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EE 4800 Final Project
Generator Protection
Introduction

Generators are vital components of a power system’s operation and overall integrity. Being that commercial generators are very large and susceptible to small system changes, it is very important to protect against possible hazards. There are many types of circumstances that can challenge the stability of the generator’s operation, and even cause damage to the generator. Many protection schemes and relays have been invented to provide adequate reliability of the generator, and the overall system.

Typical Faults/Hazards Concerning a Generator

Two types of hazards must be accounted for to protect the large, expensive, industrial generators. The first kinds of faults that need to be protected are internal faults in the generator. These consist of phase and ground faults in the stator, and ground faults in the rotor which lead to loss of excitation current. A breakdown of the generator’s insulation is the main cause for these types of faults. Stator faults usually begin as turn to turn faults that develop into ground faults or start off as ground faults. Large generators often use a grounded neutral with a very large impedance to limit the amount of fault current to the neutral. Another type of internal fault for a generator would be the loss of the excitation current, resulting in a loss of the generated E-field.

The other kinds of faults that must be protected against are system imbalances, of which the generator is a part of. One on these problems is the loss of the primary mover. The prime mover is the source used to drive the generator, for instance steam, water, or wind. If this source is removed, and the field is still excited, the generator will act as a synchronous motor being supplied by the grid. An obvious problem that may occur is overvoltage. Overvoltage can occur in certain types of system failures, and can cause severe damage to the generator. Generator voltage is related to the frequency and the magnetic flux. If voltage rises than frequency will also change. Under voltage can occur if there is a quick loss of load or if the system is operating at a point above the generators rated output.

Another type of system problem that can happen is inadvertent energization of the generator. This phenomenon occurs when a circuit breaker is closed at the wrong time. For instance, if the generator is off or running in non-synchronous operation. Unbalanced currents can be produced when powering a light load (70% max conditions). This
problem arises when pole flashovers and other such pole disagreements are present.

Overloading a generator can also be extremely damaging to the windings, as it produces a lot of heat. This is something that needs to be considered in protecting a generator.

Over or under frequency is also a situation that requires protection. These two scenarios can appear in the event of islanding. If too much or too little power is available, then it causes great system imbalances and creates fluctuation in the frequency.

Loss of synchronism is very important, and is dictated by the swing equation. If the generation source and the system voltage swing to more than 180 degrees out of phase, than the system is un recoverable, and the generator must be shut down. This leads to huge amount of down time.

**Protection/relaying Schemes**

Phase-fault backup is usually provided by phase-distance units or the (21) relay. The relay is connected to the CTs on the neutral side and set through the generator into the system. The direction of the current is determined by the location of the CTs – either looking into the system or the generator. The distance is measured from the location of the VTs.

Negative sequence current can cause severe damage in the generator by melting the wedges into the air gap. Negative sequence currents occur due to unsymmetrical power systems and unbalanced loads. The (46) relay is used to protect against this.

The (51V) relay is a voltage-controlled or voltage-restraint time-overcurrent relay. This relay is non-directional which makes it more versatile. The relay is typically connected to one phase with a phase-to-phase voltage for a 3-phase fault.

The (32) relay is used to protect against the loss of prime-mover. This is a supplementary reverse power relay. The relay operates when the reverse power reaches a percentage of the nameplate kilowatts.

| Steam turbines, condensing types | 1-3% |
| Steam turbines, noncondensing types | 2+% |
| Hydro turbines | 0.2-2+% |
| Diesel engines | ±25% |
| Gas turbine | 50+% |

*Reverse power required to spin generator & synchronous speed with no power input*
The (24) relay detects overvoltage. This protection has a constant pickup as a function of the ratio of voltage to frequency. A typical configuration uses 1 setting at about 110% rated voltage to alarm with a trip after roughly 1 minute while the other set at 120% rated voltage to trip after roughly 6 seconds.

The (67) relay is an inverse-time-overcurrent unit with 1 unit typically on each phase. They operate for reverse power into the generator. The typical pickup will be roughly 0.5 pu current with about 2.0 pu current-operating times of 0.25 s. This protects against inadvertent energization which causes severe damage to the generator.

The (61) relay protects against breaker pole flashover. It compares the magnitude levels in the 3 phases. The relay operates when one phase is above its set level and the other 2 phases are below their level. The sensitivities one might see are 20-60 mA on the lower phase and 40-200 mA on the higher phases.

The overload or (49) relay detects when the generator is being overloaded by using resistance temperature detectors within the windings. High temperature in the generator unbalances the network of detectors and operates the relay.

The (81) relay detects over and under-frequency. The under-frequency is usually set at 59-59.5 Hz and the over-frequency should be set at 60.5 Hz. The time delay is usually 0.1 s.

Under-voltage and over-voltages occur due to different circumstances. Under-voltages can occur when faults are not properly cleared. Over-voltages usually occur due to a sudden loss of load. The typical settings for the under-voltage (27) relays are 90-95% normal voltage with a 1 second delay. The typical settings for the over-voltage (59) relays are 106-110% of rated voltage.

<table>
<thead>
<tr>
<th>Generators</th>
<th>Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>105% continuous</td>
<td>110% continuous</td>
</tr>
<tr>
<td>110% 30 min</td>
<td>115% 30 min</td>
</tr>
<tr>
<td>115% 5 min</td>
<td>120% 5 min</td>
</tr>
<tr>
<td>125% 2 min</td>
<td>130% 3 min</td>
</tr>
</tbody>
</table>

Typical permissible overvoltage @ no-load
**Device list for GEN 3**

- 21G  Distance
- 21GX  Aux to 21G
- 24  Overexcitation
- 27  Undervoltage
- 27TN  Undervoltage (Third Harmonic)
- 32  Power Direction
- 40  Loss of Excitation
- 46  Current Unbalance
- 49R  Overload (RTD)
- 51GN  Time Overcurrent (Ground)
- 51V  Time Overcurrent (V Restraint)
- 59  Overvoltage
- 60V  Voltage Balance
- 64F  Ground (field)
- 64G  Ground (stator)
- 78  Out-of-step
- 81L/H  Frequency
- 86G  Lockout Auxiliary
- 87G  Differential

**If no external fault source exists, exchange connections of protection from line side CT's to neutral side CT's and vice versa.**

**Conclusion:**

We have learned the typical protection scheme of a large generator. The chances of a fault are quite low, and with the relays discussed above, most damage to the generator can be avoided. With complete protection provided, down time is minimized, and the added cost of the protection is justified.