Modelling active earth fault compensation device

FLEXe
Future Energy System

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24.02.2016, Amir Farughian, Kimmo Kauhaniemi
kimmo.kauhaniemi@uwasa.fi

Introduction

- Active Earth Fault Compensation / Active Earthing is a promising scheme for handling single phase to ground faults in medium and high voltage networks without customer outage.

- A Swedish company called Swedish Neutral has put this scheme into practice as Ground Fault Neutralizer (GFN).

- The GFN operates in resonant grounded networks. It provides fast and complete compensation of all remaining earth-fault currents – both fundamental and harmonics.

Principles of GFN Operation

- Instead of tripping the faulty feeder, GFN cancels out the fault current by injecting an anti-phase current into the neutral.
- Determining the injected current is based on measuring the zero-sequence admittance by injecting a current into the neutral.

Pre-fault: $$\underline{Y}_{0ref} = \frac{\underline{I}_{oref}}{\underline{U}_{0ref}}$$

Post-fault: $$\underline{I}_{0inj} = \underline{Y}_{0ref}\,\underline{U}_{0meas}$$

Implementation

Determination of the injected current:

1. A measurement at no fault conditions (normal operating condition) is made and taken as a reference value for the zero-sequence admittance Z_0 .
2. U_0 is monitored constantly. If it exceeds a certain value, another measurement for Z_0 is made. A fault situation is detected if the measured value differs from the reference.
3. The GFN injects to the neutral a current with a magnitude and phase angle so that the new measured zero-sequence admittance equals the reference value. This leads to zero fault current.

Principles of GFN Operation

$$\underline{I}_0 = \underline{I}_1 + \underline{I}_2 + \underline{I}_3$$

$$\underline{Z}_0 = \frac{\underline{U}_0}{\underline{I}_0}$$

Normal operating conditions:

$$\underline{Z}_0 = \frac{1}{3}(\underline{Z} + \frac{1}{j\omega C})$$

Fault has occurred:

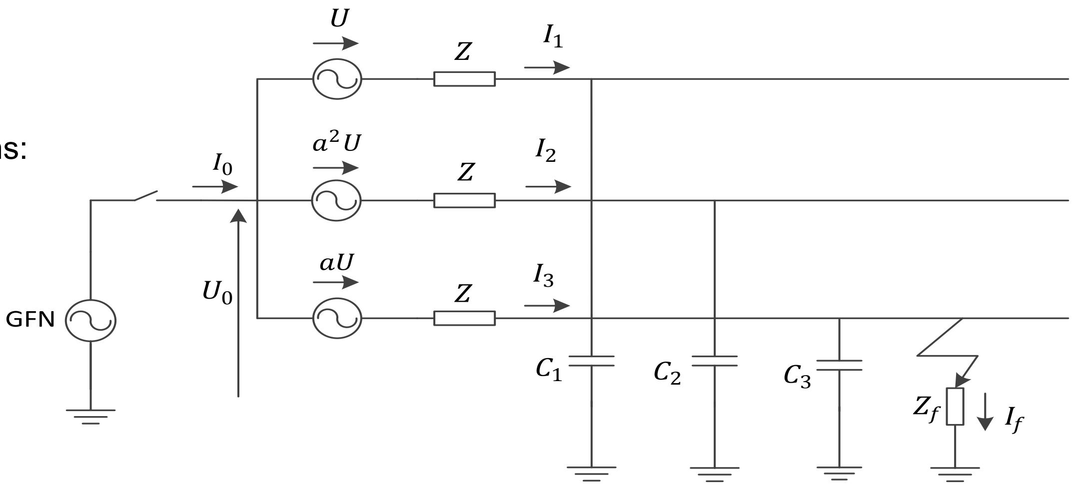
$$\underline{U}_0 - \underline{U} + \underline{I}_1 (\underline{Z} + \frac{1}{j\omega C}) = 0$$

$$\underline{U}_0 - a^2\underline{U} + \underline{I}_2 (\underline{Z} + \frac{1}{j\omega C}) = 0$$

$$\underline{U}_0 - a\underline{U} + \underline{I}_3 (\underline{Z} + \frac{1}{j\omega C} || \underline{Z}_f) = 0$$

$$\rightarrow \underline{I}_3 = 0 \ \& \ \underline{U}_0 = -a\underline{U}$$

$$\rightarrow \underline{I}_f = 0$$

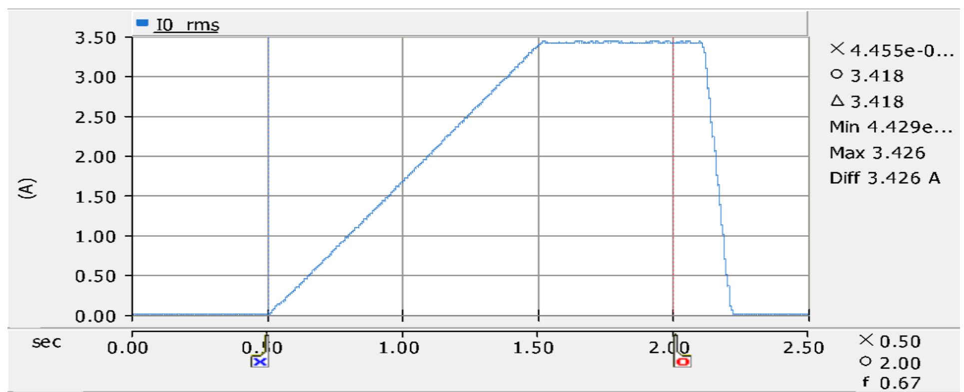


Simplified model of an MV network

Determination of Z_0 in normal operation conditions

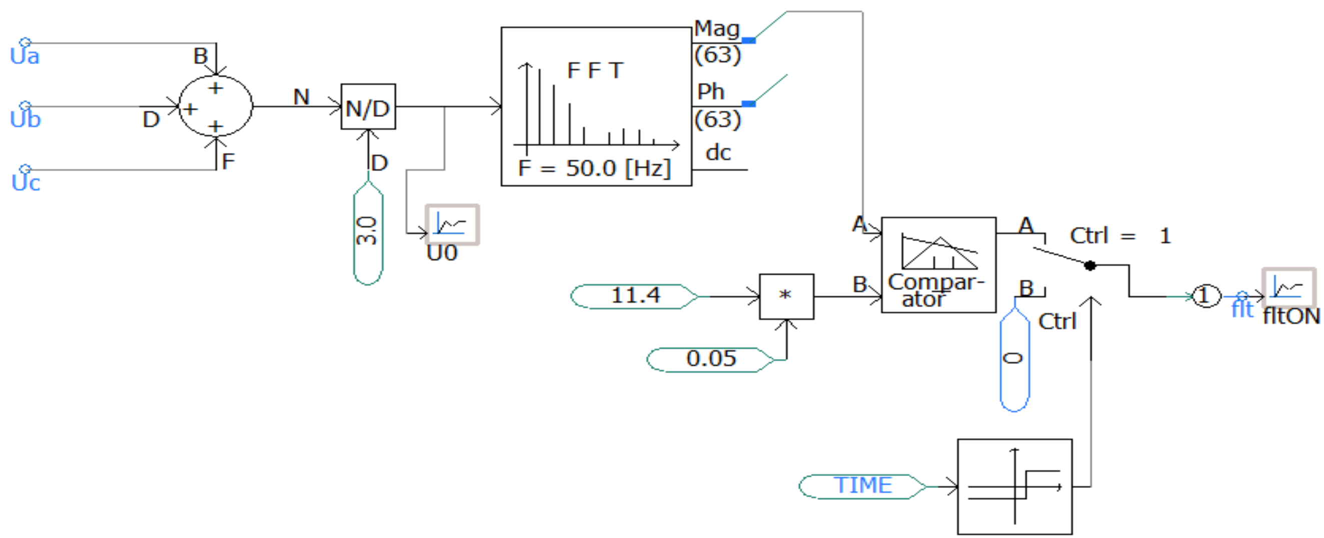
1. GFN injects a current to the neutral point as shown in the figure below.
2. At $t=2\ s$ the I_0 and U_0 are measured and with them the reference zero admittance Y_{0ref} is calculated.

-Note that to avoid any problem caused by transient states, the injected current waveform is not a square.



Fault detection

- If at any time the measured U_0 is greater than 5% of the nominal phase voltage (11.4 kV), a fault situation is detected which leads to the activation of GFN.
- Note that in the first 2 seconds of the simulation, the U_0 value changes due to GFN experiments and should not be considered as a fault condition.



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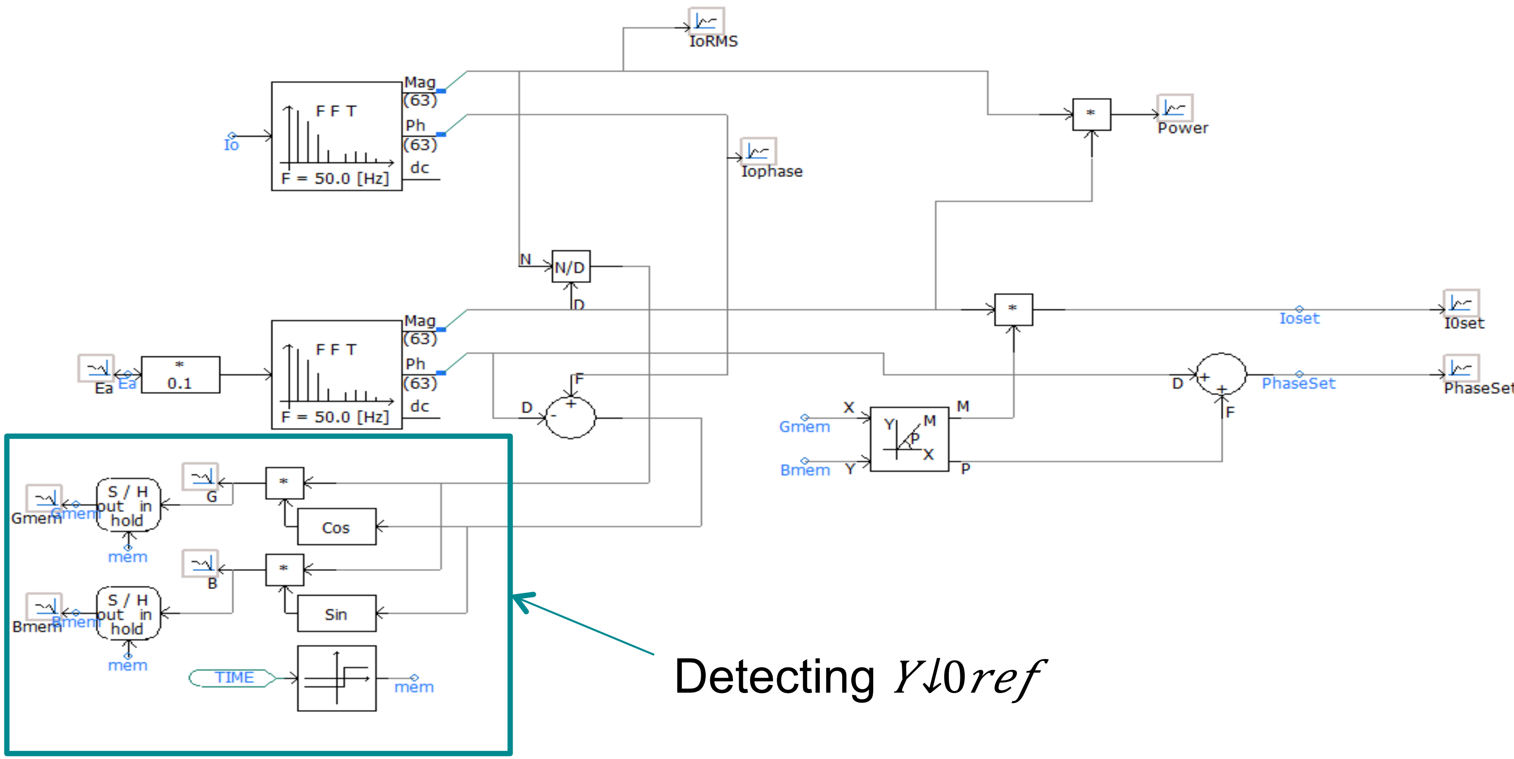
Control System



Detecting Y_{0ref}

CLIC

Control System

- The control variables are the magnitude and angle ($I_{0\,Set}$ and $PhaseSet$) of the zero sequence current required to be injected to the neutral by the GFN

- At $t=2s$ (normal operating conditions):

$$\underline{Y}_{0ref} = \frac{I_0}{U_0} \angle(\delta_{I0} - \delta_{U0})$$

- In case of fault:

$$I_{0inj} = U_{0meas} Y_{0ref}$$

$$\delta_{I0inj} = \delta_{U0meas} + \delta_{Y0ref}$$

Control System

- In the simulation model:

$$Gmem = \frac{I_{0ref}}{U_{0ref}} \cos(\angle I_{0ref} - \angle U_{0ref})$$

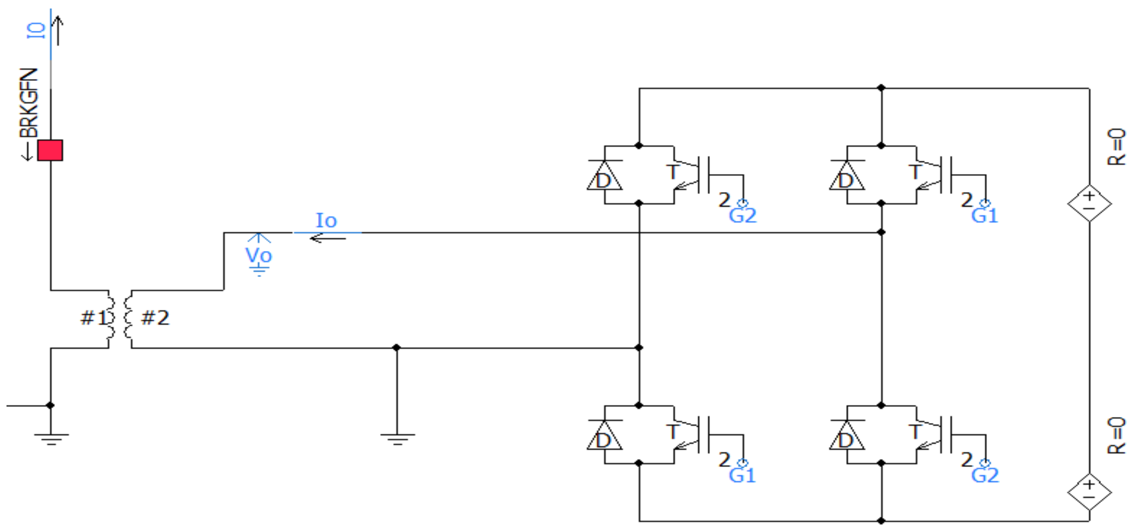
$$Bmem = \frac{I_{0ref}}{U_{0ref}} \sin(\angle I_{0ref} - \angle U_{0ref})$$

$$I_0 Set = I_{0inj}$$

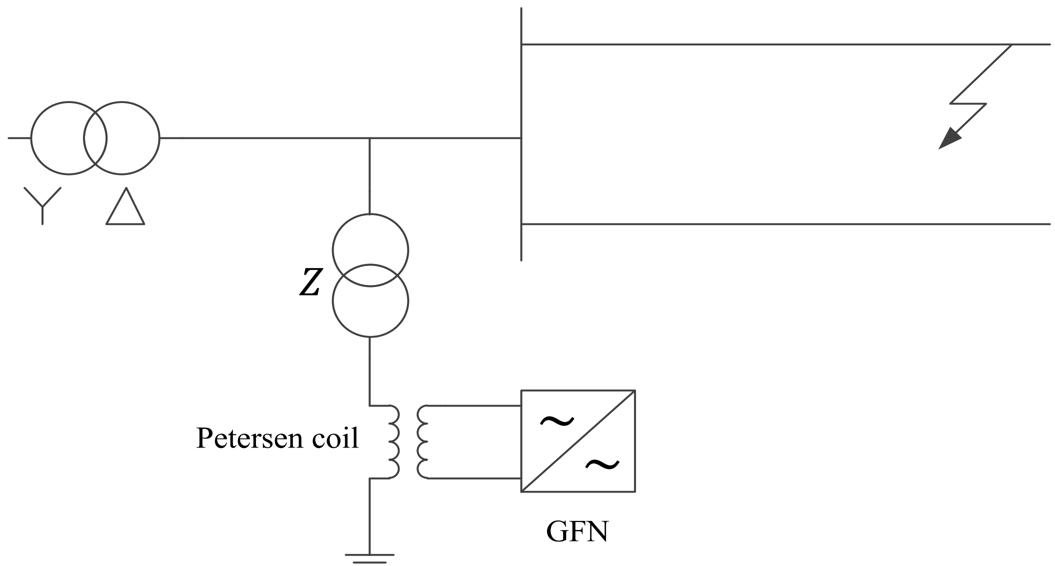
$$PhaseSet = \delta_{I0inj}$$

Current Source

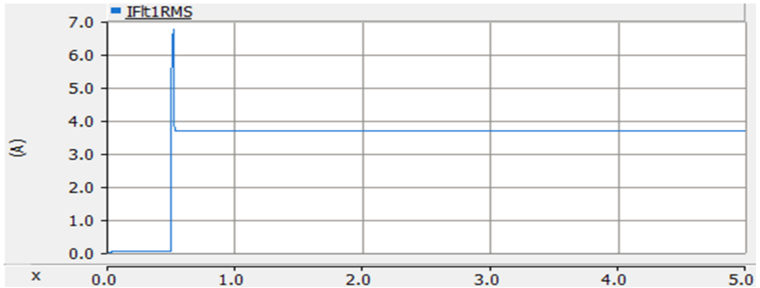
Inverter applying hysteresis based current control



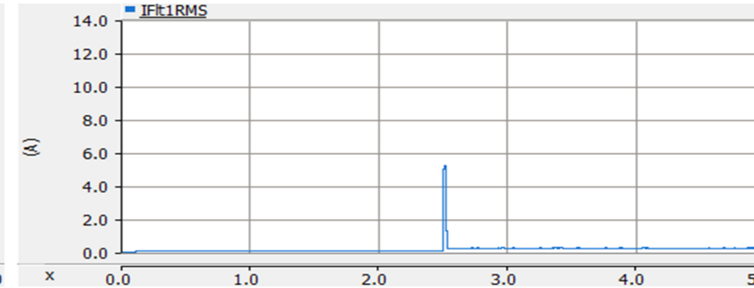
The Schematic of the Power System Modelled



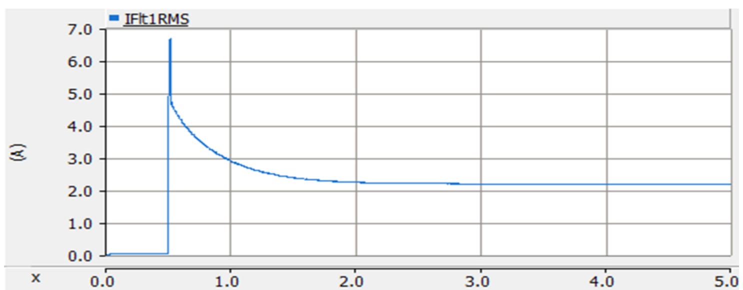
Fault Currents



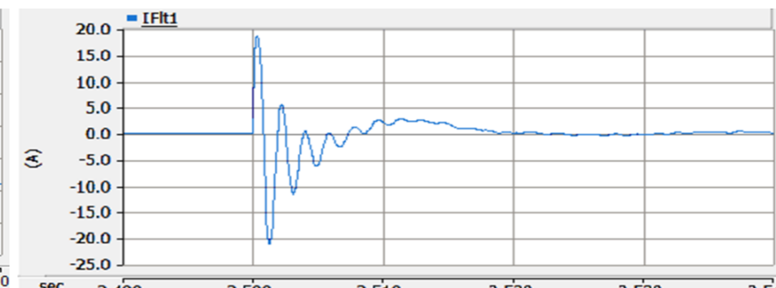
a) No GFN or Petersen coil connected (RMS value)



c) GFN connected (RMS value)



b) Only Petersen coil connected (RMS value)



d) GFN connected

References

1. Klaus M. Winter, “The RCC Ground Fault Neutralizer — A novel scheme for fast earth-fault protection”, 18th International Conference and Exhibition on Electricity Distribution, CIRED 2005.
2. J. Schlabbach, K. Rofalski, “Power System Engineering: Planning, Design, and Operation of Power Systems and Equipment”, John Wiley & Sons, 21 Jul 2008.

Appendix

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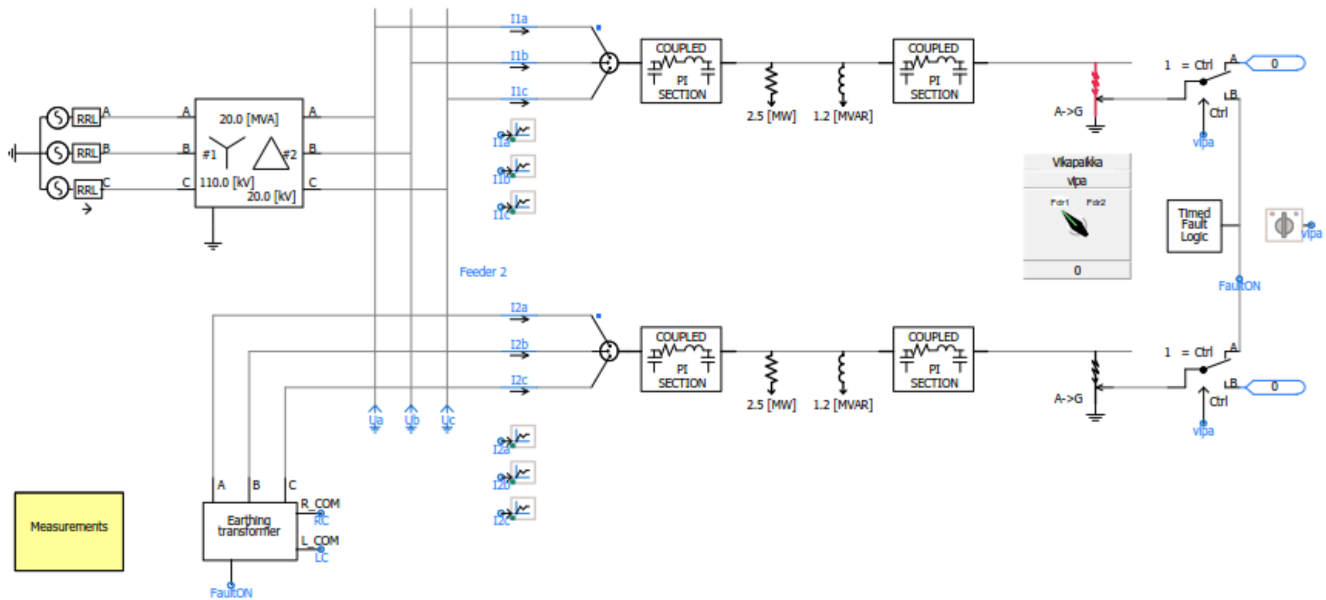
Simulated System in PSCAD

Main Page



Simulated System in PSCAD

Earthing Transformer