	6 years
Nominated project contact(s)	innovation@enwl.co.uk

2 PROJECT BACKGROUND

As part of operating an efficient network Distribution Network Operators need to maximise the use of existing assets. This forms a key part of Electricity North West's (ENWL) Innovation strategy for RIIO ED1.

ENWL has proposed that approximately 50% of the 132kV and 33kV transformers due for renewal in the RIIO-ED1 period will now be refurbished and their oil regenerated to reduce their current Probability of Failure and extend asset life.

This approach aims to maximise the life span of the transformers past their original design life thus deferring their replacement and also avoiding de-rating based on age.

There is a need for further research and development to explore the maximum life of a transformer and understand the optimum point that oil regeneration can be applied in the life cycle of the transformer to take full advantage of the technique and maximise the life of the transformer.

An optimal lifetime window for conducting oil regeneration exists according to theoretical analysis but the extent of this window could vary with ageing characteristics of the insulation, operational conditions of the transformer etc.

The project will build upon earlier First Tier research into oil regeneration towards the end of transformer life by further exploring oil regeneration in transformers at the various mid points of their nominal life to determine whether deploying the technique earlier will extend the transformer's operable life further.

The project will carry out field trials to identify the optimum point at which oil regeneration can be used in the life cycle of a transformer. To ensure a representative sample of the transformer population is analysed, a varying number of transformers with different manufacturing periods, designs and operating environments will be selected at near identical twin transformer sites.

The oil will be regenerated on one of the twin transformers and both transformers shall be left to naturally age and be monitored over the projects duration to investigate the new expected lifespan of the mid-life oil regenerated transformer compared to the untouched twin

transformer. The results will inform the optimum intervention strategy which can then be utilised in future asset investment plans.

3 PROJECT SCOPE

Previous research carried out under an IFI project suggested that oil regeneration carried out in a window at the end or near the end of a transformer's nominal life would extend life by approximately ten years. The First Tier LCN Fund project deployed online monitoring equipment at six sites where the oil regeneration technique was used.

The NIA project will build on this research by exploring the optimum point to apply oil regeneration to a transformer fleet. It is acknowledged that the life of oil impregnated paper insulation determines the maximum potential life of a transformer, although other factors may cause it to fail earlier. This project scope will aim to determine if mid-life oil regeneration can reduce the rate of paper degradation, and thereby further extend the lifespan of the transformer compared to oil regeneration at end of life.

For this project, ten 33kV paired transformers and three 132kV paired transformers (13 sites, 26 transformers) which are at various stages of their design life will be identified. At each site, only one of the transformers will undergo oil regeneration.

Online monitoring equipment will be installed on both transformers at each site to allow comparison of their oil condition and to determine the theoretical life extension over time. These results will be fed into the previously funded data visualisation software to allow consistent comparison.

ENWL will work closely with industry experts to validate the data and calibrate the life extension results. The project will allow ENWL to develop its understanding of the effects of life extension on transformer failure modes and maintenance requirements and to identify the optimum window for oil regeneration in the life cycle of transformers.

4 OBJECTIVES

This project is split into three distinct phases:

- Phase 1 is research into and design/sourcing of an oil regeneration unit to carry out the oil regeneration at the 13 sites. This phase was completed in September 2016.
- Phase 2 implements oil regeneration at 13 mid-life transformer sites and installs condition monitoring equipment. This phase was completed in 2018.
- Phase 3 is the data analysis and optimisation of the oil regeneration practice. This phase is to be completed by February 2022.

5 SUCCESS CRITERIA

- Specification and sourcing of an oil regeneration unit capable of delivering the required oil quality in a controlled manner. Completed.
- Complete the implementation of oil regeneration and condition monitoring equipment at 13 transformer sites at mid-life.

- Data acquisition, analysis, and validation to identify the optimum point of oil regeneration in a transformer life cycle. Ongoing data collection.

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

The project has successfully delivered the original aims, objectives, and criteria for optimising oil regeneration. However, to ensure the maximum learning is delivered the project was extended to September 2022 to allow more time for the final analysis.

All the sites had oil regeneration carried out by December 2018 and each transformer has been fitted with identical DGA monitoring.

As with the Combined Online Transformer Monitoring project, the chemical degradation process within oil is very complex and a slow process. The oil acts as the coolant and part of the insulation, together with oil-impregnated paper and board. Both types of material are affected by several different ageing processes, and both materials are affected by each other. Therefore, the project has run for several years to allow the chemical ageing and degradation process to occur.

All the sites had oil regeneration carried out by December 2018 and each transformer was fitted with identical DGA monitoring to monitor the following parameters:

- Oil quality parameters
    - IFT (Interfacial Tension)
    - Acidity
    - Moisture
    - Breakdown Voltage
    - Colour
- Load
- Oil Temperature
- Ambient Temperature
- DGA gases (H2, CH4, C2H2, C2H4, C2H6, CO, CO2, O2, N2)
- Moisture in oil

To aid the understanding of the analysis the parameters were combined into:

- Health Score (1-5)
- Content of Moisture in the cellulose
- Online Oil Break-Down Voltage
- Ageing Speed

Once we had collected a significant amount of data we engaged with an industry expert to validate it. This allowed the results to be reliable and consistent and allowed the process to be calibrated to provide the maximum benefits.

7 THE OUTCOME OF THE PROJECT

Our previous innovation projects researched, designed, and built an Oil Regeneration unit which ENWL used to regenerate the transformer oil at 13 sites.

Using the online and offline oil sampling a history of results has been created and analysed. The combination of the detailed data into a smaller number of parameters has provided benefit in understanding the information collected and enabling comparison between transformers.

The analysis was used to identify the optimum point of oil regeneration in a transformer life cycle and therefore satisfy the scope of this project.

The project concluded that the optimum time for oil regeneration in 132kV/33kV & 33kV/HV transformers is at the assets mid-life (30-45 years from installation).

The project reconfirmed the benefits of oil regeneration across several asset types and ages and identified a small number of key metrics and values at which oil regeneration can be optimised.

The project also reconfirmed that a major driver to transformer asset life is its electrical loading (heating effect) which can make predictions of future life measured in years difficult.

8 REQUIRED MODIFICATIONS TO THE PLANNED APPROACH DURING THE COURSE OF THE PROJECT

As the data from the regenerated transformers was being collected, collated, and analysed it was recognised that there would be additional value in extending this phase to improve the quality of the final report. This change was implemented and reported in the annual report.

ENWL believe this extension has improved the quality in findings and has been justified.

9 LESSONS LEARNED FOR FUTURE PROJECTS

Several lessons and opportunities for future work and improvement where identified. ENWL are considering if these are best progressed as a future innovation project(s) or as an evolution of business-as-usual systems and operating practice

This learning includes:

- Continued programme of online and offline oil sampling, and continued collation of data.
- Continued analysis of data to extend knowledge over a greater time period to identify any new trends.
- Improving the assessment of the impact of temperature on the speed of ageing, and how information on transformer loading and oil assessments can be combined in a practical manner.
- Amending the current frequency, scope, and quality of current sampling regime to further improve data used for analysis.
- Remaining aware of technology developments that may improve future sampling regimes.

10 PLANNED IMPLEMENTATION

ENWL now have a track record of innovation projects around major transformer asset condition and oil management. The learning from previous projects has already been implemented in the management of this asset group and the learning from this project will be rolled out in the same manner.

11 DATA ACCESS

The data gathered as part of this project is applicable to specific ENWL assets and is of limited value to external stakeholders. The data could be made available on request in line with our innovation data sharing policy which can be found on our website.

12 FOREGROUND IPR

There is no foreground IPR associated with this project.

13 FACILITATE REPLICATION

All learning from this project is published on ENWL's website and will be shared on the Smarter Networks Portal to ensure that other network operators can build on the project work or consider it for their business practices. We have held network operator dissemination sessions on oil regeneration as part of the previous innovation projects and the output of this project provides more detail on when this should be carried out.

14 OTHER COMMENTS

None.