Generator Protection

Some Review Slids
What a Generator looks like
Generator
Generator Protection Review

Abnormal Operating Conditions

• Loss of Synchronism
• Abnormal Frequency
• Over excitation
• Field Loss
• Inadvertent Energizing
• Breaker Failure
• Loss of Prime Mover Power
• Open Circuits
Abnormal Operating Conditions

The "Wild" Power System

- Over Power
- Loss of Field
- Overexcitation
- Open Circuits
- Loss of Field
- Overexcitation
- Abnormal Frequency
- Inadvertent Energizing, Pole Flashover
- Breaker Failure
- Loss of Synchronism
Generator Stator Phase Fault Protection (87G)
Over fluxing Protection (V/Hz) (24)

Causes:

• As voltage rises above rating leakage flux increases
• Leakage flux induces current in transformer support structure causing rapid localized heating.

Volts per Hertz Limiter and Protection:

• used to protect generator and step-up transformer from damage due to excessive magnetic flux resulting from low frequency and/or overvoltage
• excessive magnetic flux, if sustained, can cause overheating and damage the unit transformer and the generator core
• V/Hz limiter (or regulator) controls the field voltage so as to limit the generator voltage when V/Hz exceeds a preset value
• V/Hz protection trips the generator when V/Hz exceeds the preset value for a specified time
Over fluxing Protection (V/Hz) (24) Ct.

• Over excitation (Fluxing) occurs when the V/Hz ratio exceeds 105% at FL and 110% at no load

• V/Hz relays set at 110% with a 5 – 10 sec delay

• Generator overvoltage can occur without exceeding V/Hz relay setting due to large over speed on hydro generator
81O/U (Over/Under Frequency Protection)

**Over Frequency:**

- Significant load rejection
- Should use for protection against possible over speeding condition
- Can cause Overvoltage on hydro turbines

**Under Frequency:**

- Over load condition
- Loss of Generation
- Can cause Over excitation
- Can cause turbine blade fatigue
Out of Step Protection (78)

- High peak currents and off-frequency operation can occur when a generator losses synchronism.
- Causes winding stress, high rotor iron currents, pulsating torques and mechanical resonances.
- It will protect generator against pole slipping.
Negative Sequence Protection (46)

Causes:
- Unbalance load condition
- Unbalance fault

Effect:
- Negative sequence current interacts with normal positive sequence current to induce a double frequency current (120 Hz)
- Current (120 Hz) is induced into rotor causing surface heating
- Generator has established short-time rating, \( K = I^2 t \)

Where

\( K = \) Manufacturer Factor (the larger the generator the smaller the K value)
\( I = \) Negative sequence current

- Protects generator from excessive heating in the rotor due to unbalanced stator currents
- Rotor temperature rise proportion to I
System Backup Protection (51V, 21)

• Common practice to provide protection for faults inside and outside of the generator zone of protection

• It will use as back up for 87G

• Distance relay (21) set to include generator step up transformer and reach beyond, into the system (zone 1 for internal faults and zone 2 for external faults)

• Time delays must be coordinated with those of the system protection to assure that system protection will operate before back up

• Control or restraining function in 51V used to prevent or desensitize the overcurrent relay from tripping until the generator voltage is reduced by a fault (80% of nominal voltage)
Synchronizing (25)

• Improper synchronizing of a generator to a system may result in damage to the generator step-up transformer and any type of generating unit.

• The damage incurred may be slipped couplings, increased shaft vibration, a change in bearing alignment, loosened stator windings, loosened stator laminations and fatigue damage to shafts and other mechanical parts.

• In order to avoid damaging a generator during synchronizing, the generator manufacturer will generally provide synchronizing limits in terms of breaker closing angle and voltage matching:
  • Breaker closing angle: within ± 10 elect. degrees
  • Voltage matching: 0 to +5%
  • Frequency difference < 0.067 Hz
Reverse Power (32)

• Prevents generator from motoring on loss of prime mover

• From a system standpoint, motoring is defined as the flow of real power into the generator acting as a motor.

• With current in the field winding, the generator will remain in synchronism with the system and act as a synchronous motor.

• A power relay set to look into the machine is therefore used on most units.

• The sensitivity and setting of the relay is dependent upon the type of prime mover involved.
Reverse Power (32) Ct.

Pickup setting should be below the following motoring limits:

• Gas : 50% rated power; time < 60 s
• Diesel : 25% rated power; time < 60 s
• Hydro turbines : 0.2% - 2% rated power; time < 60 s
• Steam turbines : 0.5% - 3% rated power; time < 30 s
Loss of Field Loss of Field (40)

CAUSES

• Field open circuit
• Field short circuit
• Accidental tripping of field breaker
• Regulator control failure
• Loss of main exciter
• If the field breaker is opened, the generator will act as an induction generator (receive reactive power from the grid).
Split Phase Differential (50DT)

• Most turbine generators have single turn stator windings. If a generator has stator windings with multi-turn coils and with two or more circuits per phase, the split-phase relaying scheme may be used to provide turn fault protection.

• In this scheme, the circuits in each phase of the stator winding are split into two equal groups and the currents of each group are compared.

• A difference in these currents indicates an unbalance caused by a single turn fault.
Split Phase Differential (50DT) Ct.

- Scheme detects turn to turn fault not involving ground.
- Generator must have two or more windings per phase to apply scheme.
- Used widely on salient-pole hydro generators. Used on some steam generators.
- Difference between current on each phase indicates a turn to turn fault.
- Need to have separate pick-up levels on each phase to accommodate practice of removal of shorted terms.
Inadvertent Off Line Generator Protection (50/27)(50AE)

Protects against closing of the generator breaker while machine is not spinning / on turning gear

Causes:

• Operating errors
• Breaker head flashover
• Control circuit malfunctions
• Combination of above

Inadvertent energizing is a serious industry problem:

• Damage occurs within seconds
• Conventional generator protection will not provide protection
Generator Response and Damage to Three-Phase Inadvertent Energizing

• Generator behaves as an induction motor
• Rotating flux induced into the generator rotor
• Resulting rotor current is forced into negative sequence path in rotor body
• Machine impedance during initial energizing is equivalent to its negative sequence impedance
• Rapid rotor heating occurs $K = I^2 t$
Over-Voltage (59)

• Generator overvoltage may occur without necessarily exceeding the V/Hz limits of the machine.

• Protection for generator overvoltage is provided with a frequency-compensated (or frequency insensitive) overvoltage relay.

• The relay should have both an instantaneous unit and a time delay unit with an inverse time characteristic.

• Two definite time delay relays can also be applied.
Large Machine Protection
IEEE C37.102

- Unit Connected
- High Z Grounded

32 Reverse Power
40 Loss of Excitation
46 Negative Sequence
49 Thermal Overload
51V voltage restraint
51G Ground overcurrent
64 Ground Relay
87 Differential
References

• IEEE generator protection guide