Polaris Diagnostics & Engineering Ltd has been commissioned by Scottish Hydro Electric Transmission (SHE Transmission), to carry out a Level 1 condition assessment of Sloy GT3 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-0011 Revision 1.10 dated October 2019,both supplied by SHE Transmission.

Based on the assessment of the historical & current asset condition data, there is a high likelihood that the transformer condition will deteriorate during the RIIO T2 period, resulting in failure of the asset. The transformer should be planned for replacement.

Measured 2FAL of 1.14 gives an estimated DP of 412. 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 26% residual life remaining in the paper insulation. This is consistent with the paper insulation being in an aged condition. Between 2007 and 2014 there is an almost linear and sustained ageing rate, which is considered to be genuine. The oil intervention (either oil top up or oil processing) in 2014 has diluted the 2FAL in such a way as to manifest as an apparent increase in estimated DP which camouflages the true estimated DP in 2019, which will be in a worse condition than predicted. Extrapolation of the estimated DP between 2007 and 2014, based on the observable rate of ageing, and assuming that there is no deviation in that rate, or that the transformer is not subjected to external failure mechanism, would predict that "end of life" would be reached in the year 2026. The transformer has 6 years of operational service life remaining, which is within the RIIO T2 period.

It is known that a number of short circuits have occurred on the 11kV busbars at Sloy substation since they were installed in the 1990s. A through fault current could cause winding movement or winding clamp distortion due to electromechanical forces generated by the through fault, which would seriously compromise the through fault withstand capability of the transformer. Ageing of paper insulation would also cause winding shrinkage, which would also contribute to a reduction in the through fault withstand of the transformer, increasing the risk of instantaneous failure due to a fault on the 11kV busbars.

It is likely that there is a type defect manifesting in this transformer, as characterised by accelerated ageing of the paper insulation, which is detected by increasing levels of 2FAL in all 132/11kV transformers at Sloy substation. The root cause of this has not yet been determined and will require further investigation. In order to further assess the condition of this transformer, to establish the root

cause of the accelerated ageing and manage the asset to end of life, the following recommendations are made:

- Main tank oil should be sampled at 6 monthly intervals, in order to keep the levels of 2FAL under surveillance and to assess the ageing rate. This is in addition to routine sampling. On line monitoring of 2FAL is not presently an option as the technology is not mature.

- Electrical diagnostic testing. This is to assess the mechanical condition of the active part by Sweep Frequency Response Analysis (SFRA) and the condition of the insulation system by means of dielectric frequency response (DFR), 10kV Power Factor and 5kV Insulation Resistance. This will require an outage and the disconnection and removal of the 132kV & 11kV busbars.

The main tank oil should not be reconditioned, reclaimed, regenerated or topped up as this will affect the 2FAL concentrations, which is the primary method of surveillance used to monitor the ageing rate of the paper insulation. These interventions will mask any underlying ageing profile. This of course should be reviewed, by Transmission Operations in the case where the dielectric properties of the main tank oil is deteriorating and presenting a risk of dielectric failure of the liquid insulation.

In order to establish the root cause of the accelerated ageing an "end of life" evaluation should be carried out on this transformer, at the time when it's to be removed from the system. This should comprise of on-site testing and inspection, forensic examination during dismantling at the scrap yard and DP analysis of paper insulation retrieved from the windings during dismantling. Any recommendations derived from the "end of life" evaluation should be used to manage operational transformers of similar design.

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