




RAPID EARTH FAULT CURRENT LIMITER (REFCL) FOR FIRE PREVENTION

March 2019

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Agenda

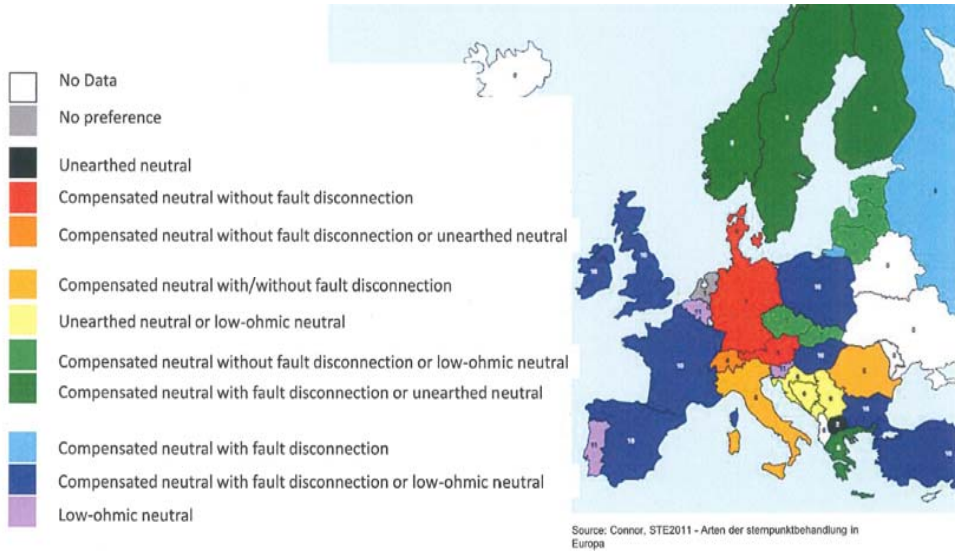
- Problem Definition
- Grounding practice
- **R**apid **E**arth **F**ault **C**urrent **L**imiter (REFCL) methods
- Implementation Challenges

Problem Definition

- Persistent drought in California led to dangerous environmental conditions that increased the fire risk
- Electrical Utilities are addressing both conventional and new solutions to minimize risks
- Electrical conductor coming in contact with vegetation or the ground can ignite a fire due to arcing caused by high fault current
- System grounding practice has significant impact on fault current and arcing behavior

Grounding Practices

- Many countries around the world have been using grounding practices to reduce the risk of arcing faults by reducing the fault current
  - Isolated
  - Inductor grounded or Peterson Coil
  - Resistance grounded
- Those systems reduce the fault current but have other drawbacks, such as higher voltages on healthy phases and protection challenges
- Australian government mandated a **R**apid **E**arth **F**ault **C**urrent **L**imiter solution to address fire risks due to arcing

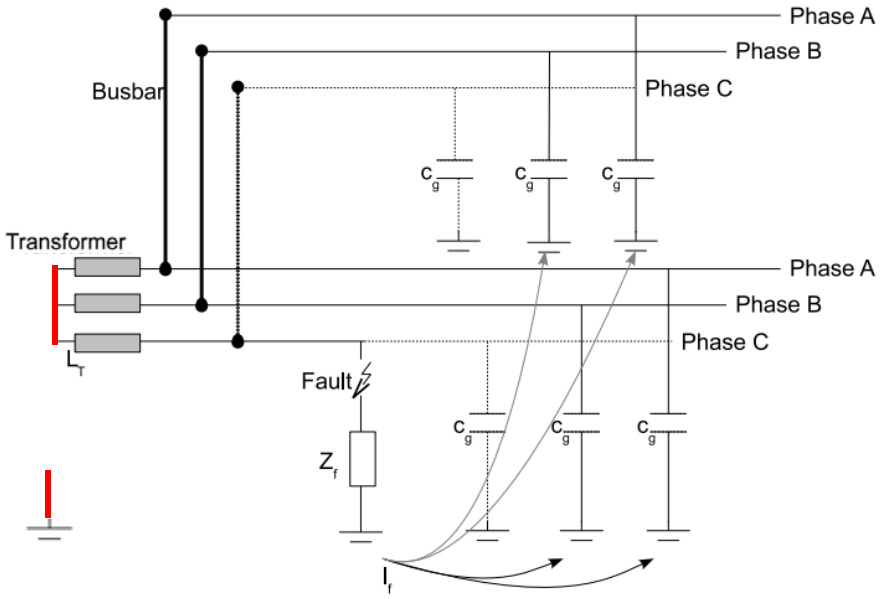


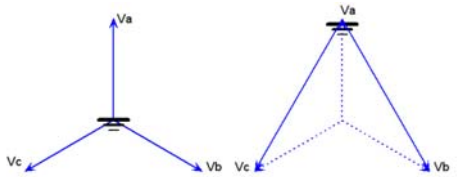
Source: Connor, STE2011 - Arten der stempunktbehandlung in Europa

Isolated Systems

Fault Current in isolated system is mostly determined by

- System Capacitance->size of system
- Fault Impedance
- System Voltage





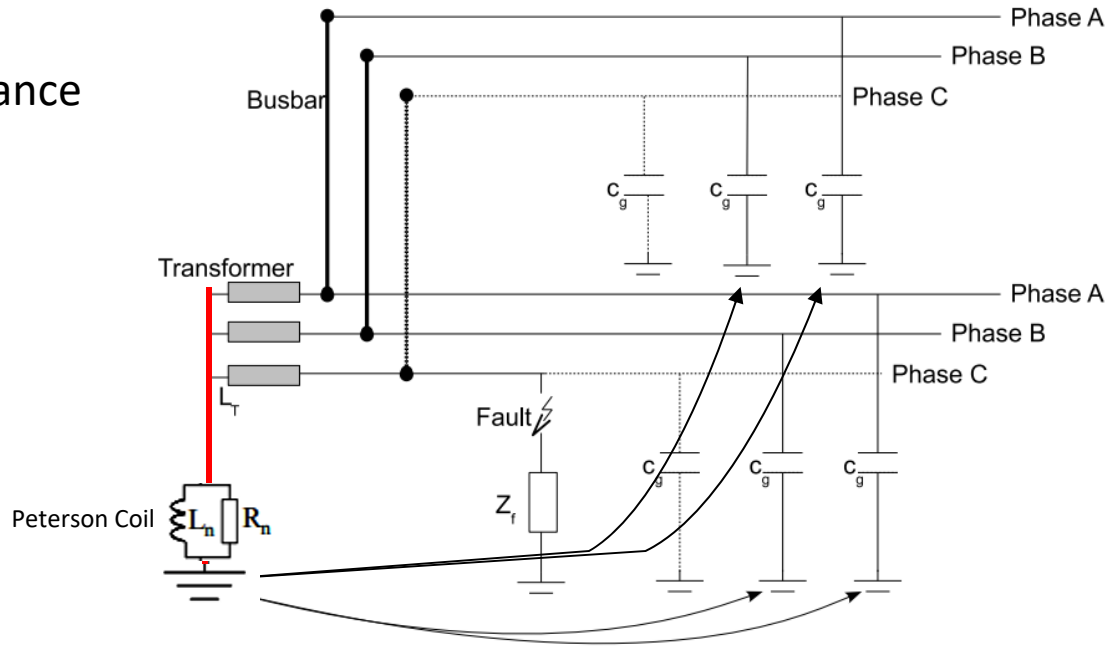
$$I_F = \sqrt{3} * \omega * V_n * C_g$$ (for Zf=0)

Typical values : <100 A

Petersen Coil Compensated System

Fault Current in compensated system is mostly determined by

- System Capacitance->size of system
- Fault Impedance
- System Voltage
- Peterson Coil reactance
- Peterson coil losses



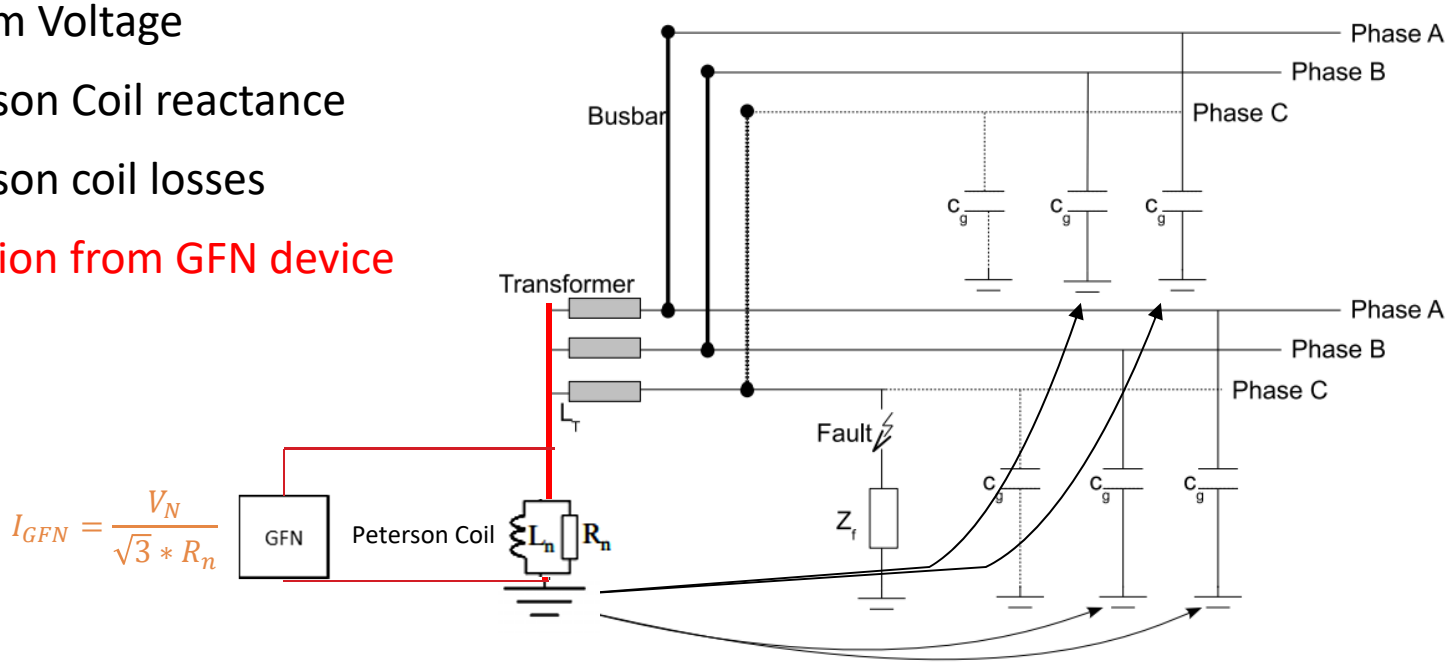
$$I_F = j\sqrt{3} * V_n * \omega * C_g - j\frac{V_N}{\sqrt{3}*\omega*L_n} + \frac{V_N}{\sqrt{3}*R_n} \quad \text{(for Zf=0)}$$

If 100% compensated $I_F = \frac{V_N}{\sqrt{3}*R_n}$ Typical values : <10 A

Rapid Earth Fault Current Limiter (REFCL) via Ground Fault Neutralizer (GFN)

Fault Current in system is mostly determined by

- System Capacitance->size of system
- Fault Impedance
- System Voltage
- Peterson Coil reactance
- Peterson coil losses
- Injection from GFN device



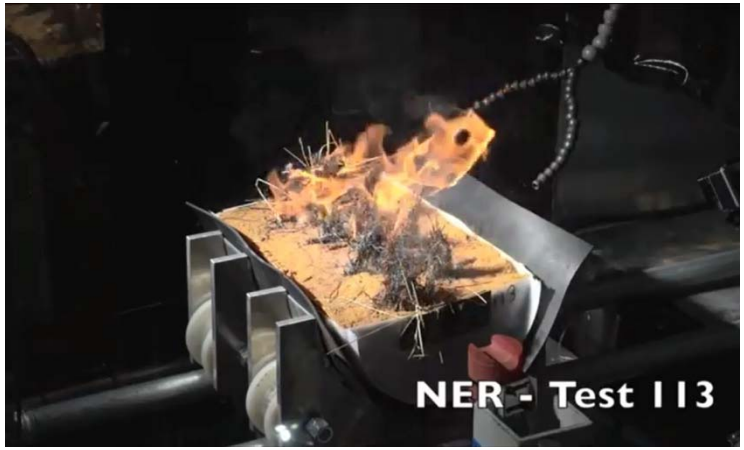
$$I_F = j\sqrt{3} * V_n * \omega * C_g - j\frac{V_N}{\sqrt{3}*\omega*L_n} + \frac{V_N}{\sqrt{3}*R_n} - I_{GFN} \qquad \text{(for Zf=0)}$$

Typical values : 0 - 50mA (after 80ms)

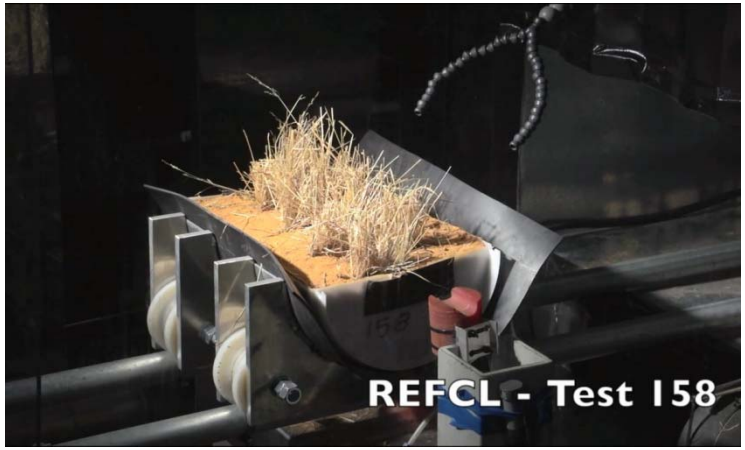
Rapid Earth Fault Current Limiter (REFCL) History in Australia

- 2009 Black Saturday fires in Victoria, Australia
  - Burned 1.1 million acres, left 180 dead, and 414 injured.
- The government performed over 2,000 separate tests to determine the what causes electrical ignition events
  - Conclusion: REFCLs are 10 times more effective in reducing bushfire risk than existing best practices.
- Utilities in Victoria are required to install 45 REFCLs in bushfire-prone areas
  - Two major utilities in Victoria have each installed four REFCLs

Normal Ground Fault



REFCL Ground Fault



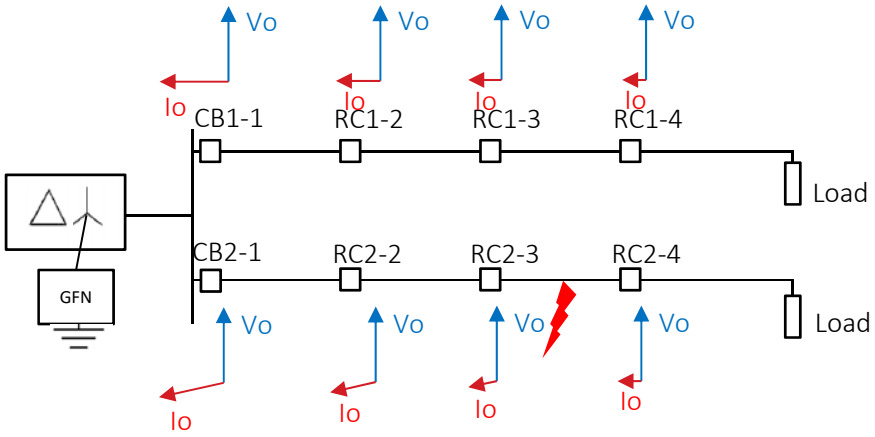
Challenges – System Design

- Arc Suppression Coil grounding cause a 1.73 times higher voltages on the healthy phases during ground faults
- All system components need to be rate for this higher voltage
  - Transformer
  - Overhead line/ cable
  - Surge arrestor
  - Etc.
- Must be operated as a 3 wire system - All transformers must be connected phase to phase
- Capacitance of the combined overhead and underground conductors must be very well balanced

Challenges – Protection and Control

Operation practice need to be redefined

- Ground fault are very difficult to detect
  - Special protection algorithms
  - Need to be cleared by switching
- Since multiple circuits will be protected by a REFCL on a bus, identification of the circuit with a ground fault is challenge



Example of implementing REFCL

- When fault occurs, circuit to remain energized for seconds prior to de-energizing to facilitate faulted circuit detection
- Reclosing to be de-activated for all types of faults
- Circuit will remain de-energized until either data determines faulted section or entire circuit patrolled