



**Power
Generation**

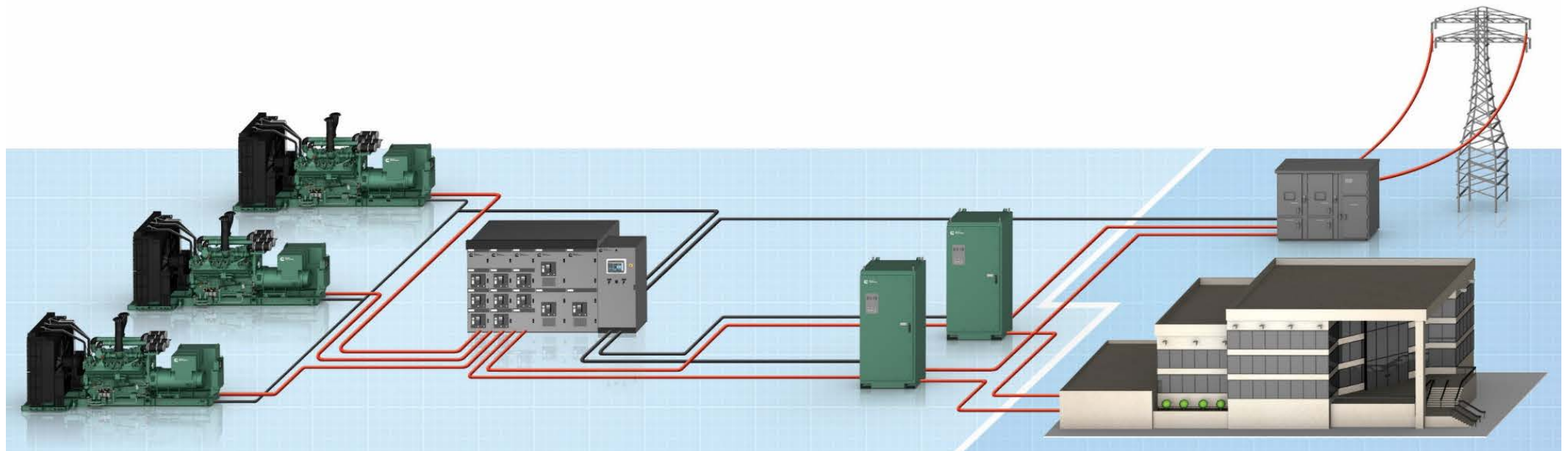
IEEE Northern Canada & Southern Alberta Sections, PES/IAS Joint Chapter Technical Seminar Series



Designing Electrical Systems for On-Site Power Generation

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Cummins Power Generation



Electrical Systems for Onsite Power Generation Systems

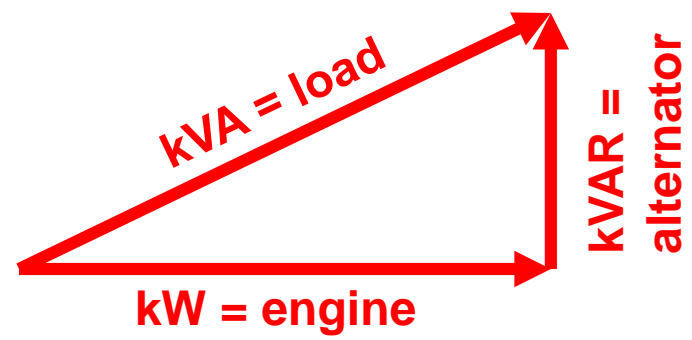
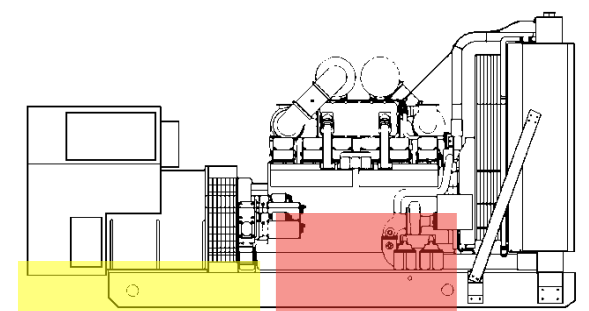
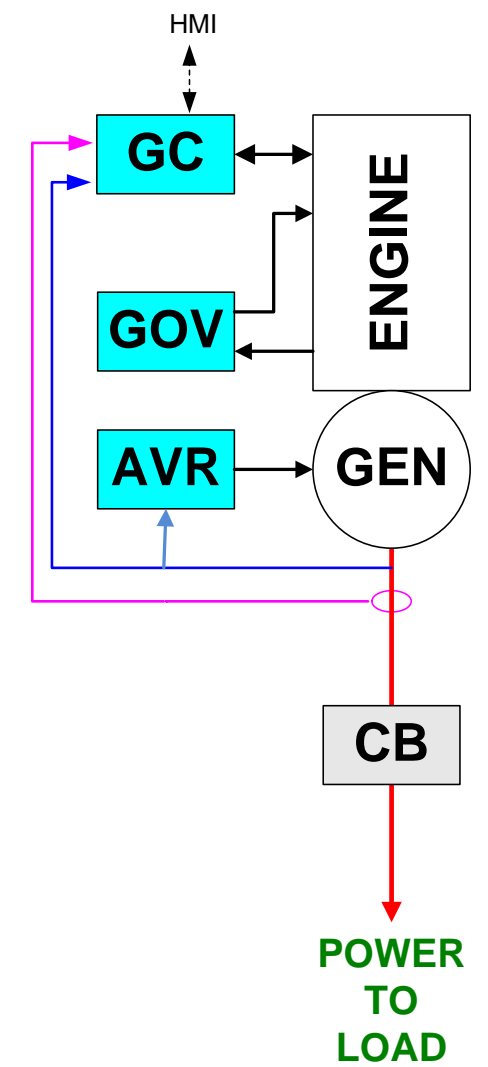
- Proper generator sizing for motor loads accounting for locked rotor kVA
 - in “across the line” motor starting applications.
 - in VFD motor starting applications.
- Generator short circuit characteristics and their effects on arc flash incident energy.
- Grounding (system and/or equipment) and ground fault detection of on-site power generation systems:
 - When to switch the neutral in emergency standby systems
 - Grounding and ground fault detection schemes for paralleled generator sets in both grid connected and islanded applications

Contents

- Generator Control Basics
- Motor Starting Requirements
- Non-Linear Loads and Harmonics
- Generator short circuit characteristics
- Arc Flash
- Generator Grounding
 - Neutral Switching in Low Voltage Emergency Standby Systems
 - Grounding of paralleled Systems

Basic Generator Set Controls

- GC: Genset Control
 - Engine Protection
 - Start/Stop
 - Operator Interface (Alarm/Metering)
- GOV: Governor
 - Measure Speed/Control Fuel Rate
- AVR: Automatic Voltage Regulation
 - Measure Voltage/Control Excitation



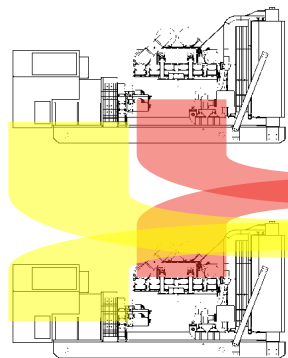
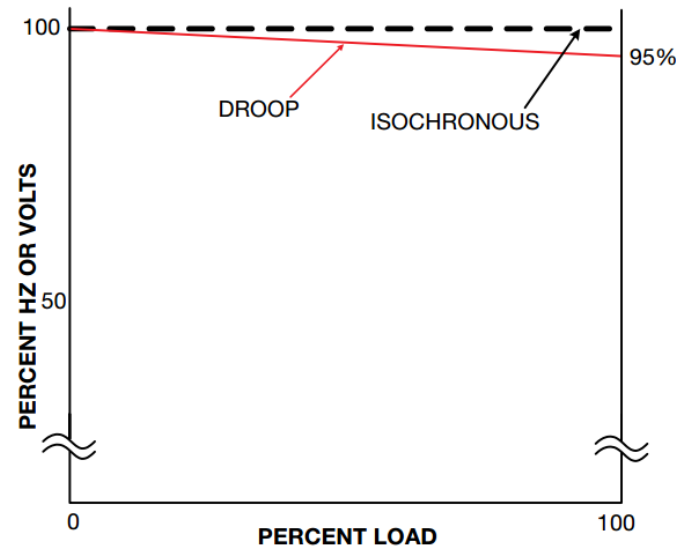
Engines produce kW--Fuel Rate Controls

Alternators make kVAR--Excitation Controls

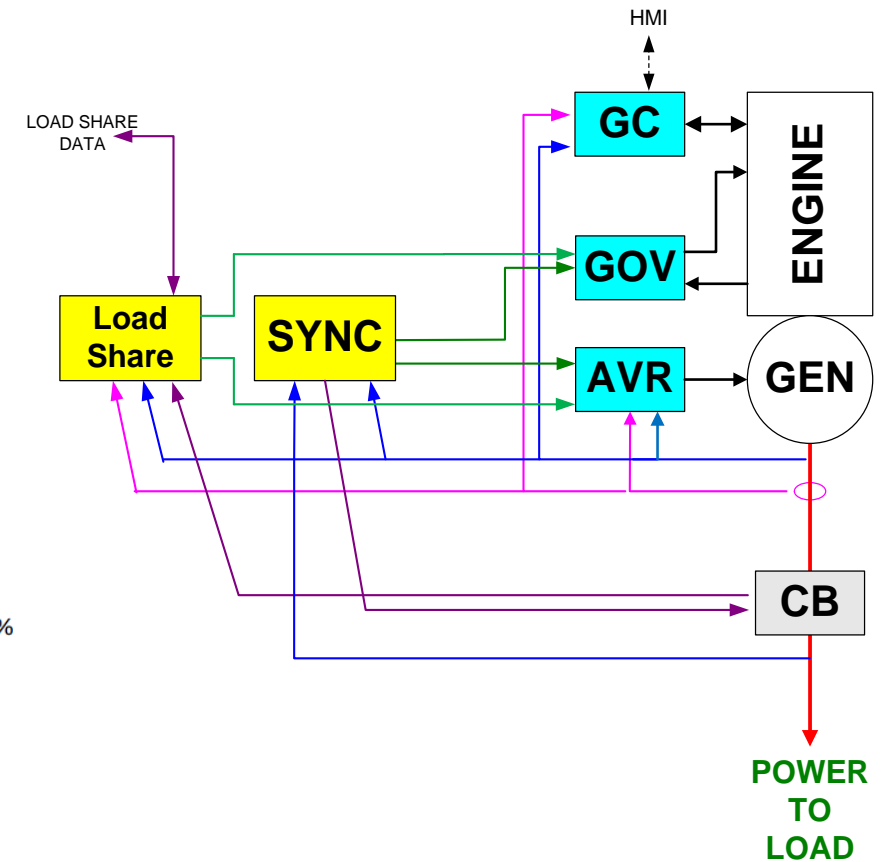
Paralleling

Load Share Control

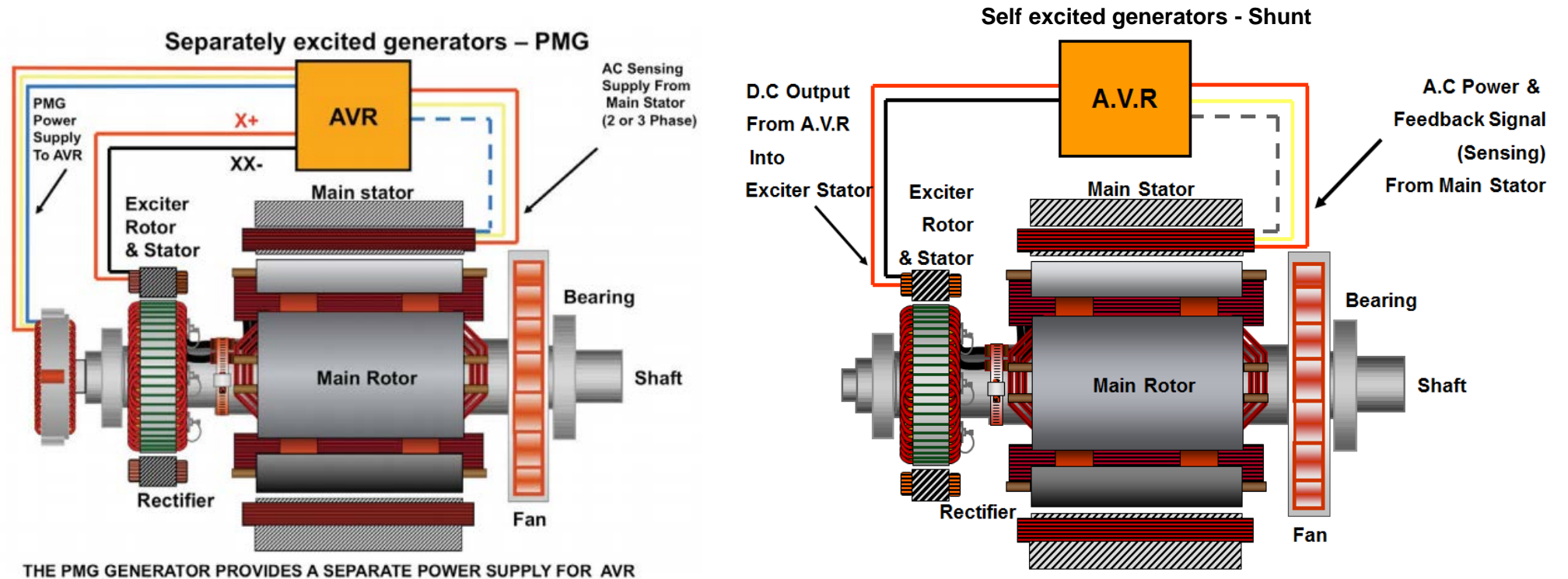
- Communicates with the load share control on the other gensets
- Adjusts governor set point to share kW equally
- Adjusts AVR set point to share kVAR equally
- Load share can be Isochronous or Droop



Sharing kW—Controlled by Fuel (Speed)
Sharing kVAR— Controlled by Excitation (Voltage)



Excitation System Considerations



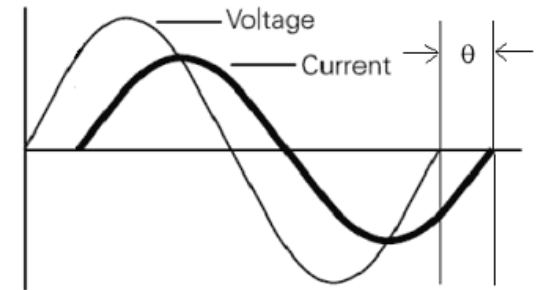
- Permanent Magnet Generator (PMG) provides constant power
- Automatic Voltage Controller (AVR) power isolated from load induced voltage distortion

Motor Starting Requirements



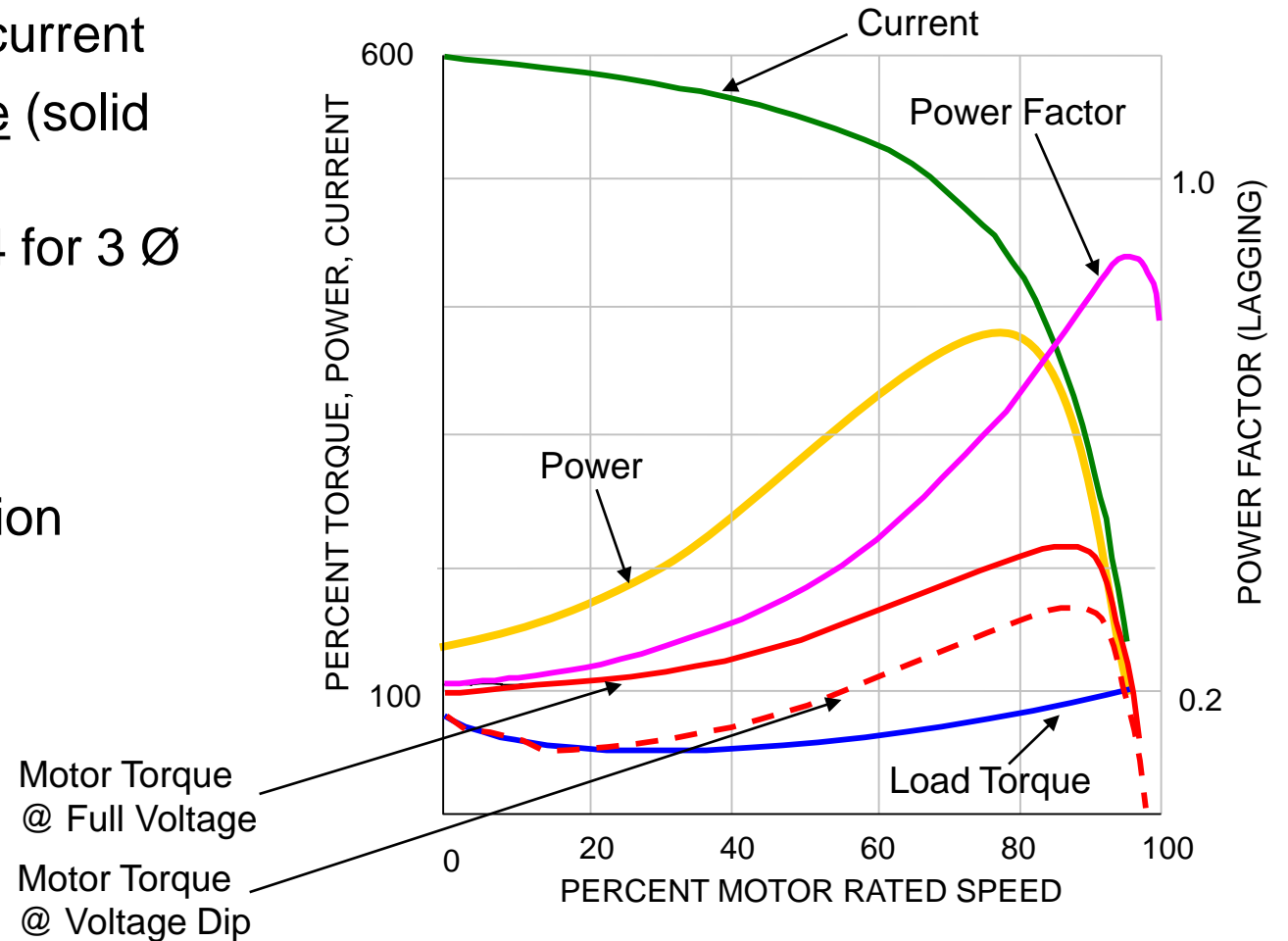
Generators and Motor Loads

- AC electric motors represent inductive loads with lagging power factors.
 - Active power (kW) – actually performs the work
 - Reactive power (kVAR) – maintains the electromagnetic fields
- Generators need to be sized to handle inrush current on across-the-line motor starting
- Motor Variable Frequency Drives may induce substantial harmonic content on the generator voltage waveform



Typical 3 Ø Induction Motor Characteristics

- Across-the-Line Start
- High locked rotor kVA (LRKVA) and current
- Torque shown for 100% rated voltage (solid red line)
- Starting (instantaneous) PF 0.2 to 0.4 for 3 Ø Motors
- Higher starting requirements for High Efficiency 3Ø and for 1Ø
- Treat synchronous motors like induction motors

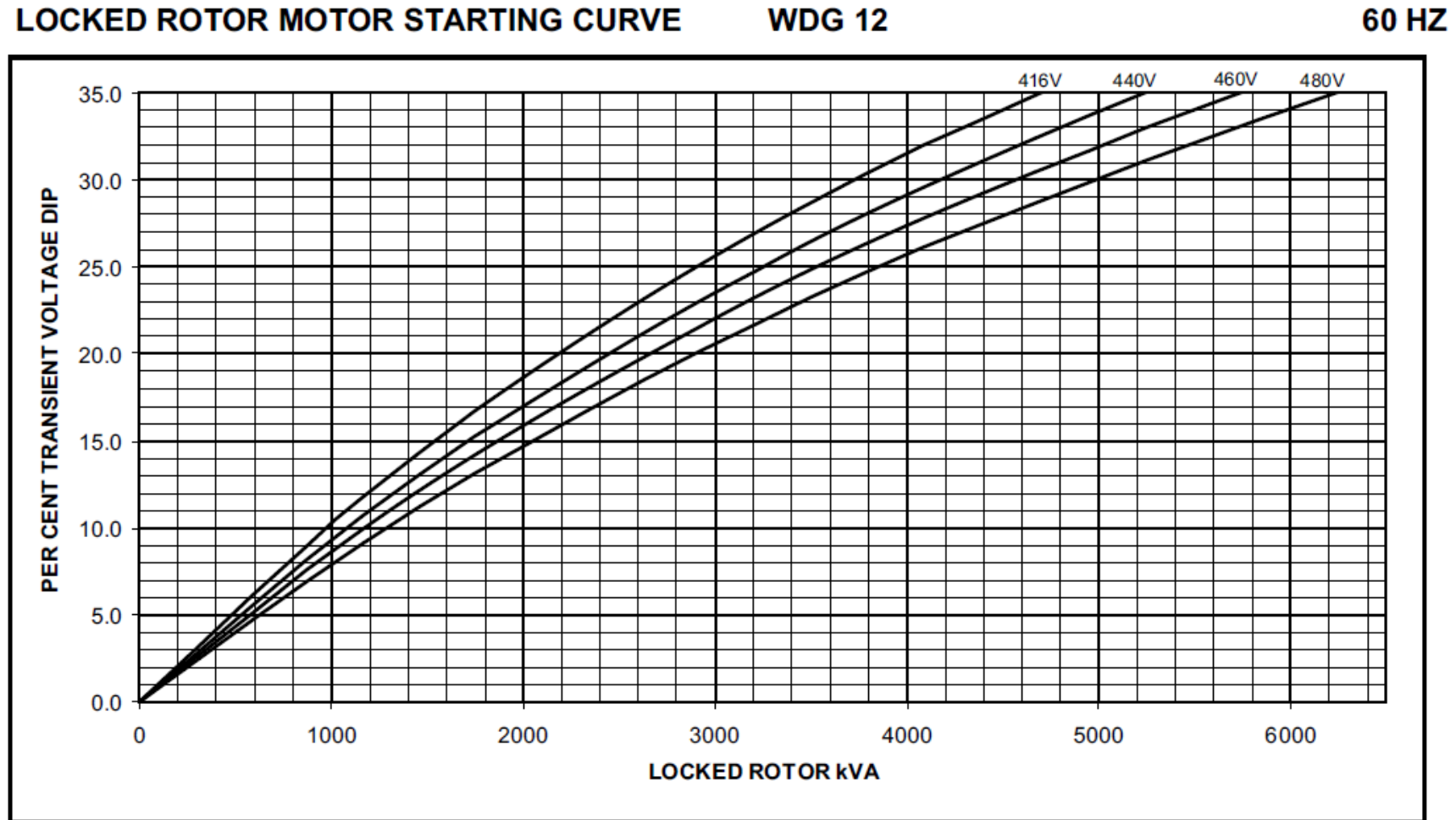


Fundamental Criteria for Motor Starting

- Sufficient LRKVA alternator capability to limit the instantaneous voltage dip.
 - Motor starting needs should not exceed LRKVA at the max specified instantaneous voltage dip.
 - f (Alternator reactance + inrush current)
 - Ensures motor contactors don't drop off.
- Ability to recover voltage.
 - Excitation system strength and response must be able to accelerate the motor and return the Genset to at least 90% operational voltage.
 - f (Exciter type and size)
 - Ensures motor can develop sufficient torque accelerate to rated speed.
- Ability of genset to recover speed.
 - The torque available from the genset must exceed the torque required by the motor load for frequency recovery

Example of Alternator Locked Rotor Curve

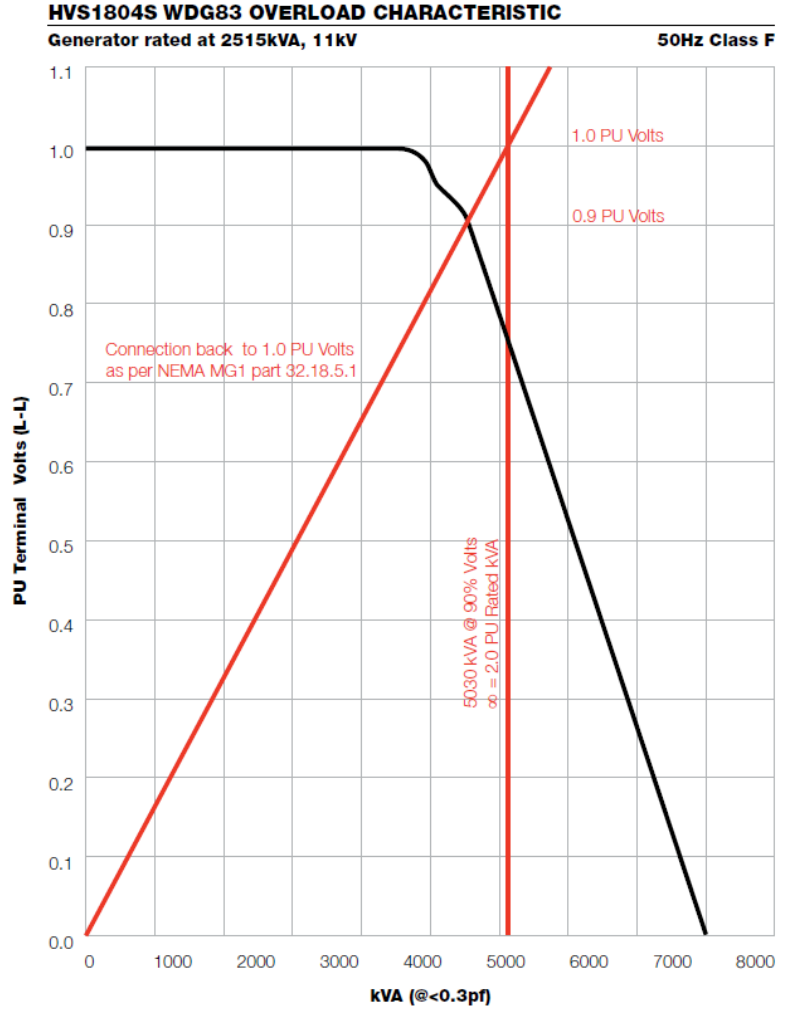
- Instantaneous Voltage dip function of alternator reactance.



Alternator External Characteristic Curve

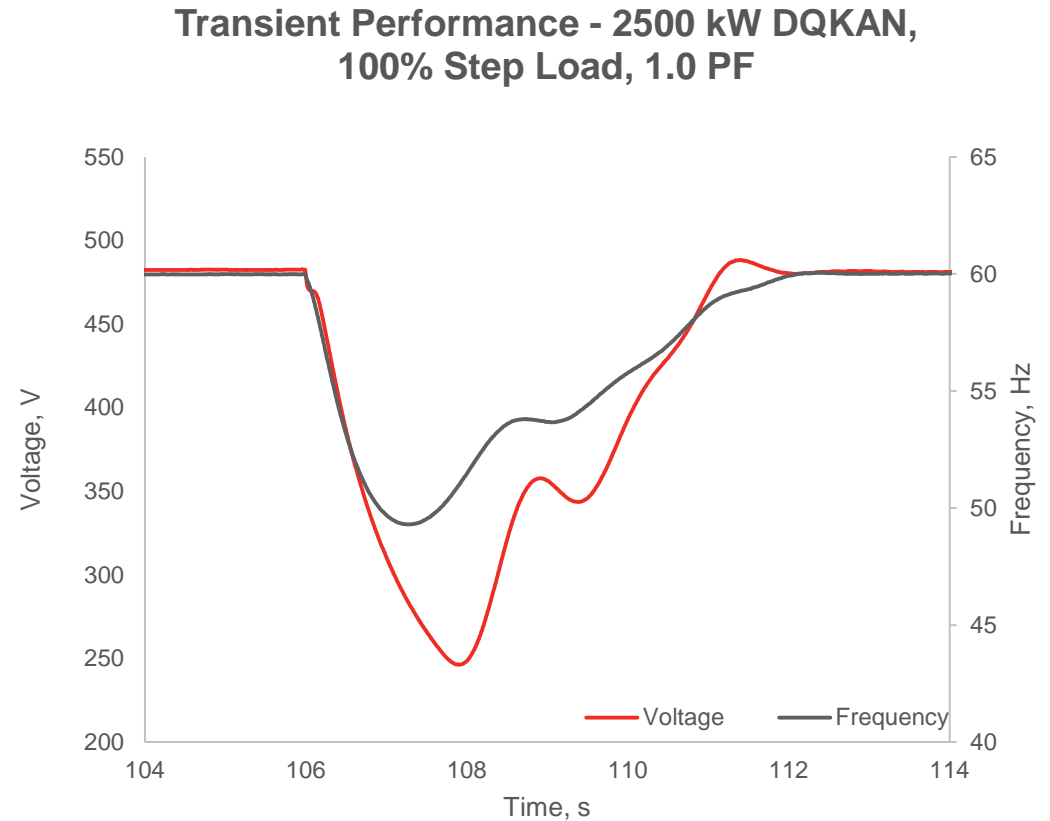
- Generator set must recover to 90% of voltage
- Typically requires excitation to be powered by PMG or auxiliary winding
 - Not shunt excited
- Maximum kVA at 90% sustained voltage is stated on spec sheets
- Motor starting kVA is expressed at 100% voltage
- NEMA MG-1 defines correction between 90% and 100% voltage

MOTOR STARTING		$\frac{416}{(12)}$	$\frac{440}{(12)}$	$\frac{480}{(12)}$	$\frac{600}{(07)}$
Maximum kVA	(90% Sustained Voltage)	8412	8412	8412	8189



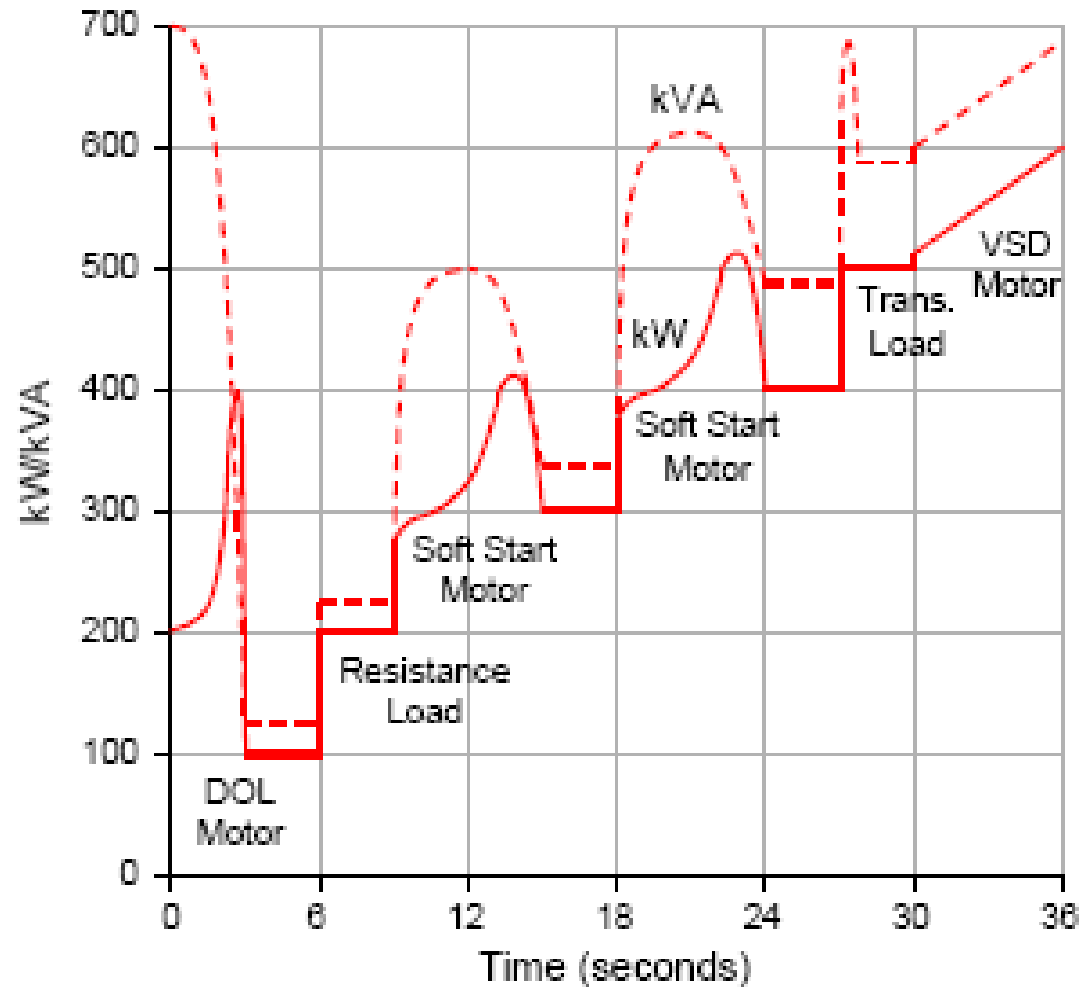
Generator Transient Response to Step Loads

- Imbalance of Energy – Demand > Supply
- Alternator must support kVA
 - Limit voltage dip
 - Recover to acceptable voltage
- Engine must support kW
 - Recover engine speed/frequency
- Volts/Hz skews voltage dip
- Dynamic response combination of frequency and voltage



Starting kW ↑ → Frequency Dip ↑ → Engine Size ↑
Starting kVA ↑ → Voltage Dip ↑ → Alternator Size ↑

Optimizing Genset Size



Step Starting Sequence

Step Loading the Genset

- Apply load in increments
- Apply large motor loads first
- Limit voltage and frequency dip
- Ultimately reduce Genset size

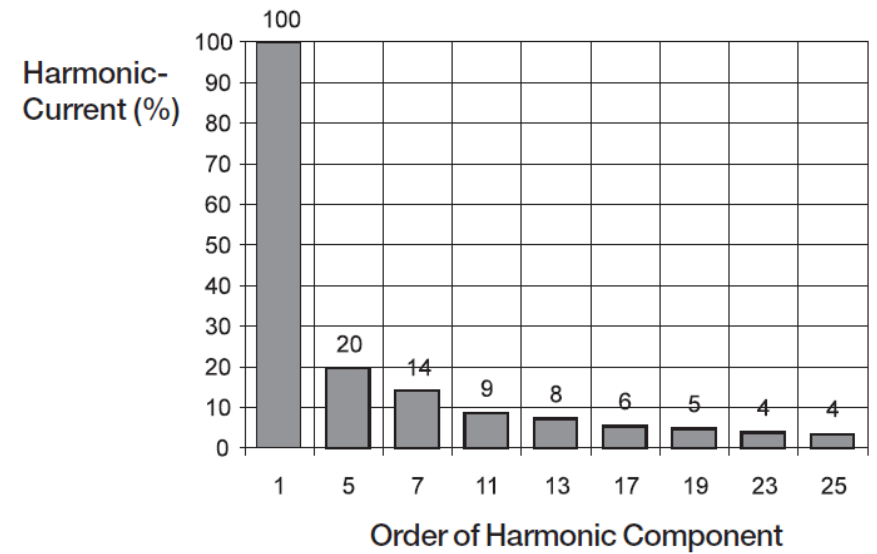
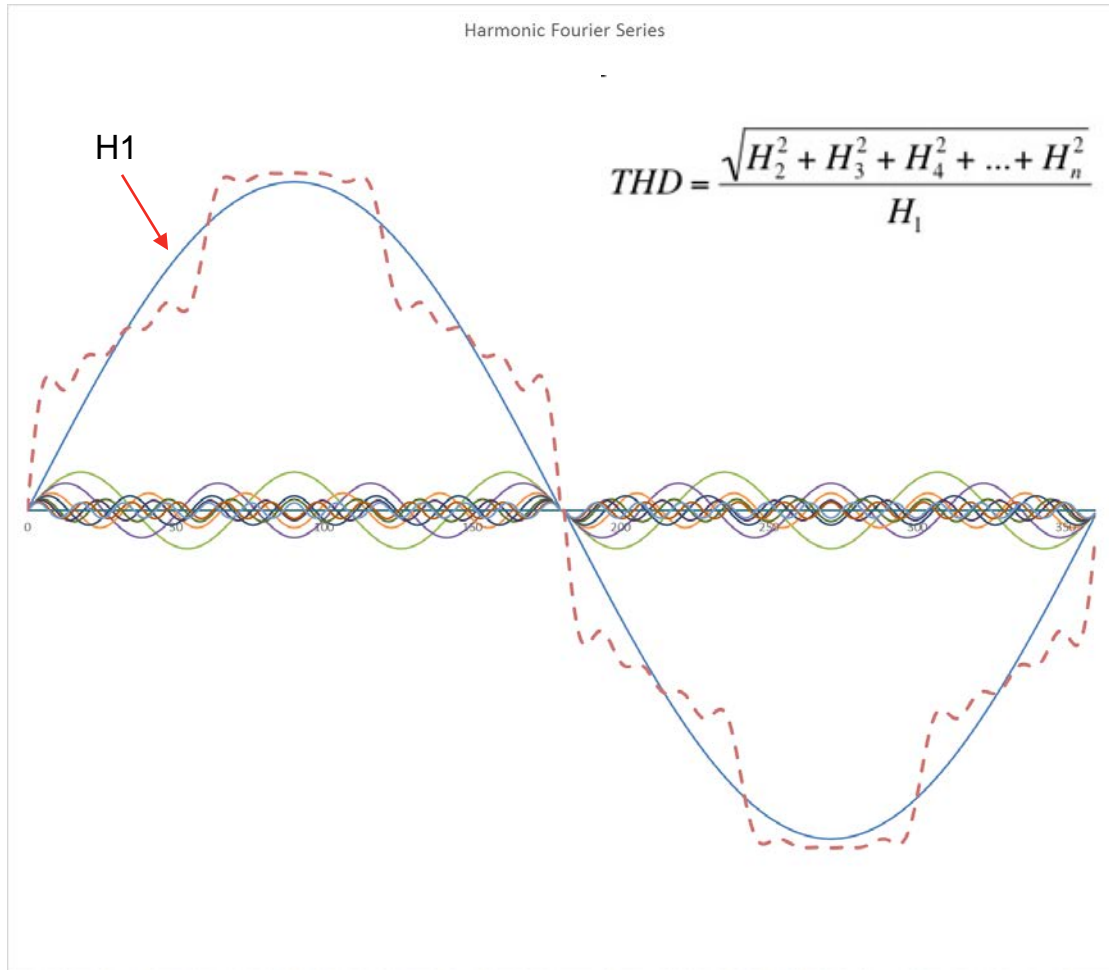
Consider

- Locked Rotor kVA
- Maximum allowable voltage dip (for each step in the sequence)

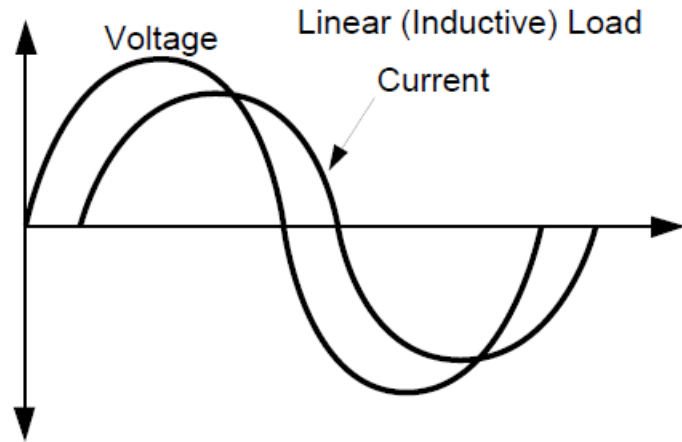
Variable Frequency Drives may reduce starting kVA

- Present generator set with non-linear load

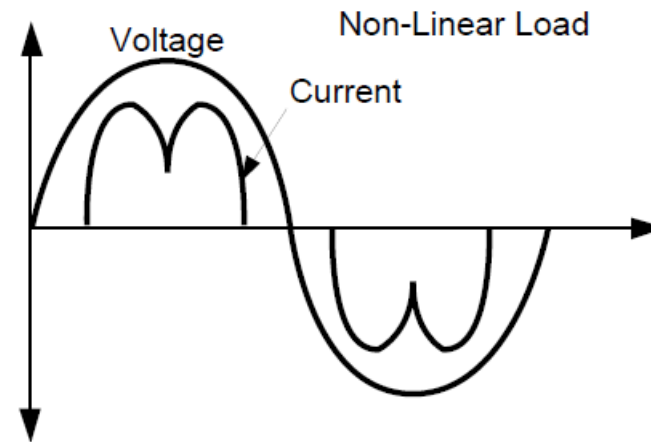
Non-linear Loads and Harmonics



Linear Load versus Non-Linear Loads

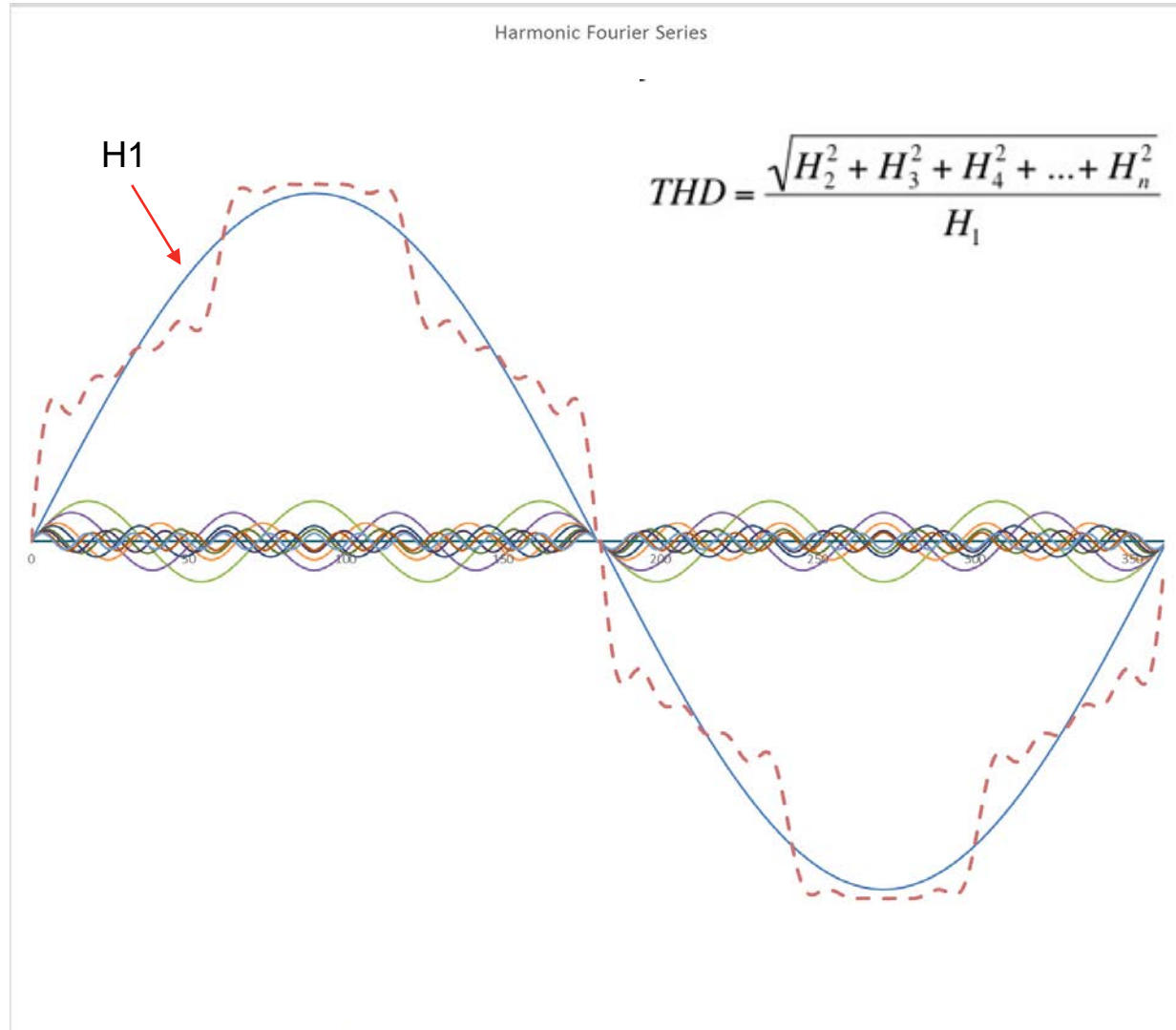


A load in which the relationship between current and voltage is directly proportional



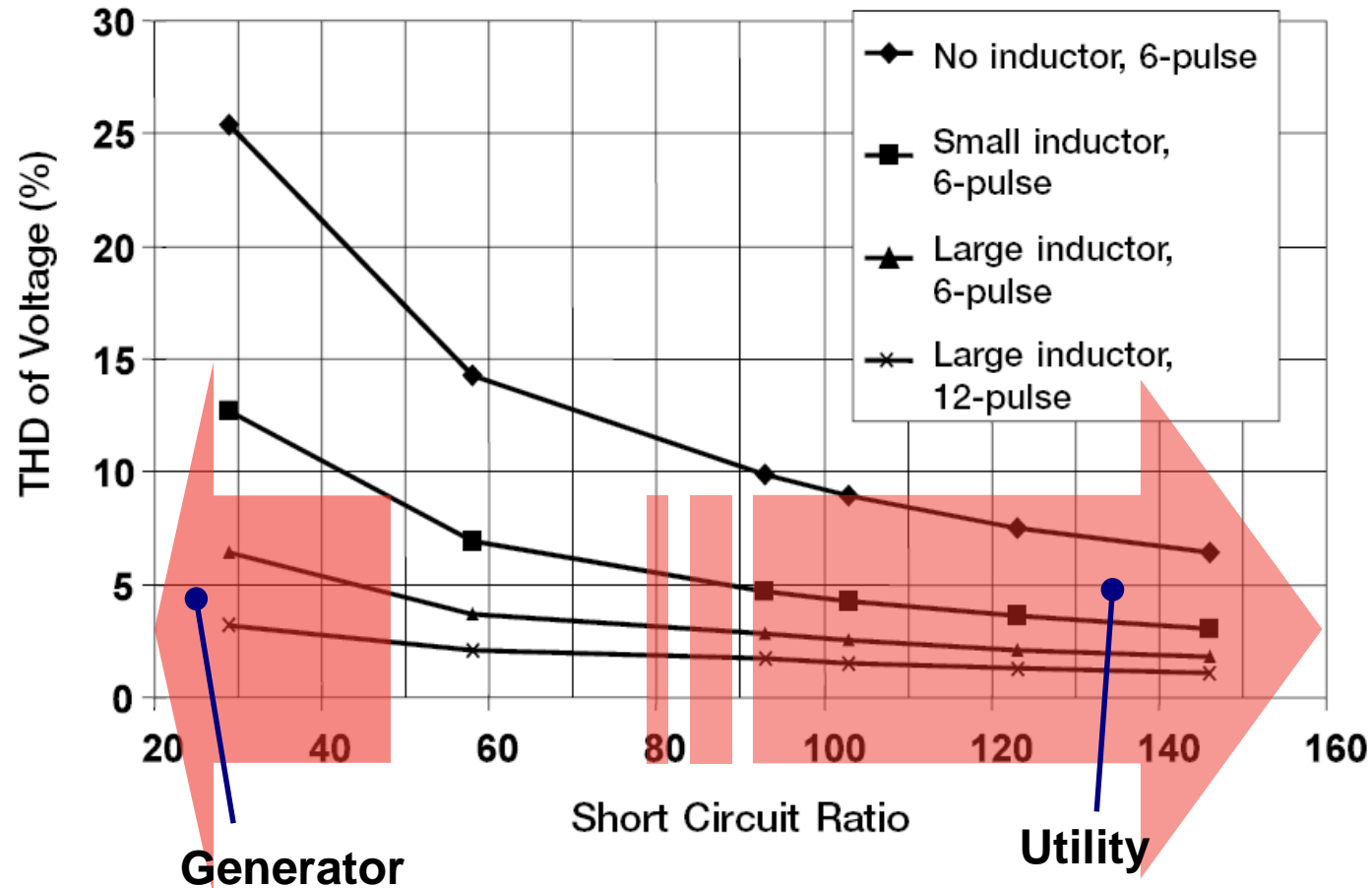
Load is switched on a sub-cyclic basis resulting in current that no longer conforms to the sinusoidal voltage

Distorted Waveform Fourier Series



- Switching current on a sub-cyclic basis results in a distorted current waveform
- The source (generator or utility transformer) induces current harmonic distortion on to the voltage waveform
- Induced voltage harmonic distortion is inversely proportional to source short circuit ratio
- Short circuit ratio = short circuit current/rated current
 - Utility Transformer SCR ~ 100
 - Generator SCR = $1/X''_d \sim 8$

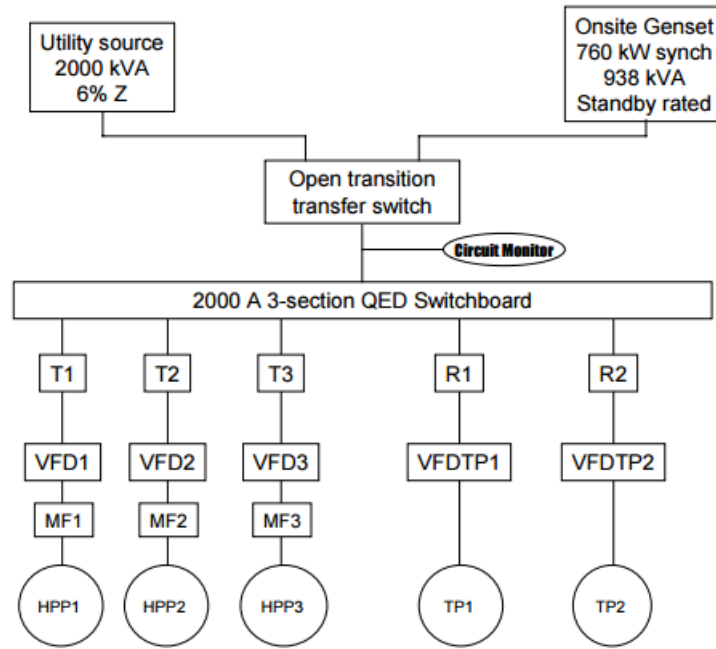
Source Voltage THD: Function of Load Harmonics and Source Short Circuit Ratio (SCR)



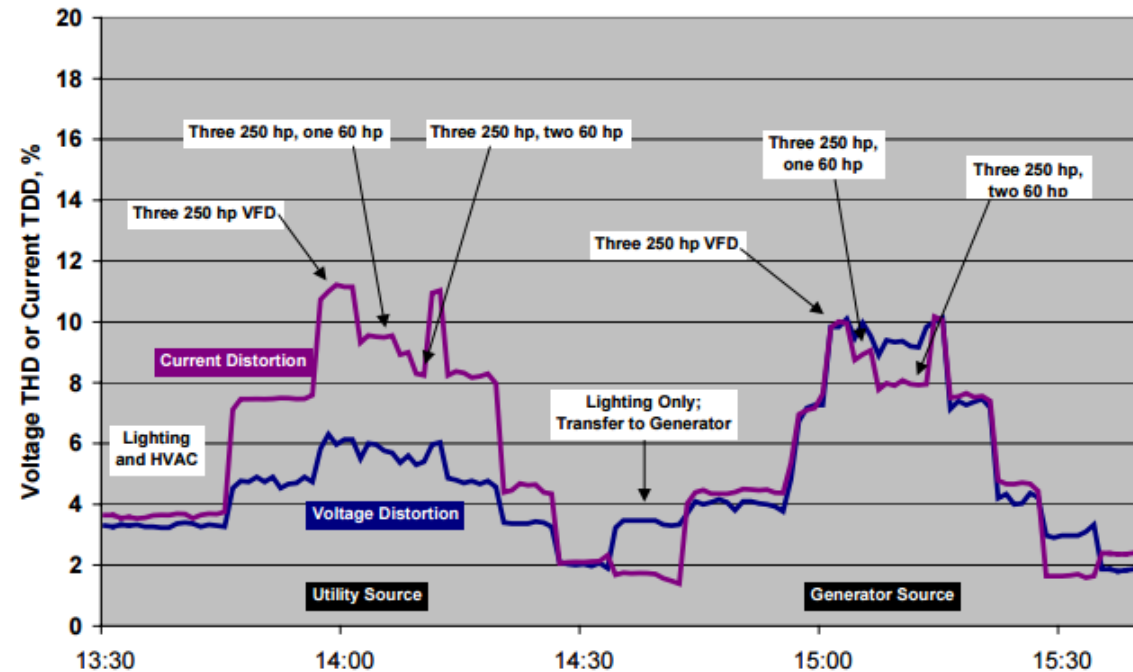
$$SCR = 1/X_s$$

- X_s = Source impedance
- For generator, $X_s = X''_d$
- X''_d = sub-transient reactance

Case Study – Harmonics at a Water Treatment Plant



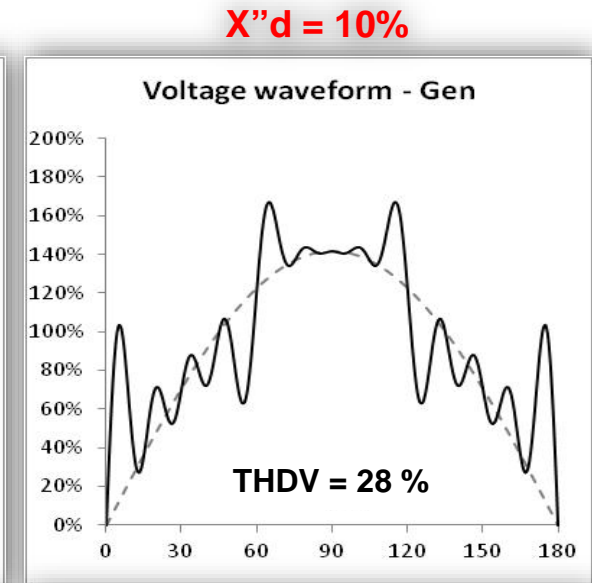
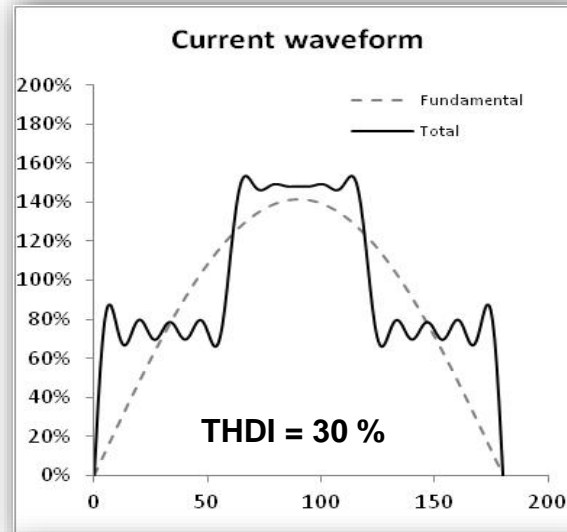
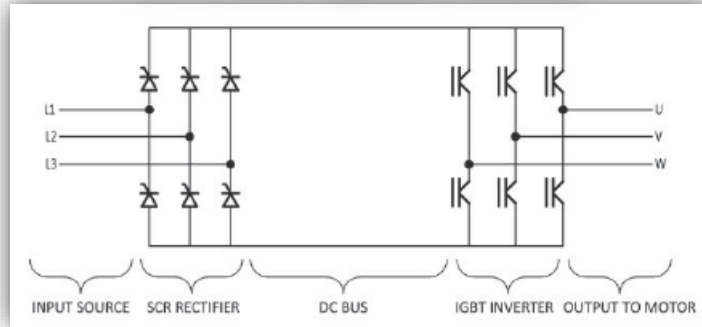
- T1-3: 270 kVA isolation transformers, 460/460V, 5.3 Z at 170 C
- R1, R2: Line reactors, 3% Z at 60 hp
- VFD1-3: 250 hp 6 pulse PWM
- VFDTP1, VFDTP2: 60 HP, 6 pulse PWM
- MF1-3: Drive output (motor) filters
- HHP1-3: 250 HP vertical suction water pumps
- TP1, TP2: 60 HP pumps



*Reference - **Generator Loading, Harmonics Monitoring and Mitigating Analysis in a Water Treatment Plant** -Eddie Jones, PE; Larry Ray, PE; Tim Shuter, PE; Square D Engineering Services

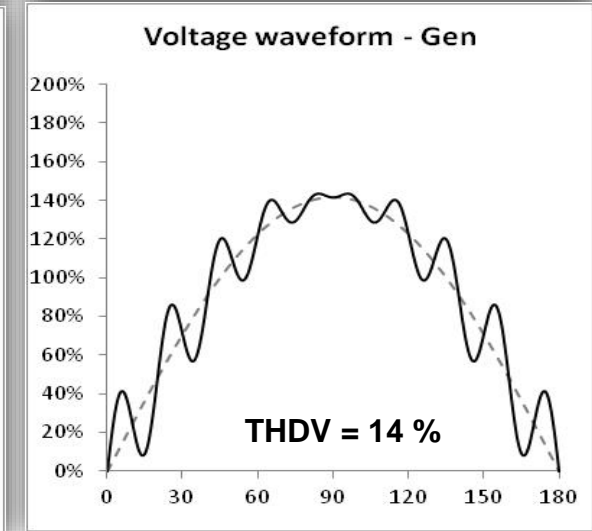
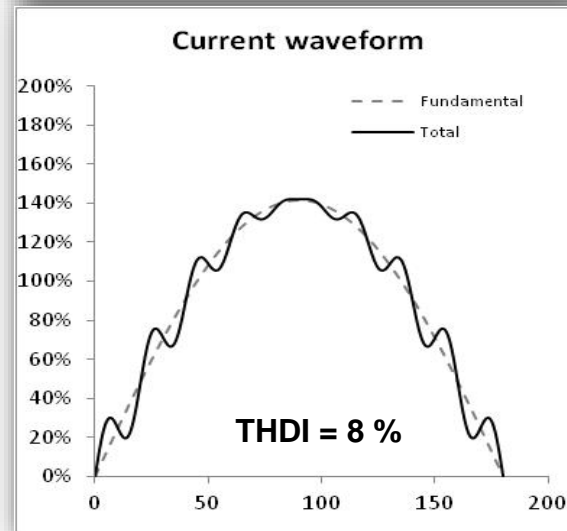
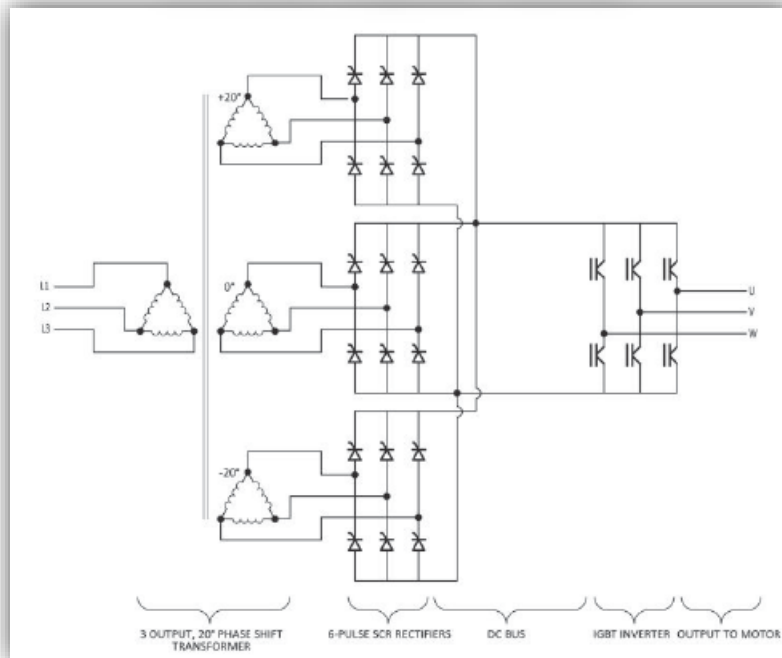
Equipment Selection and Current Distortion

VFD with 6 pulse rectifier



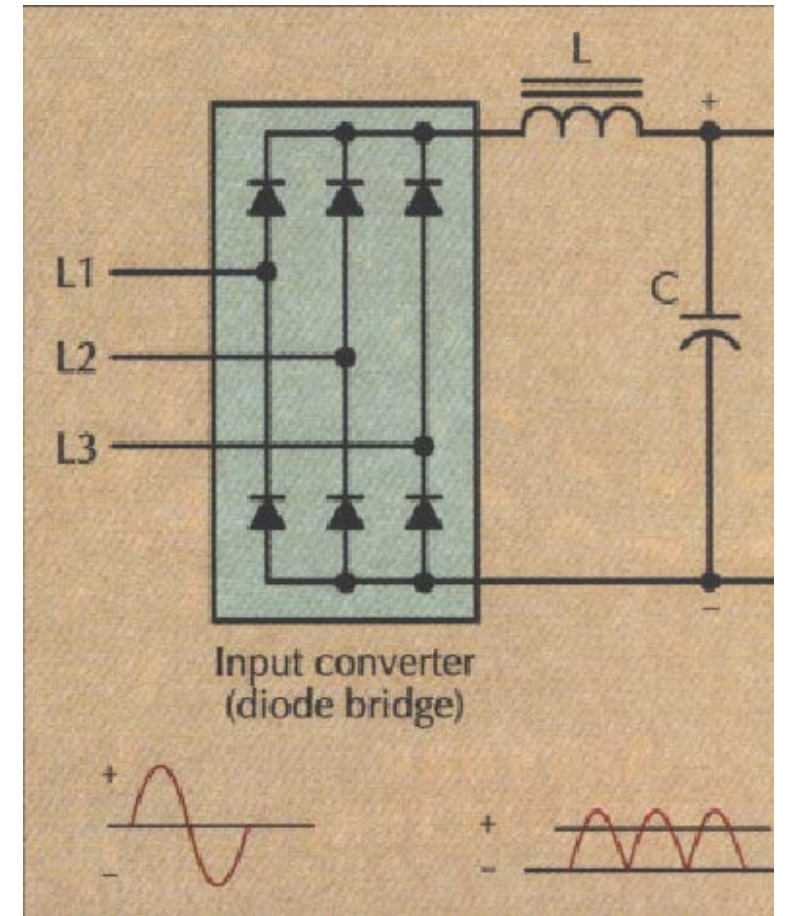
X''d = 10%

VFD with 18 pulse rectifier

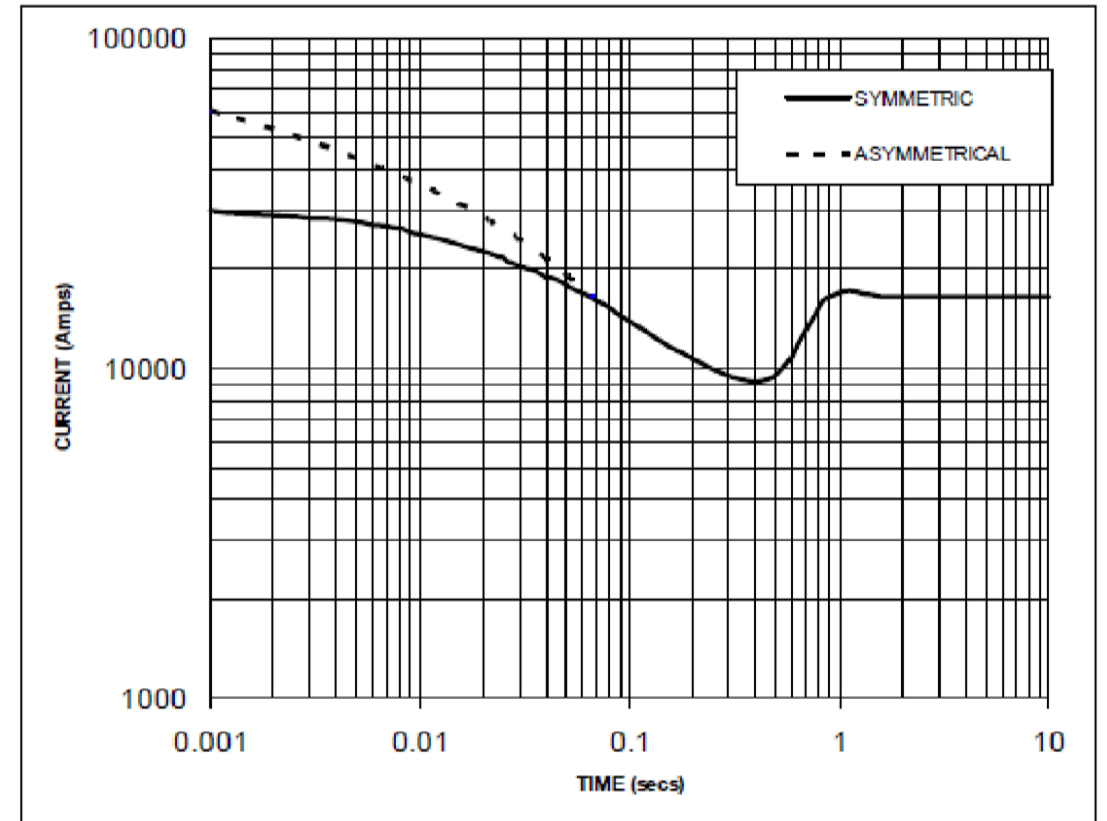
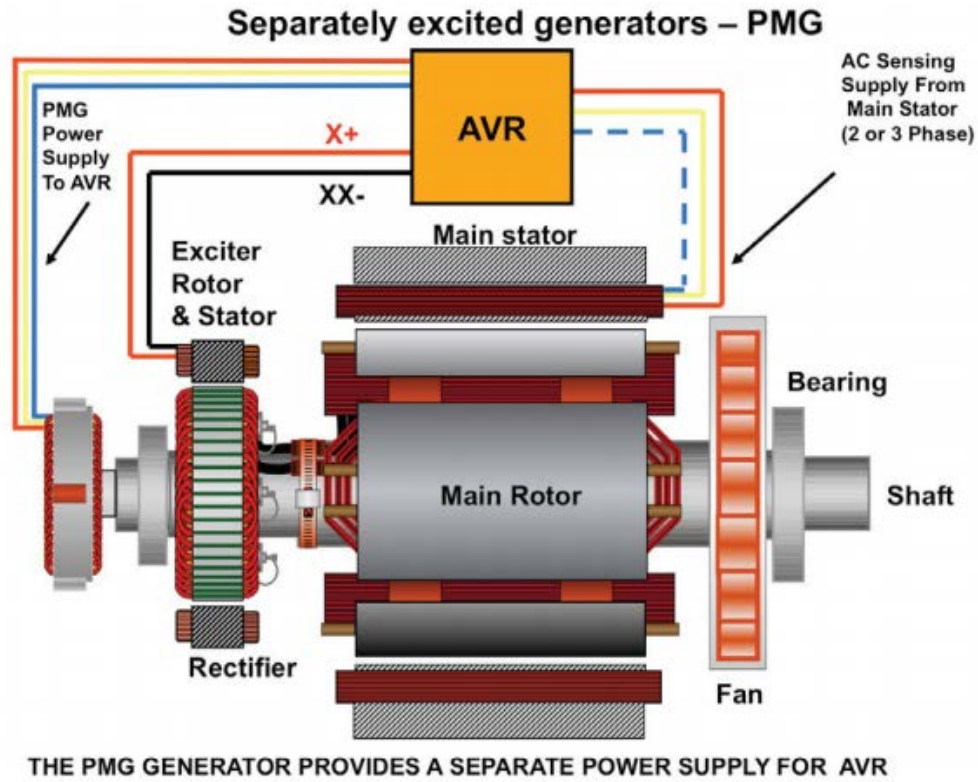


Harmonic Distortion - Key Aspects

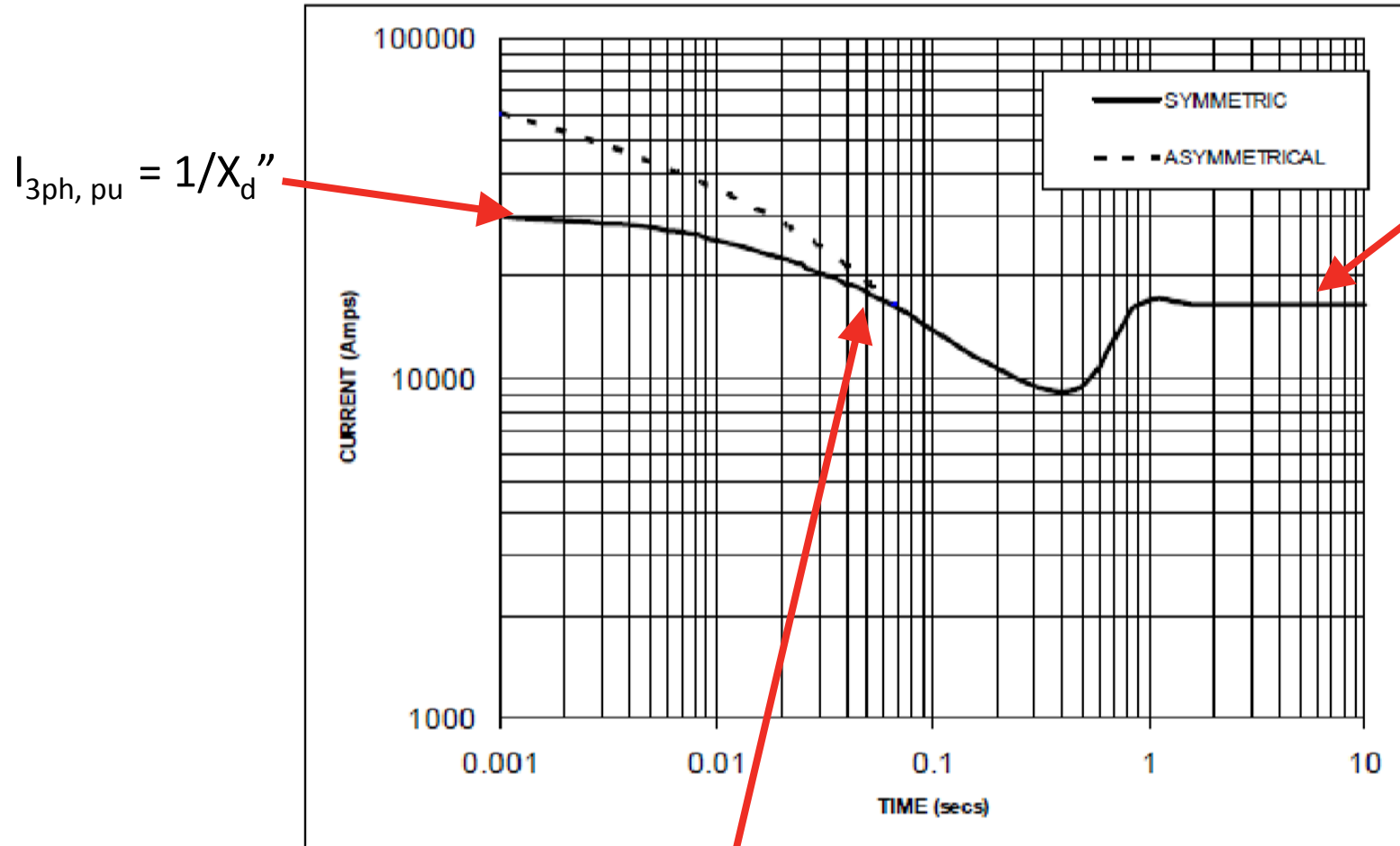
- Load induced current distortion (ITHD%) can cause pervasive voltage distortion (VTHD%) in the electrical distribution system
 - Think Ohm's law concept ...
 - $E = X * I_n$
 - $\uparrow E_n \downarrow = n * X''_d * \uparrow I_n \downarrow$
- The utility is a stiff source but the generator set is **NOT**
- The generator is **NOT** the critical component with regard to equipment damage
- The most common way to avoid problems due to harmonics is to:
 - Reduce source impedance → oversize the alternator
 - Reduce load induced current distortion → utilize low harmonic equipment



Generator Short Circuit Characteristics



Alternator Decrement Curve



Current is a function of the AVR and Excitation System

- Key points
- Alternator fault current decays, it doesn't remain constant like fault current from a transformer
 - System design software tools such as SKM account for this

$$I_{3ph, pu} = (1/X_d'' - 1/X_d') * e^{(-t/Td'')} + (1/X_d' - 1/X_d) * e^{(-t/Td')} + 1/X_d$$

Generator Fault Current Characteristics

- Decrement Curve displays generator performance in the event of a 3 phase fault
 - Standard for coordination studies
- 3 Phase Fault Current is the maximum available fault current from a transformer
- With a generator single phase faults result in a higher level of fault current
 - It takes less excitation to feed a single phase fault than it does to feed fault current in all three phases
 - The generator is not an infinite source
- Unbalanced faults (L-L, L-N, L-G) create more stress on the alternator than balanced three phase faults
- Unbalanced current results in magnetic forces on the rotor
 - With balanced current these forces cancel out
- Rotors have damper windings to counteract these forces
- Unbalanced current induces current in the damper windings
- Too much unbalanced current causes overheating in the damper windings

Symmetrical Components

Fault currents are modeled using symmetrical components

- Positive sequence (X_d'' , X_d' , X_d) represents balanced component
 - Varies with time after a fault (subtransient, transient, synchronous)
- Negative sequence (X_2) represents unbalanced component
- Zero sequence (X_0) represents neutral current

Instantaneous Fault Current

- $I_{3ph, p.u} = 1/X_d''$
- $I_{SLG, p.u} = 3/(X_d'' + X_2 + X_0 + 3 R_f)$
 - R_f = Fault resistance (resistance of cables, bus and neutral grounding resistor)
- $I_{LL, p.u} = 1.732/(X_d'' + X_2)$

IEEE Std 142-2007 (Green Book)

1.7.1 “Unlike the transformer the three sequence reactances from a generator are not equal. The zero sequence reactance has the lowest value and the positive sequence reactance varies as a function of time. Thus, a generator will usually have a higher initial ground fault current than three phase fault current if the generator has a solidly grounded neutral.”

Fault Current Calculation Example

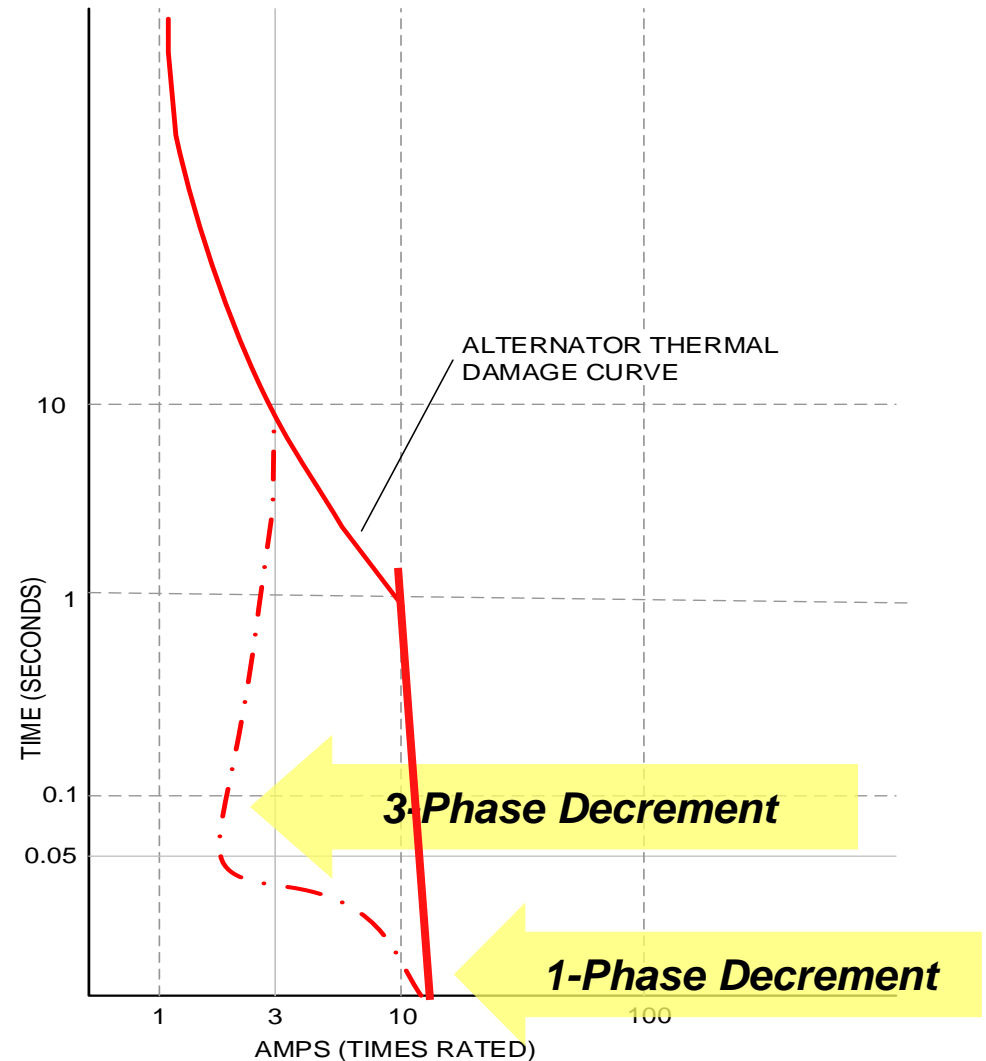
- Rated current of alternator
 - $I_{\text{rated}} = 1000 \cdot \text{kVA} / (1.732 \cdot V) = 3699 \text{ Amps}$
- Three phase fault current
 - $I_{3\text{ph, p.u}} = 1/X_d'' = 6.3 \text{ pu} = \mathbf{23 \text{ kA}}$
- Single line to ground fault current
 - $I_{\text{SLG, p.u}} = 3 / (X_d'' + X_2 + X_0 + 3 R_f) = 7.2 \text{ pu} = \mathbf{27 \text{ kA}}$
 - (assumes $R_f = 0$)
- Line to Line fault
 - $I_{\text{LL, p.u}} = 1.732 / (X_d'' + X_2) = 4.5 \text{ pu} = 17 \text{ kA}$
- Alternator reactances are published using the alternator kVA rating as a base
- Fault current calculations need to use the same base or the reactances need to be converted to the genset kW rating base

$$\frac{X_{\text{alt}}}{X_{\text{genset}}} = \frac{\text{kVA}_{\text{alt}}}{\text{kVA}_{\text{genset}}}$$

3 Ø RATINGS (0.8 power factor)			60 Hz			
(Based on specific temperature rise at 40°C ambient temperature)			416 (12)	440 (12)	480 (12)	600 (07)
163°C Rise Ratings	@27°C	kW	2556	2704	2948	2948
		kVA	3195	3380	3685	3685
150°C Rise Ratings		kW	2484	2628	2868	2868
		kVA	3105	3285	3585	3585
125°C Rise Ratings		kW	2320	2456	2680	2680
		kVA	2900	3070	3350	3350
105°C Rise Ratings		kW	2132	2256	2460	2460
		kVA	2665	2820	3075	3075
80°C Rise Ratings		kW	1860	1964	2144	2144
		kVA	2325	2455	2680	2680
REACTANCES (per unit ± 10%)			416 (12)	440 (12)	480 (12)	600 (07)
(Based on full load at 105C Rise Rating)						
Synchronous			3.400	3.217	2.950	2.800
Transient			0.250	0.237	0.217	0.217
Subtransient			0.182	0.172	0.158	0.161
Negative Sequence			0.263	0.249	0.228	0.230
Zero Sequence			0.033	0.032	0.029	0.028

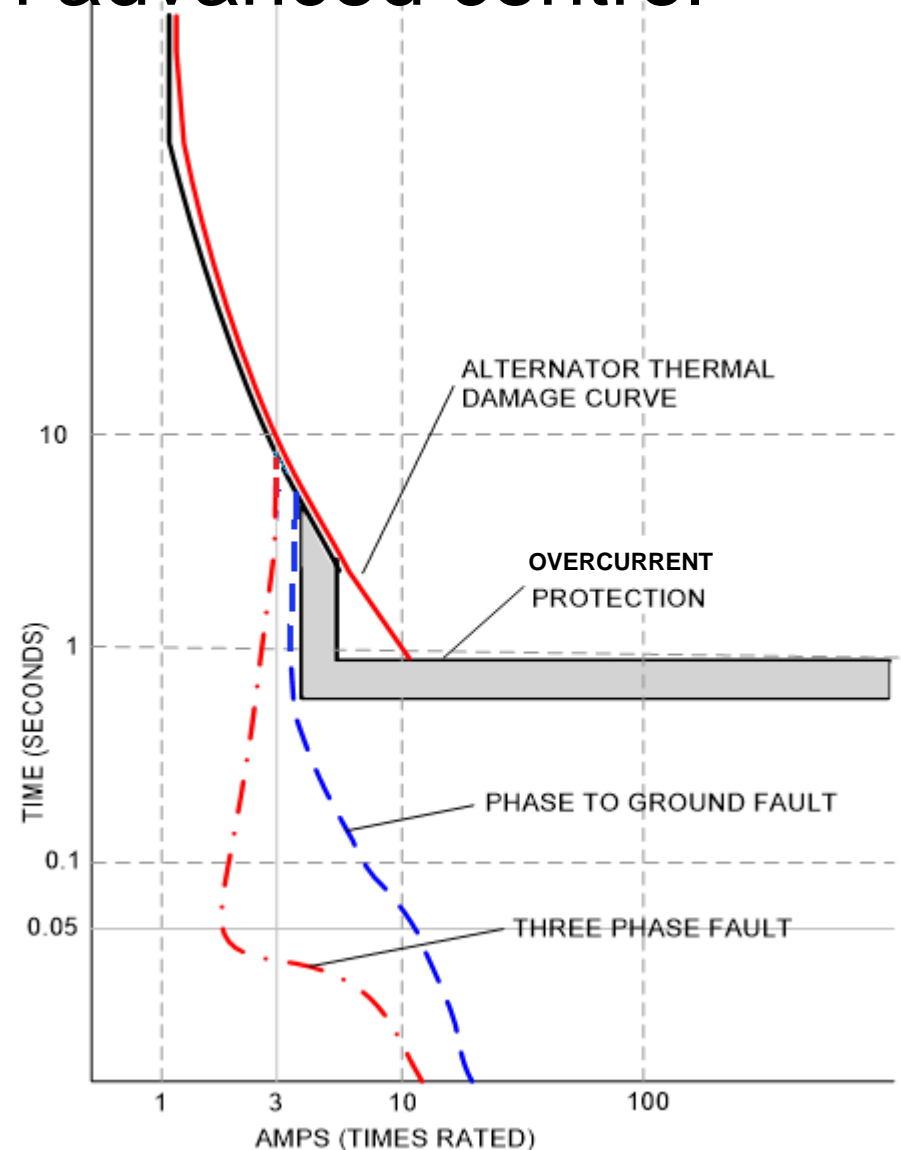
Typical Genset Response to a Fault

- 3-Phase Fault (conventional AVR)
 - Volts collapse, amps peak
 - Amps collapse
 - AVR on full
 - Approximately 3X rated
- 1-Phase fault (conventional AVR)
 - Volts collapse on faulted phase, amps peak
 - AVR on full
 - Amps don't collapse on faulted phase
 - High volts on non-fault phases
- 1-Phase fault in Genset results in a higher level of current because it takes less excitation to maintain a single phase fault



Fault Current Characteristics with advanced control

- Instead of maximizing excitation fault current is regulated
 - Amps peak on faulted Phase
 - Voltage on faulted phase collapses
 - Excitation is reduced to maintain 3X rated current output
 - Overvoltage avoided, coordination maintained
- Overcurrent protection
 - Shuts down genset down
 - Based on $i^2 \cdot t$ curve for 3 phase overcurrent
 - Indicative of a locked motor
 - Allows maximum time for coordination
 - In shorter time for LL or LG overcurrent
 - Indicative of a fault condition



Fault Current Regulation and Neutral Grounding Resistors

- Neutral Grounding Resistors are not required to protect generator sets that are equipped with fault current regulation and overcurrent protection
- NGR's may still be necessary as part of the overall grounding and protection scheme
- Fault current regulation will not limit instantaneous ground fault current
- In the event of a L-G fault current will be regulated in the faulted phase until the alternator thermal damage curve is approached at which time the generator set will shut down (or until some downstream protective device clears the fault)

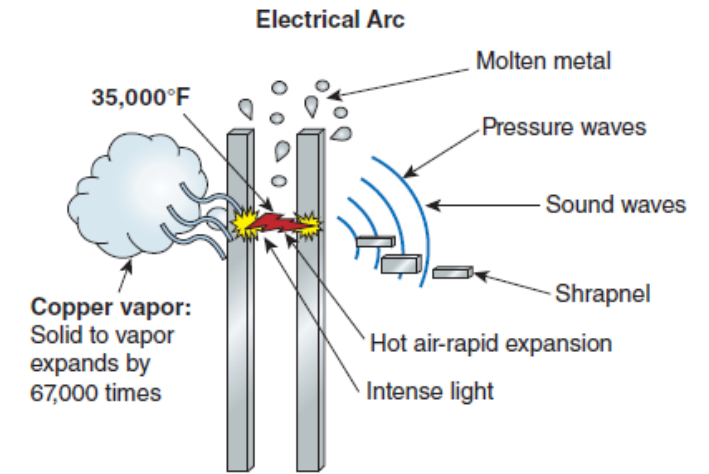
Arc Flash



What is Arc Flash?

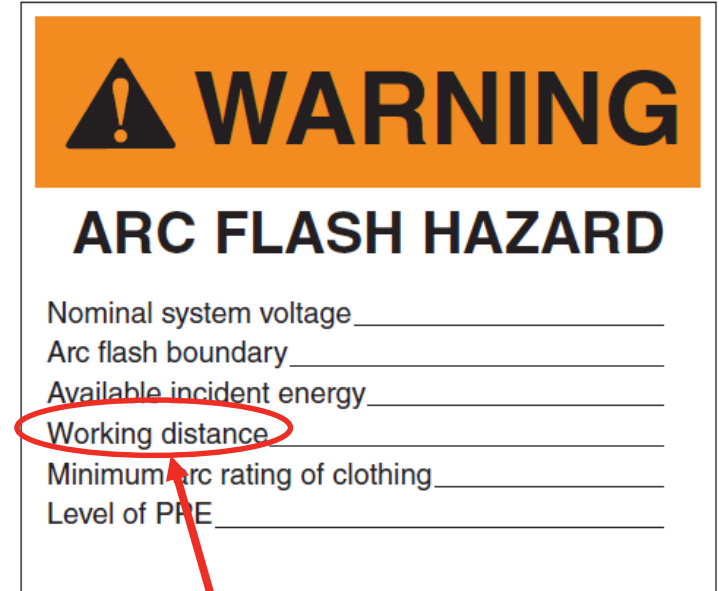
CSA Z462-15 Definitions

- Arc Flash Hazard – “A dangerous condition associated with the release of energy caused by an electric arc”
- Incident Energy – “the amount of thermal energy impressed on a surface a certain distance from the source”
- Arc Flash Boundary - “a distance from ... which a person could receive a second degree burn”
 - Incident energy = 1.2 cal/cm^2
- Arc Rating – The value attributed to materials that describes their performance to exposure to an electrical arc discharge



CSA Z462-15 Requirements

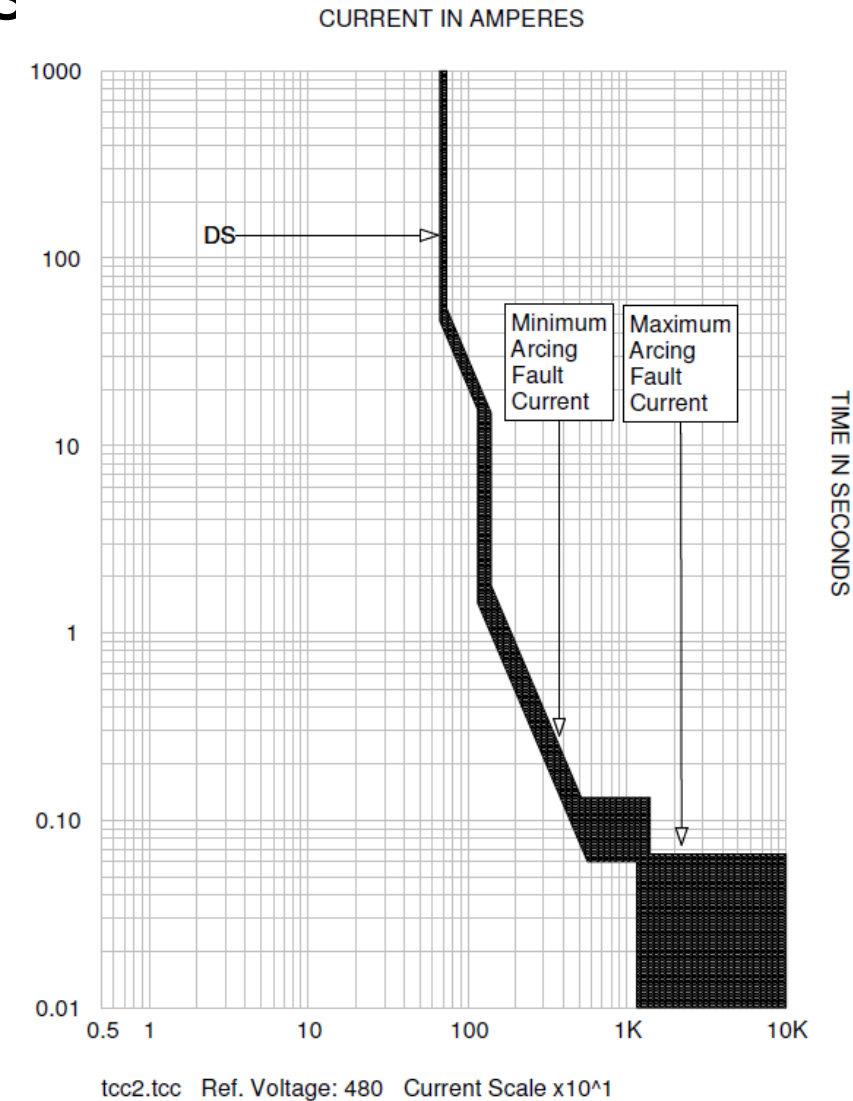
- CSA Z462-15 requires an energized work permit when a “likelihood of injury from an exposure to an arc flash hazard exists” (4.3.2.3.1)
- The work permit shall include the results of an Arc Flash Risk Assessment
- The Arc Flash Risk Assessment shall determine
 - Appropriate safety related work practices
 - Arc Flash Boundary
 - PPE to be used within the arc flash boundary
- CSA Z462-5 requires equipment to be marked to warn of arc flash hazards (4.3.5.5)



Typically 18” for LV panel boards, 24” for LV switchgear

Arc Flash Incident Energy Calculations

- CSA Z462-15 refers to IEEE 1584 calculation method for three phase systems from 208 V to 15 kV.
- Arcing current is calculated as a function of bolted fault current
- Incident energy is not necessarily maximum at maximum arcing current
 - Lower arcing current may result in longer fault clearing time
 - Incident energy is directly proportional to arc clearing time
- Incident energy is calculated multiple times
 - Once based on arcing current calculated at maximum available fault current
 - Once based on arcing current at 85% of its maximum value
 - Repeat for each source that may serve the equipment
 - Higher value of incident energy is used

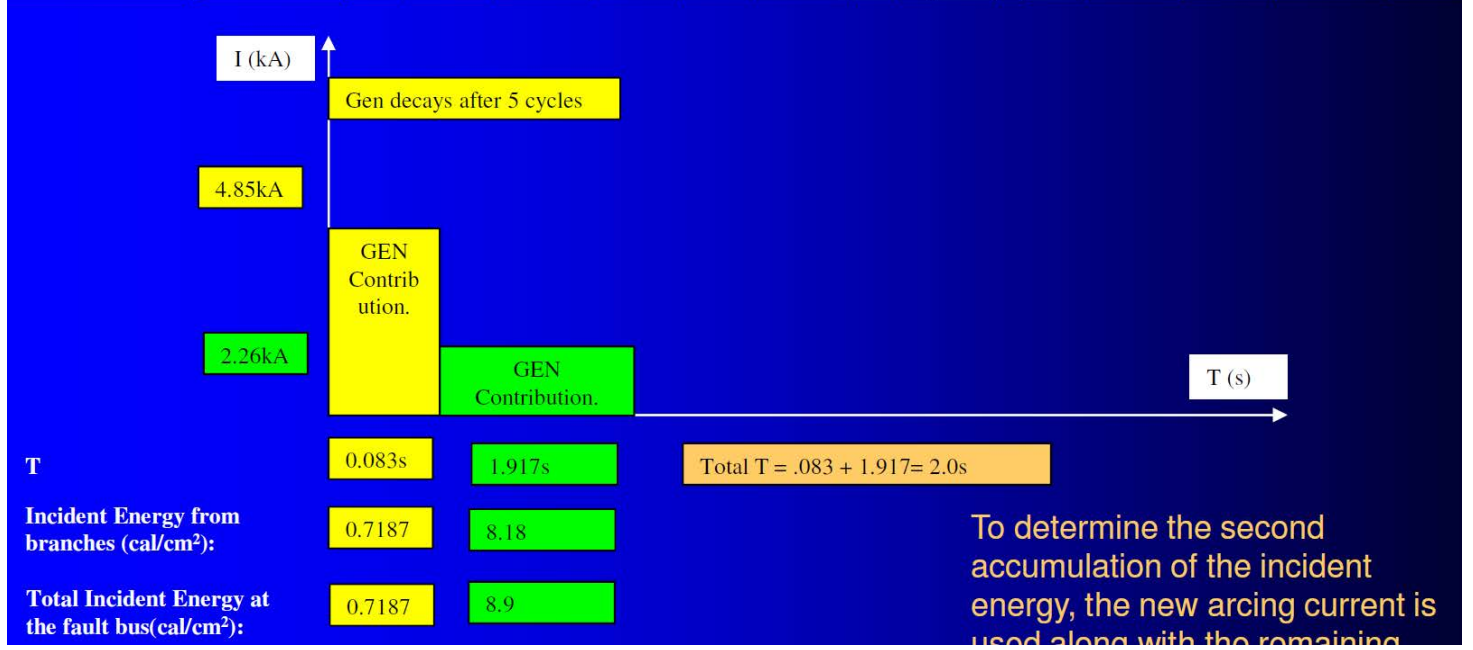


Arc Flash with Decaying Current

Some analysis programs account for decaying generator current in arc flash incident energy calculations

Arc Flash EX #1 – Generator Source reduce to 300% of rated current after 5 cycles – Recalculate Trip Time Using Reduce Current

Bus Name	Protective Device Name	Bus kV	Bus Bolted Fault (kA)	Prot Dev Bolted Fault (kA)	Prot Dev Arcing Fault (kA)	Trip/Delay Time (sec.)	Breaker Opening Time (sec.)	Ground	Equip Type	Gap (mm)	Arc Flash Boundary (in)	Working Distance (in)	Incident Energy (cal/cm2)	Requires Clothing
(1) GenBus	CB-G1	0.48	4.85	4.85	3.45	2	0.000	No	SWG	32	94	24	8.9	Category 0
(2) BT FU	CB-CL	0.6	2.60	2.60	2.25	0.175	0.000	No	SWG	32	17	24	0.74	Category 0
Category 0: Untreated Cotton														(*N9) - 10 min Duration



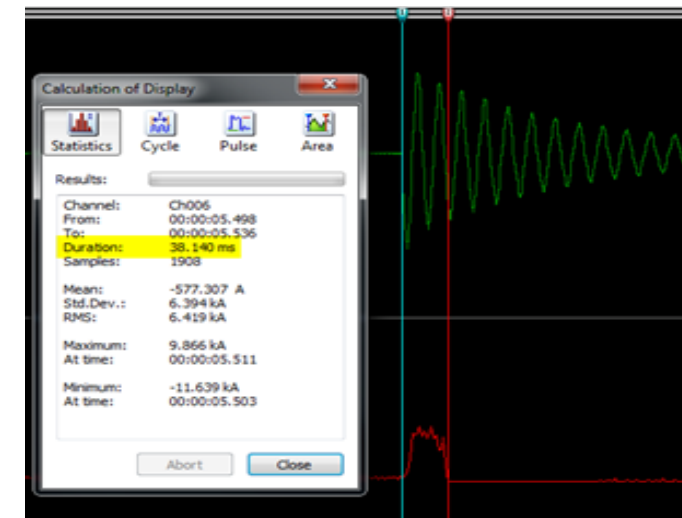
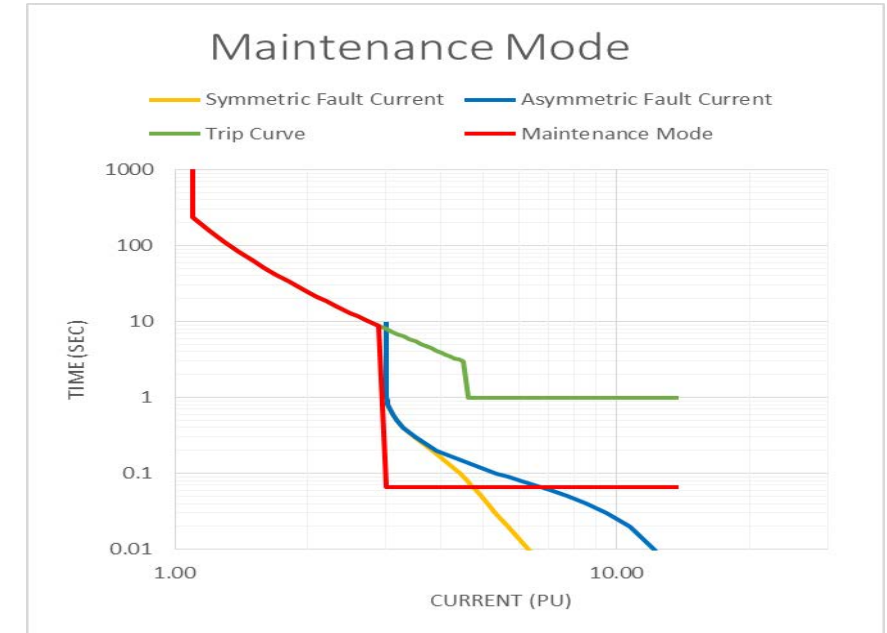
*Reference – SKM Power Tools

Arc Flash Mitigation

- CSA Z462-15 (Annex O) refers to equipment and design practices that minimize energy levels such as zone selective interlocking, differential relaying and energy reducing maintenance switching
- When activated maintenance switching in a breaker or protective relay reduces incident energy by minimizing fault clearing time
 - Bypasses all time delays in the event of a fault
- When maintenance switching is used Arc flash incident energy, boundary and PPE requirement for maintenance mode should be calculated and documented in work procedures

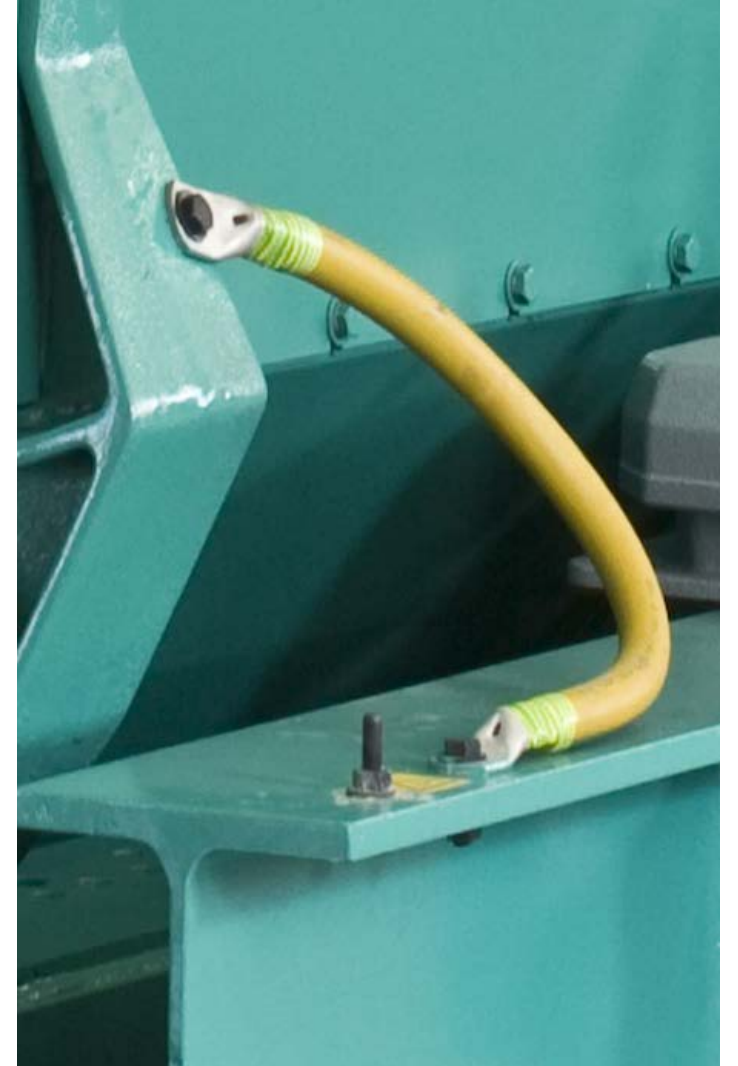
Maintenance Mode on Generator Set

- When maintenance mode is enabled genset will shut down instantaneously in the event of a short circuit, bypassing all time delays
 - Generator shuts down within 50 msec
 - Can also be configured to shunt trip a downstream breaker
- Running the genset in maintenance mode during testing reduces arc flash



Grounding of On Site Power Generation Systems

- System and Equipment Grounding
- System Grounding Methods
- Ground Fault Sensing
- Grounding of Emergency Standby Systems
- Grounding of Paralleled Sources



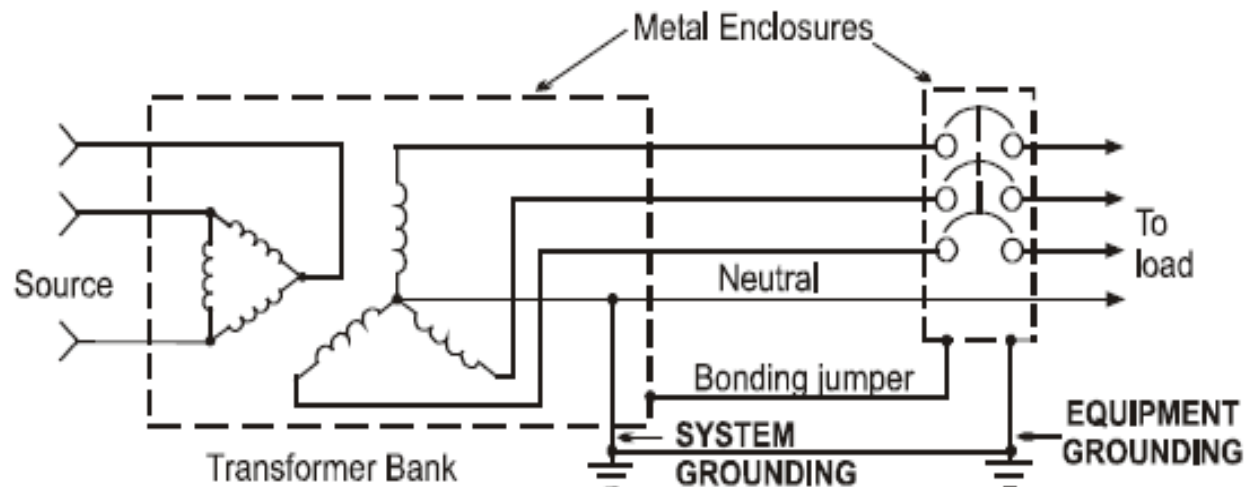
System Grounding vs Equipment Grounding

■ System grounding

- Deliberate connection between a circuit conductor of a power source and ground (earth).
- Stabilizes voltages during normal operation
- Establish a path for ground fault current to return to the source

■ Equipment grounding

- Establish (connect) a conductive path between normally non-current carrying metal parts of equipment AND between these parts and the grounding electrode
- Minimize hazards of touching live equipment
- Sometimes referred to as safety ground



Purposes of System Grounding

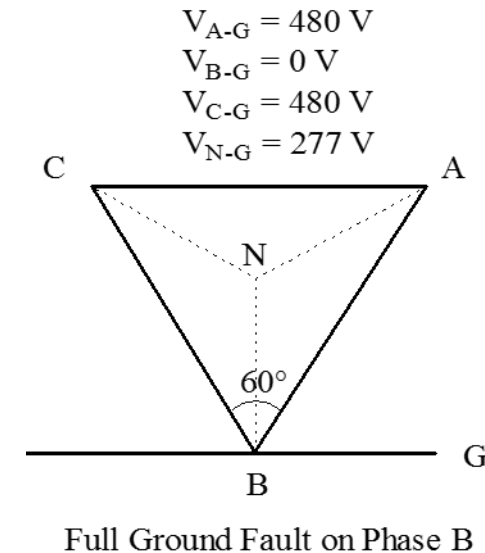
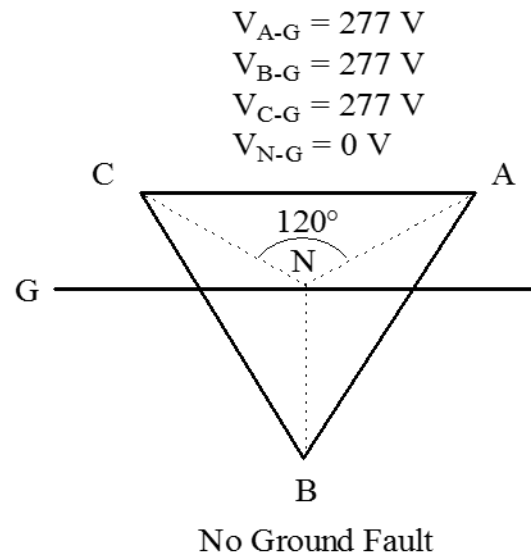
IEEE Std 142-2007 (Green Book)

System grounding is the intentional connection to ground of a phase or neutral conductor for the purpose of:

- a) Controlling the voltage with respect to earth or ground within predictable limits and
- b) Providing for a flow of current that will allow detection of an unwanted connection between system conductors and ground...

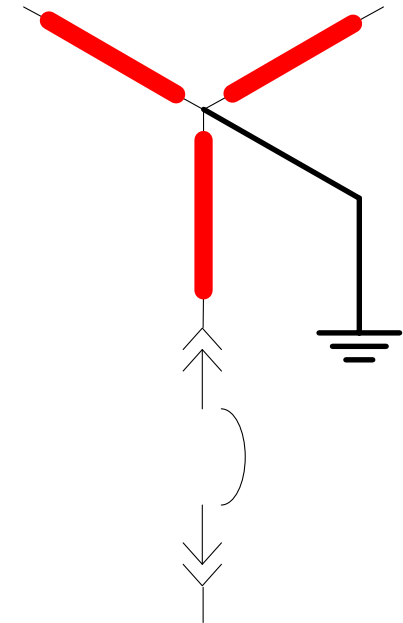
... the control of voltage to ground limits the voltage stress on the insulation of conductors...

... the control of voltage also allows reduction of shock hazards



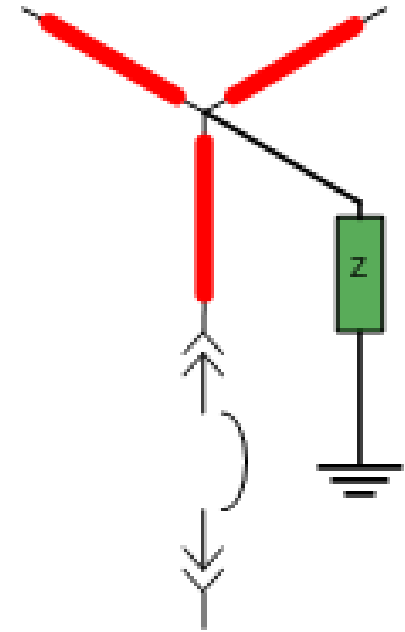
Solidly Grounded System

- Most common grounding method for low voltage generator sets
- Enables ground fault detection and thus activation of ground fault protection equipment
- Limits excess voltage on ungrounded phases during ground fault
- High level of ground fault current

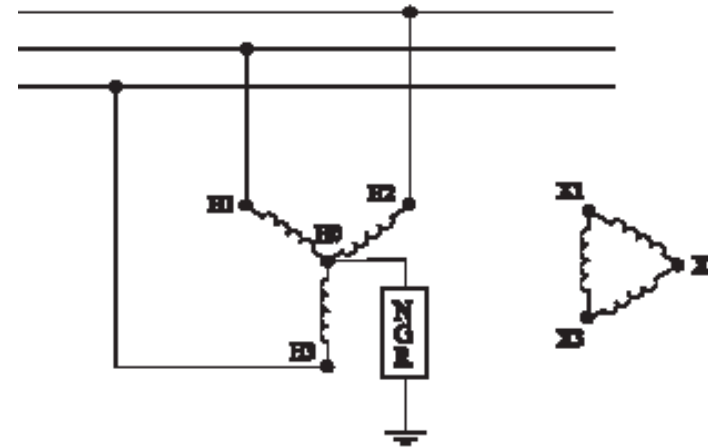
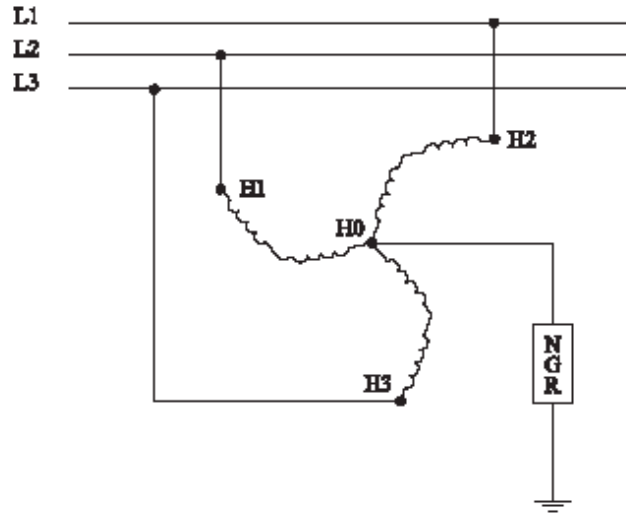


Resistance Grounded System

- Commonly used with medium voltage generators
- Limits ground fault current level
- Low Resistance Grounding
 - Fault current usually limited to 300-500 amps
 - Easily detectable with conventional CT's
 - Sufficient to trip circuit breakers
- High Resistance Grounding
 - Fault current usually limited to 5-30 amps
 - Maintain continuity of power during a fault – low current level need not be tripped allowing controlled shutdown of power system at time suitable to the load



Establishing a neutral on an ungrounded system

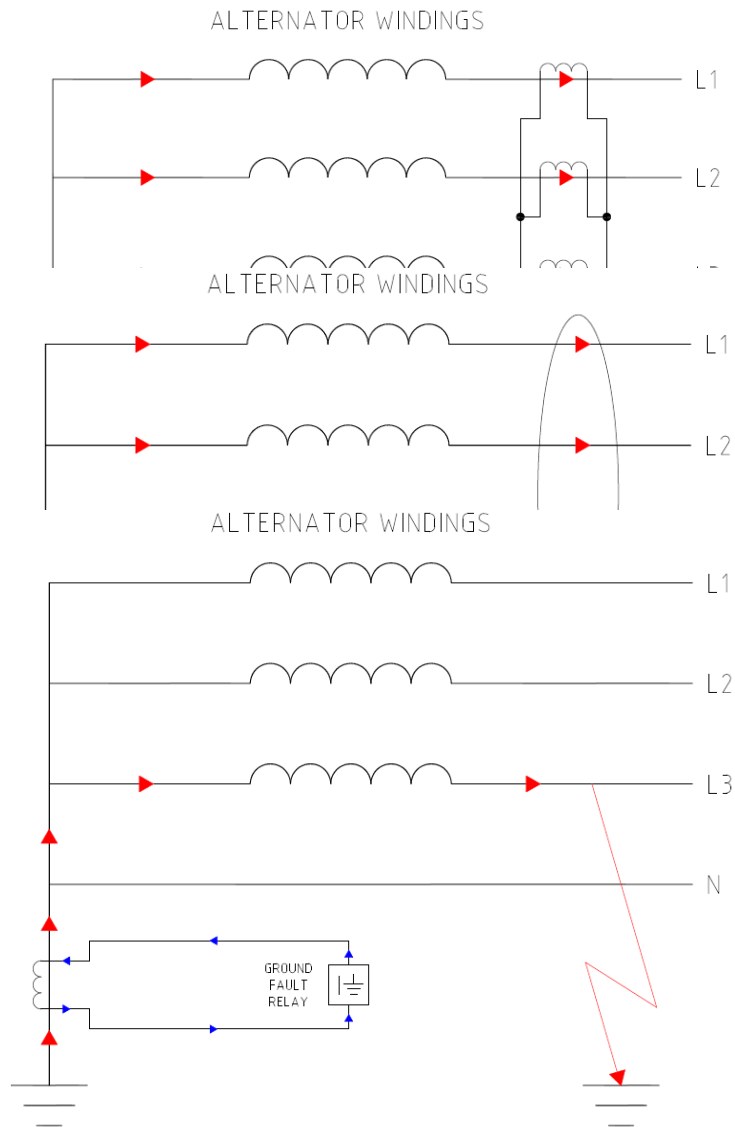


- Zigzag or wye-delta transformers may be used to obtain a neutral for ungrounded systems
- Can be solidly grounded or resistance grounded
- High impedance to balanced phase currents
- Low impedance to zero sequence (fault) currents

Ground Fault Sensing

- CEC 14-102 Requires GFP at the service disconnect (utility breaker) for systems with
 - Solidly Grounded systems rated more than 150 volts to ground and 1000 A or moreand
 - Solidly Grounded systems rated less than 150 volts to ground and 2000 A or more
- When GF Sensing is required in LV Emergency Standby Systems
 - Switch the neutral using a four pole transfer switch
 - Ground the neutral at the generator set

How do we Sense Ground Fault?



■ Residual

- Most common method for breakers
- CTs on each phase and neutral
- Vector sum of current through all CT's must be 0 ($<$ threshold)

■ Zero sequence

- Single CT around all three phases and neutral
- Same concept as residual method

■ Source ground return

- Single CT in the neutral to ground bond
- Commonly used by ground fault relays

Ground Fault Sensing in LV Emergency Standby Systems

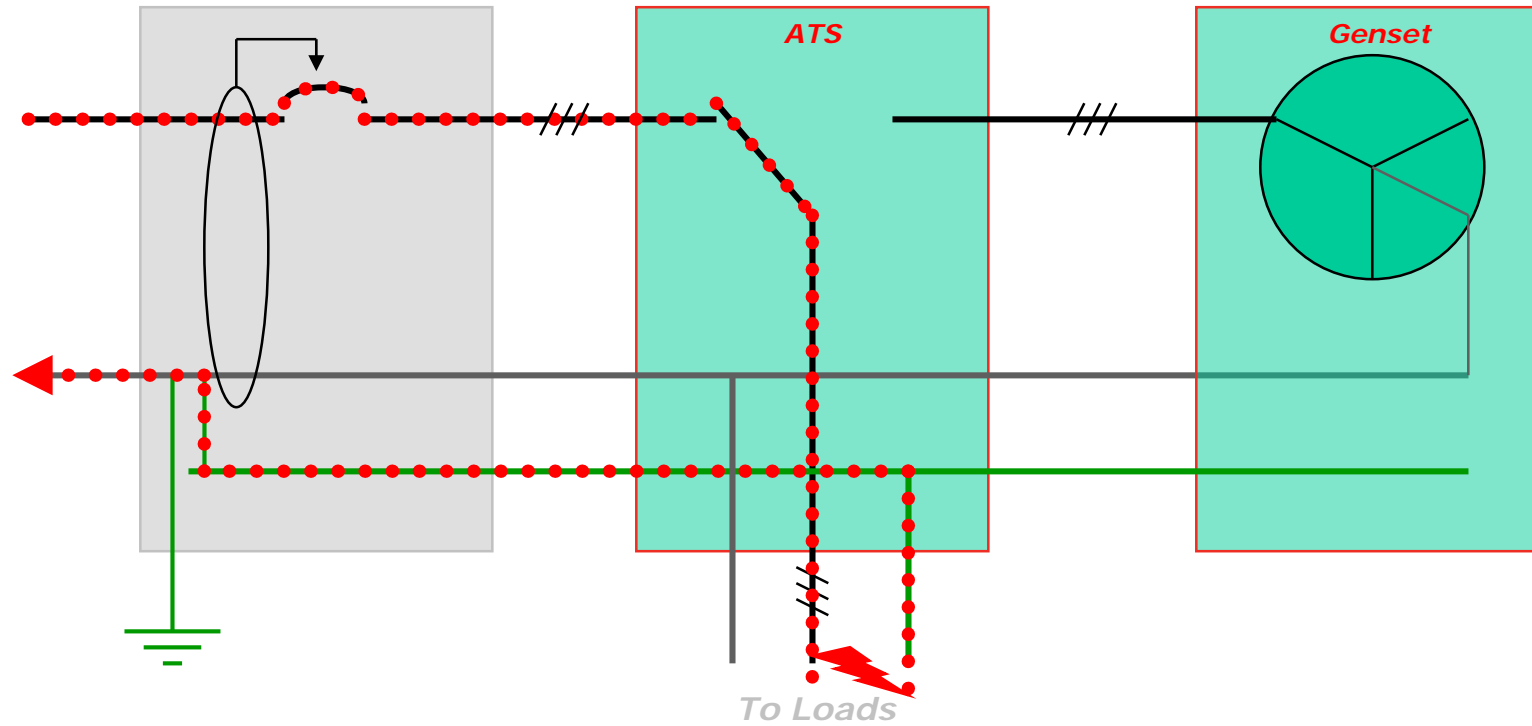
- Most common method is to use GF protection in breaker at the service disconnect
- Two rules for proper GF sensing
 - Rule #1: There must be only one neutral/ground connection on any neutral bus at one time
 - Rule #2: Ground fault sensors must be downstream from the bonding connection

These two rules drive the requirement that 4 pole transfer switches must be used when ground fault sensing is required or may be required in the future.

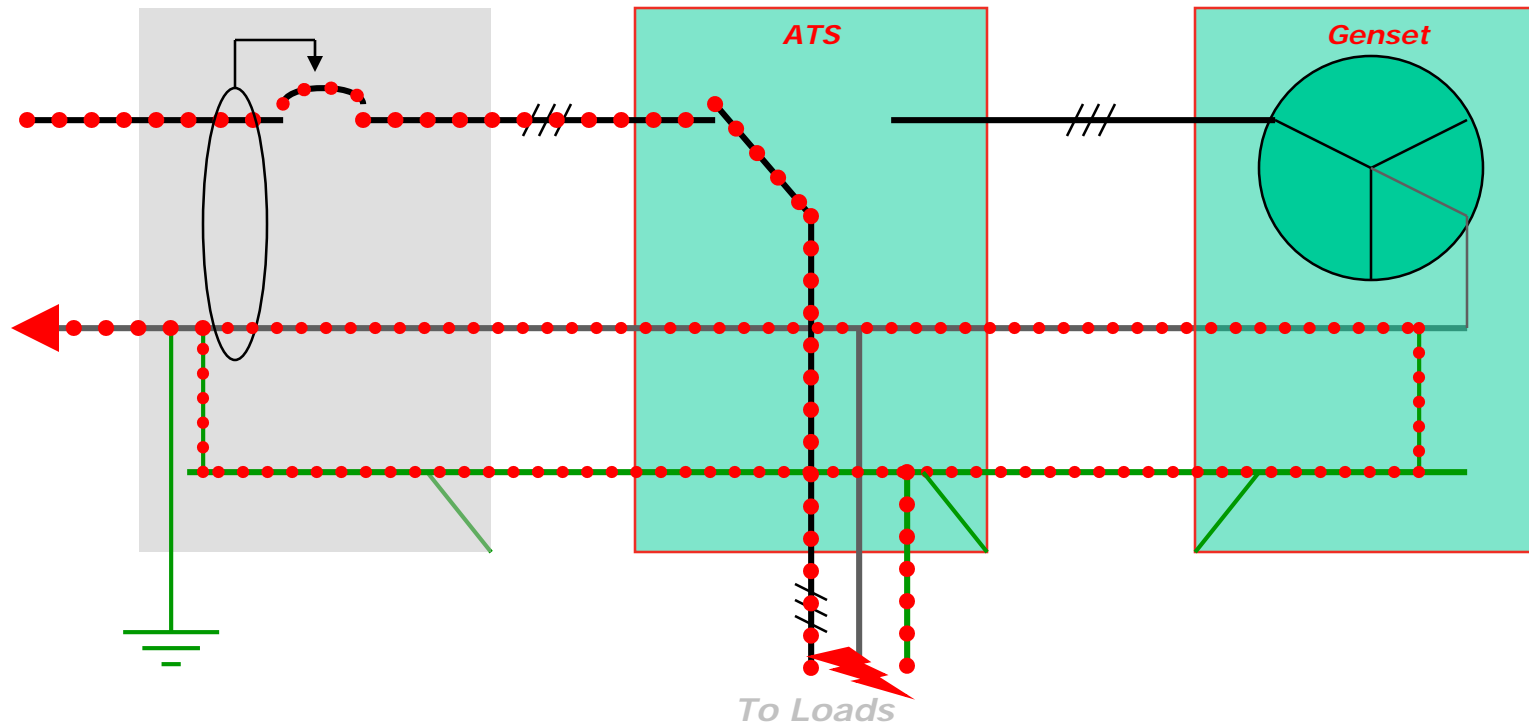
IEEE Std 446-1995 (Orange Book)

7.9.1 “for most emergency and standby power systems with ground-fault systems, switching of the grounded circuit conductor by the transfer switch is the recommended practice.”

Sensing a Ground Fault

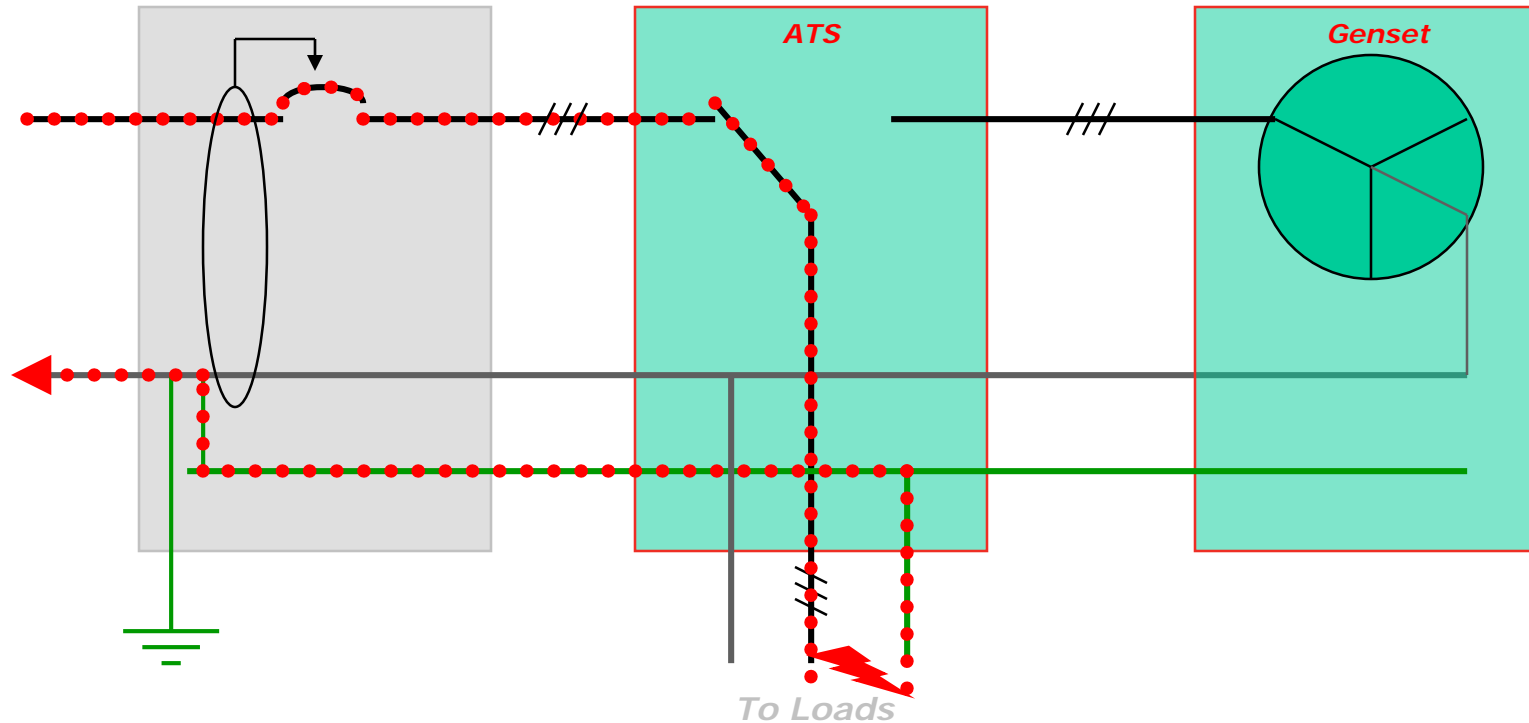


Incorrect Bonding Jumper



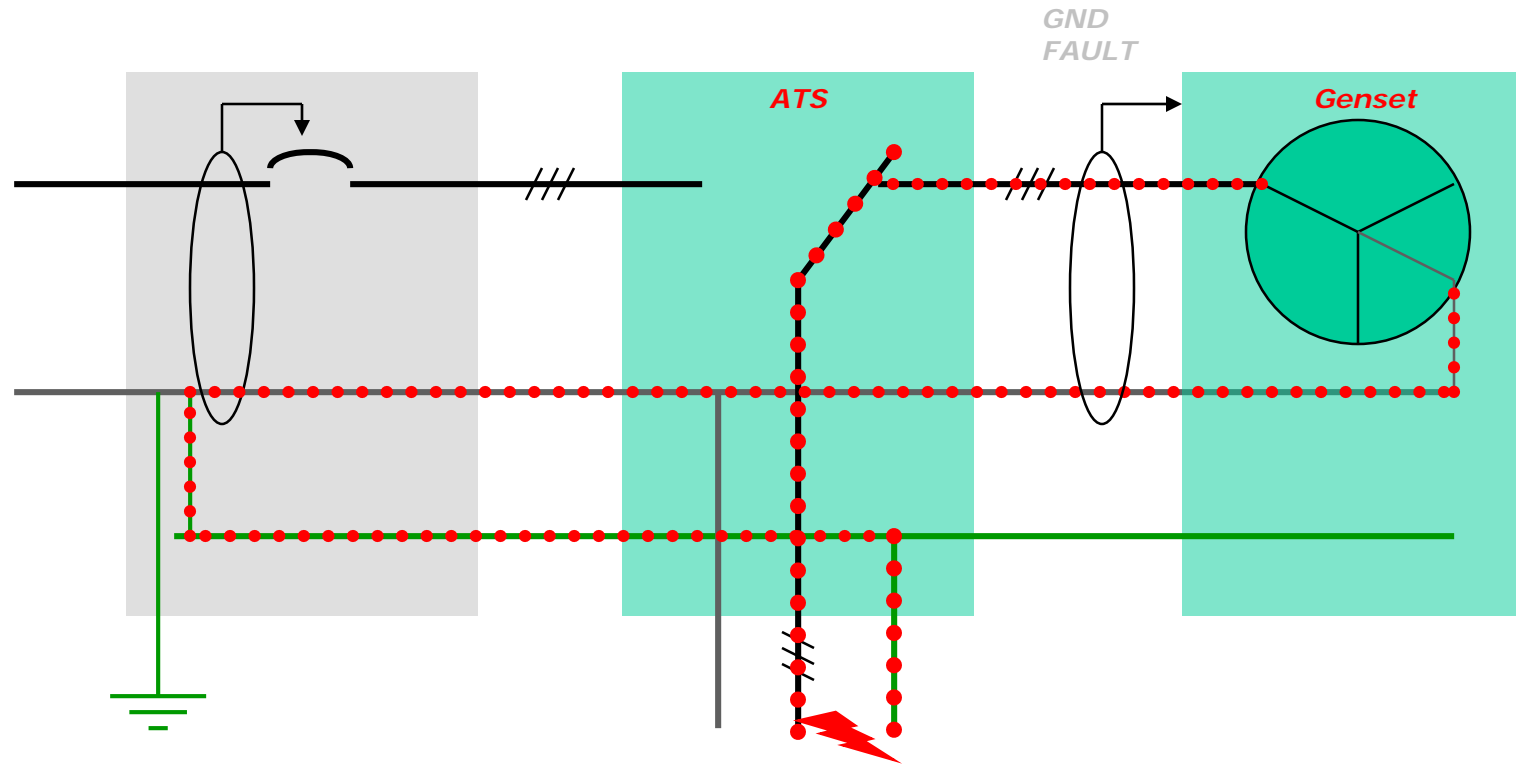
- Parallel Path for I_{GF} on the Neutral
- GFP Does Not Sense All Fault Current
- This violates "Rule #1"
- Solution: Remove Bond on Generator

Single Bonding Jumper



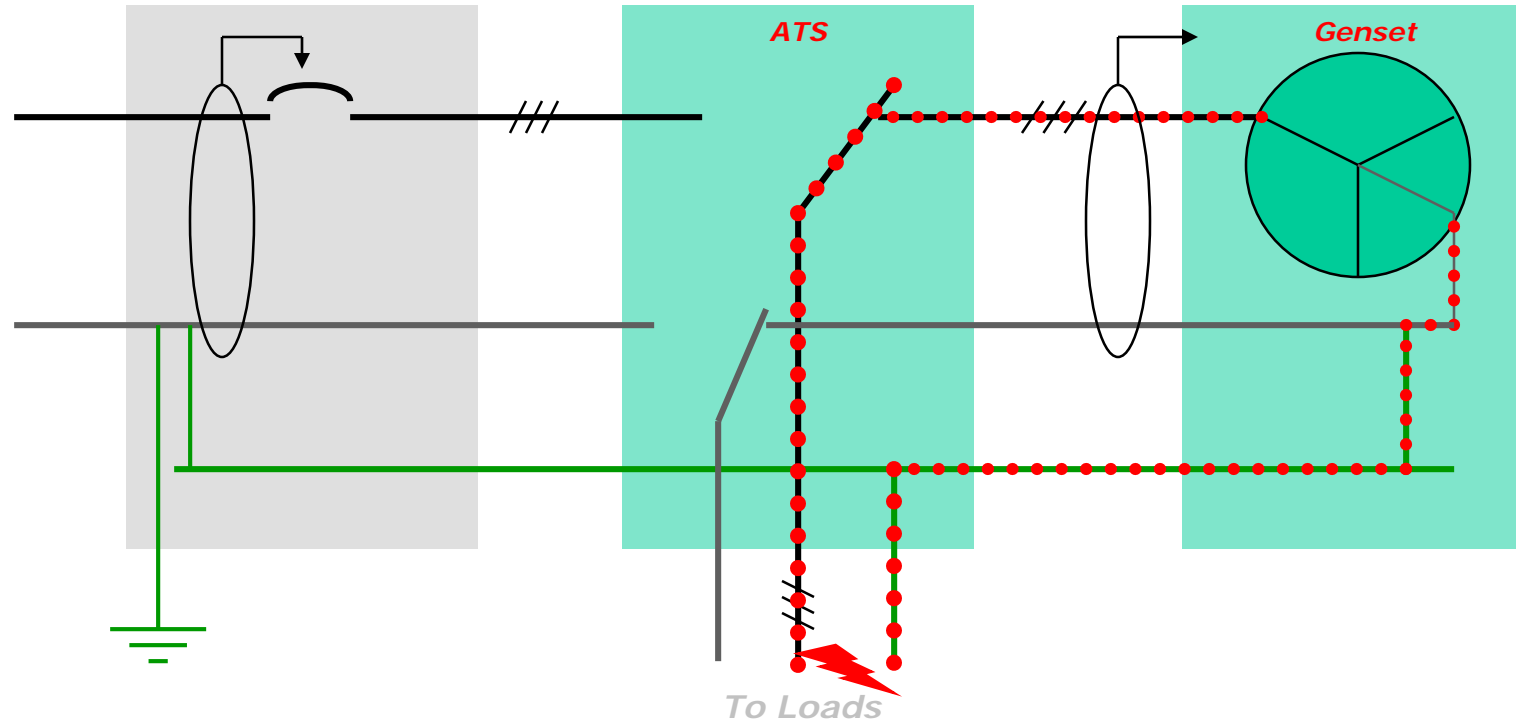
- Removing the generator neutral bond solves the problem in the previous slide
- There is now only one path for earth fault current to return to the source

3-Pole ATS Weakness



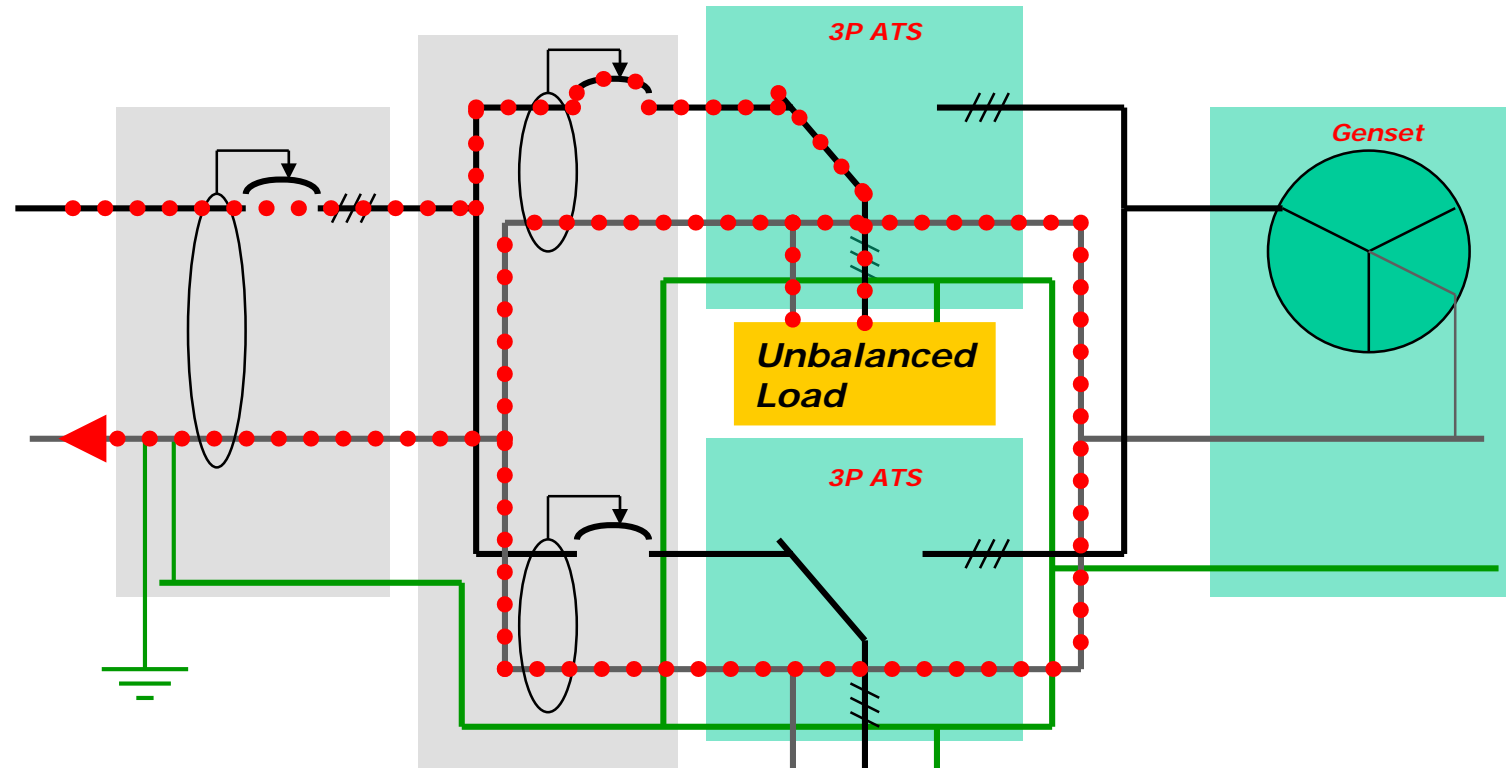
- Ground Fault Returns on Neutral
- Possible Nuisance Trip During Exercise
- This violates “Rule #2”
- Ground required on source side of sensor

Function of 4-Pole Switches



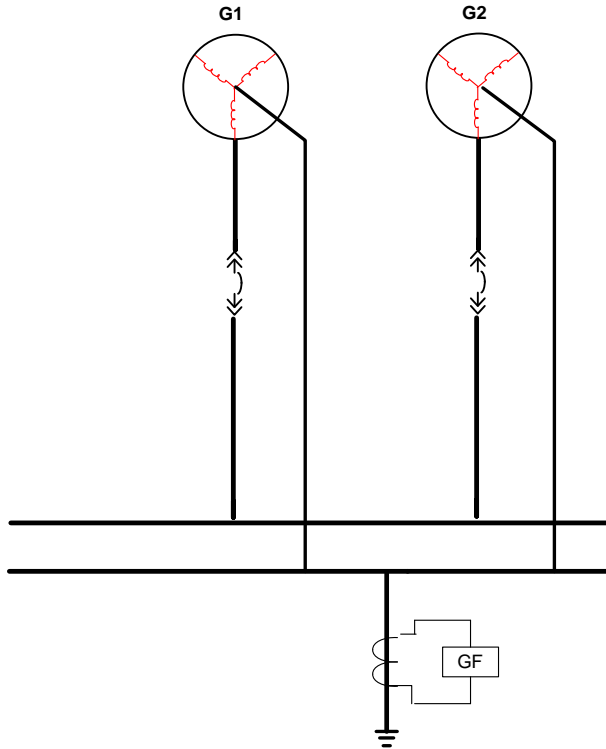
- Fourth Pole Opens the Path on Neutral
- Allows Accurate GFP Sensing, Both Sides
- At all times the neutral is grounded in only one place and ground fault sensor is downstream of the bonding connection

Multiple ATS Applications

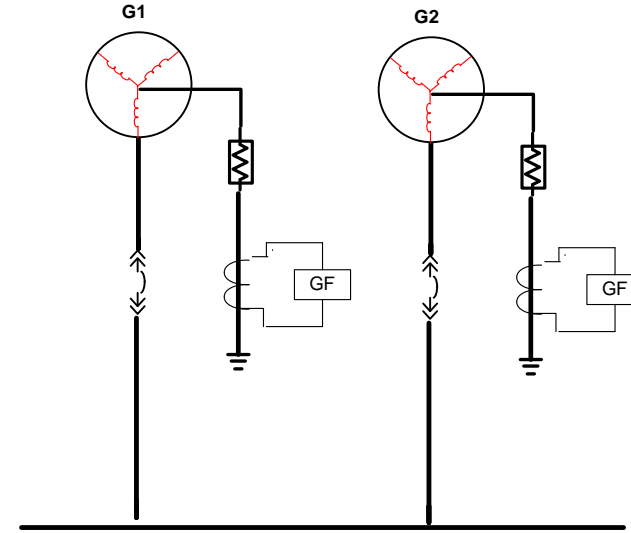


- 2 levels of GFP and 2 or more 3-pole ATS
- Neutral Current May Nuisance Trip Feeder GFP During Normal Conditions

Grounding of Paralleled Generator Sets – “Simple” Systems

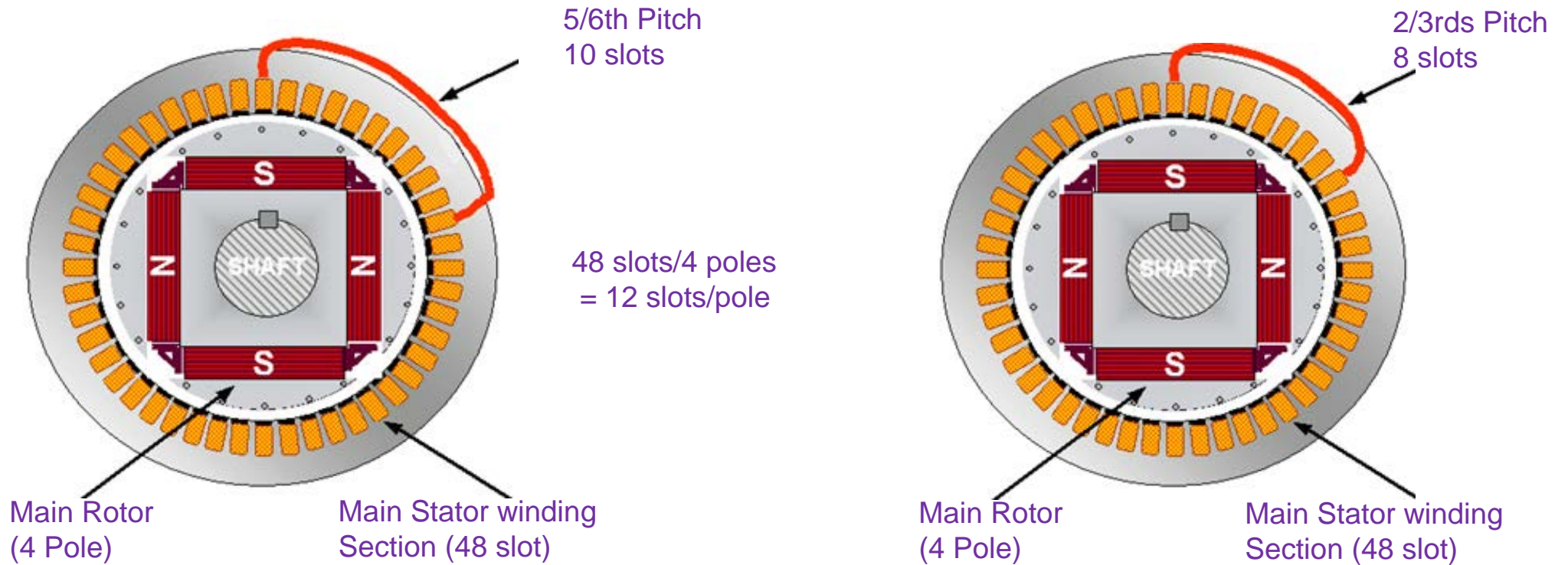


- 4 wire systems typically have a single ground in the switchgear



- Generators in 3 wire systems are typically separately grounded
- Medium or High Voltage generators are often resistance grounded

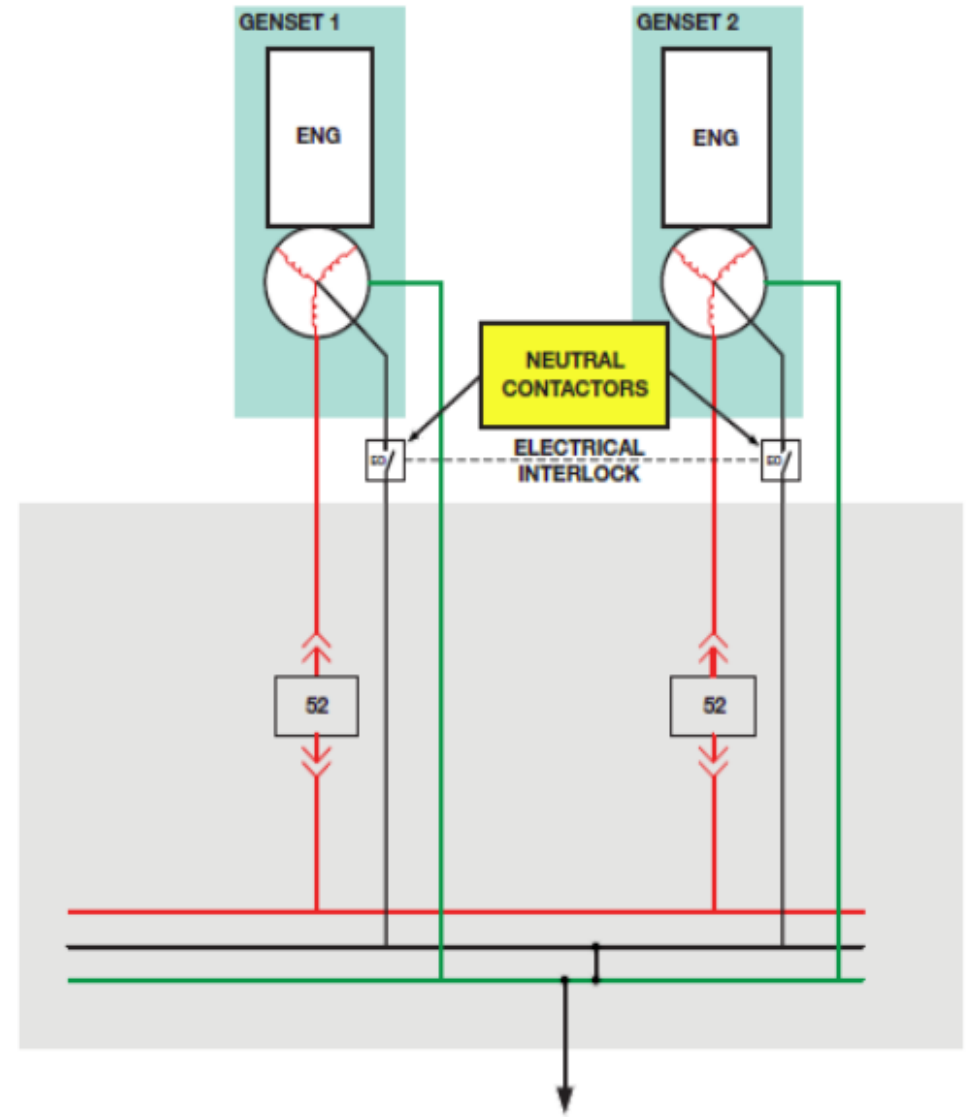
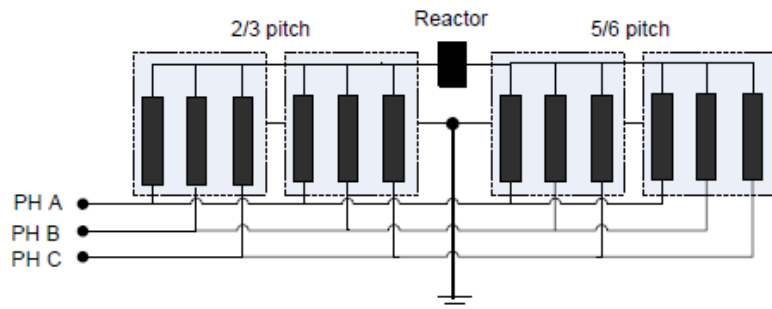
Understanding Winding Pitch



- 5/6th pitch makes most efficient use of copper and steel
- 2/3rds pitch eliminates 3rd harmonic voltage

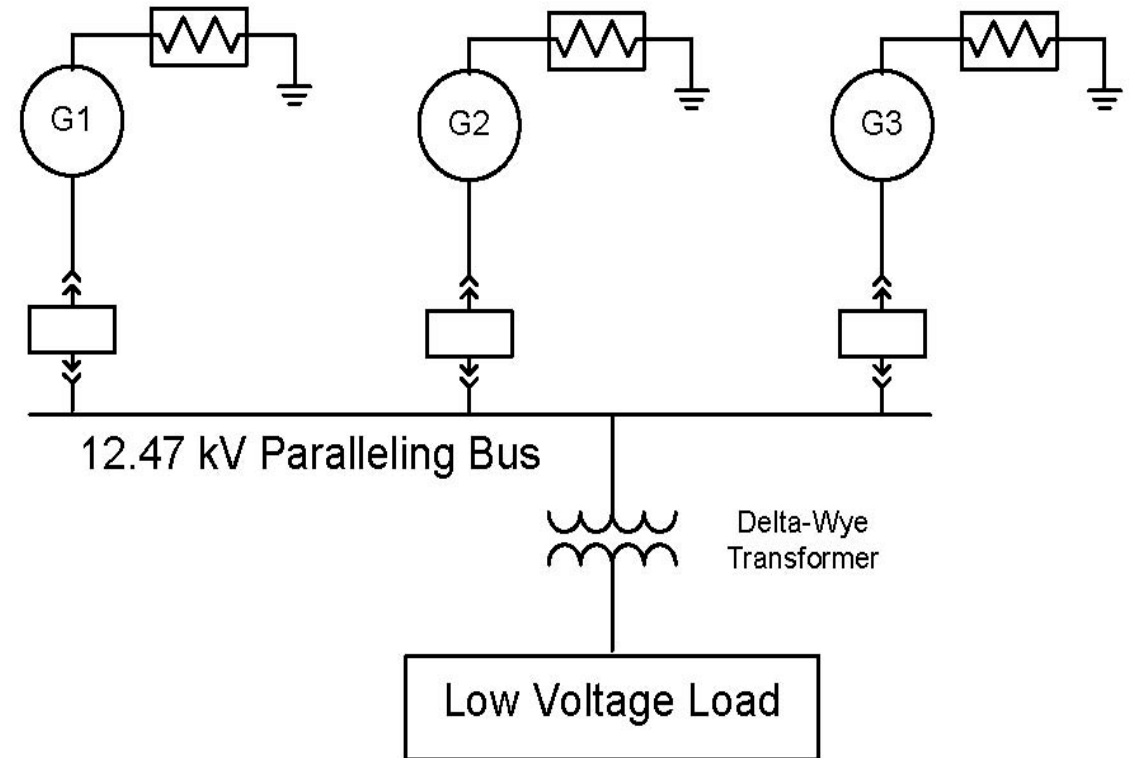
Alternator Compatibility Solutions – Low Voltage

- Differences in voltage waveform results in circulating current between alternators
- Of particular concern is circulating current flowing in the neutral connection in 4-wire system
 - 3rd harmonic currents sum directly in the neutral
- Alternators with different winding pitches should not have their neutrals directly connected together
 - This includes grounding of the star points
- Use neutral contactor to make sure that 2/3 and 5/6 pitch alternators are not both grounded
 - 5/6 pitch alternators to be grounded only if no 2/3 pitch genset is on line
 - 2/3 pitch alternators should be first to close to the bus
- Insert reactive elements in connected neutral conductors



Medium Voltage Alternators

- Generator output is connected to delta connected transformer winding
- Neutral wire is not connected to loads
- Harmonic distortion from generator is trapped in the delta winding
 - Isolated from load
- $2/3^{\text{rds}}$ or $5/6^{\text{th}}$ pitch alternators may be used
- Neutral Grounding Resistor limits neutral current

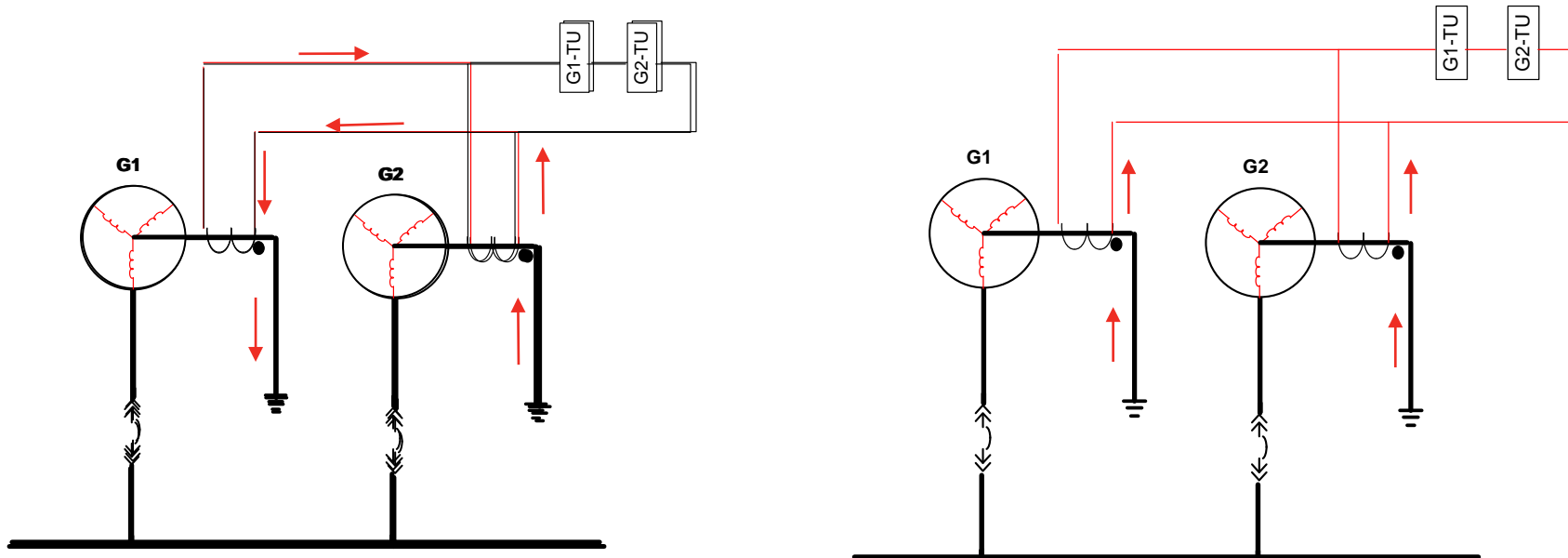


Ground Fault Sensing with Paralleled Systems

- Multiple sources and multiple grounds add complexity
- Switching the neutral with 4 pole breakers or ATS is not always practical
- Modified Differential Ground Fault Protection is required in many complex systems
 - Multiple grounds
 - 4 wire system with 3 pole breakers/ATS (not breaking the neutral)
 - Utility paralleling
 - Fault isolation is required in tie breaker applications

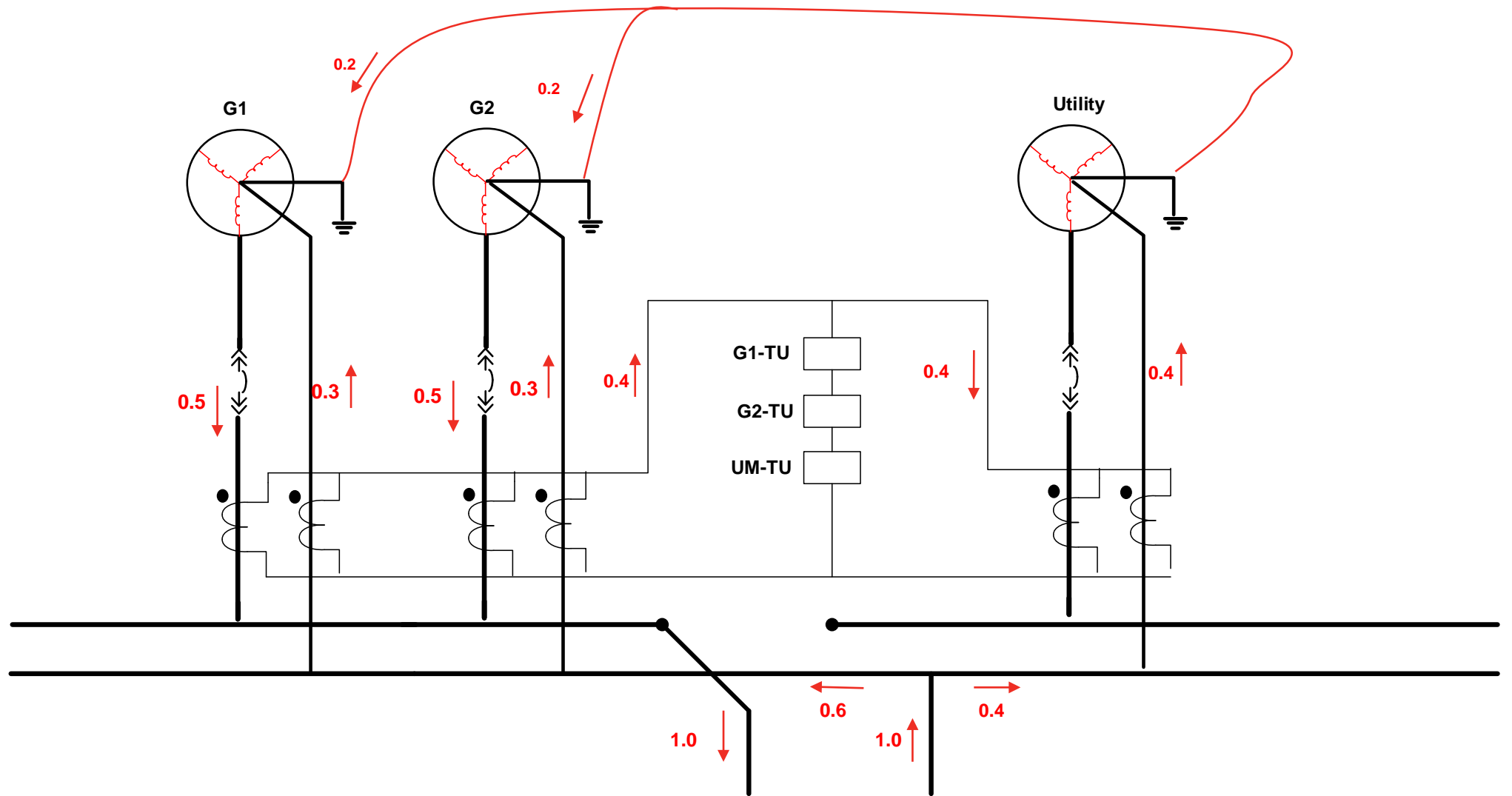
Modified Differential Ground Fault Protection

- Differentiates between circulating neutral current and fault current

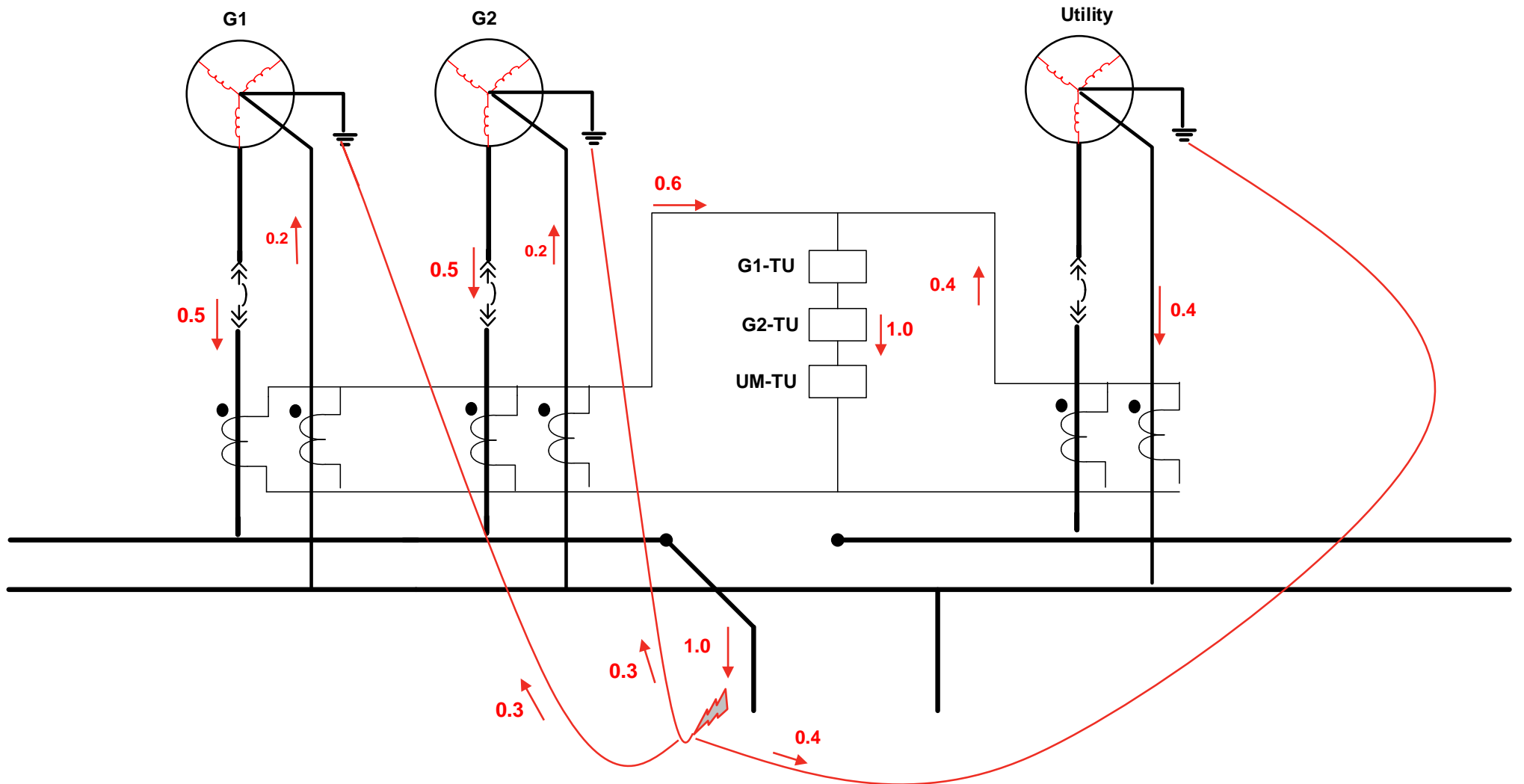


- Circulating neutral current does not result in current flowing through the trip units.
- Fault current results in current flowing through the trip units.

Gensets Supplying Load, Normal Neutral Current Flow



Gensets Supplying Load, Fault Current Flow




Summary

- A generator is not an infinite source like a utility transformer
- This results in
 - Voltage and frequency dips during motor starting
 - Proper generator sizing for motor loads accounting for locked rotor kVA
 - Higher levels of voltage harmonic distortion when serving non-linear loads like VFD and UPS
 - Decaying short circuit current
- Grounding and ground fault detection becomes more complex with multiple sources and multiple grounds

Questions?



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