Tummel Bridge GT1 132/11kV Transformer

Level 1 Condition Assessment Report
15th July 2020
Report: TUMBGT1SHET200627 FINAL

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Polaris Diagnostics & Engineering Ltd

Contents

Executive Summary

Polaris Diagnostics & Engineering Ltd has been commissioned by Scottish Hydro Electric Transmission (SHE Transmission), to carry out a Level 1 condition assessment of Tummel Bridge GT1 132/11kV Transformer.

The level 1 condition assessment has been carried out, based on a review and independent assessment of the historic oil data and SSEN Report T2BP-ACR-0016 Revision 1.0 dated November 2019,both supplied by SHE Transmission.

Based on the assessment of the historical & current asset condition data, GT1 is in reasonably good condition and there is a low likelihood that the transformer condition will deteriorate by ageing during the RIIO T2 period.

In order to further assess and manage the condition of this transformer, the following recommendations are made:

- Continue with routine oil sampling and analysis of the main tank and tap changer.
- Continue with routine maintenance.
- Continue with routine inspection.
- Detailed load flow monitoring.
- 132kV bushings should be oil sampled for DGA and moisture analysis and assessed by the criteria set out in National Grid TGN 82. In addition the bushing power factor and capacitance should be measured. This would require an outage and the removal of the 132kV and 11kV bushings to facilitate the testing.

Issue Record

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Issue Date	Issue No	Author	Amendments
27th June 2020	DRAFT	MJ Gilfeather	-
10th July 2020	DRAFT v2	MJ Gilfeather	Editorials & Clarifications
15th July 2020	FINAL	IBB Hunter	Alteration to Report Number

Issue Authority

Author	Issue Authority
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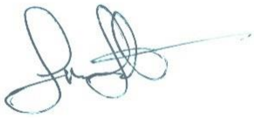	

Review

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Condition Assessment Level

A level 1 condition assessment was carried out on Tummel Bridge GT1 132/11kV transformer as defined in the table below.

TRANSFORMER CONDITION ASSESSMENT				
LEVEL	**DESCRIPTION***	**SITE VISIT REQUIRED**	**OUTAGE REQUIRED**	**ASSESSMENT CLASS**
Level 1	Oil Data and History Provided by Client for Analysis	No	No	Basic
Level 2	Level 1 & Ground Based Visual Survey	Yes	No	Advanced Basic
Level 3	Level 2 & Non-invasive Surveillance (Thermal Survey/RFI Scan of Transformer)	Yes	No	Intermediate
Level 4	Level 3 & Independent Oil Sampling and Analysis in Accordance with IEC 60422	Yes	No	Advanced
Level 5	Level 4 & Overall Visual Survey	Yes	1 day outage	Detailed
Level 6	Level 5 & Electrical Diagnostic Testing (Ranging from Ratio/mag Current, Winding Resistance, Sweep Frequency Response Analysis, Power Factor and Capacitance, Polarisation Index, Bushing Oil Sampling, Bushing Power Factor and Capacitance)	Yes	1-3 days outage	Comprehensive

* Condition assessment can be customised to meet individual client requirements.

Transformer Serial 0404862340

This transformer was manufactured in 1988, and was installed and commissioned at Tummel Bridge 132kV substation.

Tummel Bridge GT1 transformer is installed within an outdoor 132kV air insulated substation (AIS) and is fitted with both 132kV and 11kV oil to air bushings and an on load circuit tap changer. The transformer is furnished with a separate cooler bank which is free breathing.

Electrical Plant Details

Manufacturer:	Bonar Long
Serial Number:	0404862340
Year of Manufacture:	1988
ONAN Rating:	21 MVA
Ratio:	132/11 kV
Vector Group:	Unknown
Impedance:	Unknown
Tap Changer Manufacturer:	ATL
Tap changer Type:	AT319/50/44/300 CF3
Tap Changer Serial Number:	875007
HV Bushings:	Unknown
Oil Type:	Uninhibited, unknown type
Breather Type:	Free Breathing
Moisture Management:	Unknown

Oil Quantities & Weights

Unknown

Transformer Construction

No transformer construction information was made available.

Transformer Defects

Polaris Diagnostics & Engineering Ltd are not aware of any known defects associated with the design of this transformer.

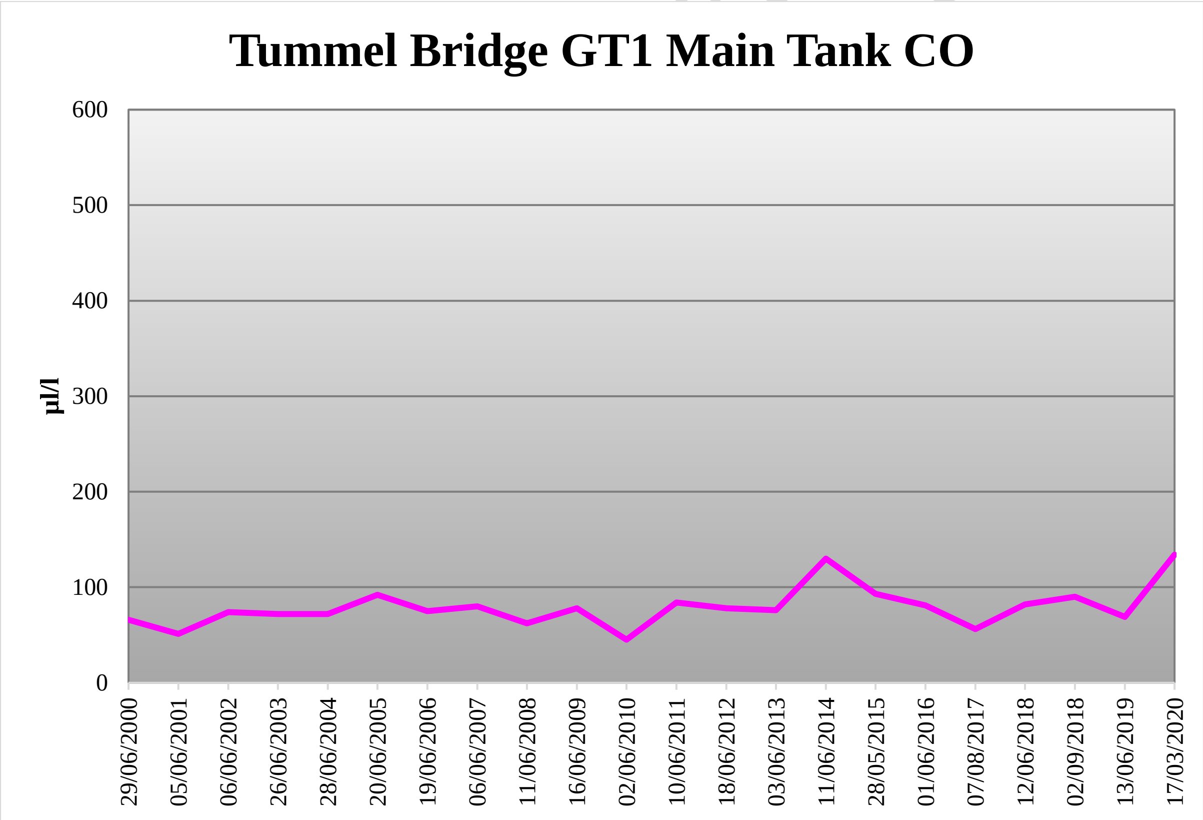
Main Tank Oil History

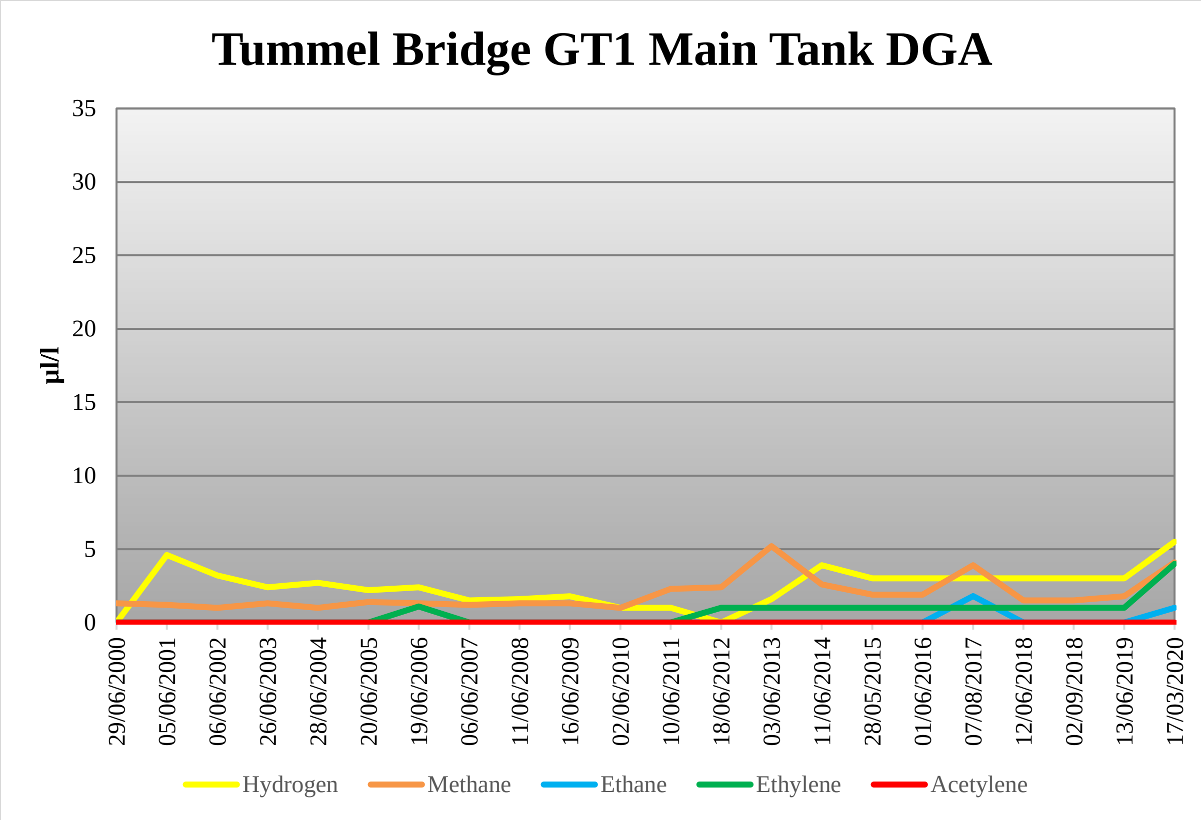
Dissolved Gas Analysis – Main Tank History

Interpretation of the DGA history is carried out using guidance from IEC 60599 "*Mineral Oil Impregnated Electrical Equipment in Service – Guide to the interpretation of dissolved and free gases analysis*". The available history spans from 2000 to 2020.

As the values of dissolved Carbon Monoxide (CO) are several orders of magnitude greater than all other diagnostic gases, the CO history is plotted separately for clarity.

The CO characteristic is considered to be relatively stable and at low levels over the sample period with no substantial increases in CO values. CO consistently remains blow "typical values" specified in IEC 60599 over the sample period therefore, the paper insulation is likely in good condition.





Hydrogen and thermal gases Methane, Ethane and Ethylene are all present in the DGA history however, all remain at low levels well below “typical Values” specified in IEC 60599.

Application of the gas ratios, as defined in IEC 60599, [0, 0.66, 4] fails to highlight any abnormality through a diagnosis of non-classification. Using the Duval’s triangle method of DGA interpretation, the same gas ratios define a “T3” condition, “Thermal faults, T > 700℃’, however, it should be noted that the Duval method, which is a closed system, will always result in a condition being identified. The magnitudes of dissolved gas levels are considered to be too low to accurately diagnose and in this case the DGA would be considered benign.

Analysis of the oil data shows no indication of partial discharge, discharge, or thermal abnormalities being present within the main tank.

Thermal Events:

It should be noted that between 2019 and 2020 there has been a slight increase in dissolved ethylene, with residual quantities of dissolved methane and ethane. Whilst these magnitudes of dissolved gases are still at low level, the dissolved ethylene should be kept under surveillance, in order to check for the manifestation of a thermal abnormality.

Discharge Events:

None

Dissolved Gas Analysis-Tap Changer

Interpretation of the DGA history is carried out using guidance from IEC 60599 “Mineral Oil Impregnated Electrical Equipment in Service – Guide to the interpretation of dissolved and free gases analysis”.

No information was made available.

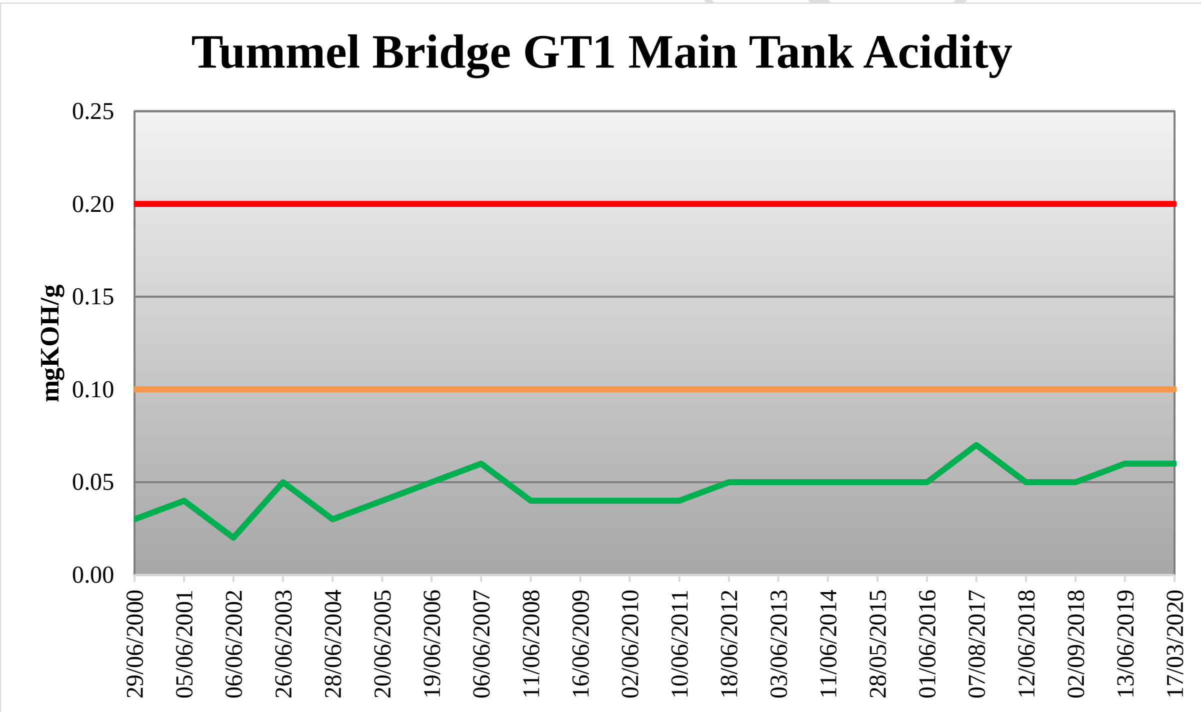
Main Tank Oil Quality Analysis

Interpretation of the oil analysis is carried out in accordance with the requirements of IEC 60422 *"Mineral insulating oils in electrical equipment – supervision and maintenance guidance."* As this transformer has a primary voltage of 132kV, it falls into the "Category B" limits as defined in the standard.

Acidity

The acidity of used oil is due to the formation of acidic oxidation products. Acids and other oxidation products will in conjunction with water and solid contaminants affect the dielectric and other properties of the oil. Acids have an impact on the degradation of cellulosic materials and maybe responsible for the corrosion of metal parts in a transformer.

IEC 60422 "Category B" Limits for Acidity	
Classification	**mgKOH/g**
Good	**< 0.1**
Fair	**0.1 – 0.2**
Poor	**> 0.2**

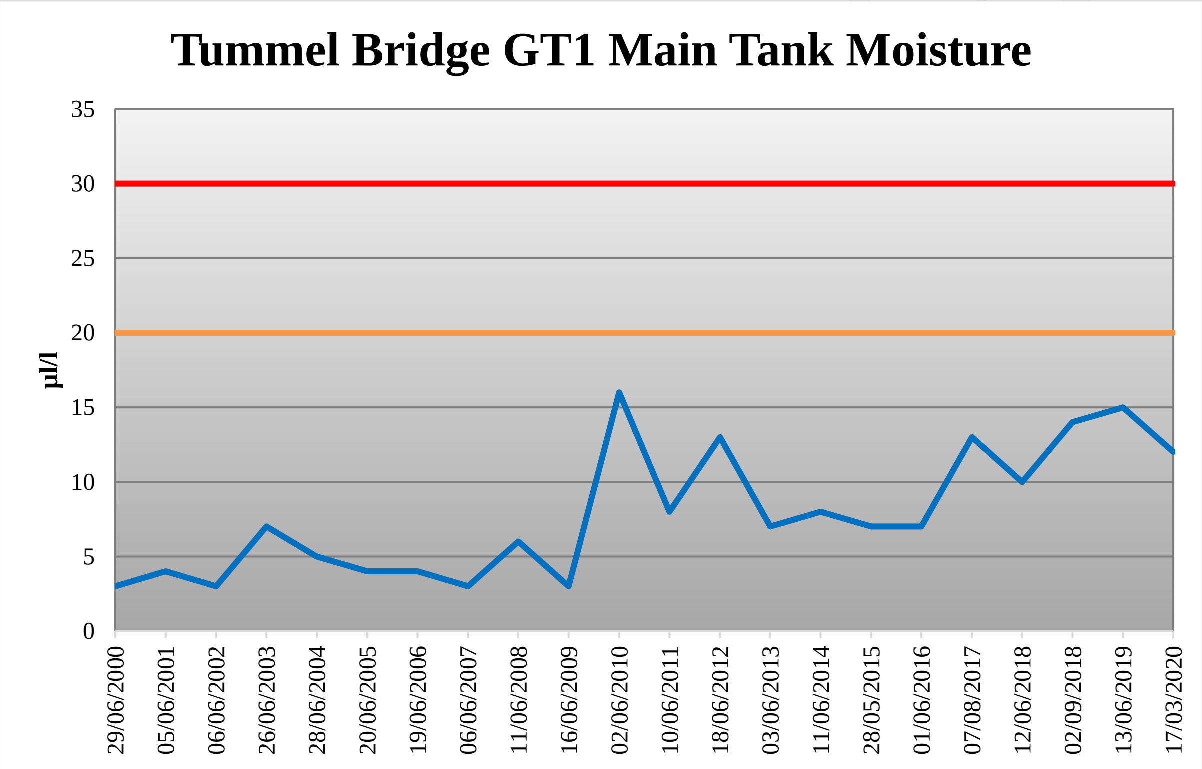


The historical acidity record contains 22 samples taken in the period of 2000 to 2020. The acidity levels are found to exhibit a very minor increasing trend over the sample period which is indicative of minor oxidisation of the oil. Over the entire historical sample range all results can be categorised as "Good" as defined by IEC 60422 for category B apparatus. The acidity is considered satisfactory.

Moisture

The moisture level influences the breakdown voltage of the oil, the solid insulation and affects the ageing characteristics of the liquid and solid insulation. There are two main sources of water, ingress from atmosphere and from the degradation of cellulose in oil.

IEC 60422 "Category B" Limits for Moisture	
Classification	**µl/l**
Good	**< 20**
Fair	**20 -30**
Poor	**> 30**

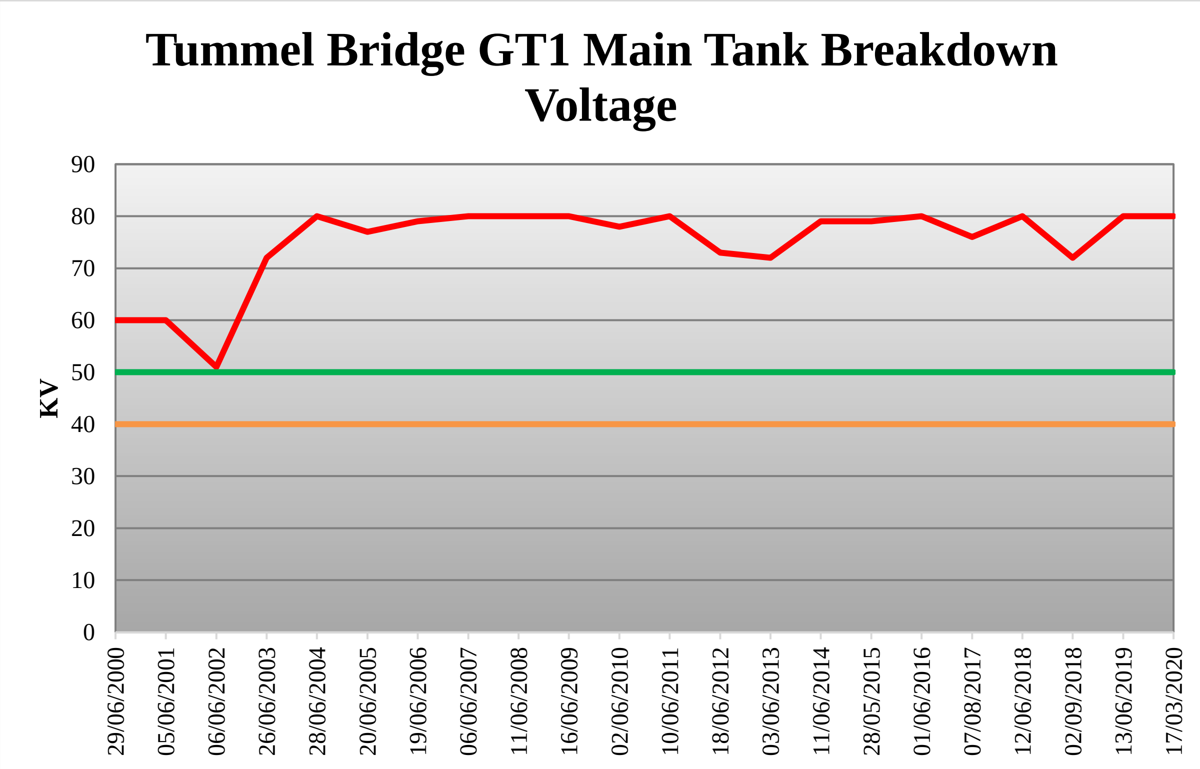


The moisture data spans 22 samples taken over the period of 2000 to 2020. Over the operational life of the transformer the moisture levels have been dynamic yet have consistently been categorised as "Good" as defined by IEC 60422, for category B apparatus. The peak moisture value is recorded in June 2010 at 16µl/l. The overall moisture trend is satisfactory.

Breakdown Voltage

Breakdown voltage is a measure of the ability of the oil to withstand electric stress. Dry clean oil exhibits an inherently high breakdown voltage. Free water and other polar and non-polar contaminants reduce the breakdown voltage dramatically.

IEC 60422 "Category B" Limits for Breakdown Voltage	
Classification	**kV**
Good	**> 50**
Fair	**40 - 50**
Poor	**< 40**

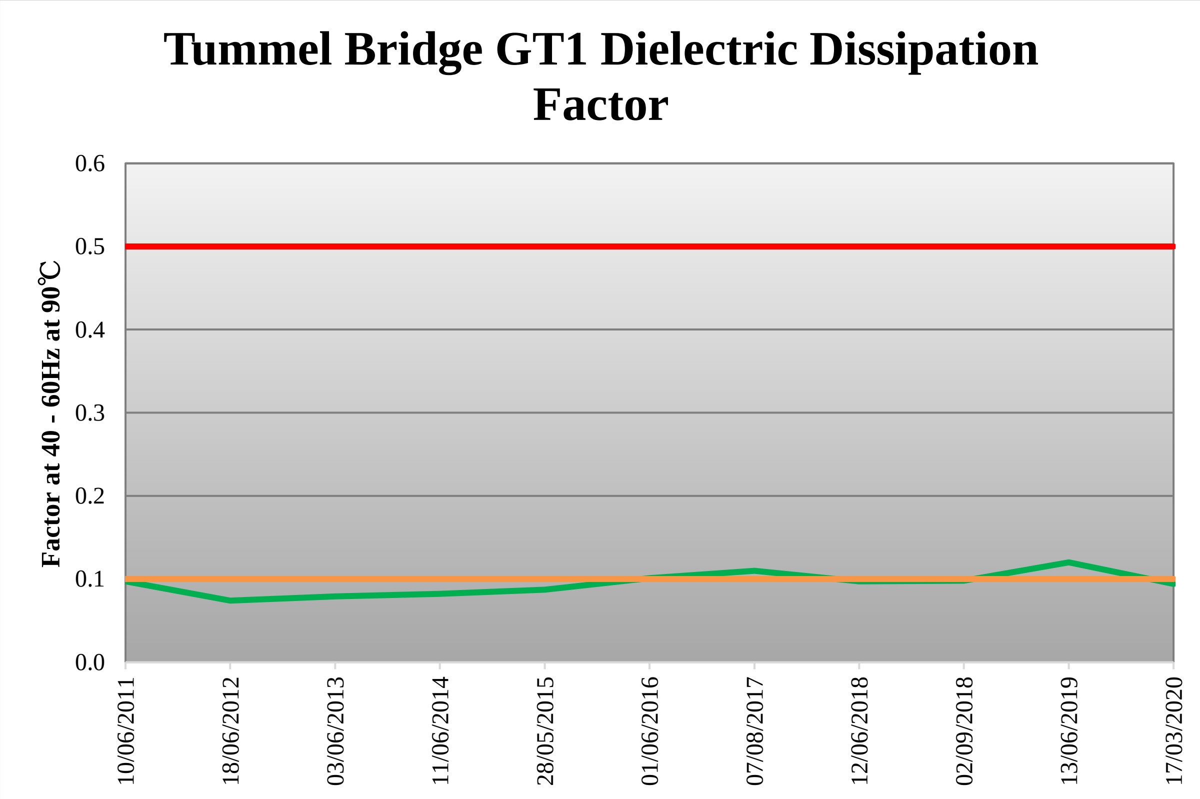


The historical breakdown voltage record spans from 2000 to 2020 and includes 22 samples. Over the sample period the breakdown voltage is consistently categorised as "Good", as defined by IEC 60422. The overall trend exhibited is relatively stable, no correlation between reduced breakdown voltage level and increased moisture content are apparent. The overall breakdown voltage level trend is satisfactory.

Dielectric Dissipation Factor

The dielectric dissipation factor is sensitive to the presence of soluble polar contaminants and ageing products in the oil. Changes in the levels of contaminants can be monitored by this parameter even when the contamination is so low as to be near the limits of chemical detection.

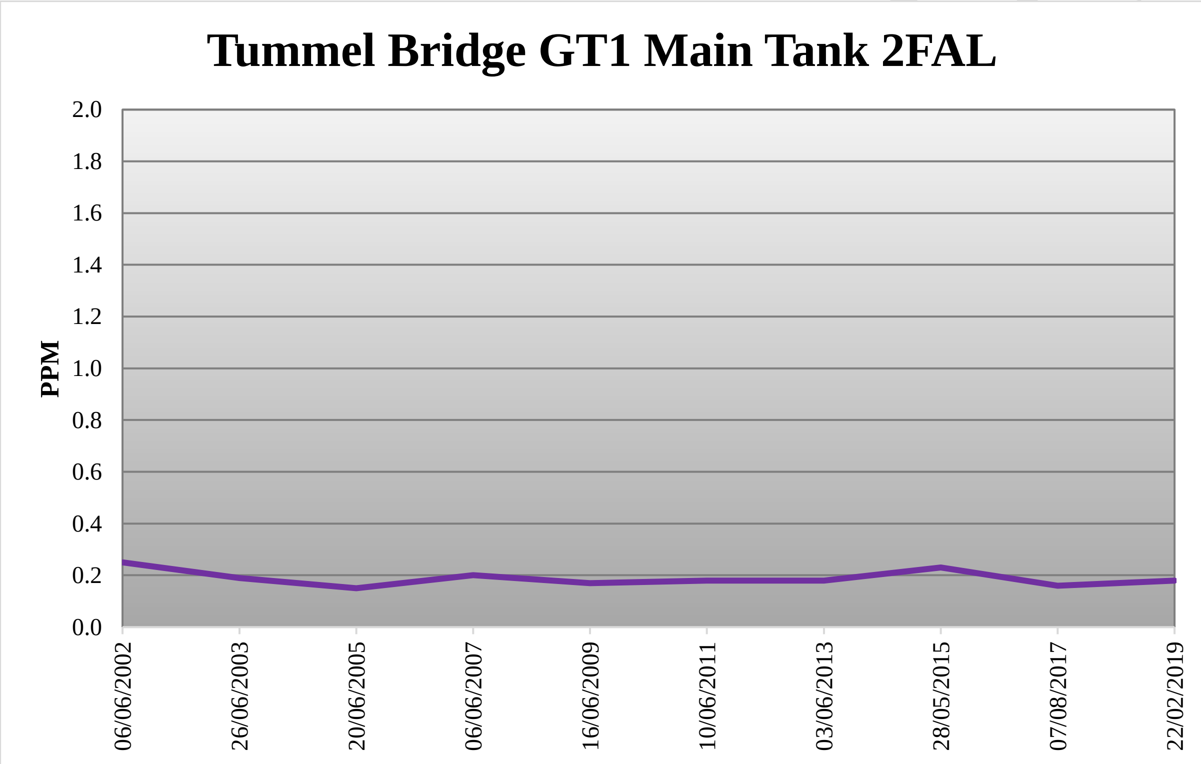
IEC 60422 "Category B" Limits for Dielectric Dissipation Factor	
Classification	**kV**
Good	**< 0.1**
Fair	**0.1 – 0.5**
Poor	**> 0.5**



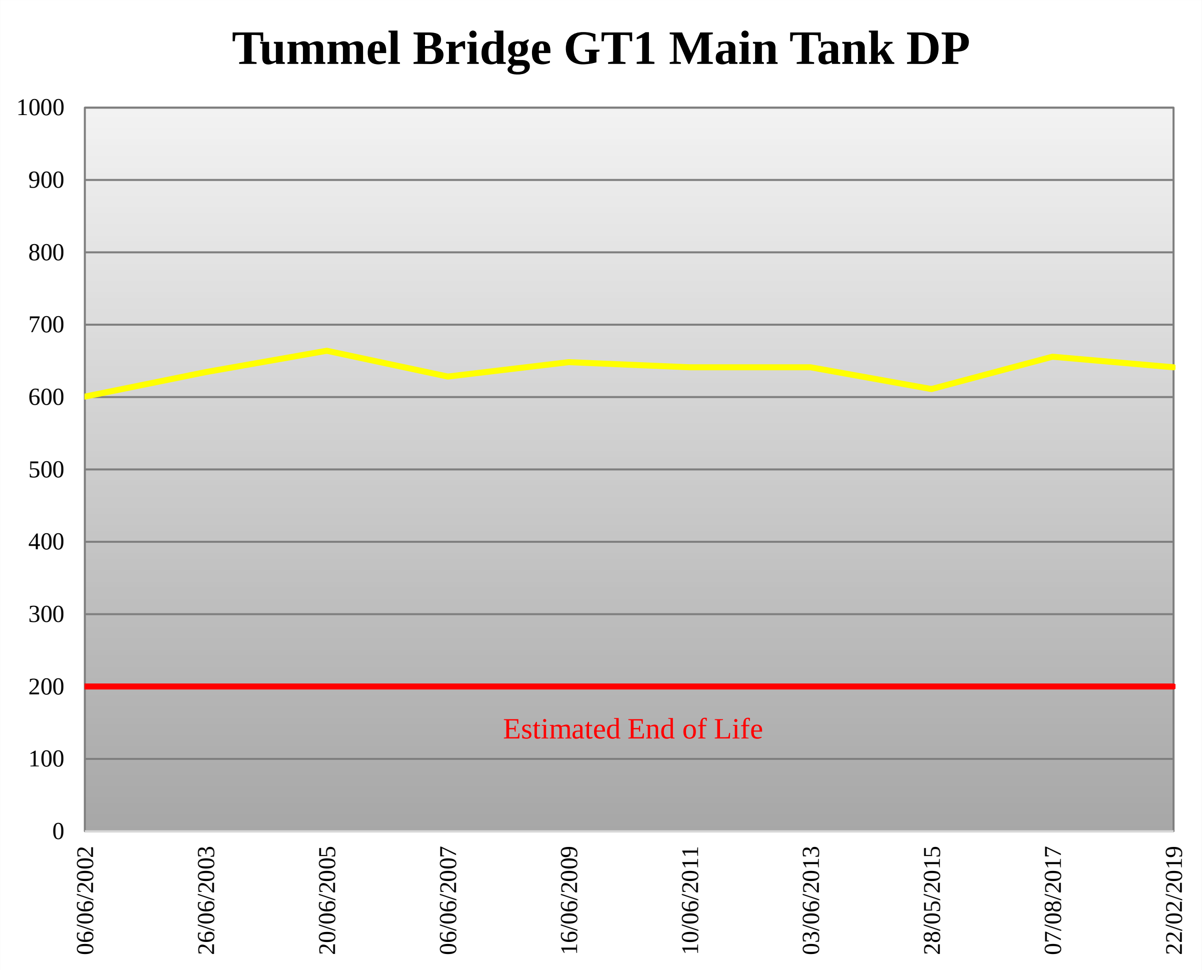
The dielectric dissipation factor spans the period of 2011 to 2020 and includes 11 samples. Over the sample period, the trend exhibited is dynamic with consistent fluctuations between levels categorised as "Good" & "Fair", as defined by IEC 60422 for category B apparatus. It may be prudent to increase the sampling frequency of GT1 due to the fluctuations in results. The most recent results for dielectric dissipation factor is "Good" but is not wholly representative of the historical sample range.

2FAL

2FAL is a class of furanic compound produced by the degradation and breakdown of cellulose within the transformer. There is a correlation between the measurable 2FAL and the estimated degree of polymerisation (DP), the molecular mechanical strength of the paper within the transformer, although this should be used as an indicator. The 2FAL can be affected by temperature, moisture and acidity, which is not taken into account in the estimation algorithms used. The sampled oil may have been diluted or contaminated during in service operations, and is therefore subjected **to high degree of uncertainty.**



The 2FAL record spans from 2002 until the most recent sample, which was taken in February 2019. The 2FAL levels are relatively stable over the sample period with minor fluctuations observed. The final value recorded was 0.18 (Est DP 641), compared to the highest value recorded in the sampling period of 0.25 (Est DP 601). The link between measured 2FAL and estimated DP is also tenuous and is reliant on an algorithmic relationship, of which there are five different variants. The Chengdong algorithm has been used to relate measured 2FAL to estimated DP. In order to estimate the DP of the insulation system, the highest value of measured 2FAL shall be used (From June 2002). Measured 2FAL of 0.25 gives an estimated DP of 601. The insulation within a new transformer has typically a DP value of 1000. It is generally accepted within the industry that an estimated DP value of 200 is "end of life". Application of this criteria, results in the transformer having an estimated 50% residual life remaining in the paper insulation. This suggests that the paper insulation is in good condition.



132kV Bushings

No data available.

General

This section is compiled by making reference to the information contained within SSEN Report T2BP-ACR-0016 Revision 1.0 dated November 2019, henceforth referred to as the document.

Previous Condition Assessments

The iSIM inspection data for GT1 are classified as either category 1 (No visible quantifiable deterioration or damage) or category 2 (Apparent normal wear intervention to be done at the next refurbishment). This highlights that there are no immediate interventions required on GT1.

Partial Discharge Survey

A partial discharge survey was conducted in November 2014 by Elimpus with no indication of partial discharge being found. There is no evidence of partial discharge activity from transformer GT1 as evidenced by the absence of elevated levels of hydrogen and methane in the dissolved gas analysis.

Infra-Red Thermovision Survey

An infra-red thermovision survey was conducted in May 2016 with two abnormalities being found. The first abnormality was identified as the yellow phase receiver contact of the 132kV disconnector 113, the second abnormality was found on a 33kV post insulator (belonging to SHEPD). In both cases poor connections are identified as the most likely cause of these abnormalities. No thermal abnormalities were found on transformer GT1.

Impulse Protection

Transformer impulse protection is achieved by coordinating gaps fitted to the 132kV bushings.

Load & Duty Cycle

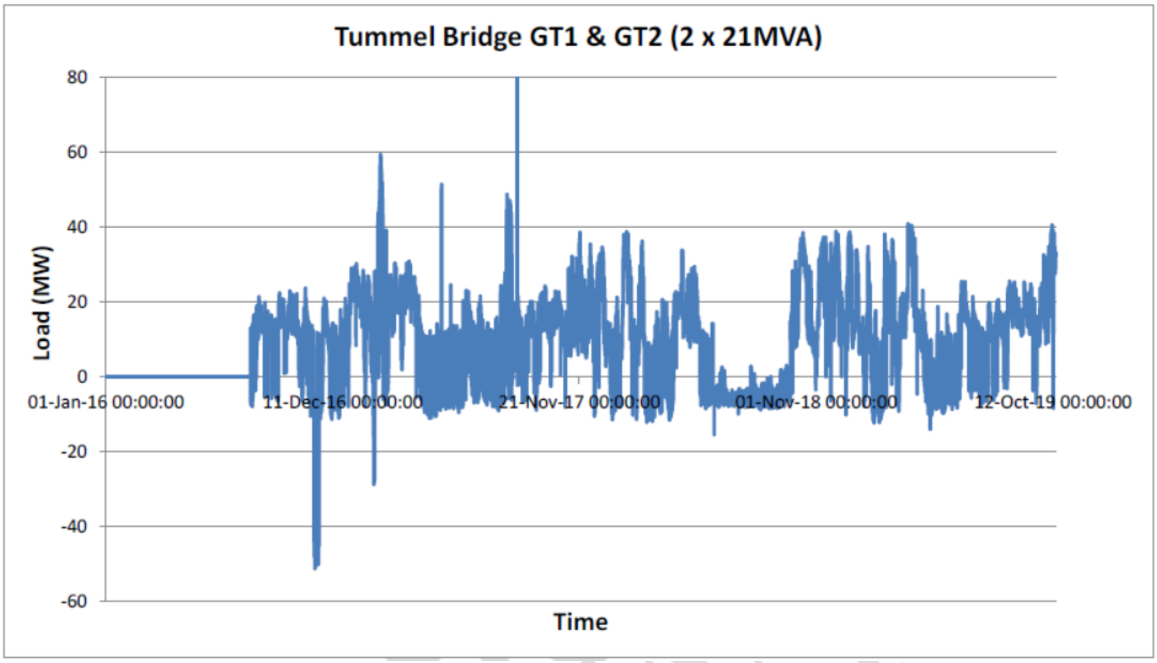


Figure 5.11 from section 5.7 of the document shows a measured combined load flow for GT1 & GT2 for the period of 2016 to 2019. The transformers have a typical maximum combined load flow of around 40MVA, which is within the 42MVA transformer capacity of the substation. There have been three periods of overloading recorded, where the combined transformer capacity has been exceeded. It is not clear from the load flow the exact magnitude or durations of these overloads.

Transformers have an inherent overload capability, which is dependent on the magnitude and duration of the overload. Sustained overload would result in accelerated degradation of the paper winding insulation and would be evidenced in the oil analysis by elevated and increasing levels of CO in the DGA and levels of 2FAL. This is not evident in GT1.

Historical Faults

No historical fault data has been provided.

Maintenance

Maintenance details obtained from PLACAR indicate that routine maintenance has been carried out over the operational lifetime of GT1. The maintenance of GT1 was carried out under contract by SSE Renewables until 2017.

GT1 - MW 132kV Grid Transformer Maintenance - 24/09/2002

GT1TAP - MW 132kV Grid Transformer Tap changer maintenance - 24/09/2002

1T0VT - MW 132kV Grid Transformer Tap changer maintenance - 11/08/2006

GT1 - MW 132kV Grid Transformer Maintenance - 11/08/2006

GT1TAP - MW 132kV Grid Transformer Tap changer maintenance - 11/08/2006

GT1 - MW 132kV Grid Transformer Maintenance - 01/09/2010

GT1EAR - MW 132kV Grid Transformer Tap changer maintenance - 01/09/2010

GT1TAP - MW 132kV Grid Transformer Tap changer maintenance - 01/09/2010

GT1 - MW 132kV Grid Transformer Maintenance - 30/04/2015

GT1TAP - MW 132kV Grid Transformer Tap changer maintenance - 30/04/2015

GT1 - iSIM Maintenance Record - 24/08/2018

GT1TAP - iSIM Maintenance Record -24/08/2018

Conclusion

The iSIM inspection data for GT1 are classified as either category 1 (No visible quantifiable deterioration or damage) or category 2 (Apparent normal wear intervention to be done at the next refurbishment). This highlights that there are no immediate interventions required on GT1.

The DGA does not exhibit any evidence of partial discharge, discharge, or thermal abnormality. The DGA history can be described as benign.

It should be noted that between 2019 and 2020 there has been a slight increase in the main tank dissolved ethylene, with residual quantities of dissolved methane and ethane. Whilst these magnitudes of dissolved gases are still at low level, the dissolved ethylene should be kept under surveillance, in order to check for the manifestation of a thermal abnormality.

The oil quality parameters comprising of moisture, breakdown voltage, acidity and DDF are all categorised as "Good" as defined by IEC 60422:2013 indicating that the insulating oil has good dielectric properties. Currently no oil intervention is required.

Measured 2FAL of 0.25 gives an estimated DP of 601. The insulation within a new transformer has typically a DP value of 1000. It is generally accepted within the industry that an estimated DP value of 200 is "end of life". Application of this criteria, results in the transformer having an estimated 50% residual life remaining in the paper insulation. This suggests that the paper insulation is in good condition.

There was no information available on the condition assessment of the 132kV bushings.

The transformers have a typical maximum combined load flow of around 40MVA, which is within the 42MVA transformer capacity of the substation. There have been three periods of overloading recorded, where the combined transformer capacity has been exceeded. It is not clear from the load flow the exact magnitude or durations of these overloads. Transformers have an inherent overload capability, which is dependent on the magnitude and duration of the overload. Sustained overload would result in accelerated degradation of the paper winding insulation and would be evidenced in the oil analysis by elevated and increasing levels of CO in the DGA and levels of 2FAL. This is not evident in GT1.

This transformer is presently in reasonable condition.

Recommendations

In order to further assess and manage the condition of this transformer, the following recommendations are made:

- Continue with routine oil sampling and analysis of the main tank and tap changer.
- Continue with routine maintenance.
- Continue with routine inspection.
- Detailed load flow monitoring.
- 132kV bushings should be oil sampled for DGA and moisture analysis and assessed by the criteria set out in National Grid TGN 82. In addition the bushing power factor and capacitance should be measured. This would require an outage and the removal of the 132kV and 11kV bushings to facilitate the testing.