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**Transmission Engineering**

**REVISE-SSE-WP03-01**

**WP3 – Understanding and Evaluating Exceedance**

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# Introduction

As the network grows and the country pushes towards net zero goals, it is important to try and maximize current infrastructure and be able to implement optimisation for future infrastructure. The REVISE project is revisiting the ratings that were assigned to Overhead Lines in the 1980’s and do not consider different regions/climates within the United Kingdom. By revising line ratings, it may be possible to optimise and increase the capacity of the network. The current circuit ratings were established in Leatherhead, Surrey, during the 1980’s. The data at this location and time is unlikely to be representative of the current Scottish climate. This project involves investigating these limits and carrying out analysis to see if ratings can be more reflective of the climate in Scotland. Multiple partners are collaborating for the REVISE project, combining different data to be able to model and investigate if the seasonal limits can be updated. This report will cover Work Package 3 which is the package that looks at understanding and evaluating exceedance.

The method behind extracting exceedance/over seasonal-limit events will involve analysing Transmission circuits (132kV, 275kV & 400kV) in SSE’s Network. Analysis will be based on the seasonal ratings defined by TGN-26 and examining if the circuits MVA has gone over these limits in the past 10 years. When a circuits MVA goes over a seasonal limit, this could suggest an exceedance event has occurred.

## Ratings

Ratings for Overhead Lines are critical for the design, operating and protection of the network. Pre-fault ratings are the maximum electrical load/current that a transmission line is designed to carry under normal, fault-free conditions. Post-fault ratings refer to the current-carrying capacity of a transmission line after a fault has occurred. These ratings are typically higher than pre-fault ratings because of the usual temporary nature of faults and the protection schemes in place. Pre-Fault ratings are 84% of the maximum continuous rating, with post-fault being 100% maximum. The ratings under investigation are static ratings. These are ratings based on worst-case conditions, often underestimating capacity. Ratings are also based on the season of the year, and these are adjusted for Summer, Spring/Autumn and Winter conditions. Seasonal ratings lack responsiveness to short-term weather fluctuations. Appendix B shows the season start/end times.

## Exceedance

A key factor to examine in OHLs is exceedance. Exceedance in OHLs is the proportion of time for which the line exceeds its profile temperature. Exceedances can arise from many factors including increasing load demand, weather/environmental issues, network constraints, generation variability and outdated seasonal ratings. Exceedances in OHLs can cause major problems such as line sag, overheating conductors, insulation failures. Such problems can lead to breaching clearances and endangering life. By examining exceedance, it helps to visualise if these ratings are too conservative. Within Scotland, different regions/areas can vary different in climate so by having different ratings depending on location and climate may be very advantageous to optimize the network. The results in this report are purely electrical, and do not take into consideration the environmental conditions. The results primarily look at amount of time the MVA has gone over the seasonal limit. Exceedance depends on both load and the environmental conditions. If a circuit is over its seasonal limit, it suggests that there is a risk of exceedance if the environmental conditions are not favourable, and conversely operating above the seasonal limit in cool/favourable conditions may have no risk of exceedance due to natural cooling. Also, prolonged periods over a seasonal limit can cause the conductor temperature to increase.

# Methodology

The following methodology outlines how data was extracted from SCADA systems to analyse instances of MVA going over a specific seasonal limit, which could suggest an exceedance event has taken place. The software used to find this data will also be presented in this report. For this study, the pre-fault rating was used, and 10 years’ worth of circuit data was used for examinations.

## Software

The software used for this project was vital for finding and evaluating instances of exceedance. The two main systems used for this investigation were PowerOn and AVEVA PI.

### PowerOn

PowerOn is a SCADA (Supervisory Control and Data Analysis) system that allows remote control and monitoring of the Transmission system. Within SSEN-Transmission PowerOn is used to provide a view into the live state of the 132kV, 275kV, 400kV & HVDC network. PowerOn represents substations that are interconnected by Overhead Lines and Cables, along with the associated equipment such as transformers, circuit breakers and disconnectors etc. PowerOn also shows interfaces between generation and distribution connections, represented with different colours from Transmission. Each substation collects data from all the equipment and sends data such as switchgear positions, analogue measurements such as volts, amps, Megawatts (MW) and alarms to show when something is in an abnormal state.

### AVEVA PI

PI is a software used for real-time data collection, storage, analysis and visualisation. The software was created and maintained by the IT Consultancy company AVEVA Group plc. Tags can be created in PI, these represent data points and can be used for many things, such as monitoring and alerting. PI tags are created for many components on PowerOn including both digitals and analogues (values such as MW, volts etc). PI tags may be searched for in PI Processbook, PI Vision and Excel with a PI add-in.

## Data Extraction & Collation

For this project a PI Tag was created that acts as a counter. This counter ‘counts’ the time in minutes when a circuits MVA has gone over its seasonal limit, in that specific season. The season changes were defined by the control room, and this was applied to the counter to ensure accurate data was collected. This tag was then used to find the total time in minutes that the MVA went over a seasonal limit, and from this it is possible to find the percentage of time over a seasonal limit, in a circuits entire operating time.

This counter tag was also used for examining circuits in more detail. When the counter showed that a circuits MVA had gone over a seasonal limit, PI Vision was used to examine the circuit data in more detail. Within PI Vision, the circuits MVA, seasonal-limits and other telemetry can be plotted for a desired time frame. From this, it is then possible to examine instances of where the MVA went over a limit in more detail. Data such as the time over limit, maximum MVA and maximum current can be examined.

PI Vision helps to visualise circuit data in a relatively user-friendly environment. Many data-points can be imported into PI Vision and analysed. Figure 1 below shows an example of circuit data that was analysed. Figure 1 above shows an example of where data was extracted. The three horizontal lines show the seasonal limits, and the white lines show the circuits MVA. This figure shows how the MVA fluctuates between seasons, shown by the undulating peaks. On the right side of the figure, we can see instances of where the MVA has gone over the seasonal limits, and this data was analysed in more detail. The MVA spikes appear to be random, with no instances of commissioning/tests or outages causing in-rush spikes. **Circuits that have spent under 10 minutes over the seasonal limit have been excluded from this report, as this is unlikely to have large effect on an OHL.**

A screenshot of a computer

Description automatically generated

Figure 1: Example Data

## Instances of Data Exclusion

From the data extracted from PI Vision and Data link, it was observed that there were several anomalies which, upon investigation, were deemed removable. These included initial circuit testing, commissioning spikes and inrush currents. Figure 2 below shows an example of a PI Vision graph with an uncharacteristic spike. This is why PI Vision proved to be a vital tool in analysis, as some of this data anomalies might not have been spotted.

A screen shot of a computer

Description automatically generated

Figure 2: Excluded Data

Figure 2 shows how this initial MVA spike may hinder the desired results, as this peak is unlikely to be the result of a naturally occurring fault.

# Results

A total of 180 Overhead Line Circuits were investigated in this study. From the ‘time over limit’ tag and discarding unwanted data, only 27 circuits showed evidence of the MVA being over a seasonal limit (over 10 total minutes). PI Vision was used to discard ‘unwanted’ data, as this software helped to visualise in-rush currents and instances of what looked to be artificial spikes. PI Vision was also used to examine the limit breach in more detail, and a report of this was shared with the University of Strathclyde.

By examining the total time, the circuit spent over a seasonal limit, and knowing a circuits total time in operation, a percentage of time over limit was calculated. This helps provide a straightforward metric and helps quantify how often a circuit spends outside the seasonal limit. A circuit that has a low percentage of time over limit suggests that this circuit may be underutilized and could indicate the limit is too conservative.

This results in Appendix A show that only 27 of the 180 circuits are spending time over their seasonal limits, and even then, they are all spending over 99% of time under the seasonal limit. This implies that circuits going over their seasonal ratings is very rare.

Circuit CM2 (highlighted yellow in Appendix A) shows increased levels of time over limit. This is due to behaviour in the circuit that does not resemble artificial issues. This is likely to be due to issues with telemetry and unnoticed artificial spikes in MVA.

The average percentage of time over seasonal limits for the 27 circuits is 0.03%. This is based on the period the circuit has been live, up to 10 years. These findings provide a strong basis for revising seasonal limits, as this low value of 0.03% illustrates that there may be highly conservative assumptions behind the limits.

# Summary

Analysing the results show that only a small number of circuits went over the TGN-26 seasonal limits. Looking at the total percentages show that the total time over the limits in 10 years is very small. All circuits shown in results still spend over 99% of their time within the seasonal limits. This suggests the circuits are adequately designed with sufficient safety margins.

These low times over seasonal limits suggest that the static line ratings are overly conservative and may not reflect the actual operating conditions in Scotland. The results show that the circuits are operating most of their time within their seasonal limits indicating that there is headroom for revising the static ratings. The benefits of revising such limits could be to increase circuit utilization and improve efficiency.

Some key areas to investigate is the role of climate change and growing demand. As the climate becomes warmer, the ratings may become less conservative and more reflective of actual operation. As demand grows and the network expands, more strain will be put on the grid meaning that conservative ratings may be beneficial in time to come.

Overall, revising the static line ratings offers a high potential of optimizing the grid and increasing the performance of circuits across the network. By aligning the limits with real-world data in Scotland, energy utilities could potentially increase efficiency, reduce costs and assist with reaching climate targets. The circuit’s 10-year performances in this study shows that they are operating within their seasonal limits over 99% of the time, and there are many circuits in the network that have never went over their seasonal limit at all. Thus, this report suggests that there is a possible margin for updating seasonal limits based on **purely electrical results.**

# APPENDICES

## Appendix A – Time Over Limit Table

|  |  |  |  |
| --- | --- | --- | --- |
| **CONDUCTOR TYPE** | **VOLTAGE (kV)** | **CIRCUIT** | **% of Time Over Seasonal Limit** |
| 1x150 - Wolf ACSR | 132 | BBN | 0.0471 |
| 1x150 - Wolf ACSR | 132 | BBS | 0.0092 |
| 1x125 Tiger ACSR | 132 | BE1 | 0.0271 |
| 1x175 - ACSR | 132 | CM1 | 0.0050 |
| 1x175 - ACSR | 132 | CM2 | 0.6299 |
| 1x175 - Lynx ACSR | 132 | CSS | 0.0002 |
| 1x175 - Lynx ACSR | 132 | ELW | 0.0143 |
| 1x175 - ACSR | 132 | ETS | 0.0071 |
| 1x175 - ACSR | 132 | FK | 0.0073 |
| 1x125 - Tiger ACSR | 132 | IDW | 0.0771 |
| 1x125 - Tiger ACSR | 132 | ITE\_IF1 | 0.0008 |
| 1x175 - ACSR | 132 | LD2 | 0.0003 |
| 1x175 - ACSR | 132 | LS1 | 0.0004 |
| 1x175 - Lynx ACSR | 132 | NL1 | 0.0006 |
| 1x175 - Lynx ACSR | 132 | NL2 | 0.0021 |
| 1x175 - Lynx ACSR | 132 | SN1 | 0.0025 |
| 1x175 - Lynx ACSR | 132 | SWE1 | 0.0002 |
| 1x175 - Lynx ACSR | 132 | SWW2 | 0.0006 |
| 1x400 - Zebra ACSR & 1x175 Lynx ACSR | 132 | TAN | 0.0005 |
| 1x150 - Wolf ACSR | 132 | TBN | 0.0015 |
| 2x400 - Zebra ACSR | 275 | TW1 | 0.0034 |
| 2x400 - Zebra ACSR | 275 | TW2 | 0.0004 |
| 1x250 - Bear ACSR | 132 | XPS | 0.0004 |
| 2x400 - Zebra ACSR | 275 | XS1 | 0.0007 |
| 2x400 - Zebra ACSR | 275 | XS2 | 0.0009 |
| 1x700 - Araucaria AAAC | 275 | XT1 | 0.0006 |
| 1x700 - Araucaria AAAC | 275 | XT2 | 0.0016 |

## Appendix B – Season Start/End Times

|  |  |  |
| --- | --- | --- |
| 2014 | Spring/Autumn | 01/03/2014 |
| Summer | 01/05/2014 |
| Spring/Autumn | 01/09/2014 |
| Winter | 01/12/2014 |
| 2015 | Spring/Autumn | 01/03/2015 |
| Summer | 01/05/2015 |
| Spring/Autumn | 01/09/2015 |
| Winter | 01/12/2015 |
| 2016 | Spring/Autumn | 01/03/2016 |
| Summer | 01/05/2016 |
| Spring/Autumn | 01/09/2016 |
| Winter | 01/12/2016 |
| 2017 | Spring/Autumn | 01/03/2017 |
| Summer | 01/05/2017 |
| Spring/Autumn | 01/09/2017 |
| Winter | 01/12/2017 |
| 2018 | Spring/Autumn | 01/03/2018 |
| Summer | 01/05/2018 |
| Spring/Autumn | 01/09/2018 |
| Winter | 01/12/2018 |
| 2019 | Spring/Autumn | 01/03/2019 |
| Summer | 01/05/2019 |
| Spring/Autumn | 01/09/2019 |
| Winter | 01/12/2019 |
| 2020 | Spring/Autumn | 01/03/2020 |
| Summer | 01/05/2020 |
| Spring/Autumn | 01/09/2020 |
| Winter | 01/12/2020 |
| 2021 | Spring/Autumn | 01/03/2021 |
| Summer | 01/05/2021 |
| Spring/Autumn | 01/09/2021 |
| Winter | 01/12/2021 |
| 2022 | Spring/Autumn | 01/03/2022 |
| Summer | 01/05/2022 |
| Spring/Autumn | 01/09/2022 |
| Winter | 01/12/2022 |
| 2023 | Spring/Autumn | 01/03/2023 |
| Summer | 01/05/2023 |
| Spring/Autumn | 01/09/2023 |
| Winter | 01/12/2023 |
| 2024 | Spring/Autumn | 01/03/2024 |
| Summer | 01/05/2024 |
| Spring/Autumn | 01/09/2024 |
| Winter | 01/12/2024 |