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Grid of the Future

Calculation of GIC in Bulk Power Systems

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Outline

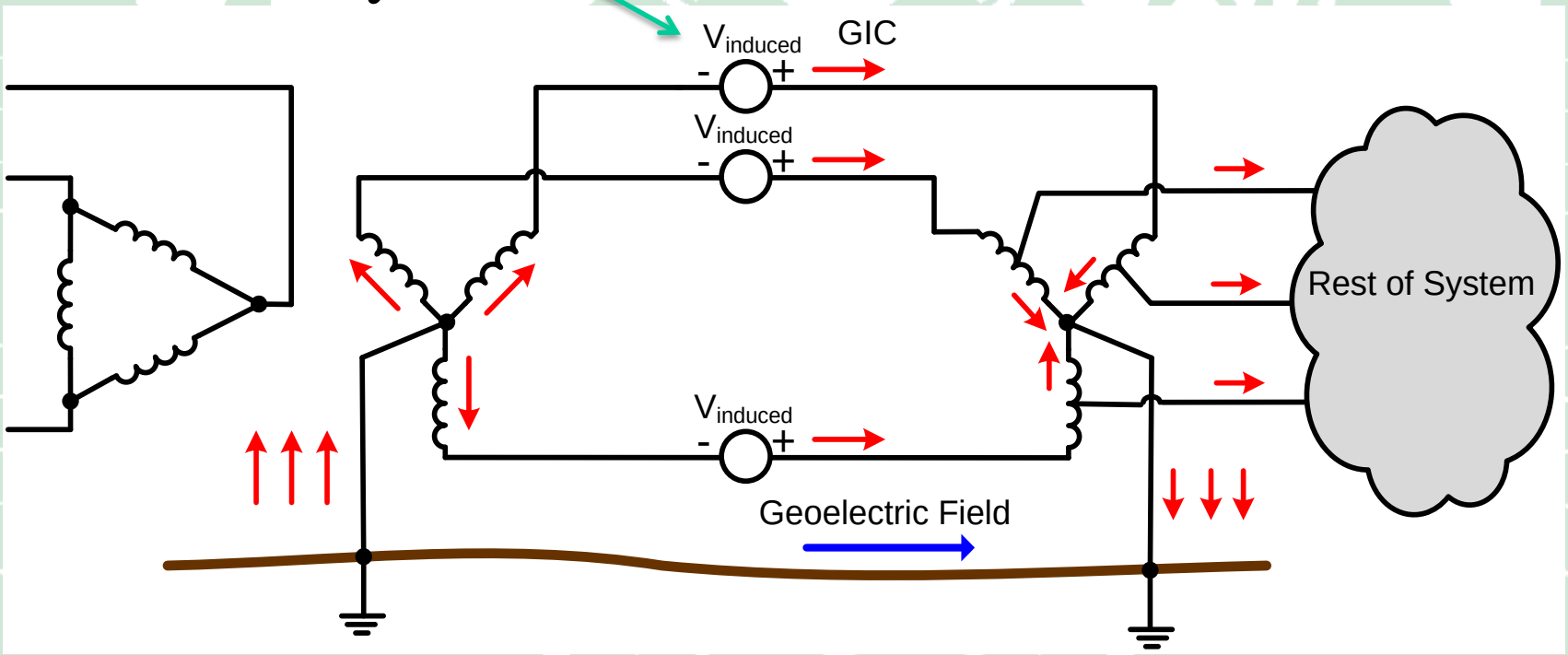
- Background
- Geoelectric Field Calculations
- System Modeling and GIC Calculations
- Conclusions

Background

- During geomagnetic disturbances, magnetic field variations at the earth's surface drive low frequency electric currents along transmission lines and through transformer windings to ground wherever there is a path for them to flow.
- Driving force is the induced EMF in the transmission lines
- GIC are considered quasi-dc because of their low frequency (10uHz – 1Hz) relative to the power frequency

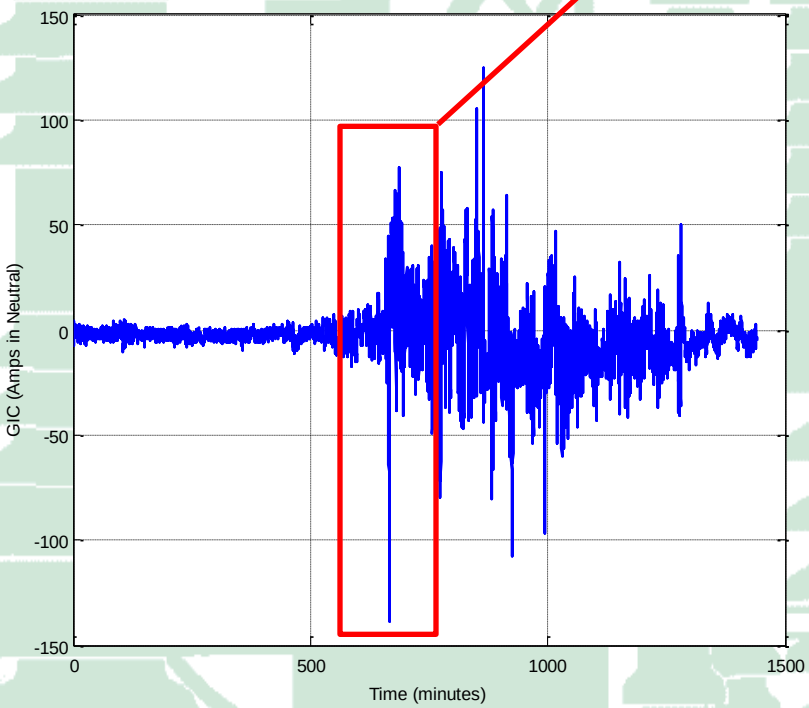
Background

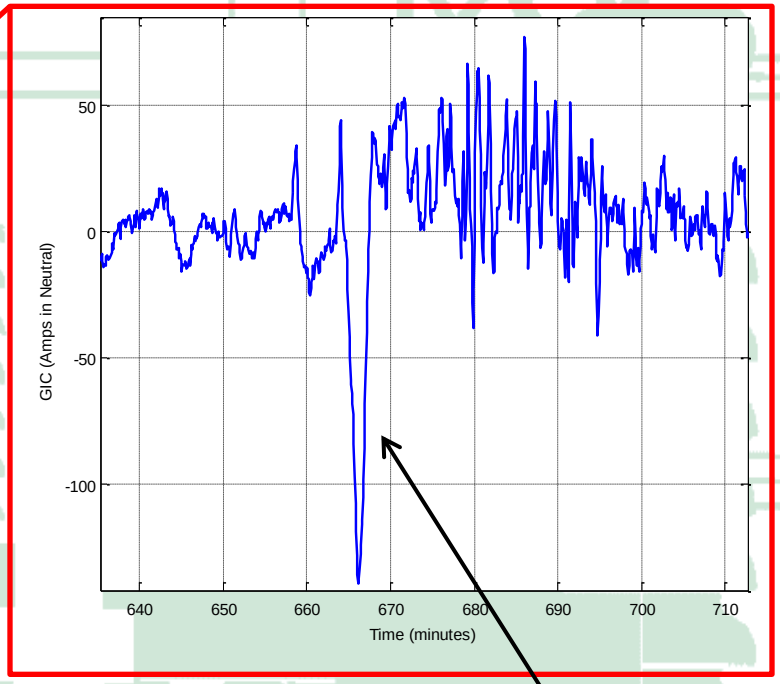
$$V = \oint \vec{E} \circ d\vec{l}$$



Background

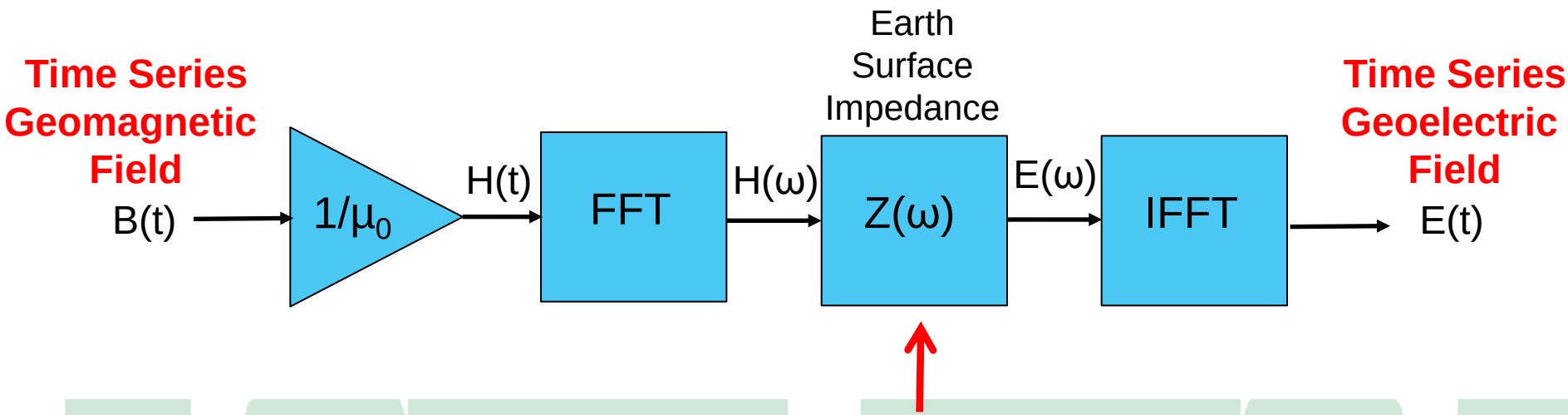
Example GIC

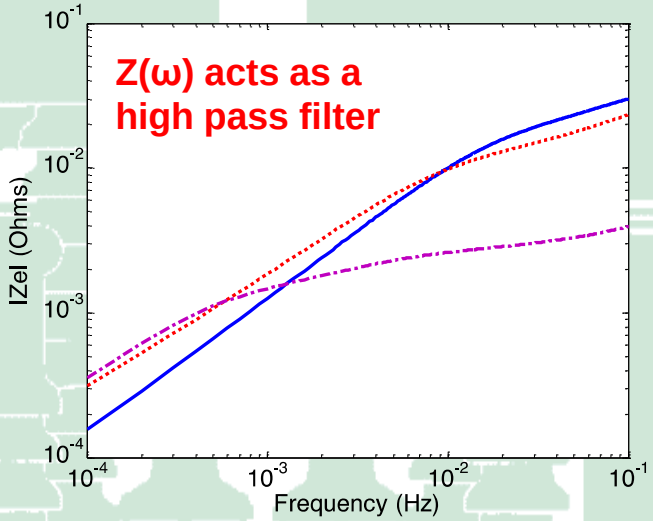




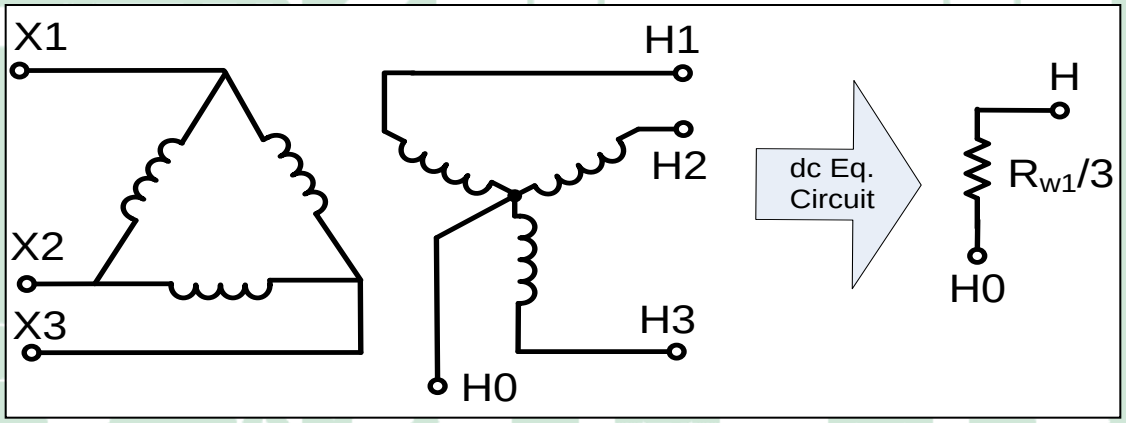
Pulse widths are generally on the order of 2-10 minutes

Geoelectric Field Calculations

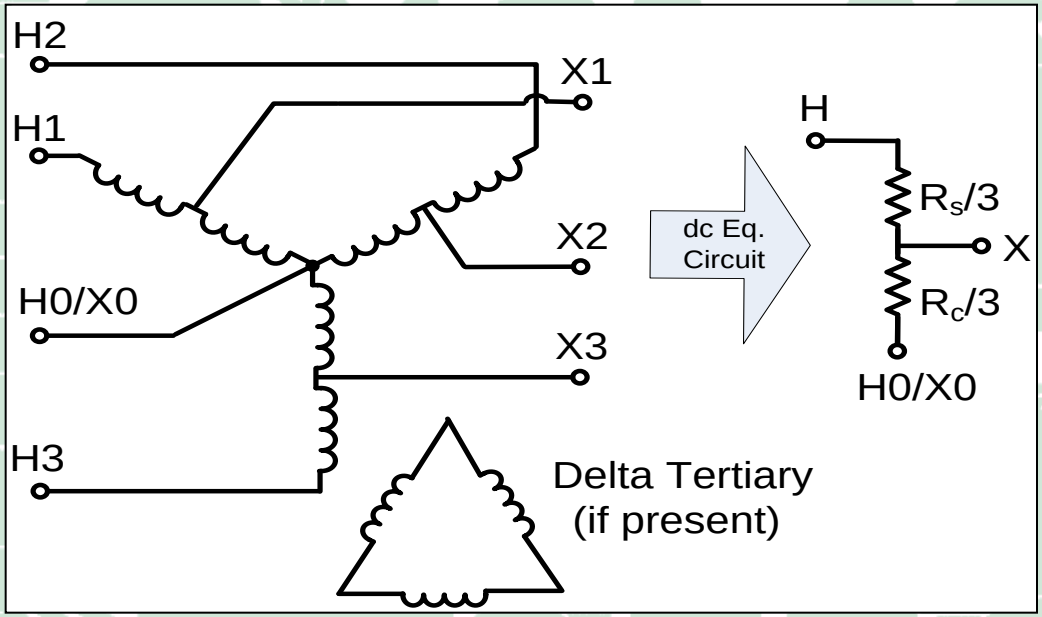




dc Transformer Model

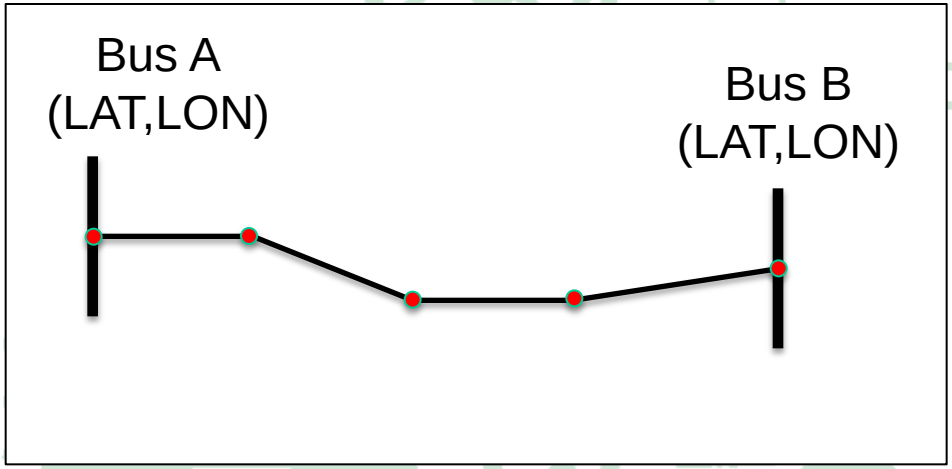


GSU Example



Autotransformer Example

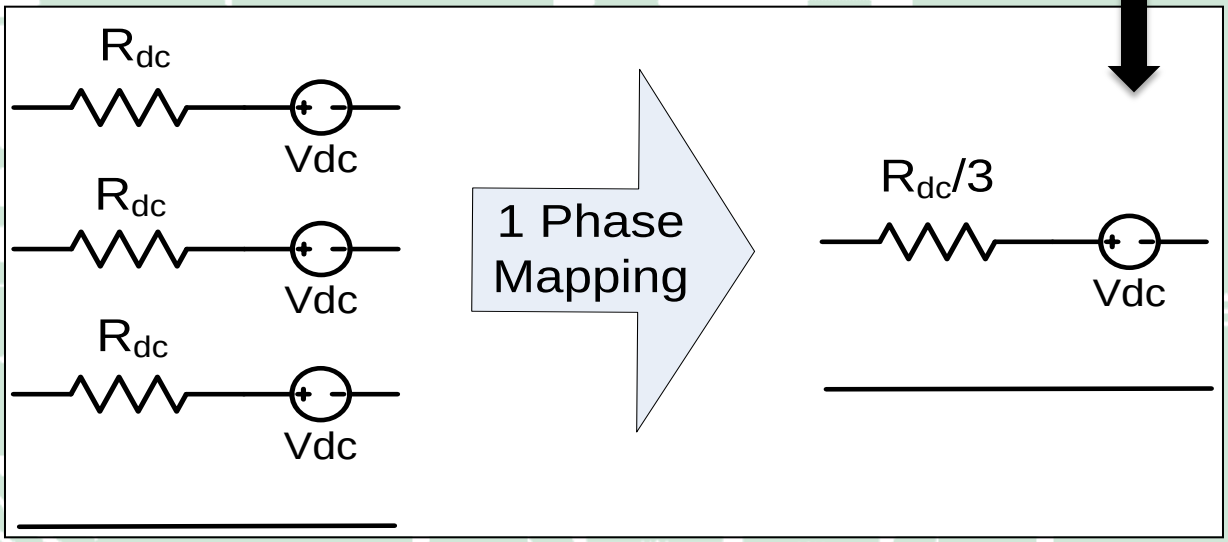
Transmission Line Model



$$V = \oint \vec{E} \circ d\vec{l}$$

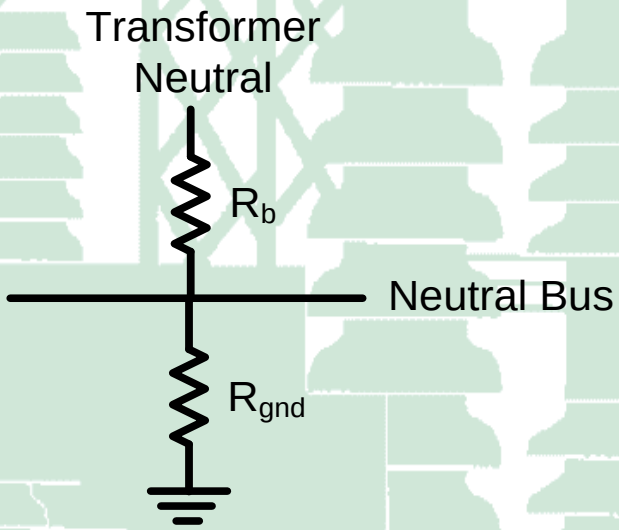
If uniform E field

$$\vec{E} \circ \vec{L} = E_x L_x + E_y L_y$$



Substation Ground Grid and GIC Mitigation Device Models

- The substation ground grid resistance including the effects of any grounded line conductors (e.g. shield wires or neutrals) is required.
- A capacitive GIC blocking device presents very high impedance to GIC; thus, it can be modeled as a high resistance (e.g. 1.0 MΩ), whereas, the actual resistance of a resistive blocking device is used.



GIC Calculations

- Once the dc model has been assembled, the resulting GIC flows can be computed using any suitable circuits technique.
  - $I = [G]V$
  - For large systems (typical), sparse matrix techniques are employed
- Node voltages ($V = [G]^{-1}I$) are computed, then the GIC flows are computed.

Conclusions

- The process for computing GIC in a bulk power system was presented.
- The various steps for determining the geomagnetic field that is to be evaluated was provided.
- Guidance on assembling the dc system model and computing the GIC flows were also provided.