Challenges Replacing Electro-mechanical Transformer Differential Relays

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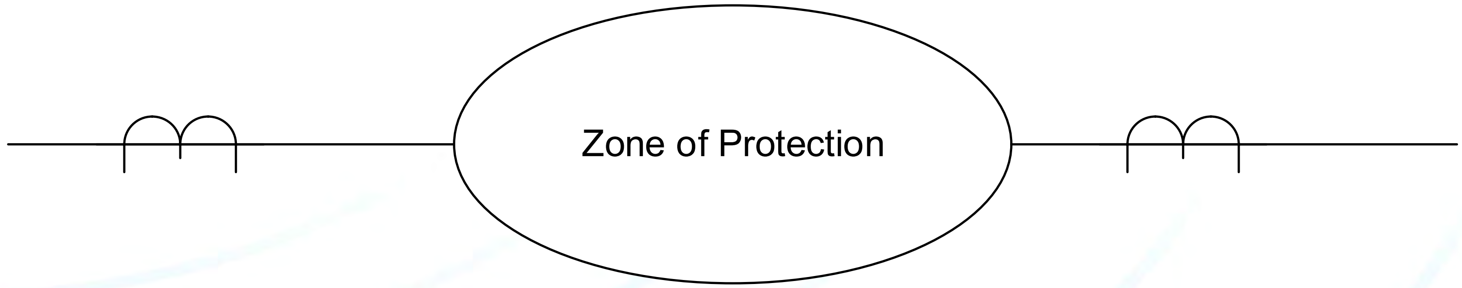
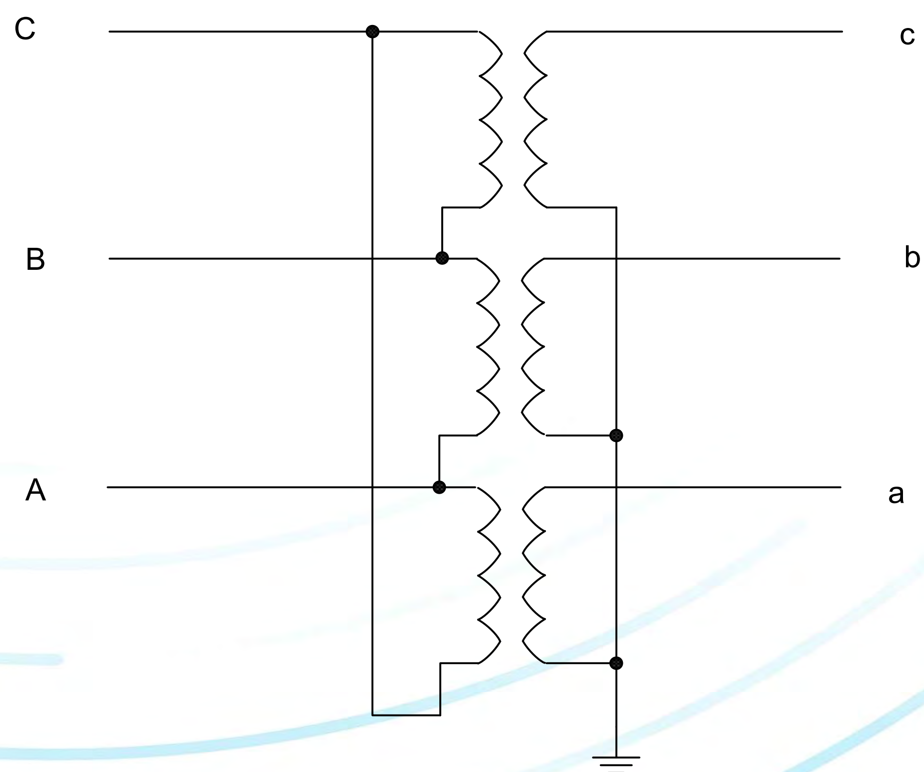
Agenda

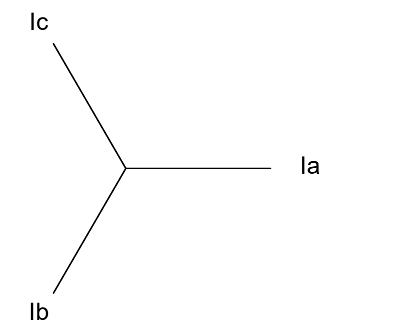
- Introduction
- EM Relays
- Micro-processor relays
- Retrofit Challenges
- Case Studies

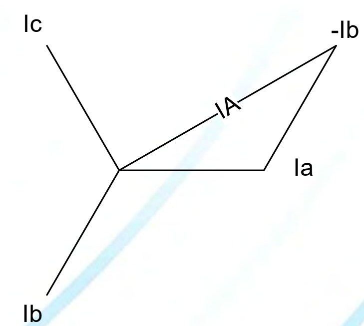
Differential



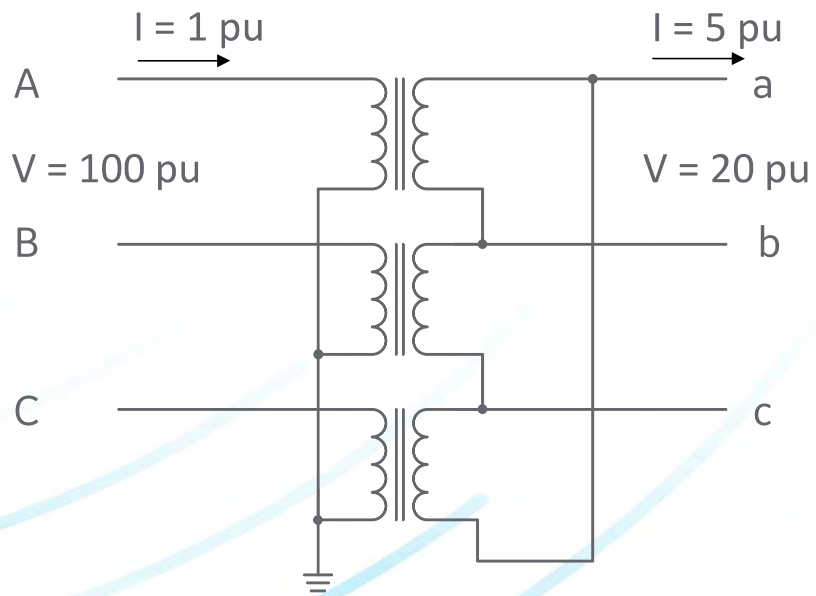
Transformer Differential – Phase Compensation



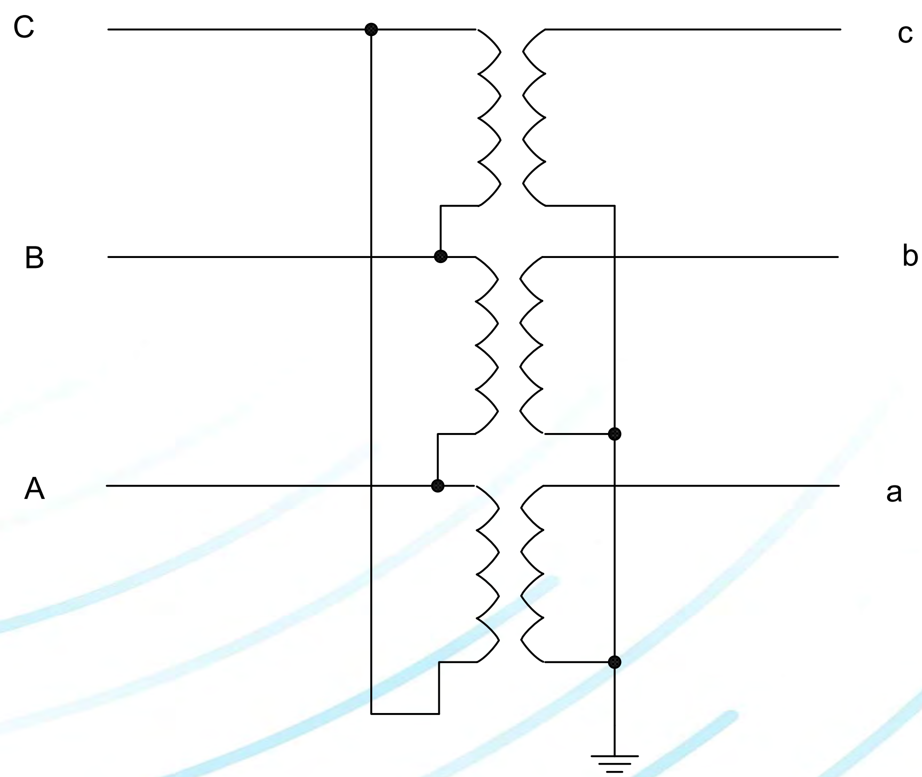




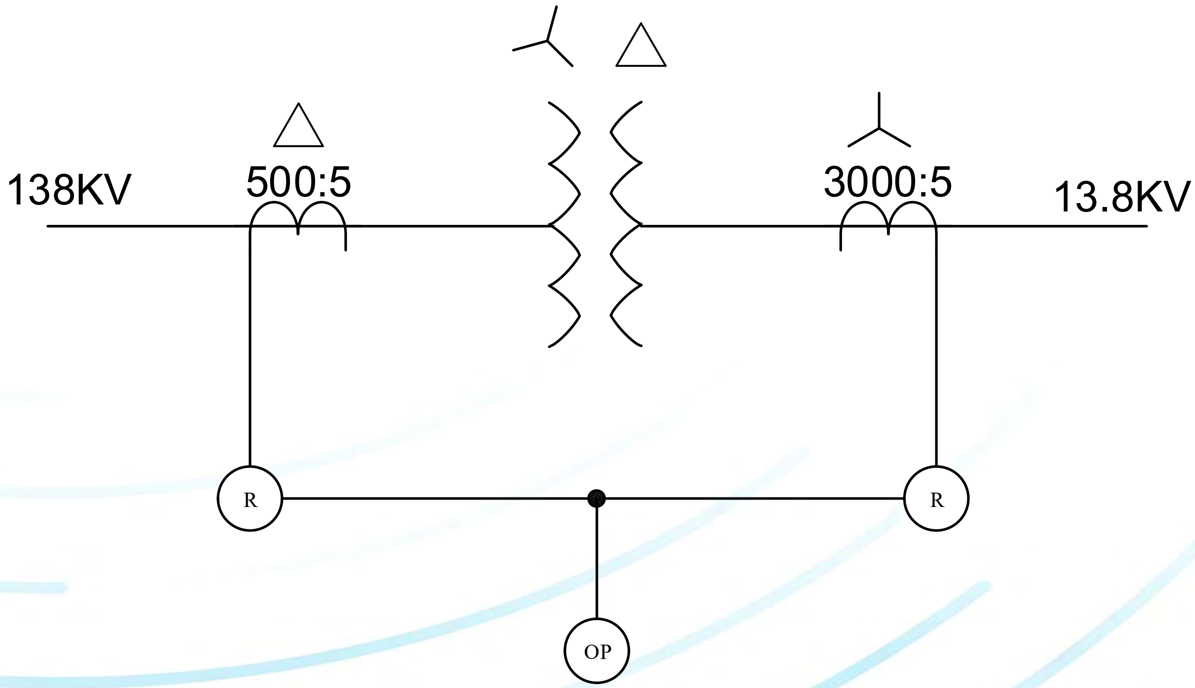
Transformer Differential – Magnitude Compensation



Transformer Differential – Zero Sequence Removal

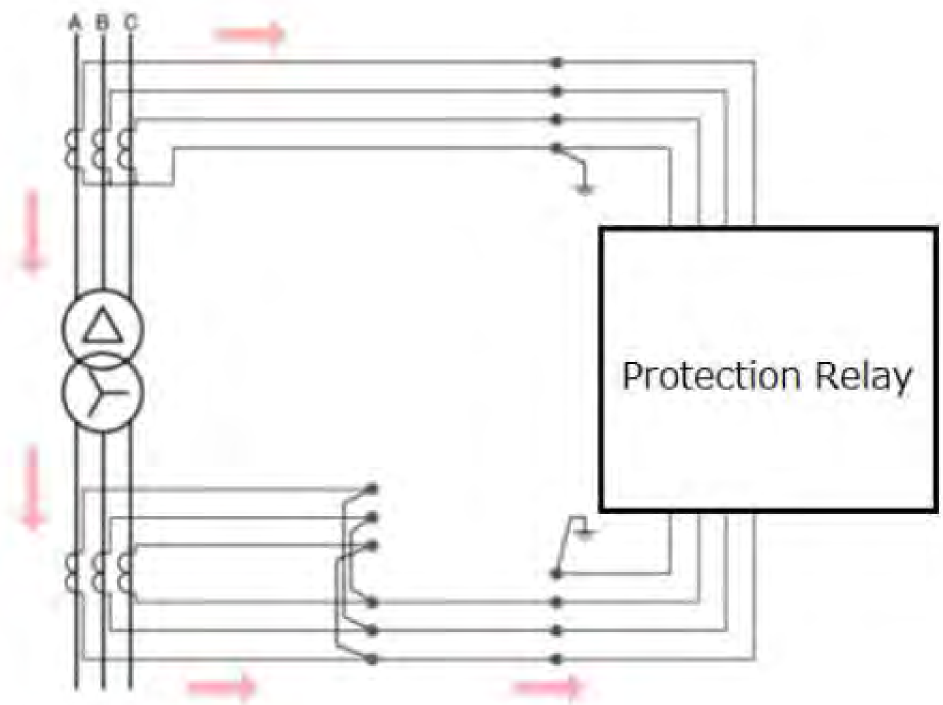


Electro-Mechanical Relays

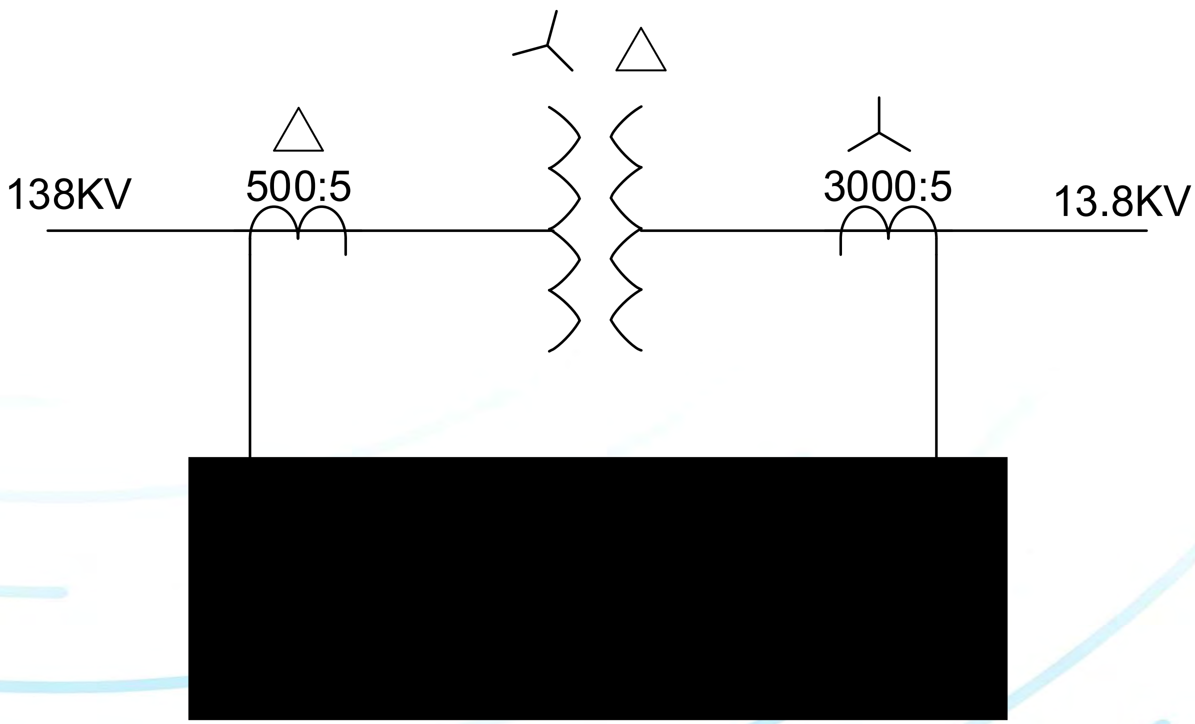


- Delta and Wye CTs take care of phase compensation
- 1000 amps into 3000:5 CTs equals 1.667A on Ct secondary
- 100 amps into 500:5 CTs equals 1A inside the delta and 1.73A outside.
- Difference can be accounted for in tap settings and restraint

Microprocessor Relays with External Compensation

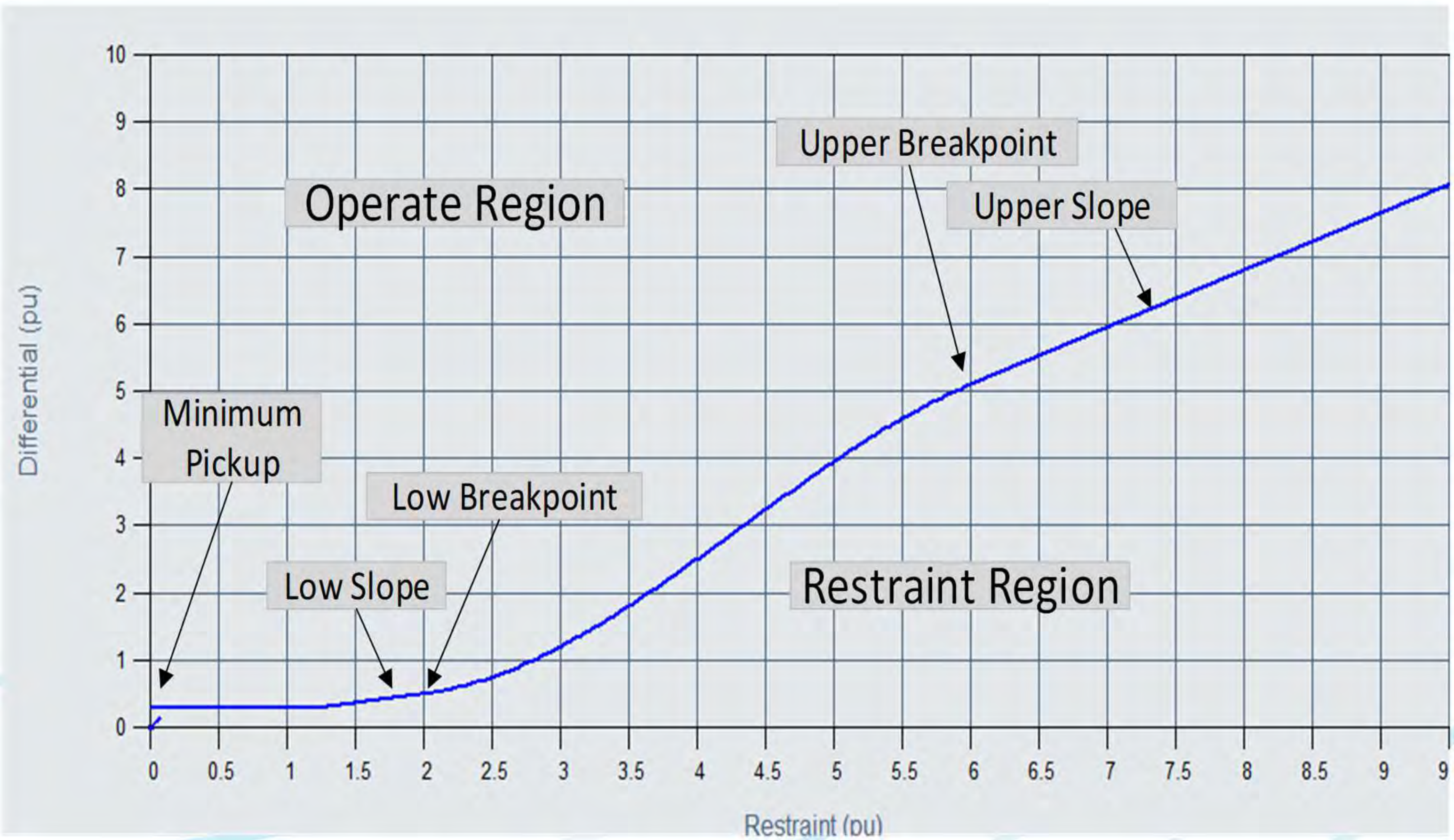


What happens if we replace with Micro-processor

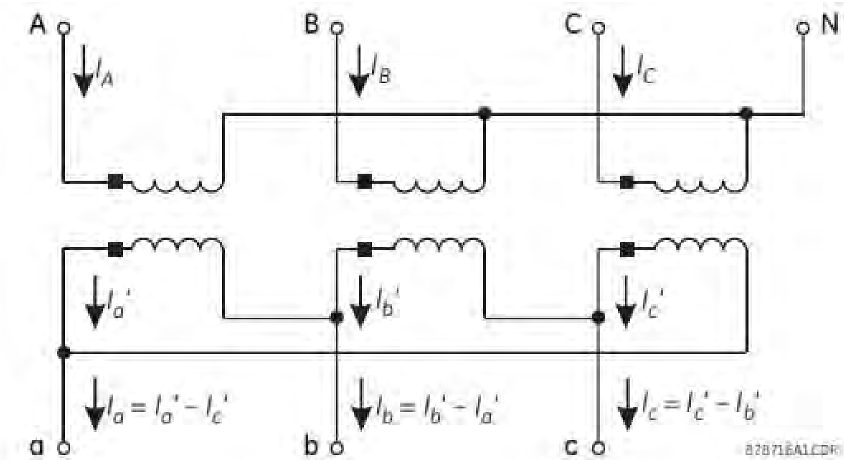


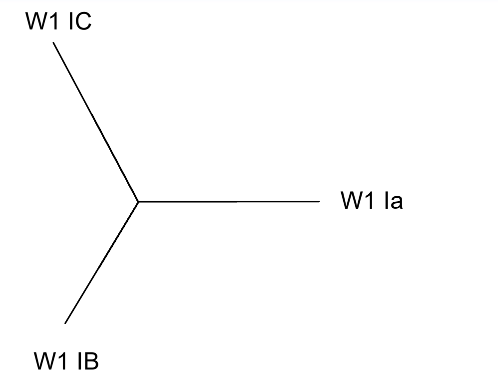
- Delta and Wye CTs take care of phase compensation so choose external compensation of 0 degree angle.
- Set transformer winding voltage to do magnitude compensation. 138/13.8KV
- CT ratio is a challenge:
- It is actually 500:5
- But you should set it as 288:5
- 3000:5 sees 1000 amps on primary
- 500:5 sees 100 amps on primary, 1 amp inside the delta and 1.73 outside.
- Because ratio is 288:5, it calculates as 100amps
- Magnitude compensation is 10 so everybody is happy

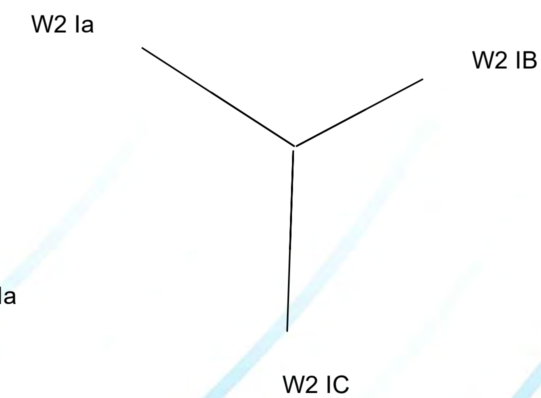
Sloped Differential Characteristic

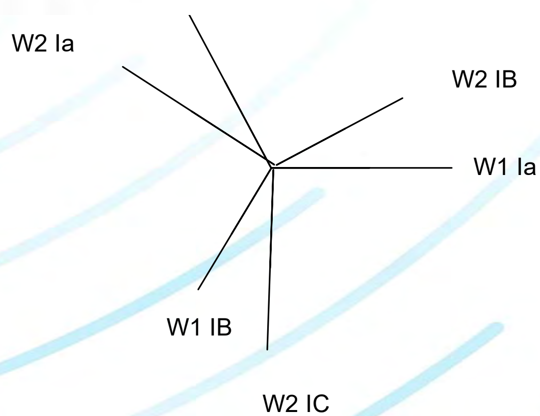


Transformer Differential – Compensation







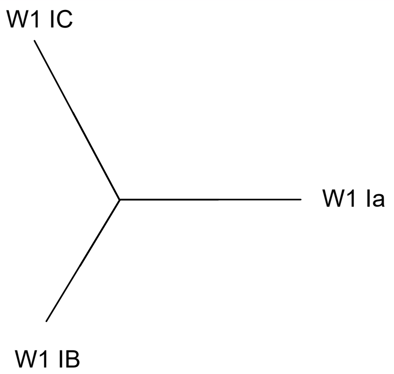


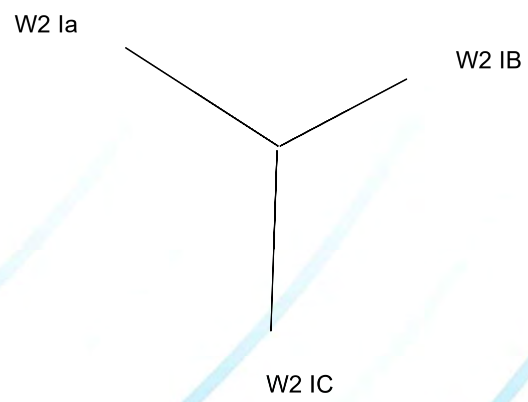
Transformer Differential – Compensation

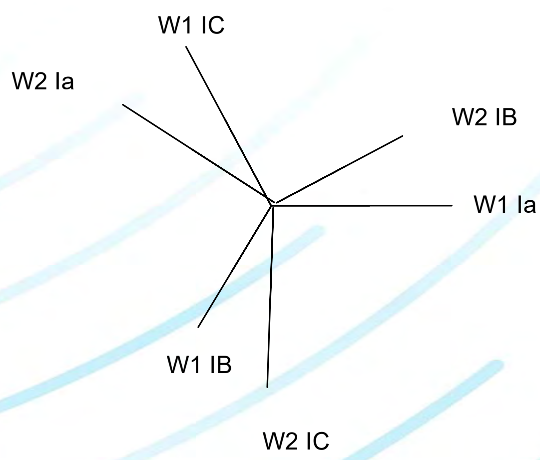
$$I_A{}^P[w] = \frac{1}{\sqrt{3}} I_A[w] - \frac{1}{\sqrt{3}} I_C[w]$$

$$I_B{}^P[w] = \frac{1}{\sqrt{3}} I_B[w] - \frac{1}{\sqrt{3}} I_A[w]$$

$$I_C{}^P[w] = \frac{1}{\sqrt{3}} I_C[w] - \frac{1}{\sqrt{3}} I_B[w]$$







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Retrofit Challenges

When retrofitting: Wye-Wye is the goal but:

- Fourth wire may not run across yard.
- External compensation requires creativity in CT or transformer ratio
- CT ratio causes problems in power metering

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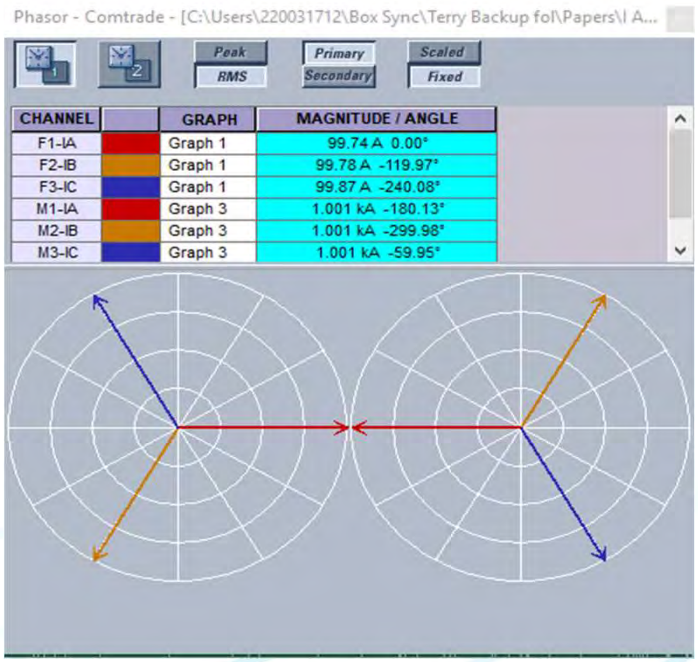
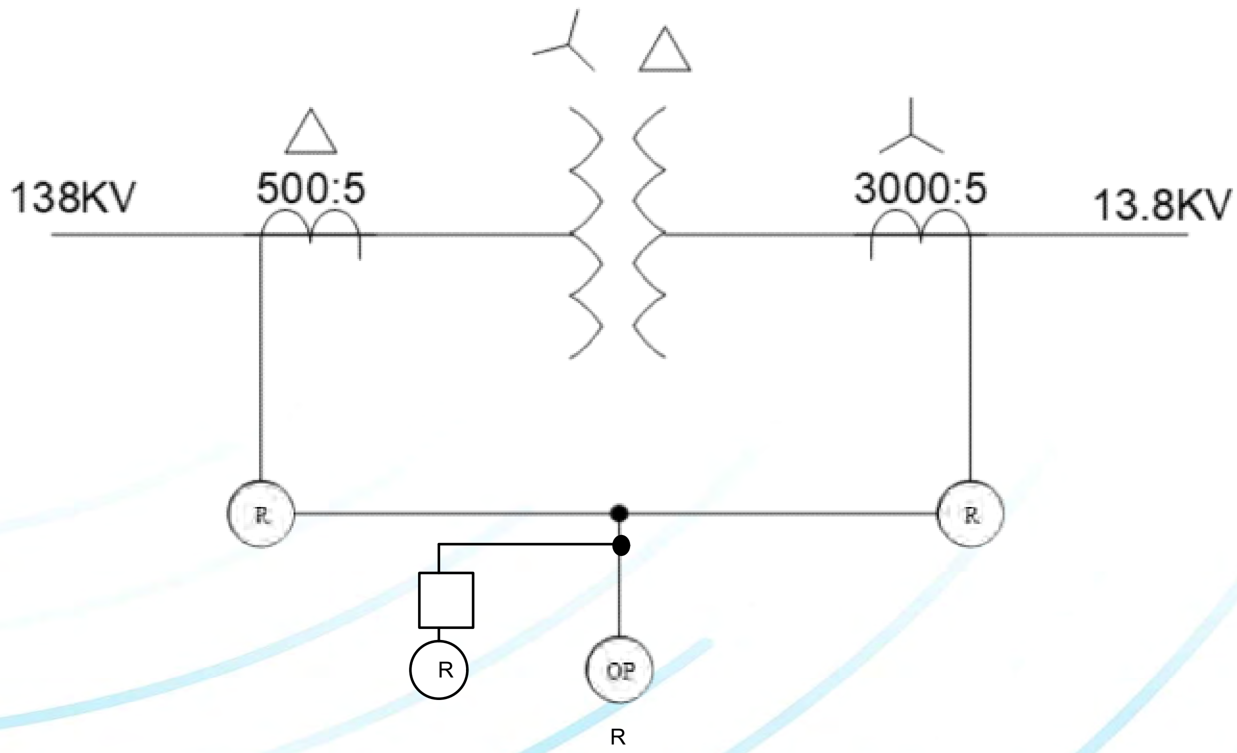
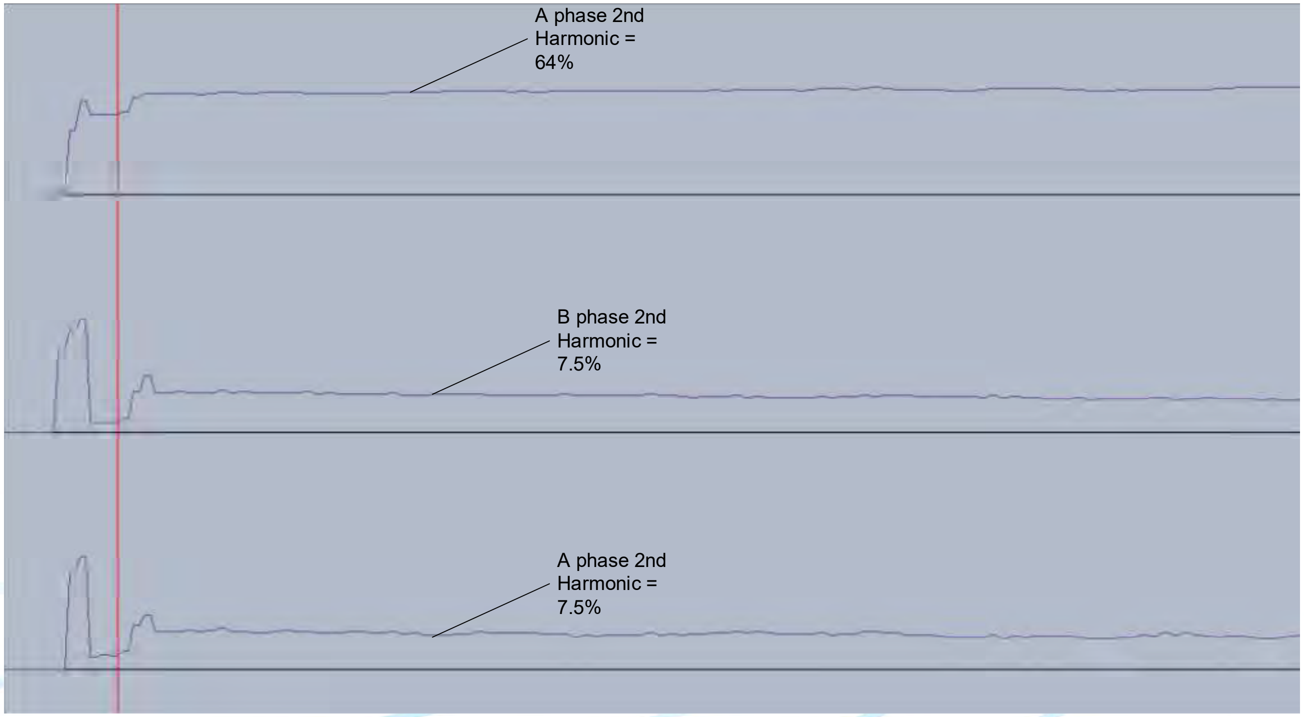
Case Study – External Compensation



Case Study – Harmonic Restraint

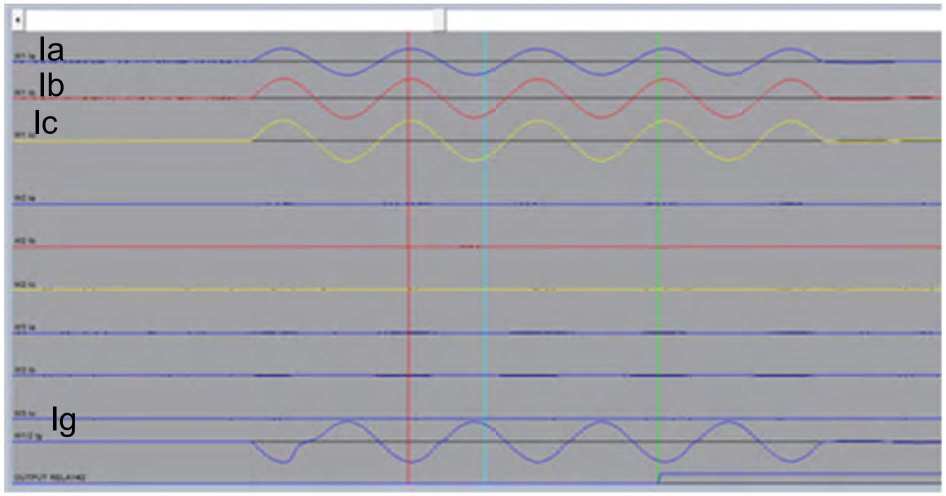


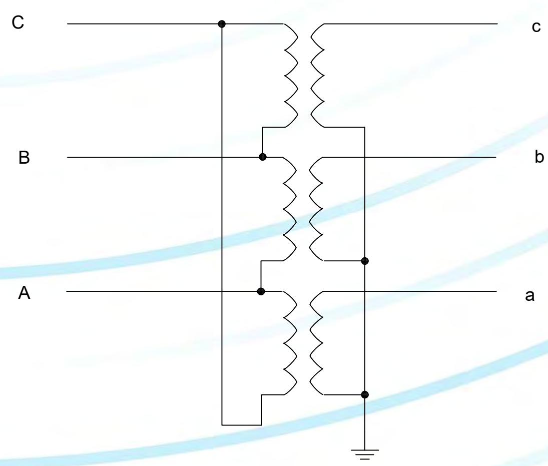
Case Study – Harmonic Restraint

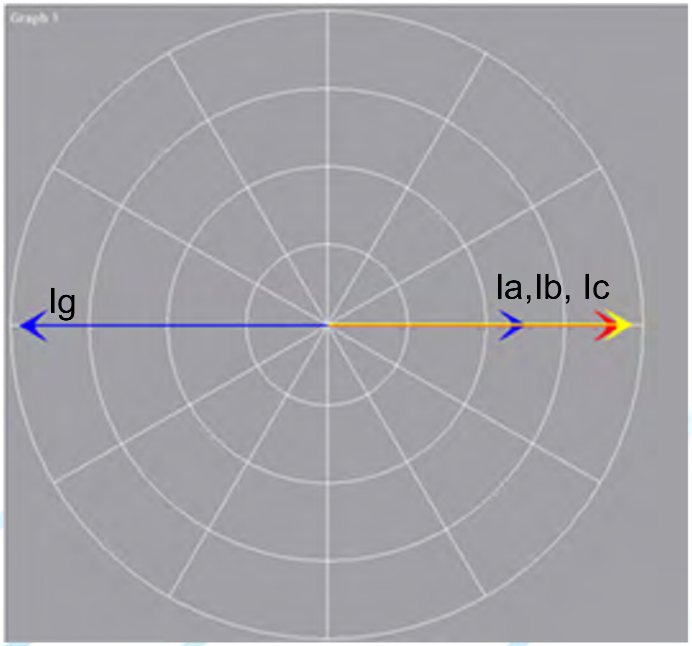


- New Transformers often exhibit a very low level of second harmonic that often cause phase segregated relays to trip
- Modern relays can be set for average inhibit which would have prevented the operation above.

Case Study – Zero Sequence Removal







Conclusions

- Most micro-processor-based relays can accommodate either internal or eternal compensation for the phase shift.
- Understanding how that compensation happens in both an electro-mechanical relay and a micro-processor relay can prevent errors.
- Micro-processor-based relays give more flexibility in dealing with harmonic restraint and zero-sequence current.

Thank You

Questions?