University of Idaho

ECE 525

POWER SYSTEM PROTECTION AND RELAYING

SESSION no. 19

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Phase B Components

$$\begin{pmatrix} IB0_v \\ IB1_v \\ IB2_v \end{pmatrix} := B_{012}^{-1} \cdot \begin{pmatrix} IAcpx_v \\ IBcpx_v \\ ICcpx_v \end{pmatrix}$$

$$\begin{pmatrix} VB0_v \\ VB1_v \\ VB2_v \end{pmatrix} := B_{012}^{-1} \cdot \begin{pmatrix} VAcpx_v \\ VBcpx_v \\ VCcpx_v \end{pmatrix}$$

Phase C Components:

$$\begin{pmatrix} IC0_v \\ IC1_v \\ IC2_v \end{pmatrix} := C_{012}^{-1} \cdot \begin{pmatrix} IAcpx_v \\ IBcpx_v \\ ICcpx_v \end{pmatrix}$$

$$\begin{pmatrix} VC0_v \\ VC1_v \\ VC2_v \end{pmatrix} := C_{012}^{-1} \cdot \begin{pmatrix} VAcpx_v \\ VBcpx_v \\ VCcpx_v \end{pmatrix}$$

The magnitudes for the phase A, B and C symmterical components will be the same, but the angles will differ. So this will matter more later.

Relay Model:

- ***Relay Settings***

Instantaneous Overcurrent Elements (secondary Amps, again leave off units) for zero sequence (ground) and negative sequence (designated with a Q). elements. These numbers are just made up so don't base your answers on these. Use magnitudes from the phase A components.

Enable the relay elements you want to use (1 means enabled, 0 means disabled)

$E50P1 := 1$ $E50P2 := 1$

$E50Q1 := 1$ $E50Q2 := 1$

$E50G1 := 1$ $E50G2 := 1$

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Relay Pickup Settings (default values)

Level_1_50P := 5   Level_2_50P := 2.5

Level_1_50Q := 5   Level_2_50Q := 2.5

Level_1_50G := 5   Level_2_50G := 2.5

determine & modify

Level 2 Time Delays   Define cycles := 1

$T_{DelP} := 5\text{cycles}$ default at 5 cycles

$T_{DelQ} := 5\text{cycles}$

$T_{DelG} := 5\cdot\text{cycles}$

- ***Relay Element Pick Up Logic***

Negative sequence element (modified to latch and stay one, no drop out for now)

Initialize arrays with all zeros: $\text{Level1Q\_pu}_v := 0$ $\text{Level2Q\_pu}_v := 0$

$$\text{Level1Q\_pu}_v := \begin{cases} 1 & \text{if } \left|IA2_v\right| \geq \text{Level\_1\_50Q} \\ 1 & \text{if } \text{Level1Q\_pu}_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

latch

$$\text{Level2Q\_pu}_v := \begin{cases} 1 & \text{if } \left|IA2_v\right| \geq \text{Level\_2\_50Q} \\ 1 & \text{if } \text{Level2Q\_pu}_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

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Enter Constants. Note that RS is the sampling rate, and the value of 16 here is assuming that the COMTRADE file was sampled at that rate.

$a := 1 \cdot e^{j \cdot 120deg}$

Phase A symmetrical components transform

$$A_{012} := \begin{pmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{pmatrix}$$

Phase B symmetrical components transform

$$B_{012} := \begin{pmatrix} 1 & a & a^2 \\ 1 & 1 & 1 \\ 1 & a^2 & a \end{pmatrix}$$

Phase C symmetrical components transform

$$C_{012} := \begin{pmatrix} 1 & a^2 & a \\ 1 & a & a^2 \\ 1 & 1 & 1 \end{pmatrix}$$

$RS := 16$

Enter vector indices for filter and relay calculations (do not change these)

$i := 0 .. rows(data) - 1$

$v := \frac{RS}{4} .. rows(data) - 1$ Offset samples by 1/4 cycles for phasor calculation

$d := 5 \cdot RS .. rows(data) - 1$ Offset samples by 5 cycles for trip calculation

$If := RS - 1 .. rows(data) - 1$

User Entered Parameters:

- I am entering typical values the current transformer ration (CTR) and voltage transformer ratio (PTR). You need to change these to match your calculations.

  $CTR := 1$ $PTR := 1$

- Relay Settings

  Moved later in the file close to the relay model and plots.

Ground (zero sequence) element (using calculated instead of measured currents):

Initialize arrays with all zeros: $Level1G\_pu_v := 0$ $Level2G\_pu_v := 0$

$$Level1G\_pu_v := \begin{cases} 1 & \text{if } 3\left|IA0_v\right| \geq Level\_1\_50G \\ 1 & \text{if } Level1G\_pu_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

$$Level2G\_pu_v := \begin{cases} 1 & \text{if } 3\left|IA0_v\right| \geq Level\_2\_50G \\ 1 & \text{if } Level2G\_pu_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

Phase current element (phase A or phase B or Phase C exceed pickup)

Initialize arrays with all zeros: $Level1P\_pu_v := 0$ $Level2P\_pu_v := 0$

$$Level1P\_pu_v := \begin{cases} 1 & \text{if } \left|IAcpx_v\right| \geq Level\_1\_50P \\ 1 & \text{if } \left|IBcpx_v\right| \geq Level\_1\_50P \\ 1 & \text{if } \left|ICcpx_v\right| \geq Level\_1\_50P \\ 1 & \text{if } Level1P\_pu_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

$$Level2P\_pu_v := \begin{cases} 1 & \text{if } \left|IAcpx_v\right| \geq Level\_2\_50P \\ 1 & \text{if } \left|IBcpx_v\right| \geq Level\_2\_50P \\ 1 & \text{if } \left|ICcpx_v\right| \geq Level\_2\_50P \\ 1 & \text{if } Level2P\_pu_{v-1} \geq 0.01 \\ 0 & \text{otherwise} \end{cases}$$

- ***Trip Logic***

Note that logic AND is Ctrl + shift + 7, the logic OR is Ctrl + shift + 6, the logic not is Ctrl + shift +1.

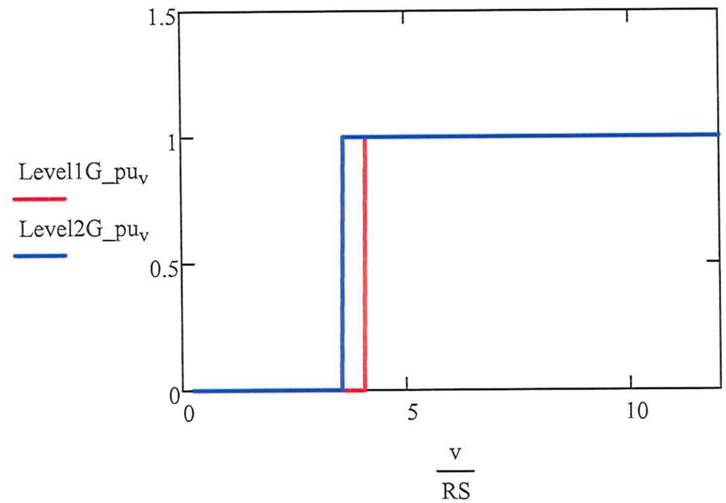
$$TR50P_d := E50P1 \wedge Level1P\_pu_d \vee E50P2 \wedge Level2P\_pu_{d-T_{DelP}RS}$$

OR

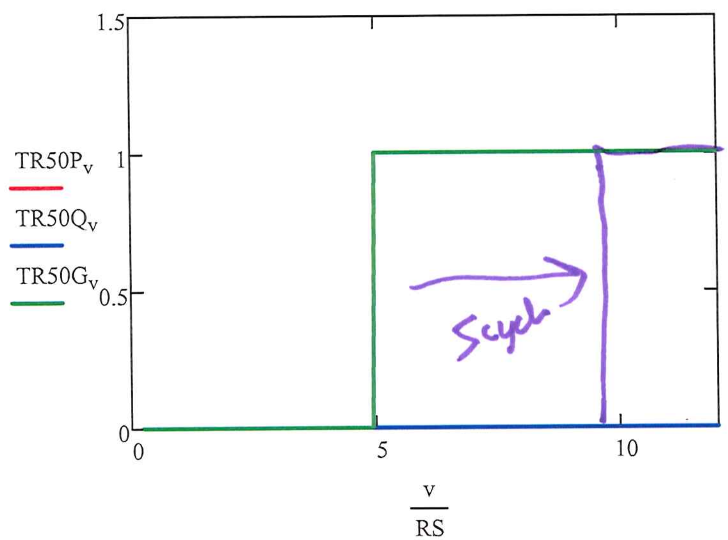
AND

Note that this includes the time delay for level 2

$$TR50Q_d := E50Q1 \wedge Level1Q\_pu_d \vee E50Q2 \wedge Level2Q\_pu_{d-T_{DelQ}RS}$$



Trip equation response



Alternate Approach for Three Phase Faults

- An alternate approach instead of the torque equation is to compare the angle single phase impedance calculated from measurements to threshholds

$$-90\text{deg} + \text{Z1ANG} < \theta_{Z1} < 90\text{deg} + \text{Z1ANG}$$ · pos seq line angle

$$\theta_{V1_v} := \arg\left(VA1_v + 0.000001\right) \qquad \theta_{I1_v} := \arg\left[(IA1)_v + 0.000001\right]$$

$$\text{Phase}_{I1_v} := \begin{cases} \theta_{I1_v} - \theta_{V1_v} & \text{if } \left|\theta_{I1_v} - \theta_{V1_v}\right| < \pi \\ \left(\theta_{I1_v} - \theta_{V1_v} - 2\cdot\pi\right) & \text{if } \left(\theta_{I1_v} - \theta_{V1_v}\right) > \pi \\ \left(\theta_{I1_v} - \theta_{V1_v} + 2\cdot\pi\right) & \text{if } \theta_{I1_v} - \theta_{V1_v} < -(\pi) \end{cases}$$

$$\text{Phase}_{V1_v} := \begin{cases} \theta_{V1_v} - \theta_{V1_v} & \text{if } \left|\theta_{V1_v} - \theta_{V1_v}\right| < \pi \\ \left(\theta_{V1_v} - \theta_{V1_v} - 2\cdot\pi\right) & \text{if } \left(\theta_{V1_v} - \theta_{V1_v}\right) > \pi \\ \left(\theta_{V1_v} - \theta_{V1_v} + 2\cdot\pi\right) & \text{if } \theta_{V1_v} - \theta_{V1_v} < -(\pi) \end{cases}$$

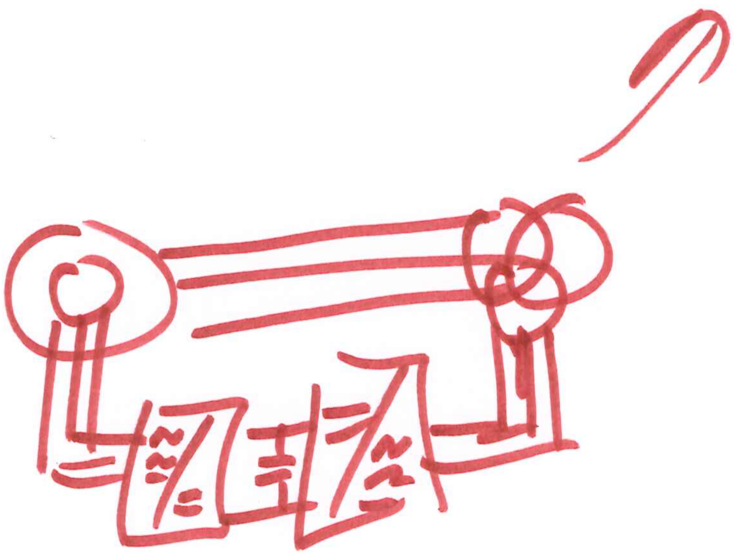
$$Z1A_v := \frac{\left|VA1_v\right|\cdot e^{j\cdot\text{Phase}_{V1_v}}}{\left|IA1_v\right|\cdot e^{j\cdot\text{Phase}_{I1_v}} + 0.00001}$$

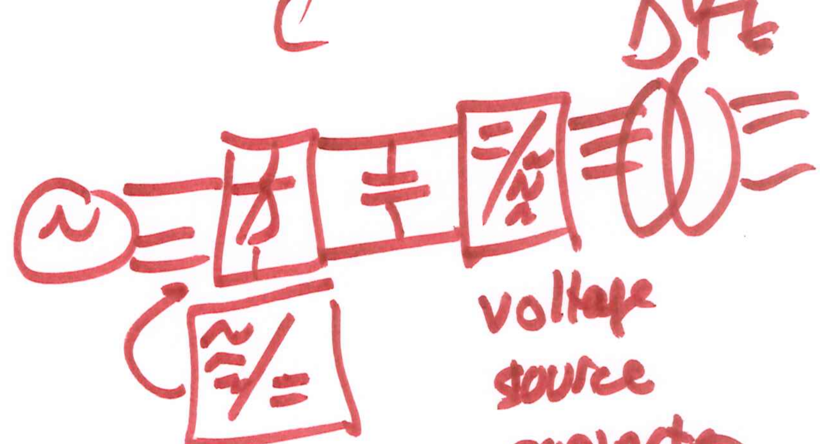
- Underlying assumptions with current based directional elements
    - → fault current has a significantly different angle than load current
    - significant I_2 and/or I_0 for unbalanced
    - → works well in the following
        1. synchronous generators
        2. solidly grounded system (low impedance grounded)

→ complications

① Inverter coupled generation

PV, wind turbines (Type 3 or Type 4)





voltage source converter

② ungrounded or high resistance grounded.

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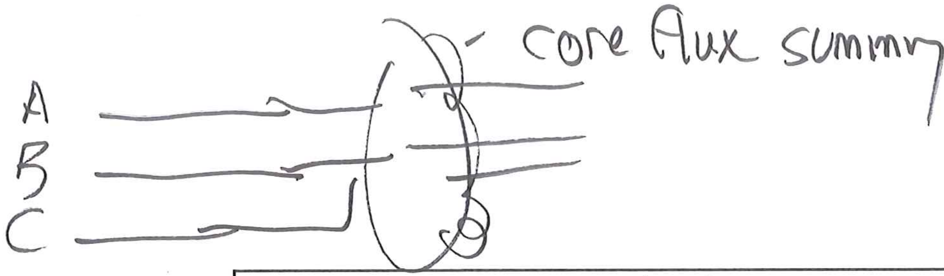

Ungrounded Protection Characteristics

- Low fault currents, some self- extinction
- Poor relay relay response and direction
- Often protect based on voltage
  - » Zero sequence or three phase voltage
  - » Or loss of injected signal
  - » Or capacitive currents in cables
- Detect first ground fault and alarm, since second ground fault has big current

High Impedance Ground: Resistive Type

- Large resistance connected to neutral
- Common in large generator protection (sometimes transformer in neutral)
- Size resistance to limit fault current to 25A or less
- Neutral voltage shifts, over voltage relay connected across resistor
- Poor directional capability

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Issues with Ungrounded Systems

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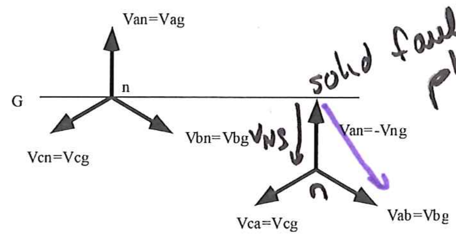
- No intentional ground on neutral/phases
- Ground fault causes neutral shift



solid fault on phase A-G

- Need L-L voltage rating on insulation

Ungrounded Systems

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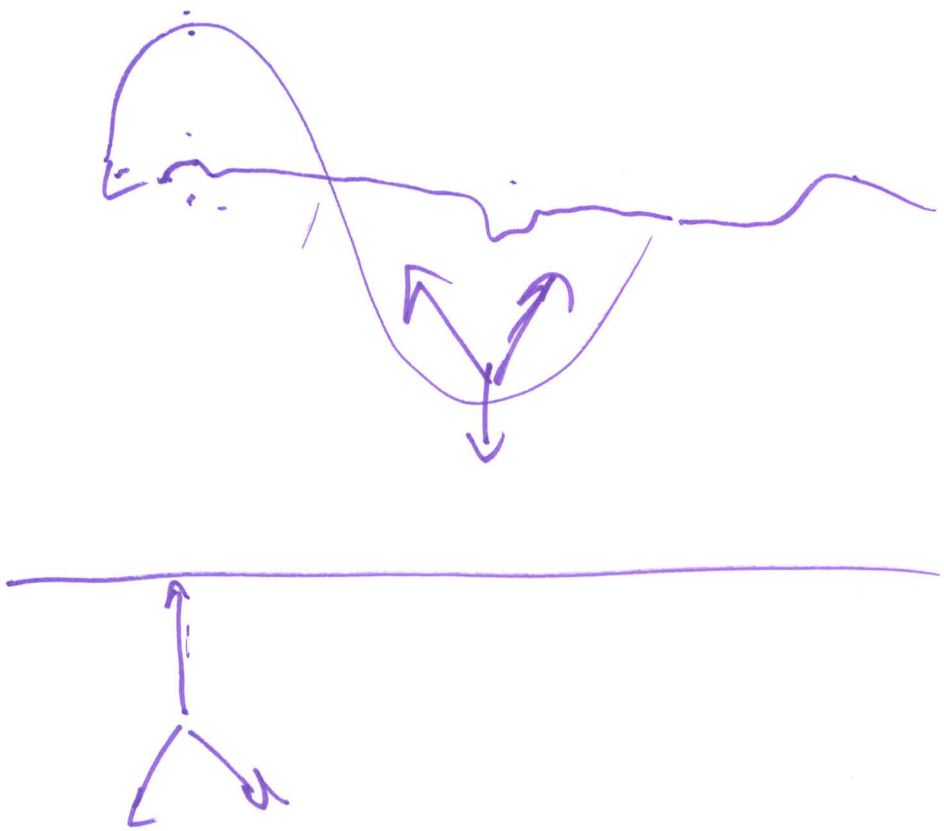
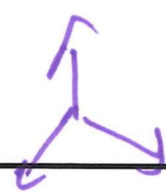
- Parasitic capacitance in all components
- Resonates with line inductance, often doubles transients over voltage
- Equipment damage may result from voltage, but not likely from fault currents unless a second ground fault occurs

Sputtering ground fault





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Summary of the Impacts of Grounding on System Protection

Grounding

- System grounding big impact on ability to detect ground faults
- Common ground options:
  - » Isolated ground (ungrounded)
  - » High impedance ground
  - » Low impedance ground
  - » Solid or effective ground