SynchroTeq – Transformer Switching

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Executive Summary

This report was produced by Enspec Power LTD, it details the application of the SynchroTeq device for transformer switching. The document outlines the application and theory of controlled transformer switching and then presents two commissioned and operational site examples, one from a UK Solar Farm and another from a Wind Farm in Scotland. In conclusion, the document demonstrates how the SynchroTeq can mitigate inrush currents during the energisation of transformers and provide site compliance with the P28 limit of 3%.

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1 Introduction

When a transformer is energised it may draw a large transient current from the supply connection point. This large current draw results in a voltage dip. According to the UK standards (Electricity Council's Engineering Recommendation P28), the maximum change in the voltage at the POC is **3%** measured **30ms** after the switching event for events occurring at least **750** seconds apart. Due to this it has been common practice to install a Pre-insertion Resistor (PIR), that is placed in circuit during the transformer energisation to reduce the inrush current and thus voltage dip. However, a PIR requires an extra circuit breaker, has a significant footprint and can be expensive. The SynchroTeq is a controlled switching device that can provide equal or better inrush mitigation to that of a PIR without the need for an extra breaker or costly install. This document will cover the theory, installation and performance of the SynchroTeq when applied to transformer switching and will end by presenting two operational SynchroTeq installations.

2 Transformer Controlled Switching

When a transformer is de-energised, the magnetic core will contain a certain amount of residual magnetic flux. This residual flux is dependent on the voltage across the transformer at the time of de-energisation, and can intensify saturation leading to a high transient inrush current on re-energisation. The possibility or magnitude of saturation and thus inrush current is dependent on the point of re-energisation (angle) in relation to this residual flux. This effect can be seen graphically in Figure 2-1 below.

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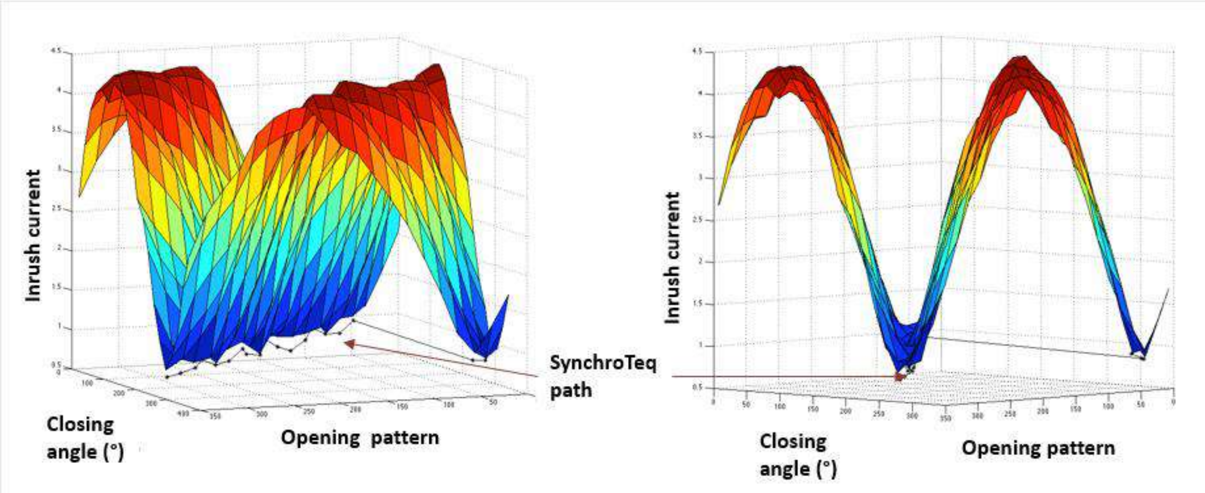

Figure 2-1 - Inrush Current due to Opening and Subsequent Closing Angle

The above Figure 2-1 shows the inrush current obtained across all possible closing angles for each possible opening angle. As can be seen, there is a best and worst case closing angle for each opening angle. When switching a standard transformer arrangement there is equal possibility of hitting a bad point as a good point, and thus a possibility of a high inrush current. The SynchroTeq works by monitoring and calculating this residual flux, with knowledge of the residual flux it can calculate the optimum closing angle. This is seen graphically in Figure 2-1 above as ‘SynchroTeq path’.

The SynchroTeq then becomes an interface between the open/ close commands (manual, remote or protection) and the Circuit Breaker. Using the calculated residual flux and knowledge of the Circuit Breaker operation time, the SynchroTeq can target this optimum closing angle, thus mitigating high inrush currents. This process can be seen graphically in Figure 2-2 below.

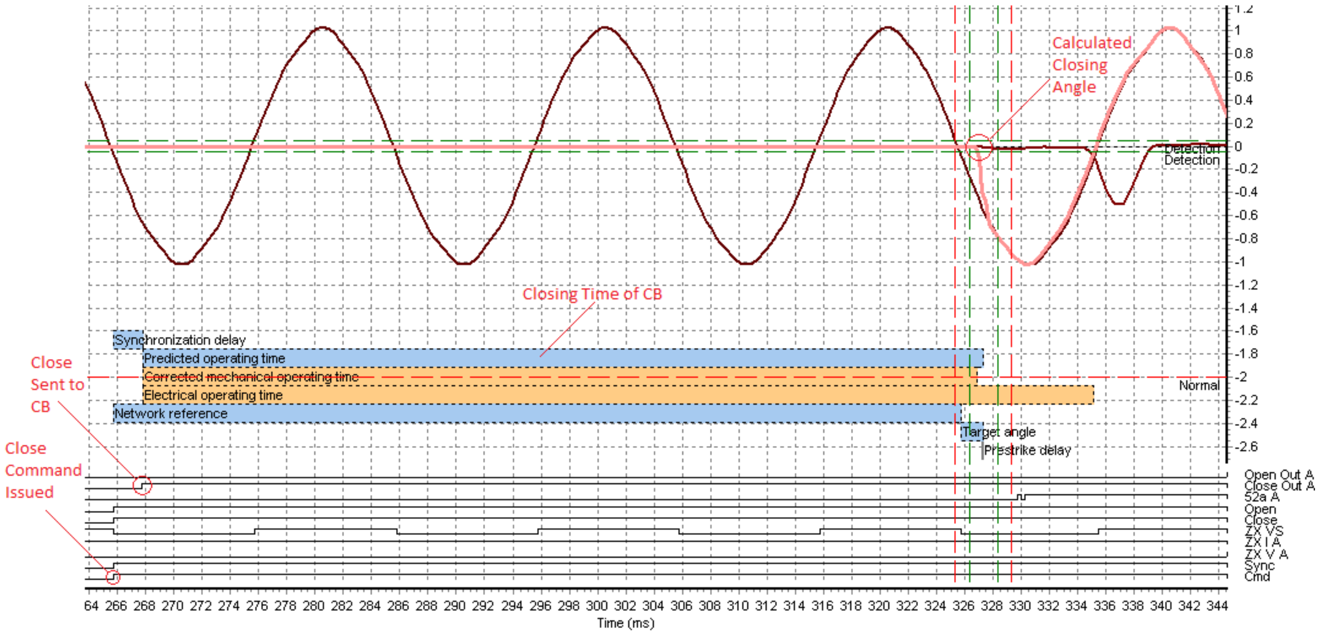

Figure 2-2 - SynchroTeq Controlled Close Operation (Phase A)

The above Figure 2-2 shows a closing operation carried out via the SynchroTeq (Phase A). In this example the calculated closing angle, based upon the calculated residual flux, is around 220 degrees. Firstly, the close command for the CB is issued to the SynchroTeq, the SynchroTeq then waits until the target angle is the CB closing time ahead (predicted operating time), and then the close command is sent to the CB. The result here is the CB closing at the desired angle with minimum inrush current.

The SynchroTeq can mitigate inrush current using any modern CB. The CB can be a 3-pole gang operated device or a 3-pole individual pole device. When operating via a 3-pole gang operated device, the SynchroTeq cannot close the CB at the optimum point for each phase, in this instance it calculates the optimum point for all three phases to keep inrush current to a minimum. When operating via an individual pole device inrush current can be completely avoided for unloaded transformers.

3 SynchroTeq Application

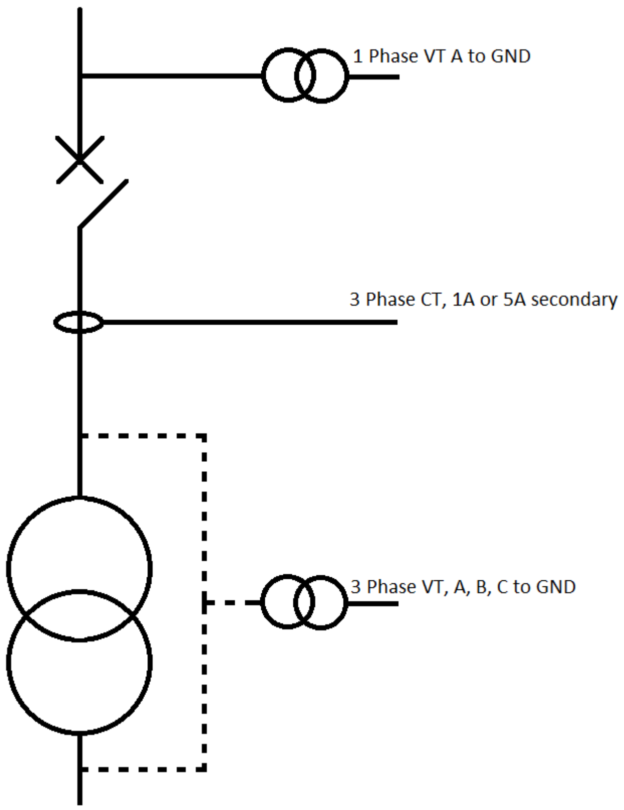

Figure 3-1 - SynchroTeq Signal Requirements

The above Figure 3-1 shows the signal requirements for transformer switching with a SynchroTeq device. The single-phase VT is used for voltage synchronisation, the CT's are used to measure inrush current and the three-phase VT allows the SynchroTeq to calculate residual flux. The SynchroTeq then forms an interface between the circuit breaker open/ close commands and the circuit breaker itself.

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4 Actual Application and Results

4.1 UK Solar Farm

The following results are for a SynchroTeq MVX installed on a UK solar farm. The SynchroTeq was used to control the simultaneous energisation of the sites 2MVA and 1.77MVA 11/04kV transformers. A diagram of the site layout can be seen below in Figure 4-1.

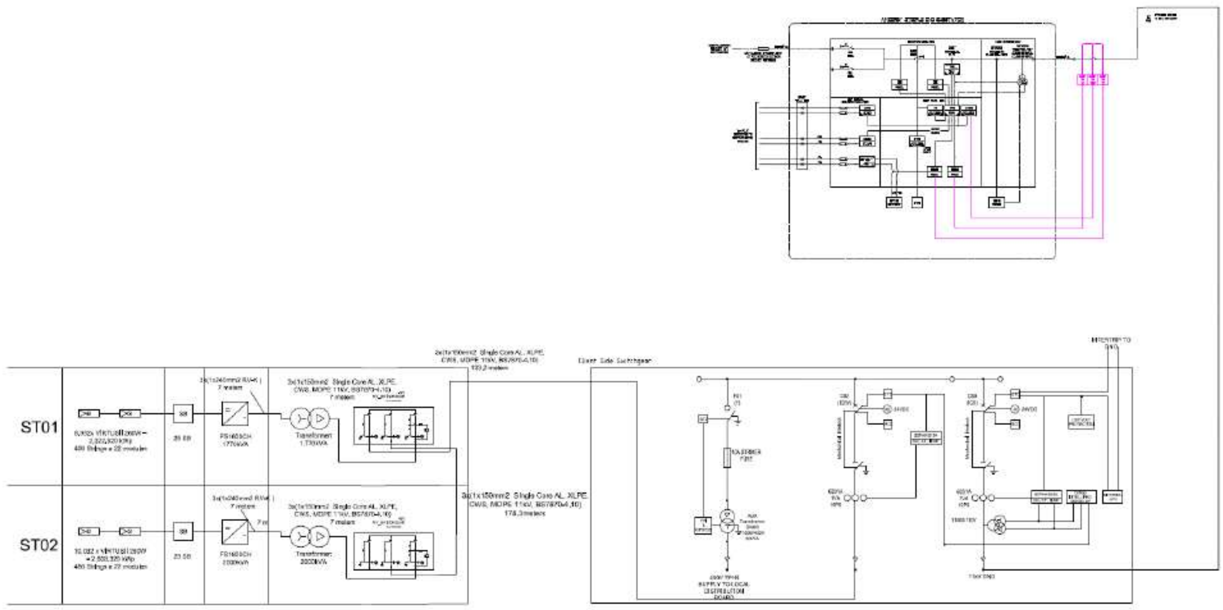

Figure 4-1 – Site SLD

The SynchroTeq MVX was mounted in the client substation and controlled the energisation of the main CB. The initial P28 studies for the site highlighted a 50^{th} percentile voltage dip of 8.2% for the simultaneous energisation of the sites transformers, this can be seen below in Figure 4-2.

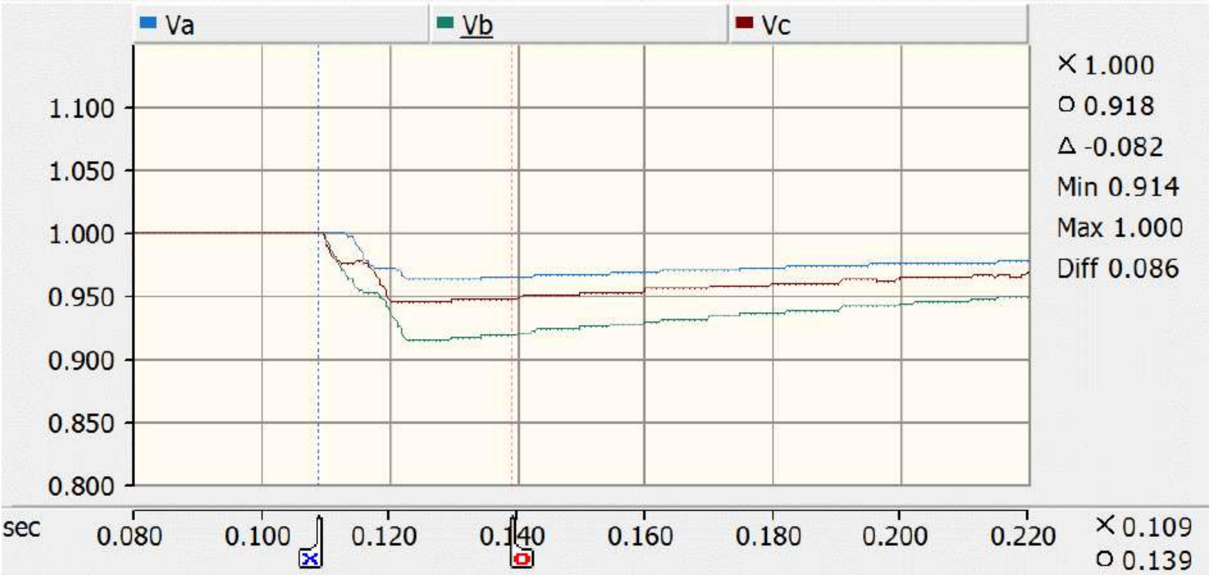

Figure 4-2 - PCC Voltage Dip for Whole Site Energisation

The DNO for this site stipulated a maximum voltage dip at the PCC of 6% due to the whole site energisation. The below Figure 4-3 shows the result of the SynchroTeq MVX commissioning.

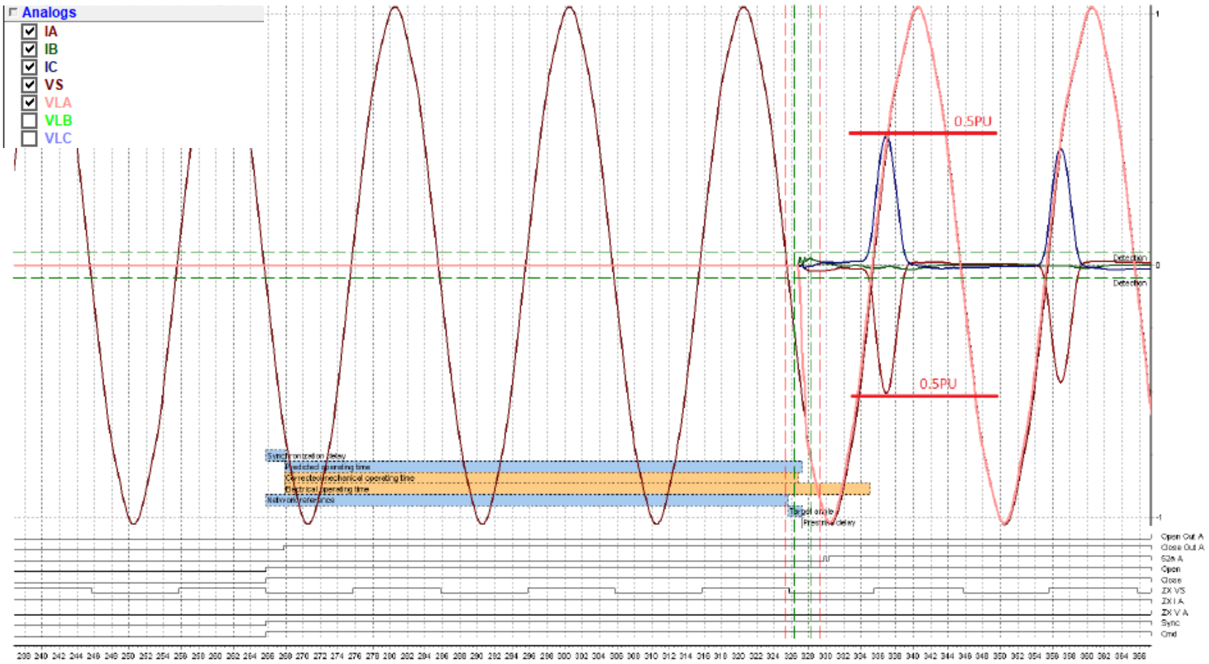

Figure 4-3 - Commissioned SynchroTeq Inrush Current

As can be seen from the above figure the resultant inrush current was 0.51PU (101A).

This resultant inrush current was then used to obtain a new voltage dip using the original P28 simulation model.

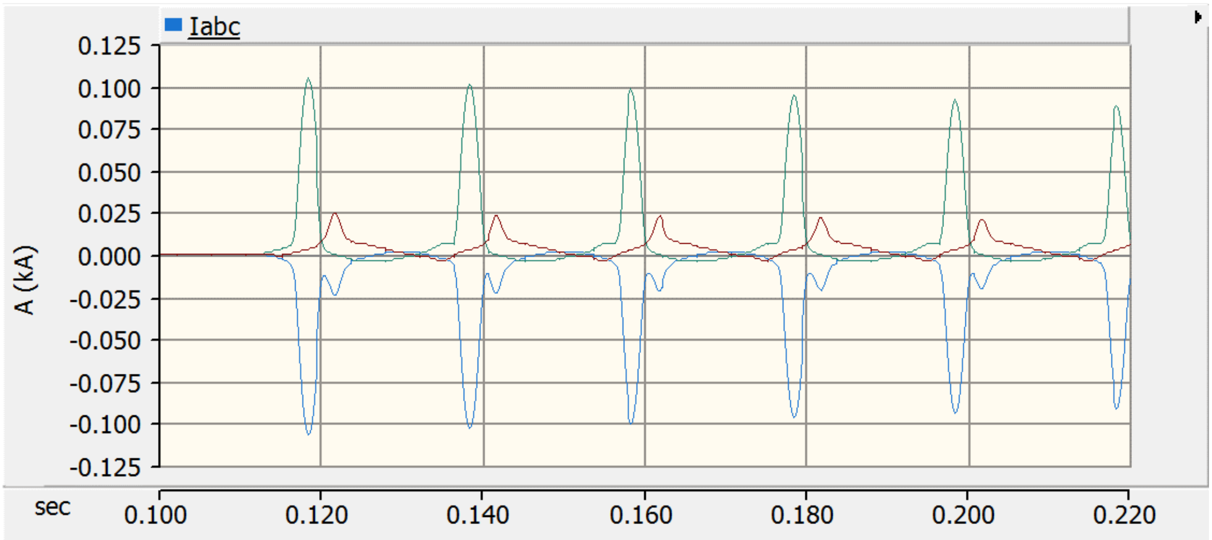

Figure 4-4 - SynchroTeq Resultant Inrush Current in P28 Model

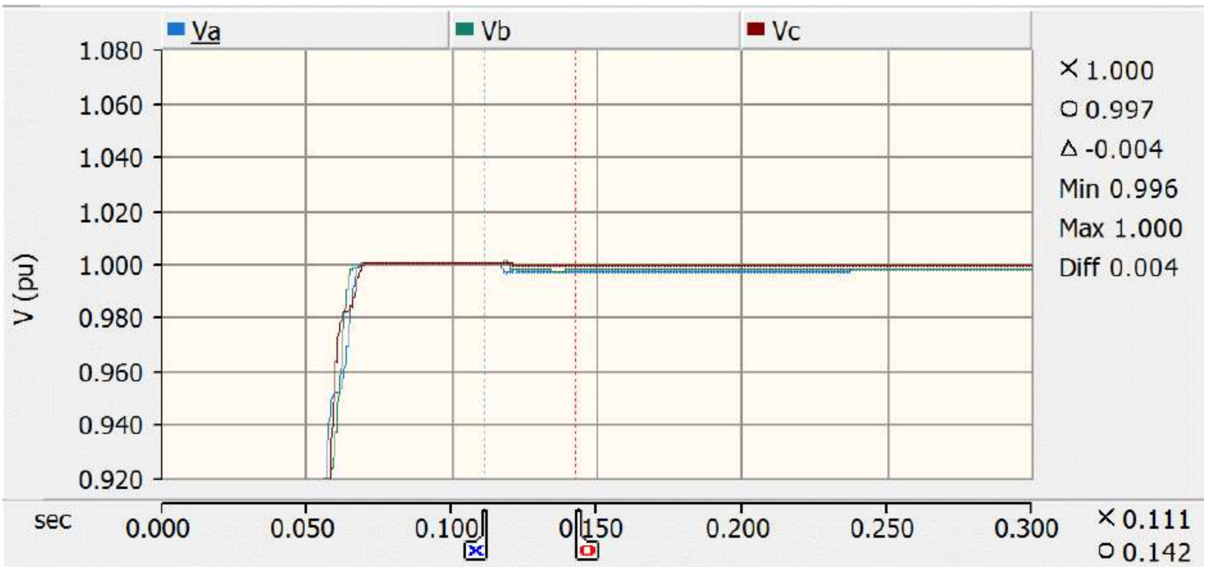

Figure 4-5 - Simulated Voltage Dip Based on SynchroTeq Inrush Current

As can be seen from the above figures, simulation of the resultant inrush current led to a PCC voltage dip of 0.4%. As the switching is now controlled by the SynchroTeq this level of inrush current will result from every future energisation, making the site fully P28 compliant.

4.2 Scottish Wind Farm

The following results are for a SynchroTeq Plus installed on a Scottish Wind farm. The SynchroTeq was used to control the energisation of the sites 90 MVA 132/33kV transformer. Figure 4-6 below shows the layout of the site.

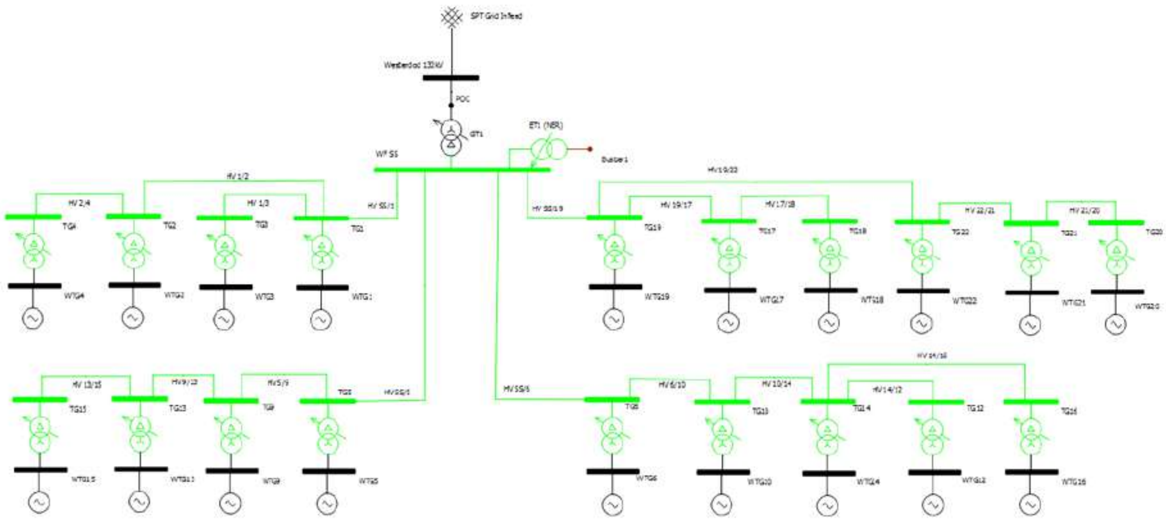

Figure 4-6 – Site SLD

The SynchroTeq Plus was mounted in the 132kV Control room and controlled the energisation of the main 132kV CB. The initial P28 studies for the site highlighted a maximum voltage dip of 17.9% for the energisation of the sites transformer, this can be seen below in Figure 4-7.

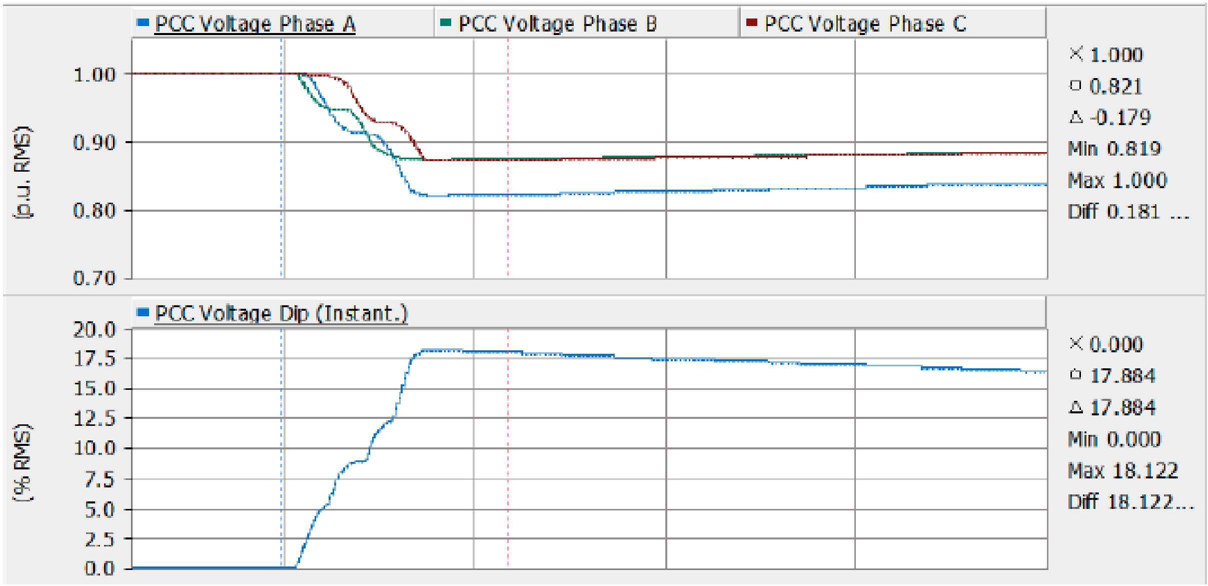

Figure 4-7 - PCC Voltage Dip for 90MVA Transformer Energisation

The DNO for this site stipulated a maximum voltage dip at the PCC of 6% due to the transformer energisation. The below Figure 4-8 shows the result of the SynchroTeq Plus commissioning.

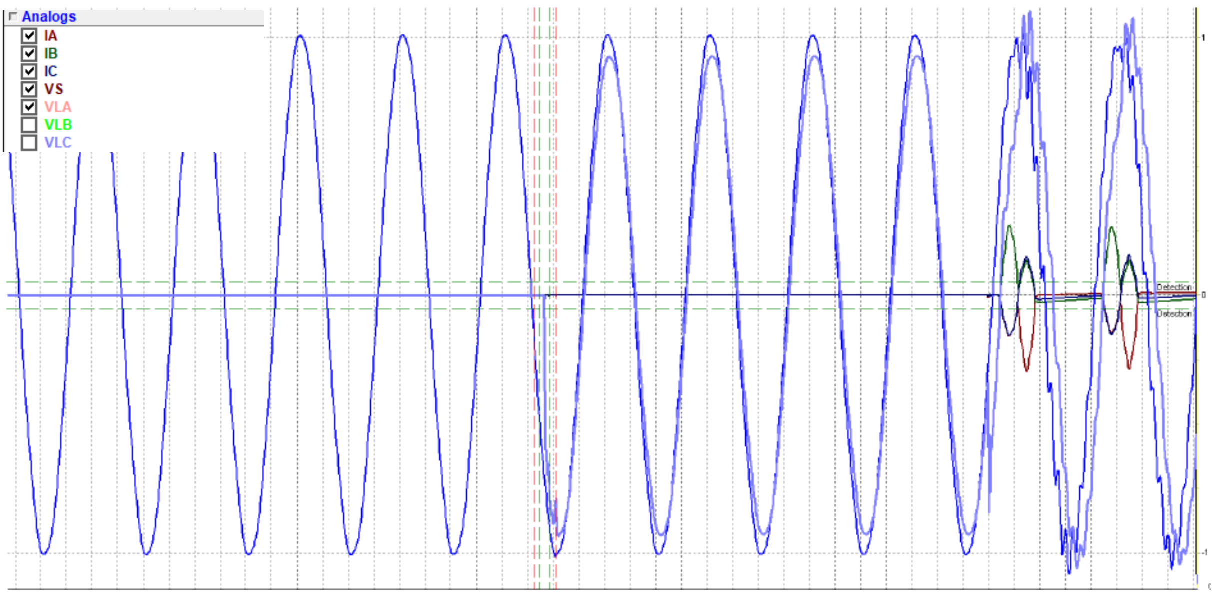

Figure 4-8 - Commissioned SynchroTeq Inrush Current

As can be seen from the above figure the resultant inrush current was 0.3PU (118A). A fast-acting voltage recorder was also connected to the 132kV VT and the recording during this switching event can be seen below in Figure 4-9.

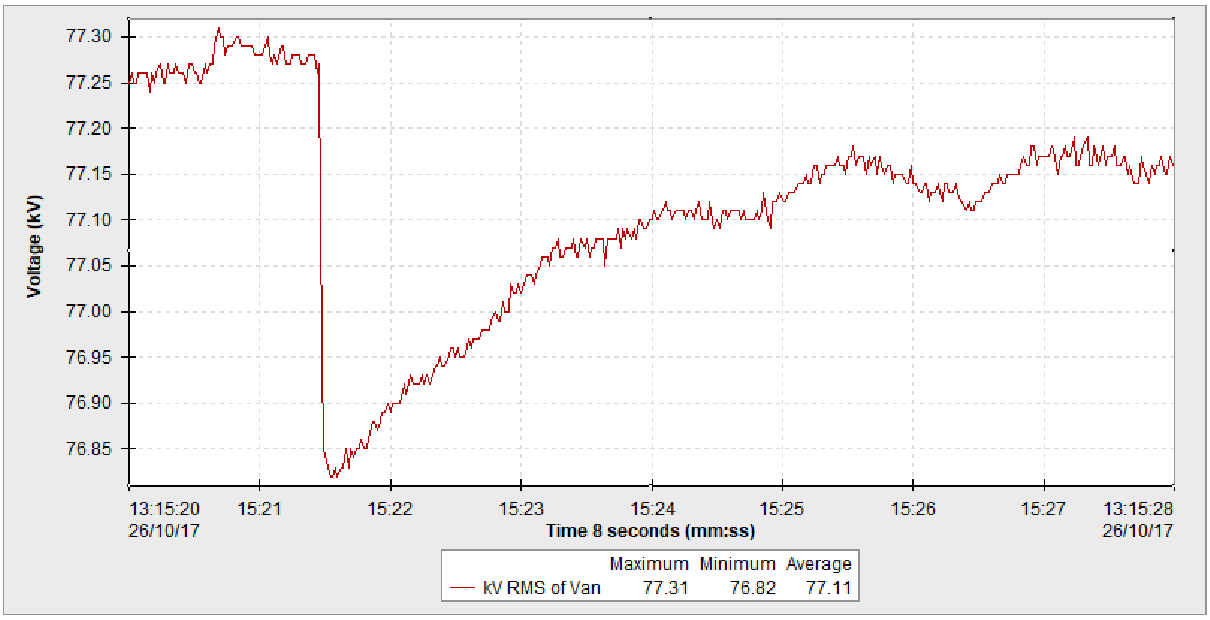

Figure 4-9 – Recorded Voltage Dip During SynchroTeq Energisation

As can be seen from the above figures, after commissioning of the SynchroTeq the obtained PCC voltage dip was 0.63%. As the switching is now controlled by the SynchroTeq this level of inrush current will result from every future energisation, making the site fully P28 compliant.

5 Conclusion

In summary, it has been shown that by using the SynchroTeq device, inrush current caused by transformer energisations can be significantly reduced. Two installed and commissioned cases have been presented that show the potential of the SynchroTeq to ensure P28 compliance when initial system studies predict potential for large voltage dips.

6 Appendix

Powersystems engaged Enspec Power to supply and commission a Vizimax SynchroTeq Plus to control the energisation of a 90 MVA 132/33 kV transformer at Aikengall II Wind Farm. Our initial simulation studies of the transformer showed that there would be a significant voltage dip of up to 18% on the 132kV system when the transformer was energised which exceeded the limits stipulated by Scottish Power. We integrated the SynchroTeq Plus into our bespoke transformer protection panel and used a GE Grid Solutions 132 kV circuit breaker with segregated pole switching to control energisation of the transformer. The performance results during commissioning were excellent: The SynchroTeq Plus reduced the transformer inrush current to 0.3pu and reduced the 132kV voltage dip to 0.6%.

The Enspec engineers were helpful in reviewing our primary plant layout to ensure we had the correct VT's, CT's, and circuit breaker positioning to allow the scheme to work and they also reviewed our schematic drawings to ensure we were correctly integrating the SynchroTeq Plus with the 132kV circuit breaker. We found the on-site commissioning process went smoothly also. The Enspec commissioners were able to quickly identify and resolve a cross-phasing issue with the wiring we had installed. This was primarily because the visualisation of the recorded voltage waveforms and circuit breaker closing times on their software made the issue easy to identify. It has given us confidence that point-on-wave control is a viable option for mitigating transformer inrush currents even for large grid-scale transformers.

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Figure 10 - Testimonial Powersystems UK