Oil Regeneration in 132kV and 33kV Transformers

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Agenda

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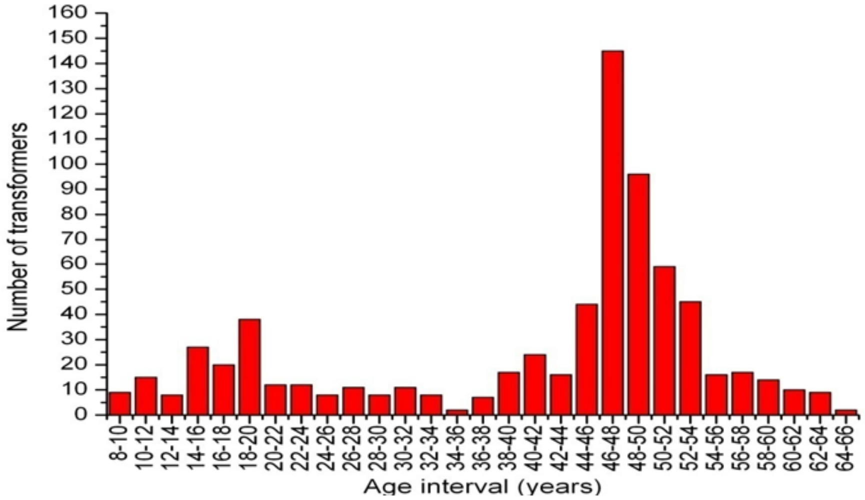
- Introduction
- Research
- IFI oil regeneration project
- Oil regeneration results
- Oil regeneration in asset management
- Optimising oil regeneration

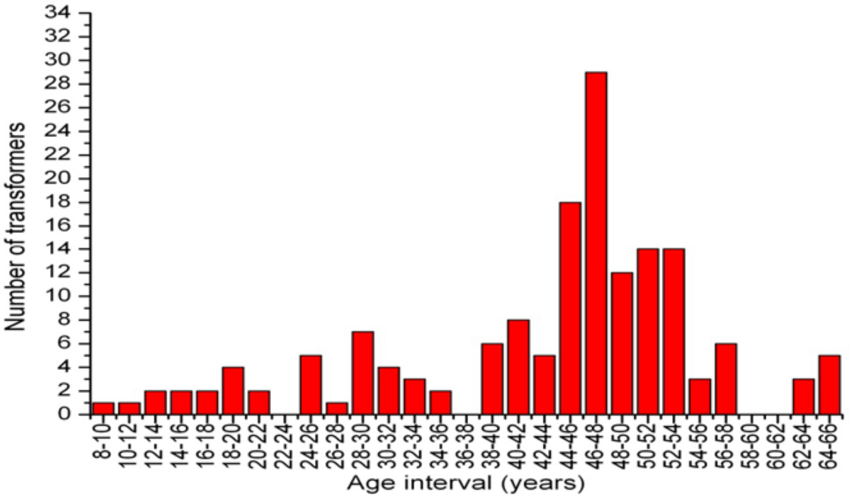
Transformer fleet

33 kV transformers



720 units
345 predicted end of life by 2023
100 units viable for re-generation

132 kV transformers



180 units
45 predicted end of life by 2023
20 units viable for re-generation

Transformer strategy – our focus today

Objective £40 – 50 million savings

Use CBRM to reliably manage the fleet

85% reduction in unit cost v replacement

Improve unit reliability

25% Bushings and connections

5% Tank and radiator

~15% Tap changer

~55% Insulation

Ageing of oil-paper insulation system

Transformer’s lifetime depends on mechanical strength of paper – the degree of polymerisation

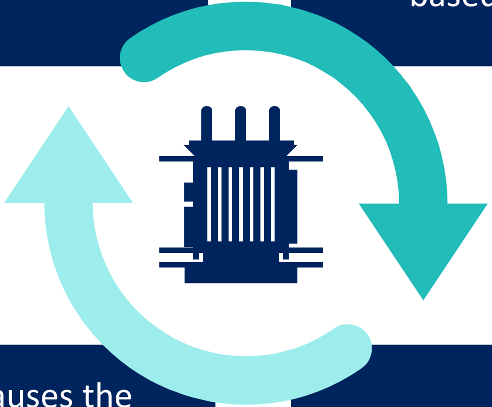
Ageing and degradation of insulation is complex Influenced by thermal, electrical, mechanical and chemical stress

Three parameters dominates ageing rate of oil and paper: temperature, water and acids

Insulating oil

Oil degrades in the presence of moisture and temperature

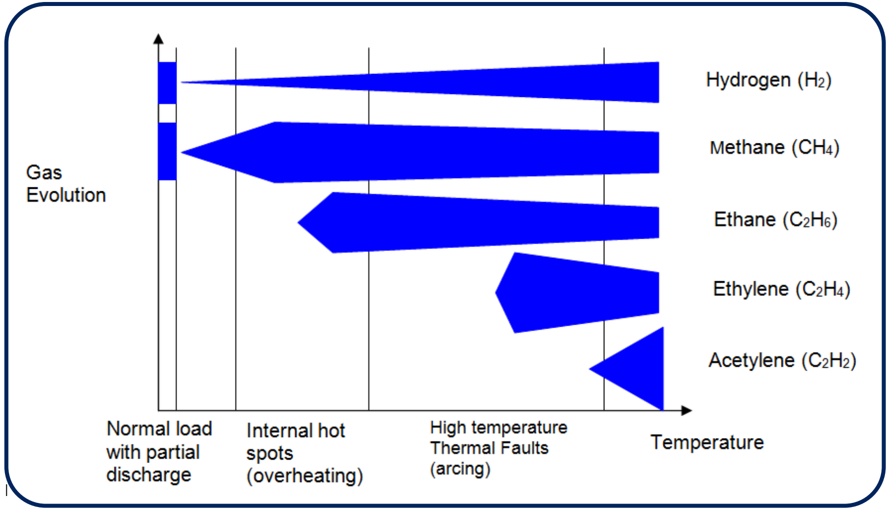
As oil degrades it produces acid which undermines cellulose based paper



As cellulose breaks down it releases more moisture into the oil

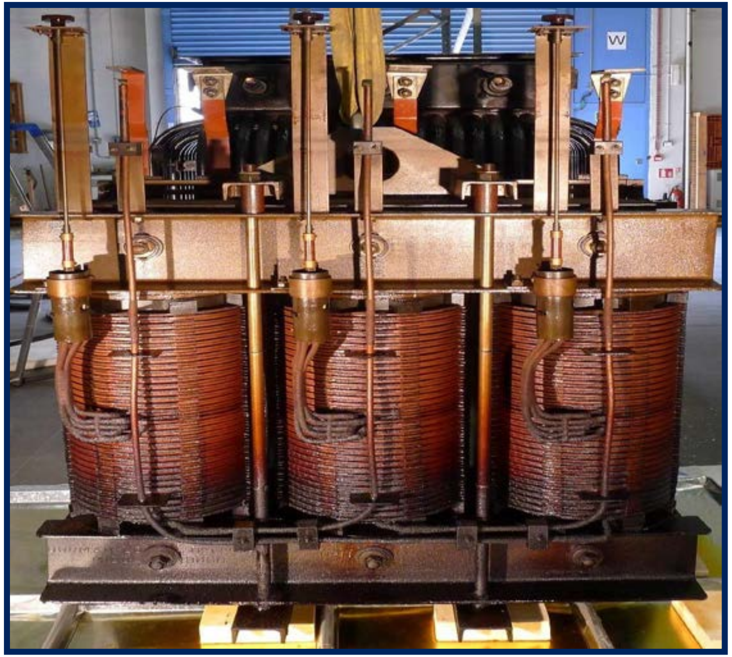
Which causes the paper insulation to irreversibly age and provides moisture to accelerate the process

Parameter	New Oil	Cautionary
Breakdown Strength	60 kV	Less than 30 kV
Acidity	0.02 mg KOH/g	0.10 to 0.15 mg KOH/g
Moisture	<10 ppm	15 to 20 ppm

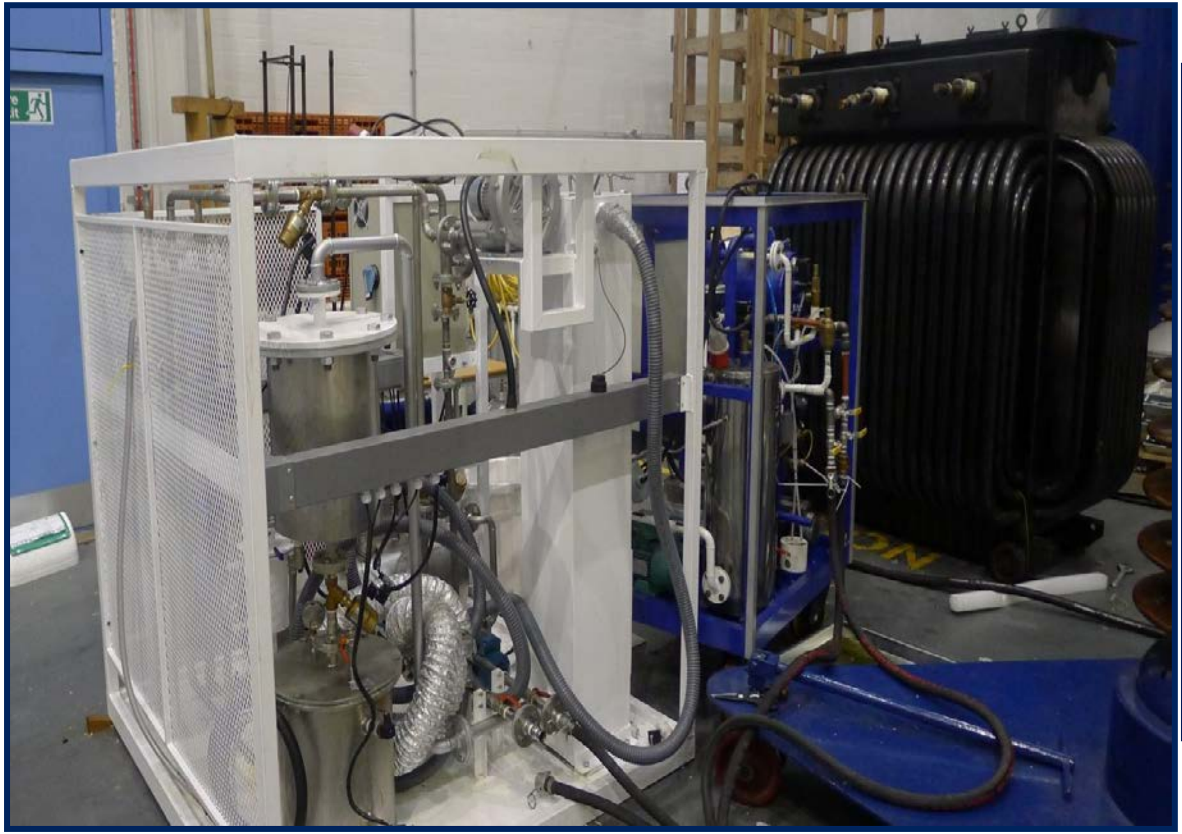


Research at UOM

Oil regeneration is not new, we are building on existing research.
Aim was take it to the next level by research into regenerating a 11kV distribution transformer where we were able to take the core temperature readings and paper samples

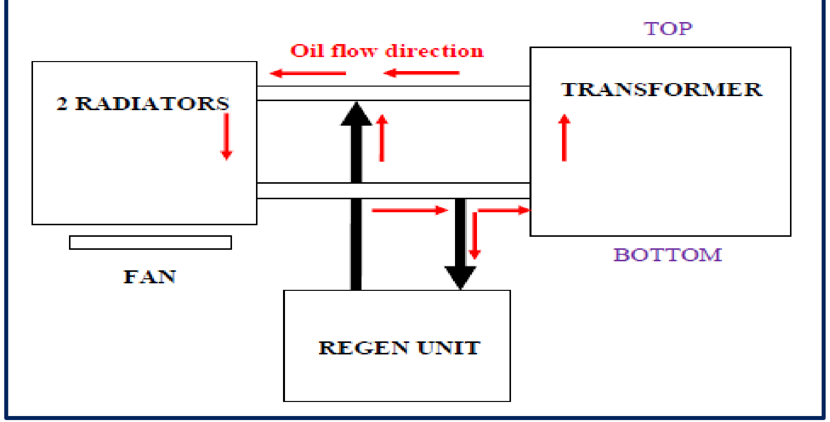


Regeneration of 11kV transformer



Trial on a 132kV transformer at Bredbury GT3

Oil regeneration process and oil flow direction during transformer on-load



The oil circuit is broken between the transformer and the radiator

'Old oil' removed from the bottom

'Reprocessed oil' fed back at the top

Became apparent during the process that the transformer had to be 'on-load'

Oil regeneration unit had to account for hot oil flowing out from the top of the transformer flowed more quickly than cold oil flowing back into the bottom

Results from Bredbury – post analysis

Parameter	Before oil re-generation	2 months after oil re-generation	8 months after oil re-generation	6 Years after oil re-generation
Acids (mg KOH/g)	0.2	0.01	0.02	0.02
Water (ppm)	20	13	13	14
Furans (ppm)	0.09	0.09	0.1	0.12
Breakdown voltage (kV)	32	60	60	60
Hydrogen (ppm)	11	0	17	12
Methane (ppm)	6.8	3.1	6	6
Ethane (ppm)	2.9	0	0	5
Ethylene (ppm)	3	4.2	6	5.8
Acetylene (ppm)	2.1	0	2	4
Carbon monoxide (ppm)	370	60	230	371
Carbon dioxide (ppm)	3010	530	1070	2782

Oil regeneration

Research proved there is an optimum window to carry out oil regeneration near end of life

Too early is not cost effective

Too late it will have limited benefit

Key learning that differs from tradition oil regeneration is we are apply a two stage approach to oil regeneration

Stage one is the traditional oil cleaning process widely used

However if left at this stage the water and sludge in the papers can migrate back into the oil typically in a year, to a slightly better state than before

Our approach is to apply a second stage oil regeneration to clean the core/papers as 95% of the moisture is held within the papers

Second stage oil regeneration

The second stage is started after the traditional oil regeneration process has been completed and acceptable levels achieved

High temperature are required as this stage as it improves the reclamation, dehydration and degassing efficiencies

Research has proven that if we get the core to 65/85Deg c we are able to accelerate second stage regeneration

These temperatures are commonly the aniline point of mineral oils used in electrical apparatus

At the aniline point, mineral oil becomes an effective solvent for its own decay product including sludge

Through hot oil circulation through the core the sludge and water on the cellulose paper insulation are at the most efficient point for removal

Second stage oil regeneration

Therefore we are able to accelerate the natural migration of water and sludge back into the oil which naturally can takes years

We are now able to complete a second oil regeneration phase for 7 to 21 days which arguably 'cleans the papers' in the transformer and eliminates traditional post regeneration natural migration

CORD mobile regeneration unit

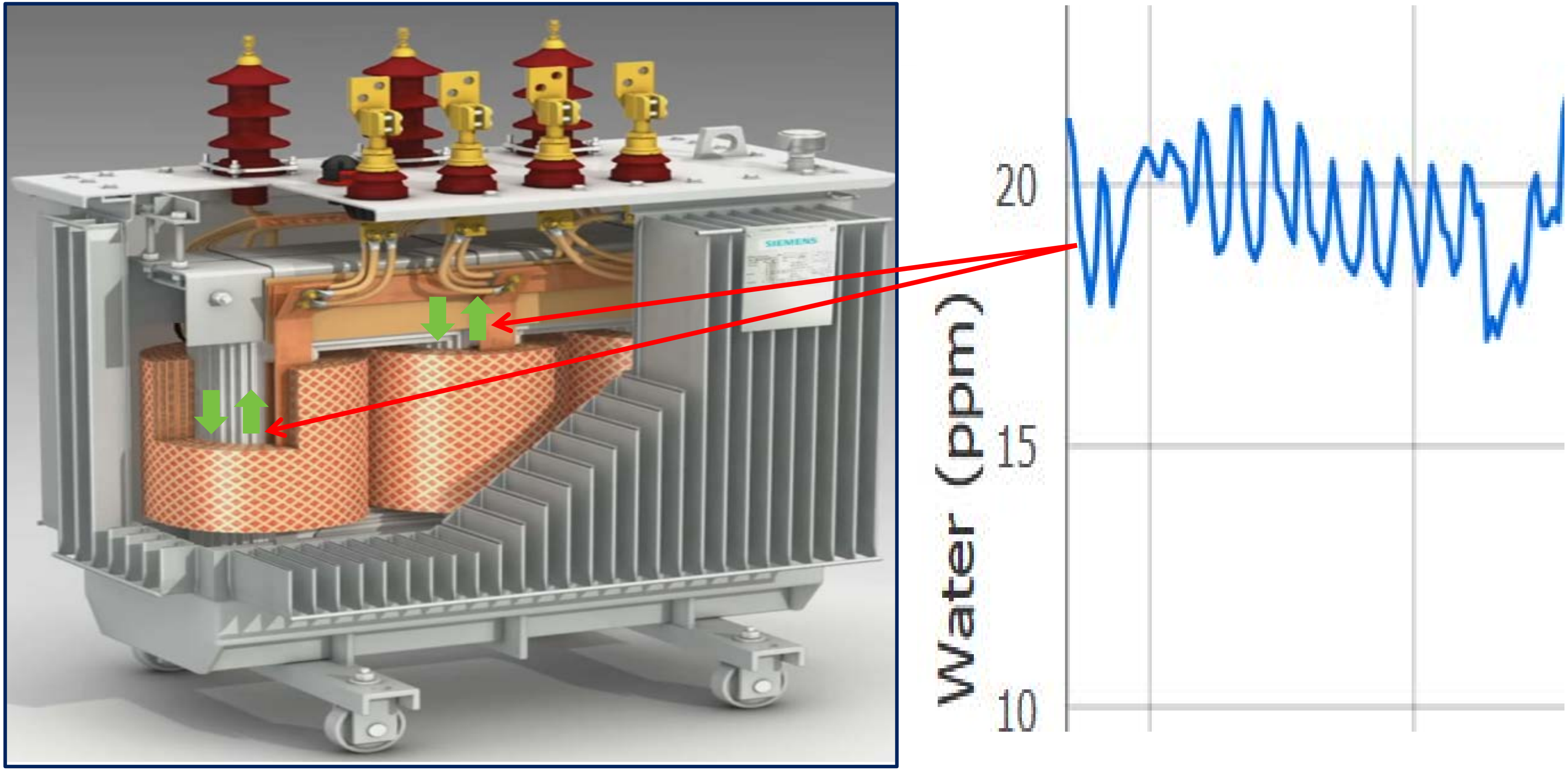
Central Oil Reprocessing Department

Mobile oil units

New modular oil regeneration unit

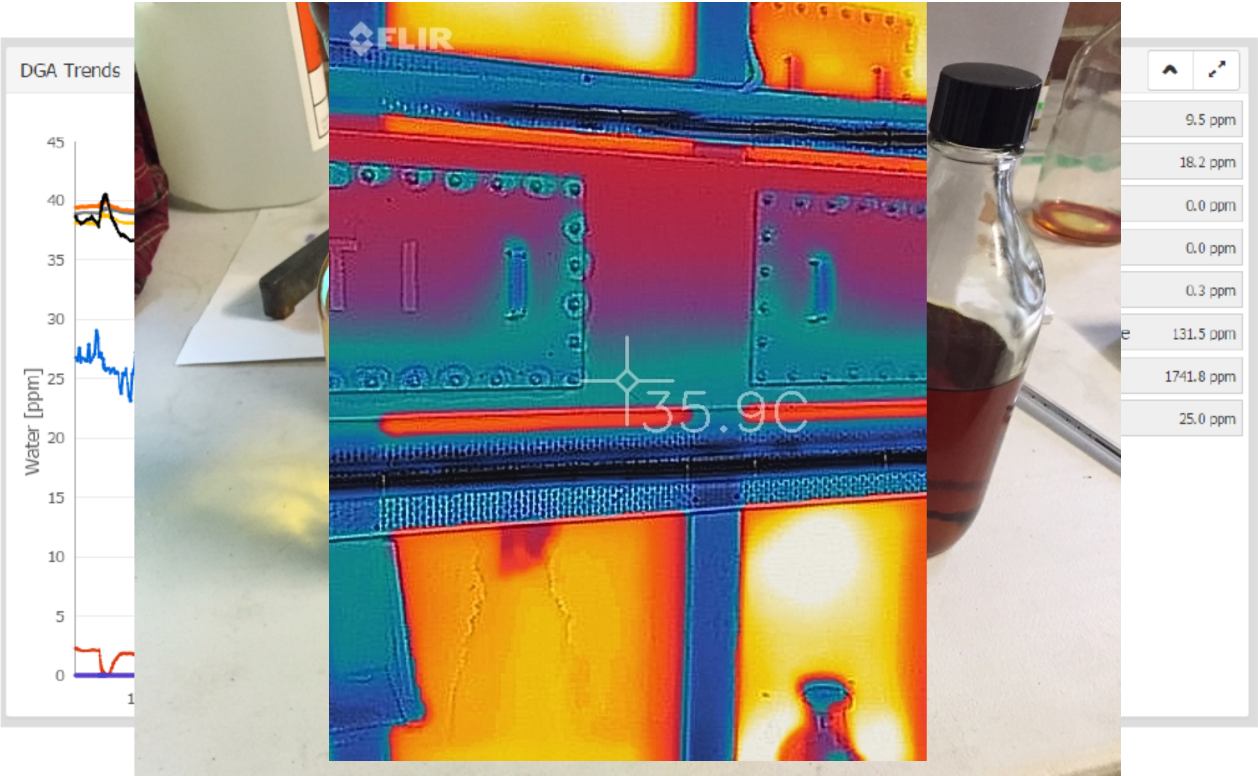
Heating & coarse filtering – regeneration – fine filtering – drying and degassing

Transformer breathing



Early failures - Barton Dock

Moisture has returned to pre-regeneration levels

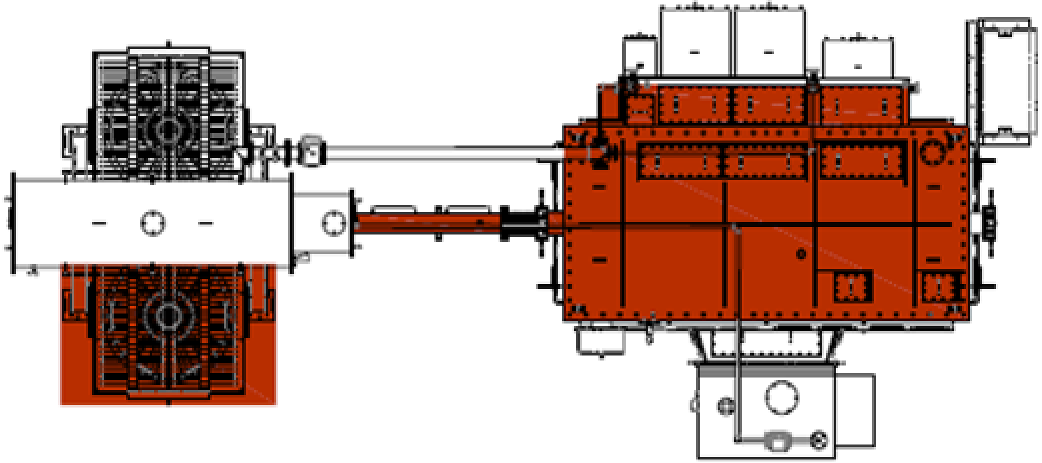


Learning at this stage

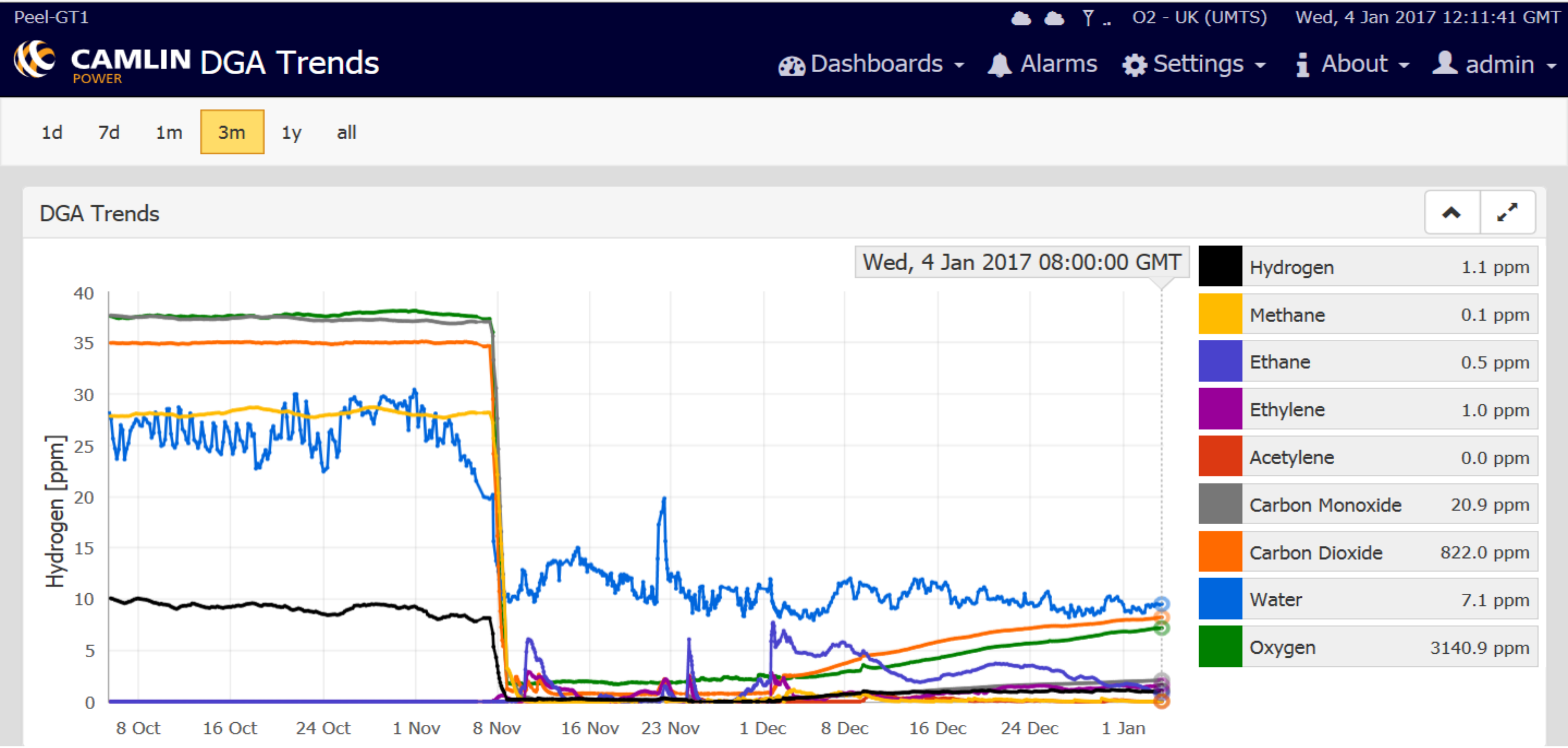
Technical challenges

- Raising the transformer core to 65degC – live
- Staggering taps, thermal insulation – de-rating of TX
- Network security – network restoration plans
- Creation of turbulence of oil within the tank
- When is the second stage completed with different TXs
- HV and LV earthing
- Noise complaints and sites security as unmanned

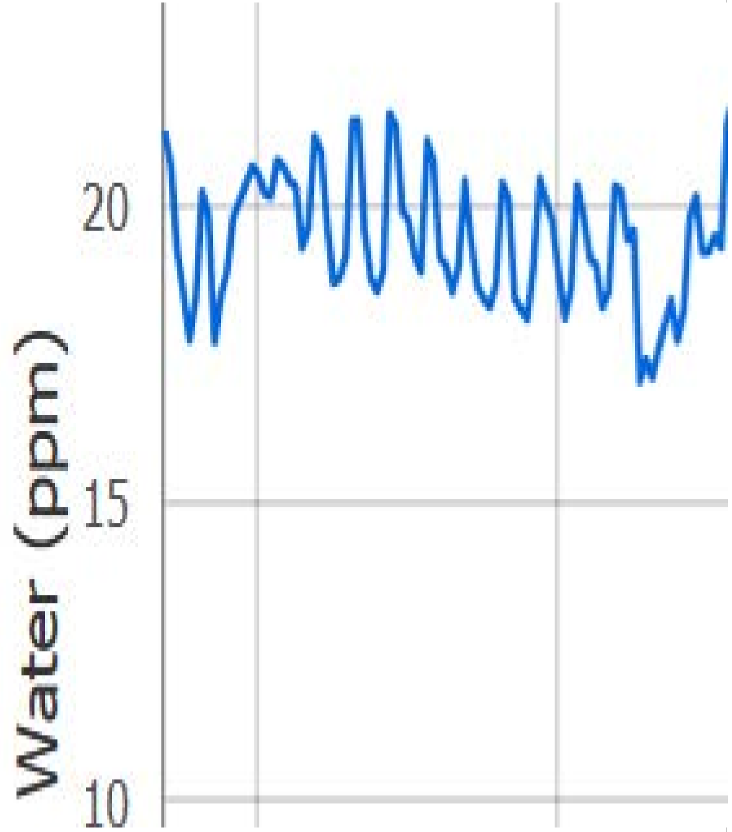
Peel success



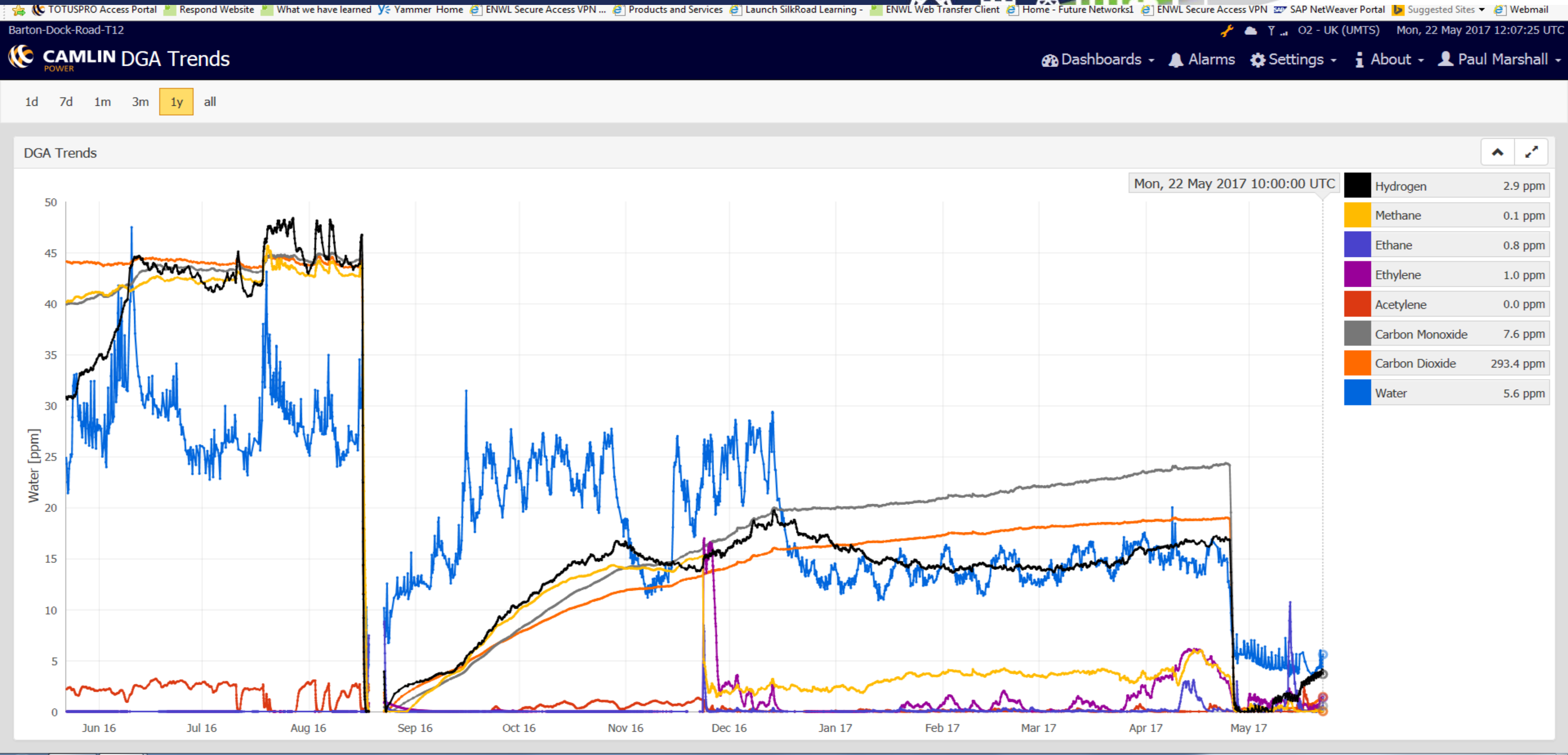
Peel success



Peel – before and after



Barton Dock



TOTUSPRO Access Portal
Respond Website
What we have learned
Yammer Home
ENWL Secure Access VPN ...
Products and Services
Launch SilkRoad Learning -
ENWL Web Transfer Client
Home - Future Networks1
ENWL Secure Access VPN
SAP NetWeaver Portal
Suggested Sites
Webmail
Barton-Dock-Road-T12
O2 - UK (UMTS)
Mon, 22 May 2017 12:07:25 UTC
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Dashboards
Alarms
Settings
About
Paul Marshall
1d
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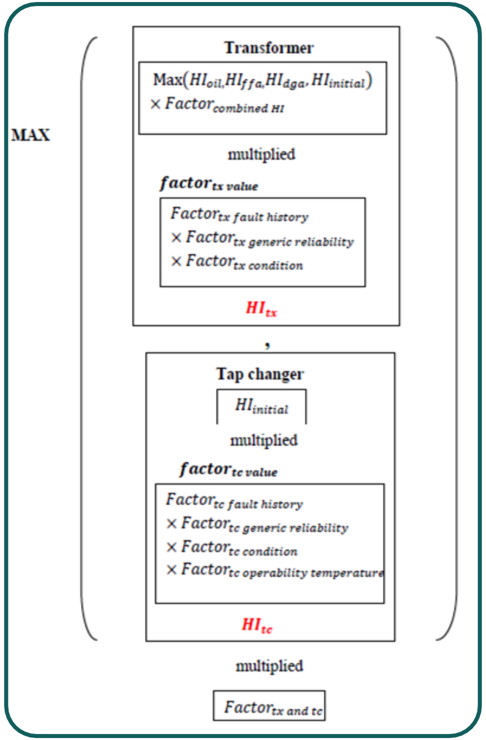
all
DGA Trends
Mon, 22 May 2017 10:00:00 UTC
Hydrogen 2.9 ppm
Methane 0.1 ppm
Ethane 0.8 ppm
Ethylene 1.0 ppm
Acetylene 0.0 ppm
Carbon Monoxide 7.6 ppm
Carbon Dioxide 293.4 ppm
Water 5.6 ppm
Water [ppm]
50
45
40
35
30
25
20
15
10
5
0
Jun 16
Jul 16
Aug 16
Sep 16
Oct 16
Nov 16
Dec 16
Jan 17
Feb 17
Mar 17
Apr 17
May 17

How are the results quantified

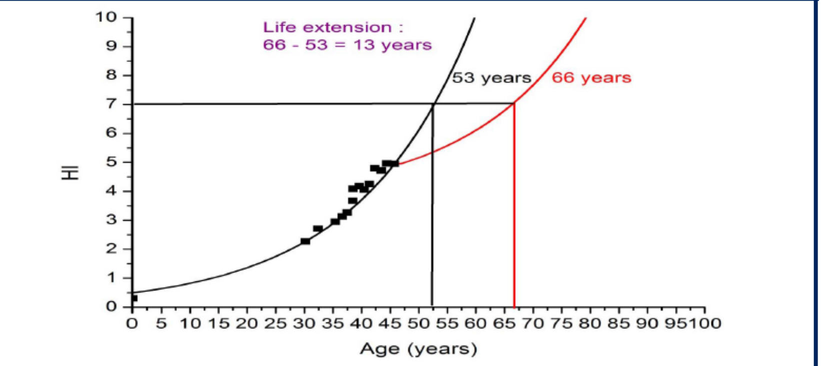


Life estimation of a regenerated transformer

Key is how it impacts on the CBRM health index

Recognised measure used by the regulator

Life extension using existing HI model (Combined HI)



Before oil regen GT3 has 7 years left (HI reaches 7.0 @ 53 yrs)

After oil regen GT3 has 20 years left (HI reaches 7.0 @ 66 yrs)

RIIO challenge

RIIO Challenge

	Need to maximise the use of existing assets
	50% of our transformers due for renewal in RIIO will be refurbished and oil regenerated
	Extend the life span of the transformer by deferring replacement and avoid derating

RIIO transformer management strategy

Transformer management	Oil regeneration	Replacement & refurbishment
CBRM health index driven	Major contributing factor to CBRM health index	CBRM health index and inspection driven
Cost effective intervention strategy	The timing of an intervention is critical to maximise the potential life extension	The chosen intervention(s) must be appropriate to manage the HI within unit cost
Safe and reliable management of ENW's transformer fleet	Online condition monitoring	Online condition monitoring

Transformer life extension risk

Transformers now operating way beyond their original design life. Condition?

Traditionally off line monitoring is slow, costly, open to margins of error and open to operator interpretation

Intervals between testing are now too long to trend the asset condition reliably for new and arguably quicker failure modes

QUALITY

Need for more accurate, quicker and richer condition monitoring

To manage the risk on re-generated units we need near real time total system monitoring

Dissolved Gas Analysis (DGA)

DGA control units are installed at each site

Allows for continuous oil measurement

Typically oil supplied from top fill valve on the transformer and returned to bottom drain valve

Load and temperature sensors are also fitted

3G comms links for each unit are installed

Oil sample taken post installation

Partial discharge monitoring

PD control units were installed

Tap adapters are connected to the HV bushing

Monitoring discharge in the tank and bushings

Top, bottom and ambient temperature measurements are taken

An RF CT is fitted to the transformer neutral connection and is used for noise gating

Allows correlation between PD, DGA, temperature and loading on the transformer

End vision

Affordable monitoring to accurately measure key indicators

Emerging faults repaired before customers affected

Optimum asset management strategy

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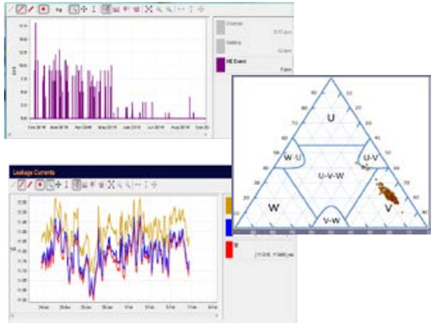
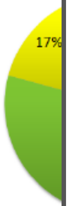


Data collection/analysis

Fleet Overview

Total num

Number o



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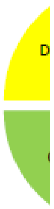
Bispham GT



off-line oil

54% of moni

While there significantly i

Transformer

Urgent

Plan Oi

Plan Ele

Connec in prog

* Camlin Condition Group

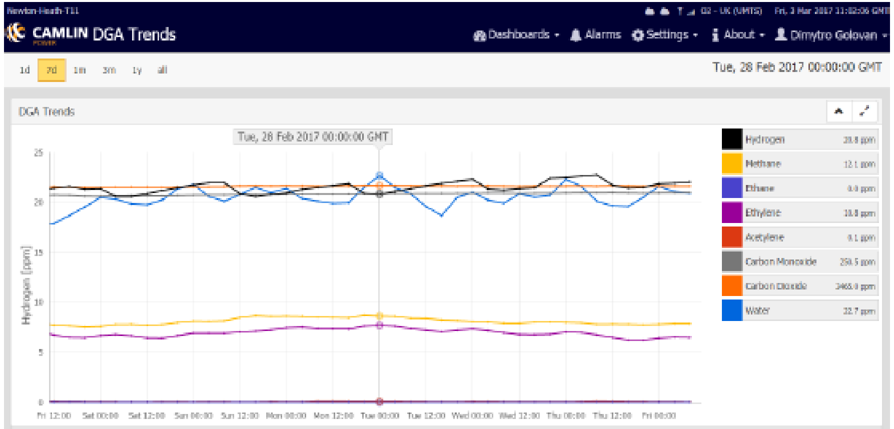
Activity required	Tra
	Nelson T1
	Newton H
	Hindley G
	Broadhea
	Hindley G
	Bamber B
	Bamber B
	Droylsde
	Nelson T
	Bispham
	Barton D
	Huncoat
	Home Ro
	Tardy Ga
	Barton D
	Wigan G
	Lower Da
	Lower Da

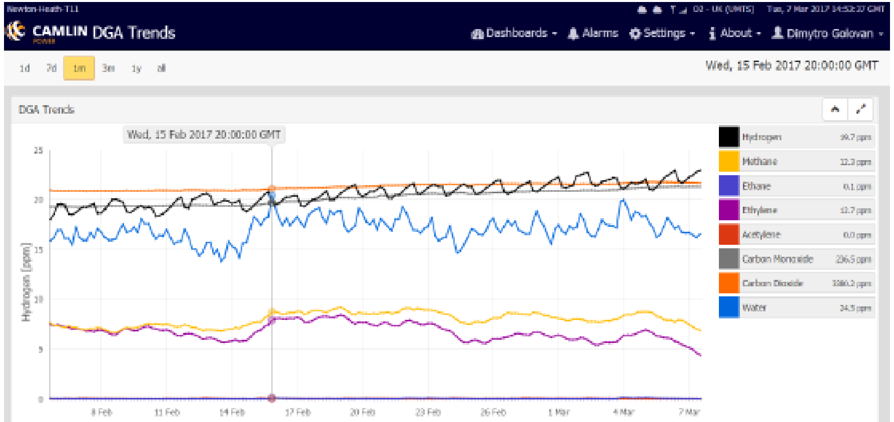
Transformer

Trans
Nelson T12
Newton Heat
Hindley Green
Broadheath T
Hindley Green
Bamber Bridg
Bamber Bridg
Droylsden GT
Nelson T11
Bispham GT1
Barton Dock F
Huncoat GT1
Home Road T
Tardy Gate T1
Barton Dock F
Wigan GT2
Lower Darwin
Lower Darwin
Huncoat GT2
Home Road T
Settle T11
Sale Moor T1
Peel GT1
Chorley South

Additional notes

DGA trends are normal showing that there are no active defects in the main tank. Moisture in oil level is quite high (on Wednesday the 15th of February was recorded 24.5 ppm) and after top oil temperature rise the moisture content in oil rose as well. That was the reason of Condition Group deterioration and moving it into Group 3.





Summary

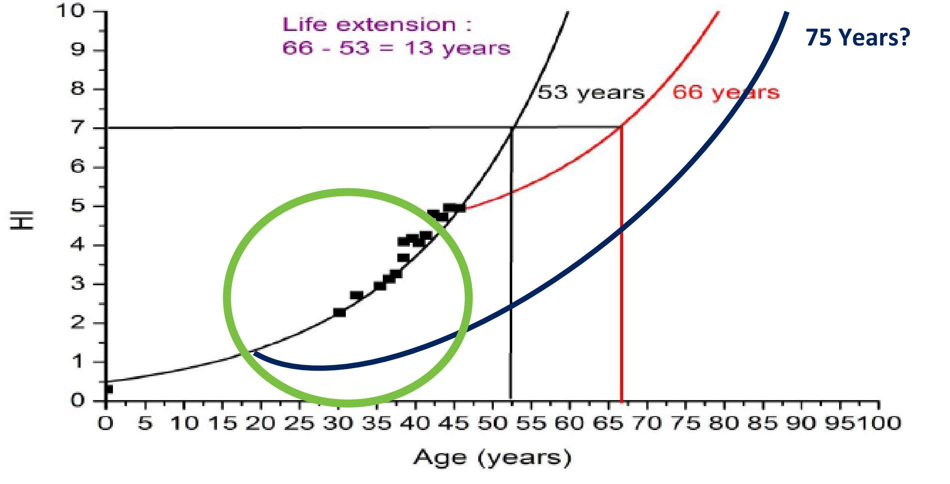
Regeneration combined with DGA, PD and acoustic condition monitoring allow significant savings with predictable risk

Risk management	Safety and reliability	RIIO asset strategy	Asset management	Carbon reduction
Detection of early asset deterioration in assets that are approaching or exceeded design life	Improved reliability of transformer fleet and in turn improved operator safety	Confidence in transformer refurbishment, oil regeneration & replacement strategy	Allow more accurate and timely health indices of assets	Minimises carbon-intensive infrastructure

Explore optimum life of transformer

Traditional life extension is normally at end of the assets life

Life extension using existing HI model (Combined HI)



What if we intervened earlier could we extended the asset life even further?

Optimising oil regeneration

Previous research aims to extend life span of transformers near end of life

Next phase determines if earlier oil regen can reduce rate of paper degradation and further extend transformer life

33kV and 132kV ‘sister’ transformers at various stages of design life have been identified

Only one transformer per site will undergo oil regeneration

Online monitoring equipment will allow comparison of oil condition and determine life extension over time

Aim is to explore optimum point that second stage oil regeneration can be applied to maximum benefit

For more information

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