ADVANCED CONCEPTS IN HIGH RESISTANCE GROUNDING

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Content

- Resistance Grounding
- LV systems
- MV Systems
- Energy dissipation in the fault
- Case Studies
- Recommendations

Rationale for this paper

Resistance grounding is the most misunderstood

Most articles focused on simple single source systems

Resistor applied to Neutral only up until now.

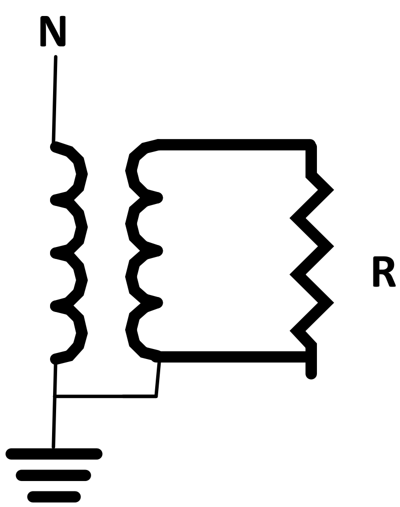
Share Advances in the art of Resistance Grounding

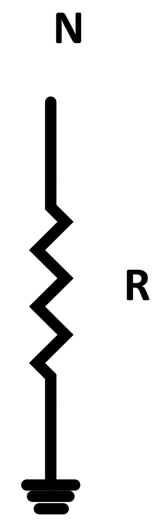
Future work

Resistance Grounding

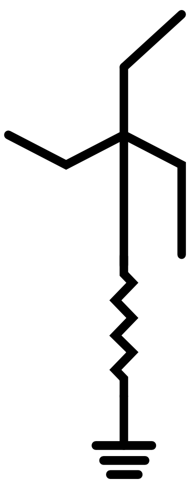
- Resistance Grounding is applied to limit the line to ground fault current on Low and Med. voltage systems 3 W systems
- When limited to 10 A or less , up to 5kV.– High Resistance grounding – continuous operation, faulty circuit is not tripped
- When resistor let through current is higher than 10 A – Low resistance – faulted circuit is tripped – fault damage is low , no arc flash .

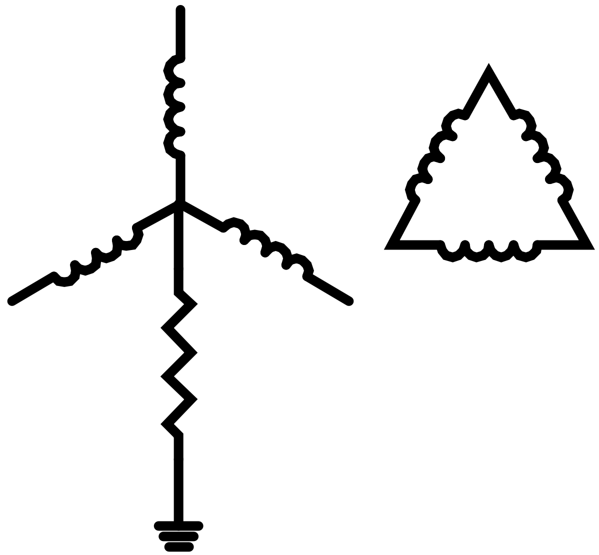
Methods of grounding Neutral available

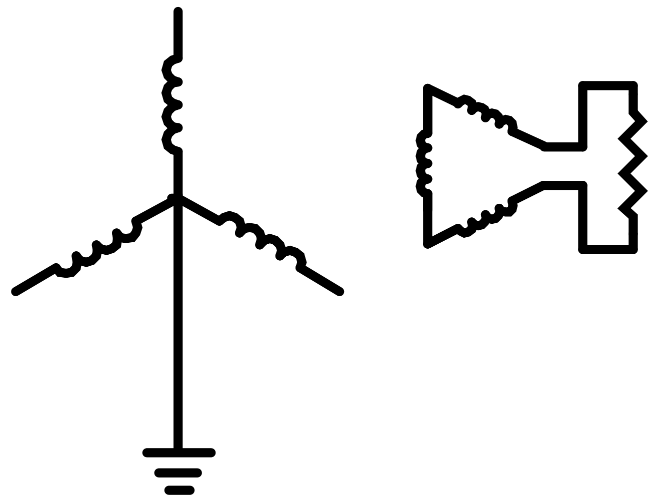




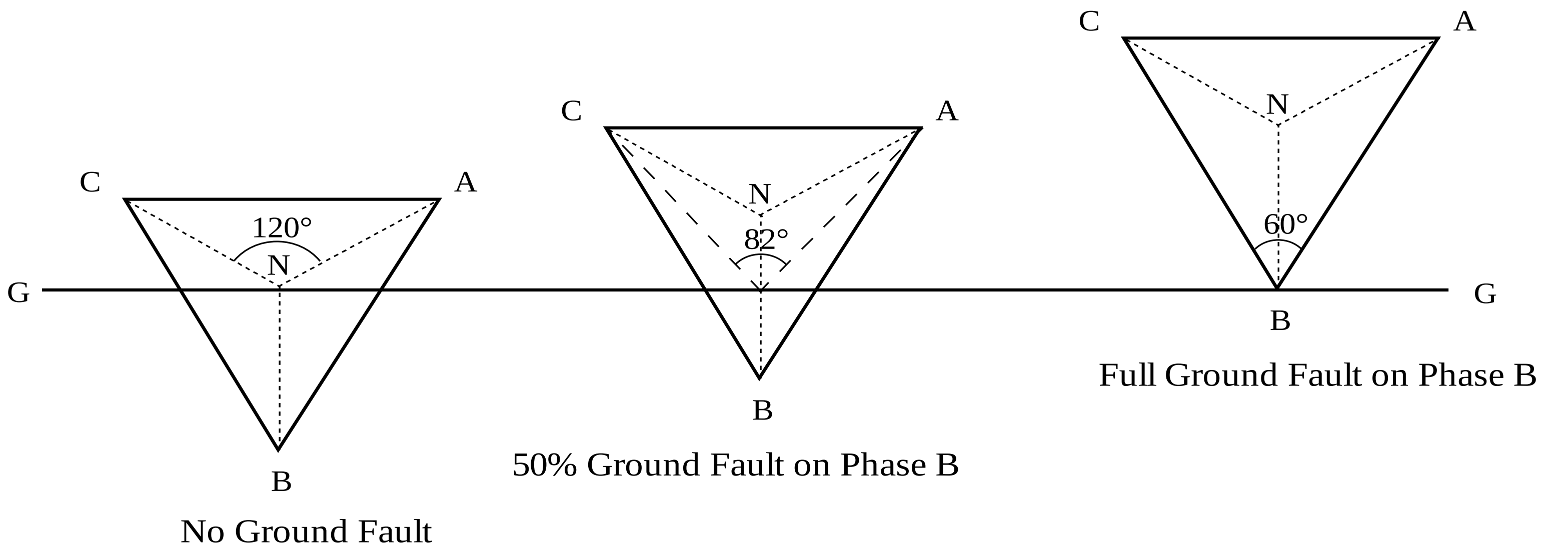
Methods of grounding Neutral not available



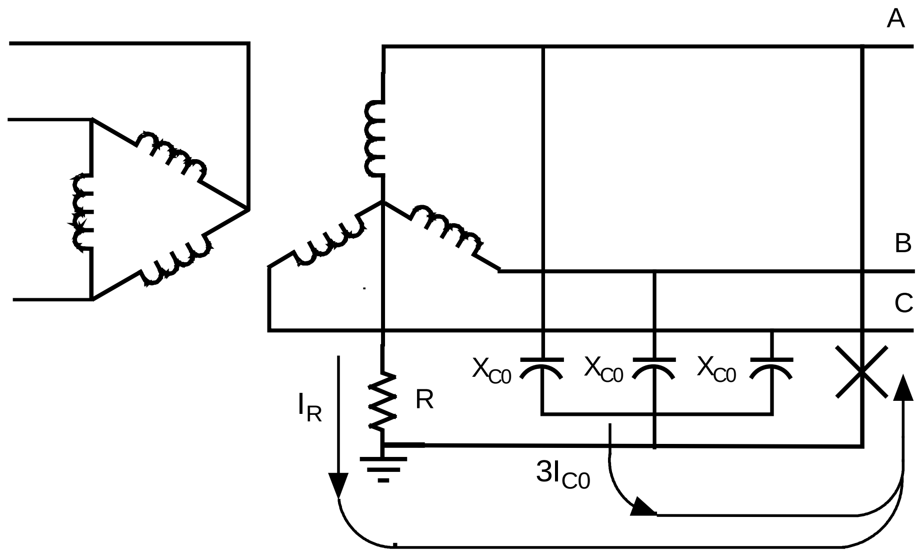




Ground Fault
on Ungrounded and High Resistance Systems



Fault Current on HRG System



$$I_F = \sqrt{(I_R)^2 + (3I_{C0})^2}$$

$$I_{F_{MIN}} = \sqrt{2}(3I_{C0}) \qquad \text{At minimum fault current, } I_R = 3I_{C0}$$

Resistance Grounding

- On the occurrence of L-G fault, the voltage to ground on the other two unfaulted phases increases to line to line voltage
- All equipment is required to have insulation suitable to withstand V_{LL} and the fault duration
- Fault current is $\dot{I}_R + 3\dot{I}_{CO}$
- To prevent voltage escalation beyond line to line voltage $\dot{I}_R > 3\dot{I}_{CO}$

Why High Resistance Grounding

• Reliability	• Power continuity, No trips on ground fault
• Safe	• No Arc Blast or Flash Hazard on Ground Fault
• Cost effective	• 3 Wire Systems are less expensive than 4 wire

Why High Resistance Grounding

- Scheduled Maintenance
  - Faulty equipment can continue to run
  - Optional Time Delay on First Fault 1-99 Hours
  - Lower repair cost
  - Fault location assistance

- Prioritized load
  - Overcurrent Coordination maintained Selective second fault protection feasible
  - Inhibit Tie closure on faults in both systems.

High resistance Grounding

- Limit ground fault current to 10 A or less
- Provides service continuity on first ground fault
- Prevents arc flash incidents on first ground faults
- Allows faults to be located without de-energizing feeders (ground fault pulse locating)
- Used in continuous process industries, hospitals and data centers where unscheduled downtime is costly
- It has been applied in Petro chemical Industry since 1956 (Refinery in Texas)

Resistance Grounding Application

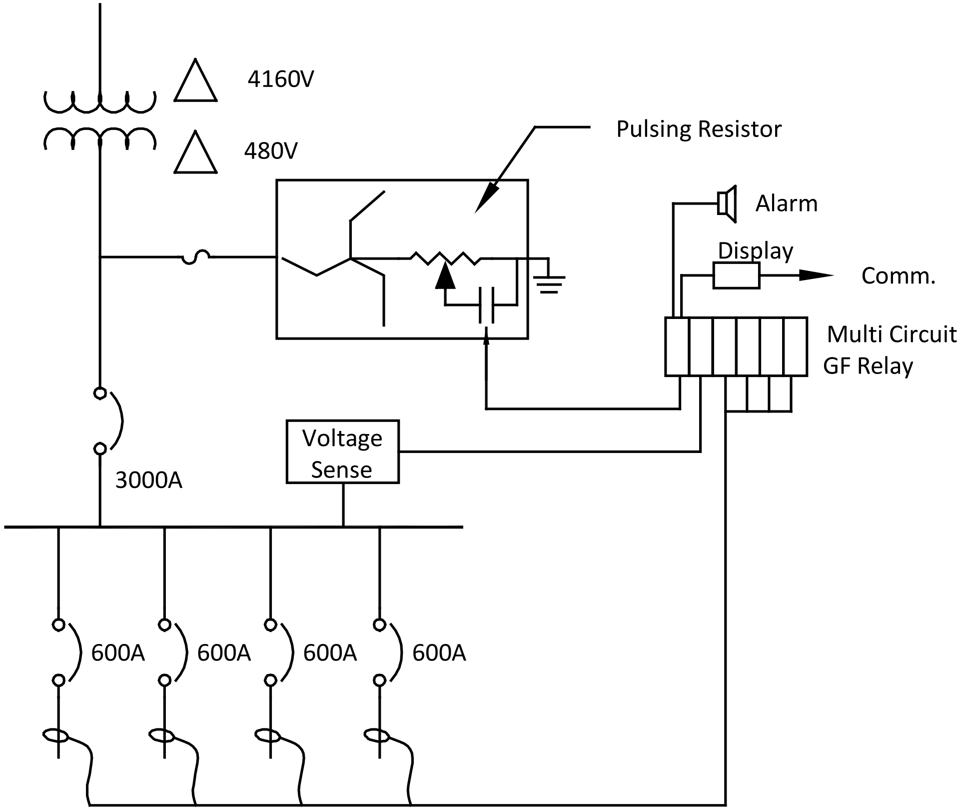
- Resistance grounding is not enough
- Must sense ground faults
- Either alarm only, and provide assistance to locate the fault
- Or trip on fault
- Measure voltage to ground on the three phases
- Measure Zero sequence current

Single Source systems

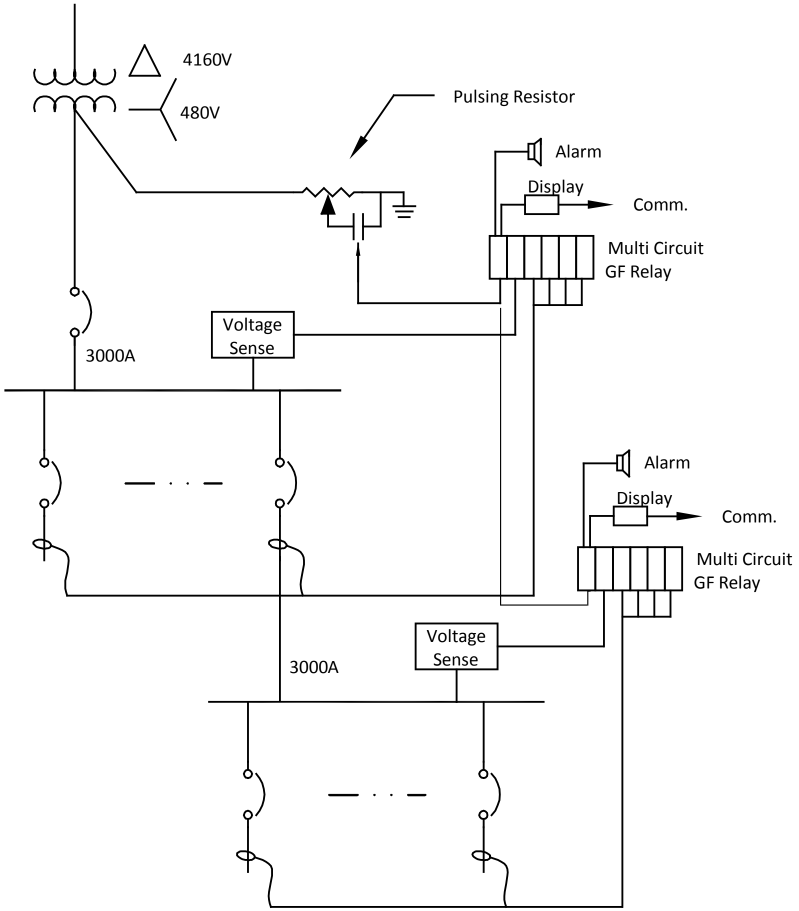
- Neutral available – use NGR
- Neutral not available – use grounding transformer, such as Zig Zag transformer
- Apply Ground fault detection with Voltage to ground and Zero sequence current measurement on feeders – fig 1
- Continue to monitor the system and in the event of a second fault on another feeder on another phase, trip one feeder – fig 2

Single Source systems

- Apply Ground fault detection with Voltage to ground and Zero sequence current measurement on feeders –



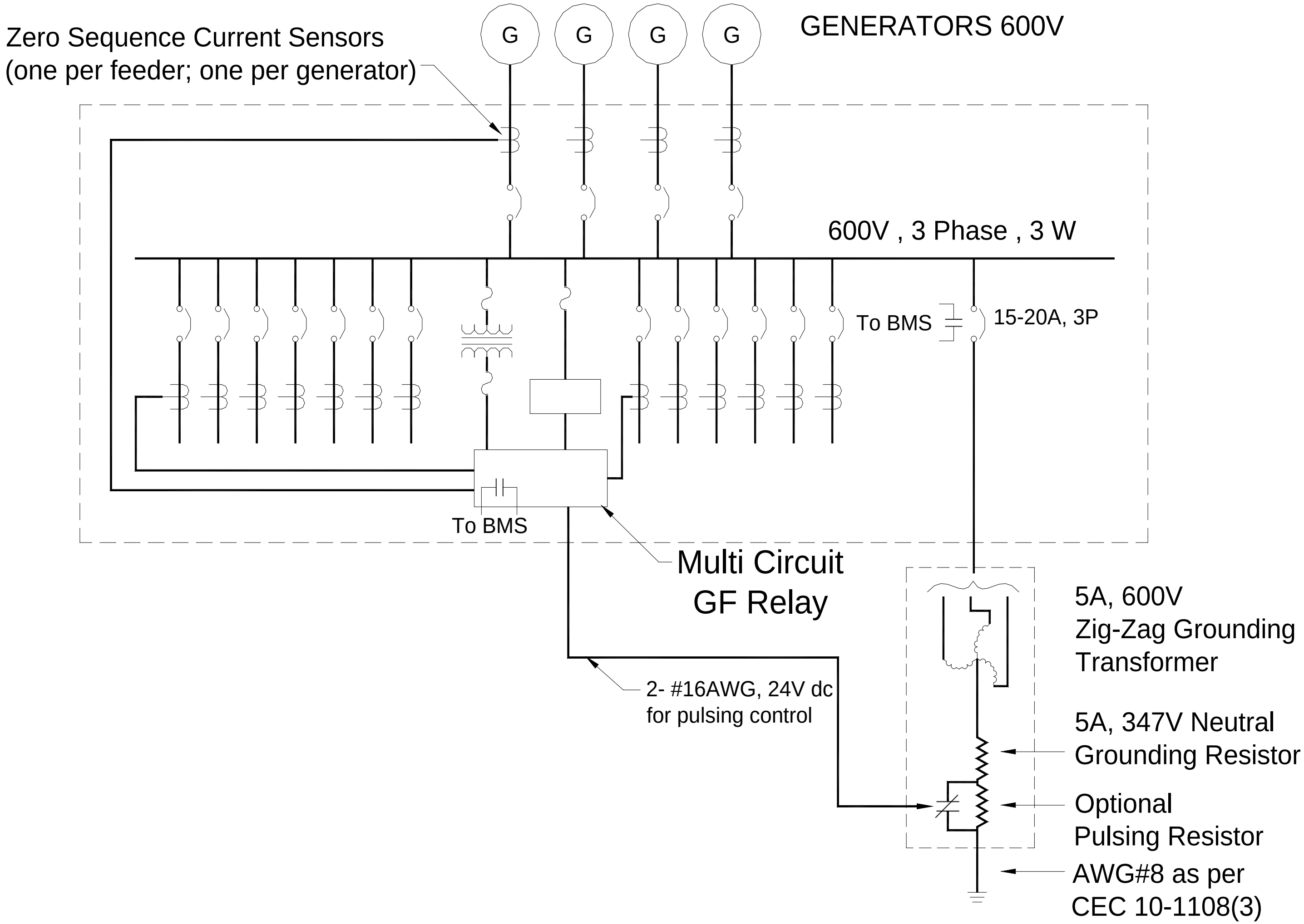
Single source fully selective system



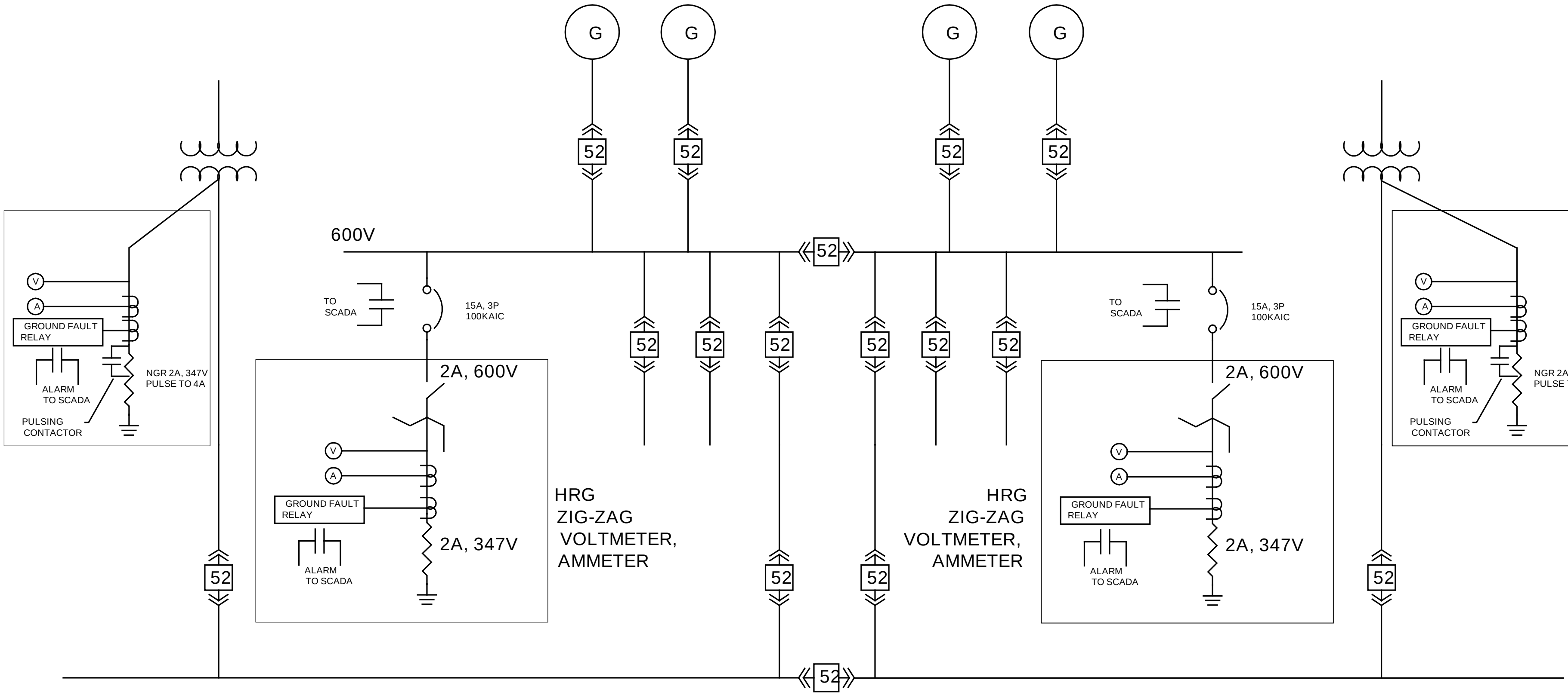
Multiple sources

- When more than one source is in operation apply resistance grounding so that the fault current does not vary with the number of sources
- Helps in relay settings, keeps fault damage low
- Apply grounding at the main bus – Fig 3

Multiple sources



Multiple sources



Low Resistance Grounding

- Used on medium voltage (MV) distribution systems (5KV – 36 KV)
- System charging current too large for high resistance grounding or retrofits
- Ground fault current limited to 20– 100 A typically
- Trip on ground fault
- Prevents arc flash incident on ground fault

Low Resistance Grounding

- NGR Sizing
  Dependent on $3I_{CO}$, and
  Protection Relay Sensitivity

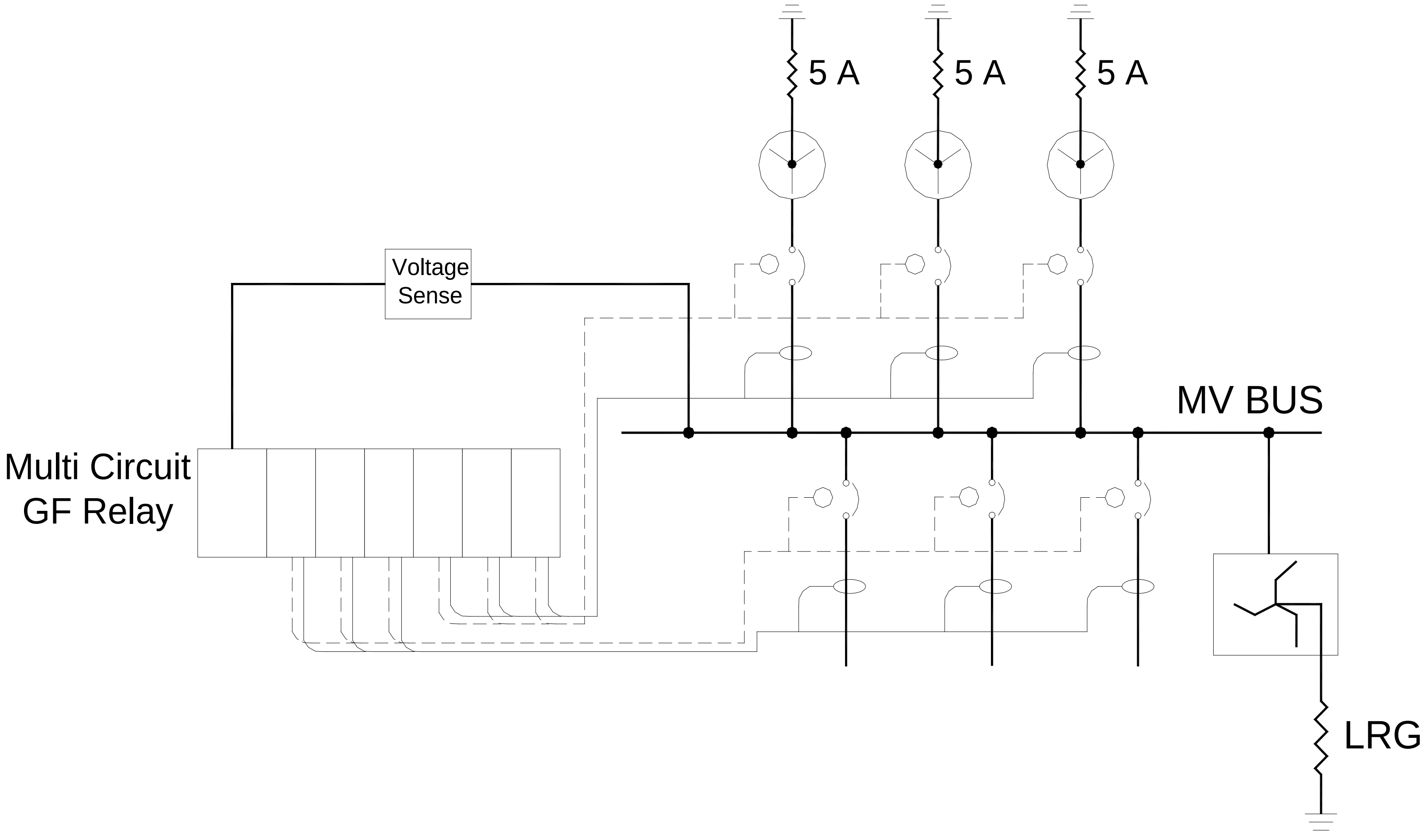
Neutral Grounding Resistor

- Resistors are made to IEEE -32 std
- The standard limits the temperature rise for continuously rated resistors to 375 °C
- The temp rise on short time resistors is limited to 750 °C
- The Resistor should made with materials which have low temperature coefficient of resistance so that the fault current will not reduce significantly – risk of relay drop out
- Typically resistor material should have temp coefficient of Resistivity less than .0002/°C or the fault current should not reduce by less than 10 %

Medium voltage Systems

- Only 1 rule is different than for low voltage.
  - Cable insulation
  - 133% insulation when fault is on system for upto 1 hour
  - 173% insulation when fault continues beyond 1 hour

Hybrid Grounding



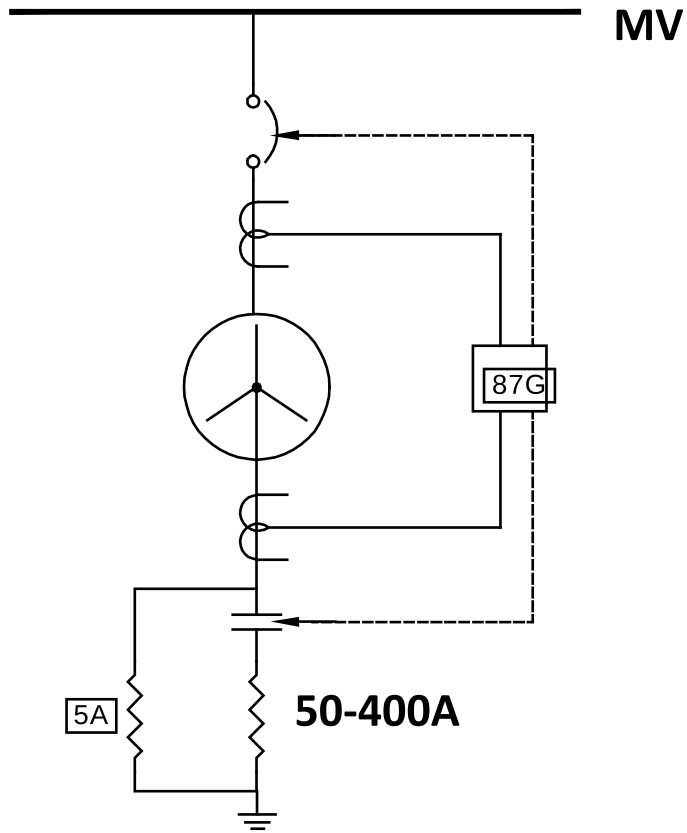
Generator grounding

- Stator windings in Generators are braced to with stand 3 phase short circuit current.
- On solidly grounded generator the Line to ground current will be larger than the three phase short circuit current
- Large generators need to impedance grounded because the zero sequence impedance is less than the positive sequence impedance to ensure that the L-G current will be less than 3 phase short circuit current.

Hybrid grounding of generators

- For generators with MV out put and 10MW and larger size the damage due to a line to ground fault in the stator winding can be minimized and protection provided by hybrid grounding of the generator

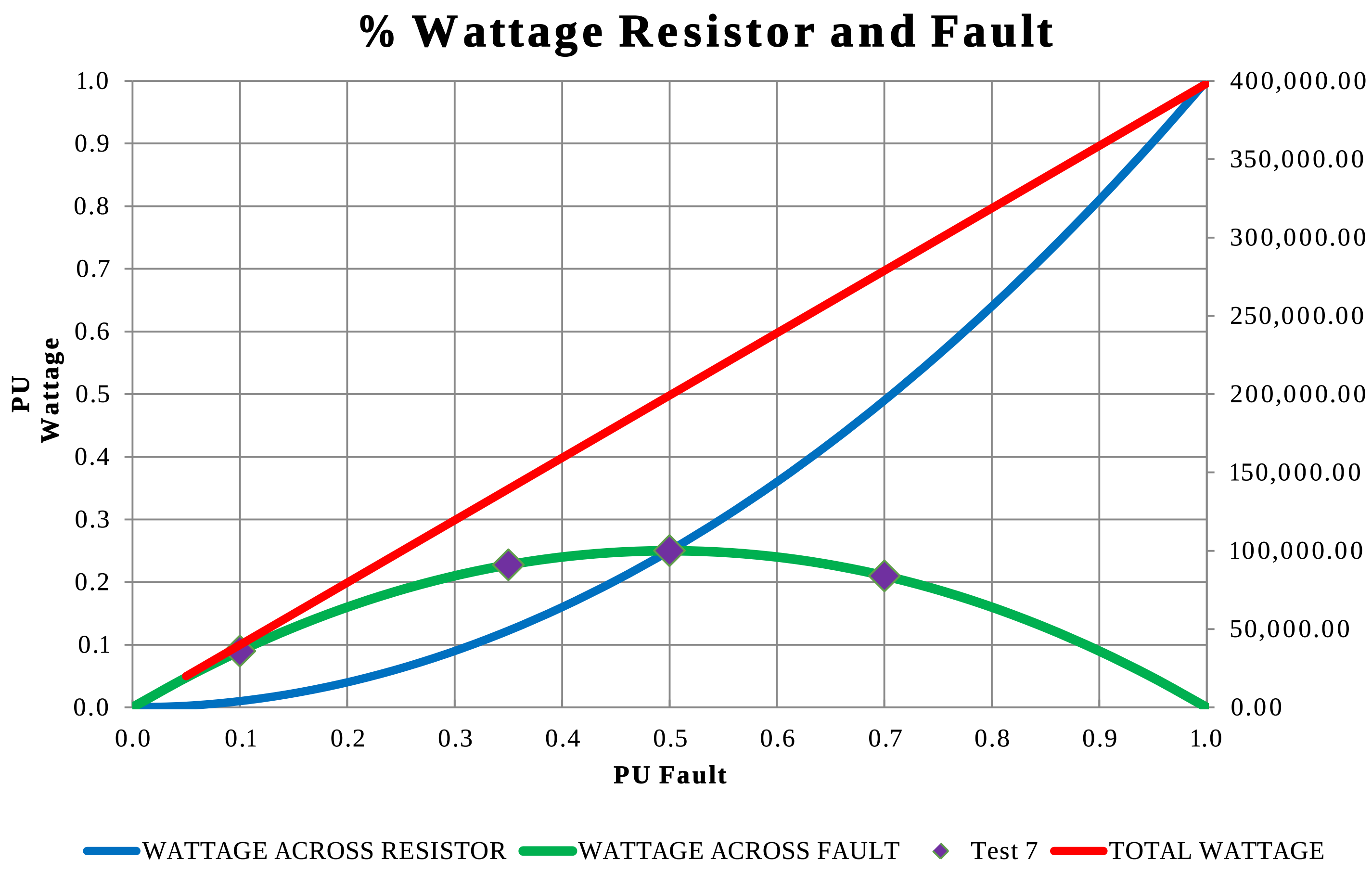
Hybrid Grounding of Large Generators



Fault Energy

- From early works of Francis Fox and Bruce McClung 1972 Paper 13.4 A I_{C0}
- Test 7

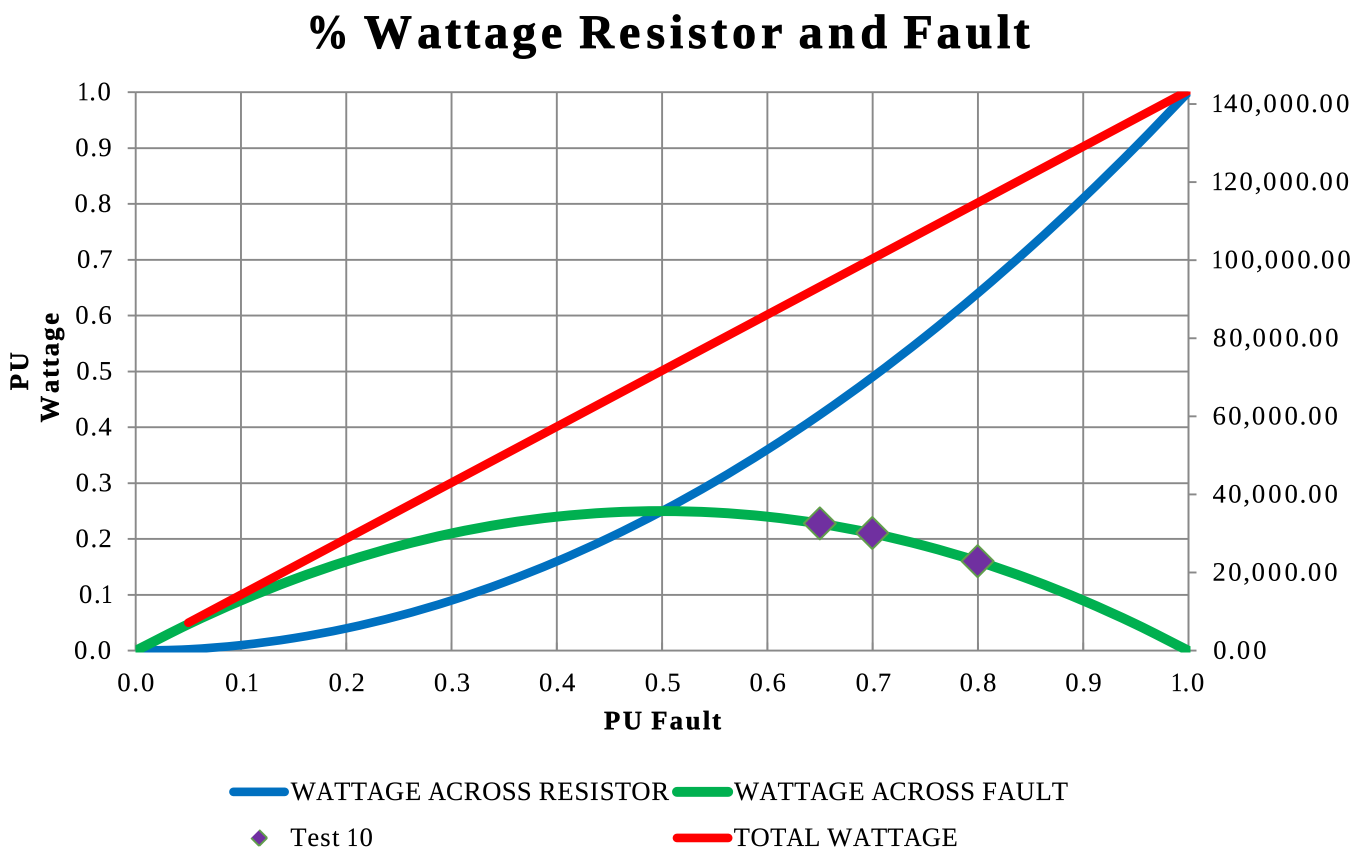
Current(A)	Approx. Arc Voltage(V)	Approx. Heat in Arc (kW)
29	4000	116
7	7000	49
40	2500	100
34	4000	136
25	5000	125


% Wattage Resistor and Fault
PU Wattage
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400,000.00
350,000.00
300,000.00
250,000.00
200,000.00
150,000.00
100,000.00
50,000.00
0.00
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
PU Fault
WATTAGE ACROSS RESISTOR
WATTAGE ACROSS FAULT
Test 7
TOTAL WATTAGE

Test 10

- I_R reduced to 18 A.

Current(A)	Approx. Arc Voltage(V)	Approx. Heat in Arc (kW)
18	1600	30
16	1500	25
16	2700	43
16	2500	40



% Wattage Resistor and Fault
PU Wattage
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
140,000.00
120,000.00
100,000.00
80,000.00
60,000.00
40,000.00
20,000.00
0.00
0.0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1.0
PU Fault
WATTAGE ACROSS RESISTOR
WATTAGE ACROSS FAULT
Test 10
TOTAL WATTAGE

Heat statement

$$I_f^{1.5} t = 250\ I_R$$

Where I_f *is the Actual Fault current*

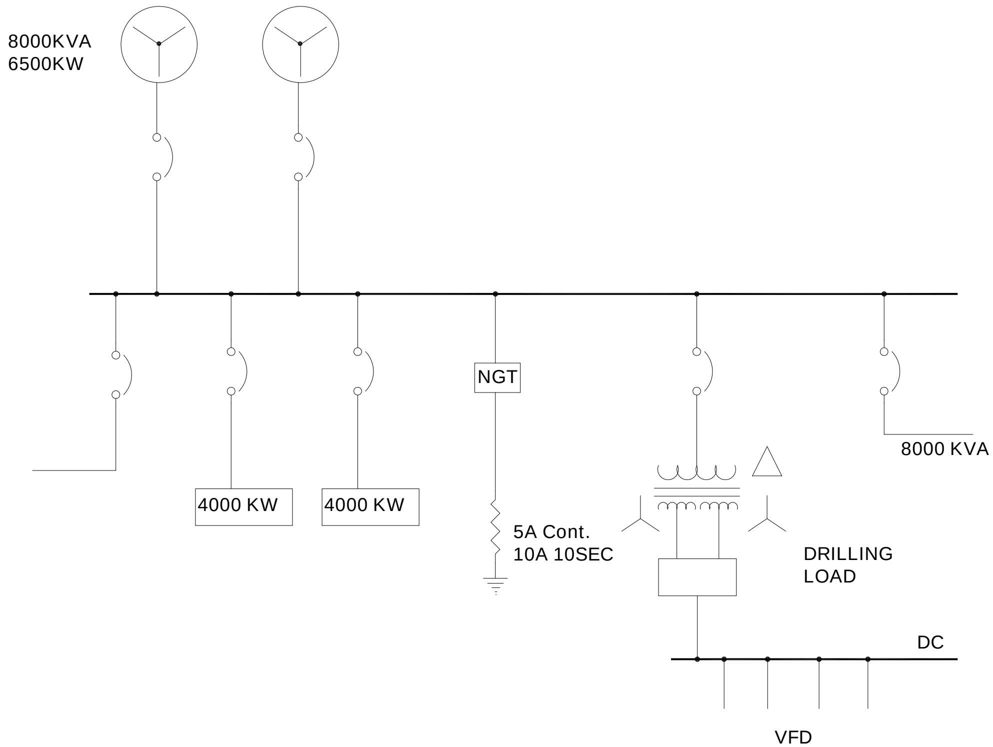
t Fault Duration

I_R Equipment Rated current

A threshold of insignificant damage is 30 kW-s

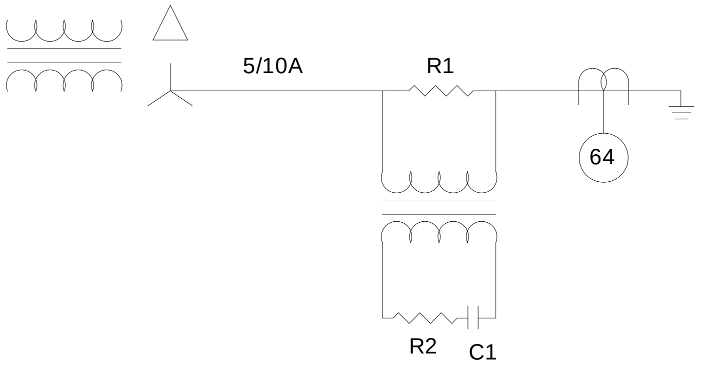
Case Study 1

Fig. 8 Deep sea drilling electrical service



Case Study 2

Fig. 9 Mass transit MV HRG system



Recommendations

- Suggest 15 A. at 13.8 kV as limit for HRG

This would result in 29kW fault at 50%

Thank you

- Questions?
- Comments?