Comments from referee #1

The authors describe their work to complete the end to end modelling of GIC flow in the Swedish high voltage power grid using magnetic field measurements, the SMAP conductivity model and the RAISE representation of the power network. They investigate the October 2003 storm and then extend this to a 1-in-100 year storm using magnetic latitudinal bands of different scaling based on a recent statistical analysis of geoelectric fields.

They find the peak geoelectric field to lie between 10-30 V/km in some regions of Sweden. They use the model to identify lines that are expected to be more vulnerable to high current flow, though represented as total integrated voltage along particular lines. They discuss the implications and compare to regions where known outages have occurred before. They have generated two informative movies to illustrate the dynamic nature of the GIC flow.

This is an extremely well written paper and I could not find any issues with the logic, clarity or flow of the manuscript. The figures and tables are excellent and the results are useful for the operator. The authors are to be commended.

We thank the reviewer for the positive and encouraging assessment of our study. Please see below for detailed replies to all comments. The original review is written in black and our replies in red.

My only minor comments are:

1. Why are the values of the line and transformer resistance under national security restrictions? They are available in other countries for example, so are probably similar in Sweden. Average values of resistance per km are given in e.g. Viljanen et al (2012) doi: 10.1051/swsc/2012017if you wanted to model GIC and use a standard 0.5 Ω for the grounding resistance.

Detailed electrical parameters of transmission networks (e.g., line resistances) are considered sensitive because they allow the reconstruction of high-fidelity power-flow models. Such models can be used to identify critical nodes, simulate contingencies, and design cyber-physical attack scenarios capable of causing temporary or large-scale blackouts.

From a legislative perspective, this type of technical information falls under the protection of critical infrastructure regulations. In the EU, electricity transmission and distribution systems are explicitly classified as "critical entities" (see Annex of Directive (EU) 2022/2557 on the resilience of critical entities). As a result, operators are required to restrict access to operationally sensitive data that could compromise system security.

Available online:
https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32022L2557

We agree that the resistance-per-kilometre values provided in Viljanen et al. (2012) can be used to estimate GICs. For example, Rosenqvist et al. (2025) used 0.5 Ω for the grounding resistance and typical line resistances of 0.022 Ω/km for 200 kV lines and 0.008 Ω/km for 400 kV lines. Accurate modelling of power-system behaviour requires not only the resistances but also detailed knowledge of network topology and line connectivity. Without this information, the resulting GIC estimates could lead to substantial uncertainties and potentially misleading conclusions about system vulnerability.

2. Why not use Belsk, Brorfelde and Wingst observatories in the analysis to capture variations outside and to the south of Sweden in October 2003?

Thank you for this observation. The main reason we did not use Belsk, Brorfelde, or Wingst is that our analysis relied on magnetic field from stations that provided consistent 10-second data within the IMAGE network. Among the three stations mentioned, only Wingst is part of IMAGE, and its data coverage in IMAGE began in 2015.

We nevertheless examined the data available from all three observatories for the October 2003 event. Each provides 1-minute magnetic field vectors (Belsk in Poland, Brorfelde in Denmark, and Wingst in Germany via INTERMAGNET). In contrast, our modelling uses 10-second resolution data, which is necessary to capture the rapid geomagnetic variations relevant for GIC calculations. Using 1-minute data would introduce temporal smoothing and reduce the accuracy of the derived electric fields.