This is Gourab Banerjee, an M.Sc. in renewable energy (EUREC) in the year 2013-15, worked in Fraunhofer IEE, Kassel, Germany (formerly Fraunhofer IWES) from 2015 until 2017 and then in the department of "Energiemanagement und Betrieb elektrischer Netze" at the University of Kassel, Germany in collaboration with Fraunhofer IEE, Kassel, Germany as a researcher since 2017. My research topic is related to the protection study for distribution grids focusing on the grounding protection, and now concentrating on the grid planning for distribution grids. I recently have a publication in the IEEE SEST 2018 international conference, Spain. Kindly find the summary of the publication as follows:

Topic of the Paper: "Analysis of the Impact of Grounding System on HV Distribution Grid for Islanding Mode by Network Restoration from Black-start"

<u>Introduction and Motivation</u>

The purpose of this research is to investigate the impact of the grounding design on the high voltage end (110 kV) during a bottom-up network restoration process during the different islanding formations from black-out. Compensated grids and resonant grounding are majorly used in Germany and Middle-Europe for medium and high voltage grids. To avoid the hazardous effect of the ground fault during network restoration processes with the connection of DER, it is important to analyse how the grounding is affected by the changing topology and grid configuration. Different grid configurations are analyzed in this paper and the grounding safety range is established during the investigation process.

<u>Objectives and Research questions</u>

The objective of this research is to investigate the impact on the grounding system in HV distribution grid during the step-wise network restoration from black-start. The main research questions are as following:

- How will the conventional grounding system, here resonant grounding in Germany, be impacted and affected during the bottom-up network restoration process after black-out?
- How will the grounding design be adapted to maintain the limits of the earth-fault residual current and ensure grounding safety during the bottom-up network restoration process?

<u>Investigation and Different Stages of Network Restoration</u>

In this paper, a 110/20/0.69 kV network is modelled from the grid data of a distribution system operator in Germany using DIgSILENT PowerFactory as the simulation software. In Fig. 1, the grounding operation and the flexibility of the HV network is analyzed during islanding and grid connected mode from black-start in four different configurations (shown in different colors). The grid configurations are considered based on the network restoration from a set of wind power plants, connecting the HV lines and then feeding the load in different islanding modes. The value of the total earth-fault current and earth-fault residual current is calculated in each grid configurations, and the Petersen coil is designed in each steps so that fault current can be compensated in the range of the under- and over- compensation limit of DIN VDE 0228. Then, a range of coil selection is established to ensure the grounding safety in all grid configurations.

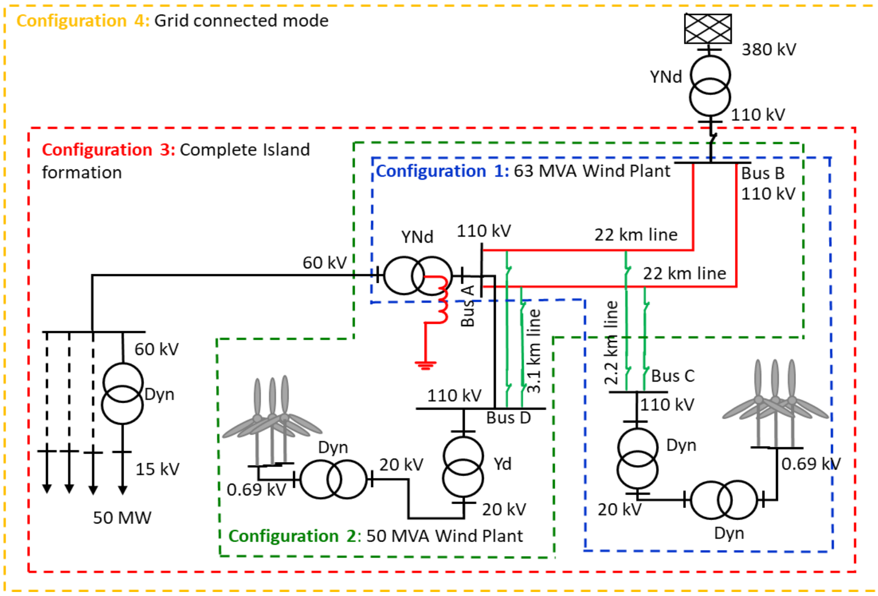

Figure 1: Grid topology with different grid configurations considering aggregated grid model for lines, wind turbines and loads of the network restoration topology [1]

Results and Observations

- The coil operating range in the normal operating condition is shown in Table 1 in the grid configuration 4, which is state of the art. The results shown in grid configuration 1, 2 and 3 represent the coil operating ranges in different islanding mode.
- The key finding is that the Petersen coil range selection has to be modified during islanding grid operation in different grid configuration in comparison to the normal operating mode. The coil selection range is shown in Fig. 2, based on the four different grid configurations in this study case.
- Although the simulation results are shown for a particular grid type, this study can be used to give general recommendations which can be applied by the DSOs for their grounding design of the HV/MV/LV grid.

Table 1: Petersen coil selection in all grid configurations [1]

Summary of ground fault current compensation (under- and over-compensation) and Petersen coil selection				
Grid configuration	***Grid length (in km)***	***Ground-fault current (in Amp)***	***Residual current (in Amp)***	***Value of Petersen coil (in Ω)***
Configuration 1: 63 MVA DER connected	48.4	662 - 920	105	96 - 69
Configuration 2: 50 MVA DER connected	50.2	714 - 962	105	89 - 66
Configuration 3: Complete island formation	60.6	836 - 1134	105	76 - 57
Configuration 4: Grid connected mode	60.6	836 - 1134	105	76 - 57

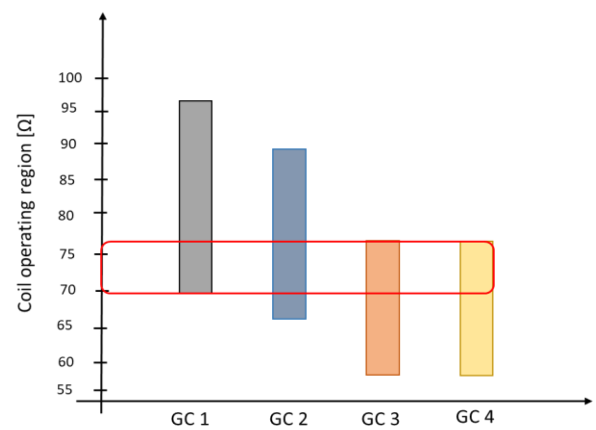

Figure 2: Coil selection range considering all the grid configurations (GC) [1]

Conclusion and recommendation

- Change of the line length has a major impact on the ground-fault current.
- The ground fault current is affected by the line topology in the HV grid, not directly by the short-circuit contribution of DER units.
- The selection of the transformer vector group and the grounding is important for DER and load connection.
- A suitable and robust technical solution for bottom-up network restoration will be to use an automatic tuning coil for resonant grounding.

Acknowledgement

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For detailed knowledge, kindly see the full paper:

[1] G. Banerjee and M. Braun, "Analysis of the Impact on the Grounding System in 110 kV Grid During Bottom-Up Network Restoration", IEEE Smart Energy Systems and Technologies (SEST), Seville, September 10-12, 2018. (Available online: https://ieeexplore.ieee.org/document/8495738)