SolidGround™ grid stability system
Geomagnetic Storm Induced Currents (GIC) and Electromagnetic Pulse (EMP) E3 protection
SolidGround™ GIC grid stability system

The Emprimus SolidGround™ System automatically blocks DC currents from flowing in the neutral of large power transformers protecting the grid against effects of Geomagnetic Storm Induced Currents (GIC) and Electromagnetic Pulse (EMP) induced currents of any size.

Why a GIC grid stability system?
Various solutions to remediate ground currents in grid transformer neutrals have been examined – all involving placing some form of impedance continuously in the transformer neutral. Although there are varying degrees of effectiveness, all have the disadvantage of continuously modifying transformer operations from the designed operating condition of a solidly grounded neutral conductor – modifying operating conditions, relay settings and system reliability. And, resistor solutions do not work effectively for large geomagnetic storms because they only partially reduce GIC.

SolidGround™ cost effectively solidly grounds the transformer at all times. Under normal operating conditions, presence of this protection is completely transparent to Grid operations as the transformer neutral has a complete metallic path to the ground.
Features

- Provide a metallic ground path which solidly grounds the transformer neutral when geomagnetic induced currents (GIC) are not present. (99.8%) of the time.
- Automatically senses the presence of GIC or GIC induced harmonics, triggering removal of the metallic ground, leaving the neutral grounded through a one ohm power resistor and 5,600 Kvar capacitor bank. Unit is then in the GIC mode. Electronics incorporate amperage, harmonic content and time delay user settable adjustments.
- When in the GIC mode, SolidGround™ effectively blocks geomagnetic induced currents which prevents:
  - Transformer half wave saturation
  - Generation of harmonics on power lines
  - Unwanted extreme MVAR flows
  - Power grid instability
  - Thermal damage to transformers identified as being unable to handle GIC
- Utilizes a metal-oxide surge arrester to prevent over voltages in the event of a ground fault when in the GIC mode.
- System operator override to control the unit as well as system status.

Transformer application

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transformer rating</td>
<td>115 to 765, 150 neutral BIL</td>
</tr>
<tr>
<td>Transformer configuration</td>
<td>Neutral of single or 3-phase</td>
</tr>
<tr>
<td>Neutral quasi DC current attenuation</td>
<td>&gt; 40 db below 0.6</td>
</tr>
<tr>
<td>Neutral GIS current sensing trigger</td>
<td>A 6 to 500 (selectable)</td>
</tr>
<tr>
<td>GIS induced harmonic sensing trigger</td>
<td>% 1.5, 3, 5, 10 (selectable)</td>
</tr>
<tr>
<td>Input power</td>
<td>volts 120 DC</td>
</tr>
</tbody>
</table>

GIS: Geomagnetic Induced Current
THD: Total Harmonic Distortion
EMP: Electromagnetic Pulse
IEMI: Intentional Electromagnetic Interference
SolidGround™ grid stability system

**Capacitor bank**
During a GIC event, the capacitor bank effectively blocks the quasi-DC ground currents in the transformer neutral while providing a continuous AC grounding path.

**Power resistor**
A 50kW, 1 Ohm power resistor effectively damps neutral and phase transients while the system is in GIC mode.

**Leg extensions**
Purpose-built leg extensions are available to provide appropriate high voltage clearance if the system is installed in an open area.

**Fully assembled prior to shipping**
Fully assembled prior to shipping
SolidGround components are factory assembled to ensure performance and minimize installation effort and costs in the field. Typical installations involve concrete piers, bolting of extension legs, completing the electrical connections, and commissioning.
AC grounding switch
After measuring DC currents or system harmonics, the AC and DC switches are automatically opened to leave the transformer ground through the resistor and capacitor bank; maintaining a continuous effective ground path while blocking quasi-DC currents.

Surge Arrester
A specially mounted MOV surge arrester assembly provides system protection in the unlikely event of a simultaneous ground fault while the system is in GIC mode (grounding switch open).

Sensing and control electronics
Continuous monitoring measures for both DC currents and system harmonics. User settable thresholds allow for site-specific customization. System can be operated in automatic or manual modes.

SACE DC disconnector
The Emax DC disconnect switch is designed to very quickly break DC and quasi-DC currents after neutral DC currents or system harmonics cross a user-settable threshold.
Sequence of operations

The switch “S” is two separate switches: a high speed grounding switch and a DC disconnect. The DC disconnect switch is designed to break DC and quasi-DC currents. The voltage ratings of the commercially available DC disconnect switches are lower than the neutral voltages expected during ground faults. This switch assembly is comprised of a DC disconnect switch connected in series with an AC grounding switch.

When a flow of GIC is detected, the switch control logic opens the switch assembly before the neutral voltage exceeds the rating of the DC disconnect switch. The AC grounding switch opens nearly simultaneously. Once both switches are opened, the DC disconnect switch is reclosed but the grounding switch remains open until a predetermined amount of time passes or a system operator declares the GIC event to be over. The capacitor then blocks the DC and quasi-DC ground currents in the transformer neutral while providing continuous AC grounding. A series resistor is utilized to effectively damp neutral and phase transients (see Figs. 2-3). The AC grounding switch is automatically closed if a fault is detected. The system operator then closes the grounding switch by SCADA to bypass the blocking capacitor and directly grounds the transformer.

Also, the system operator has the ability to insert the blocking capacitor by initiating the DC disconnect switch and grounding switch sequence by SCADA.

Blocking components

“Rsh” in the diagram is a very low impedance, high capacity heavy duty brass shunt resistor utilized for measuring DC and quasi-DC current in the transformer neutral. The capacitive voltage transformer (CVT) provides waveform information to the SolidGround™ electronics for harmonic distortion computation. When abnormal ground current and/or harmonic distortion is detected, the switches “S” are opened to force the ground through the resistor and capacitor. The resistor is a high-power, low-impedance power resistor rated at 50 KW. The capacitor bank comprises 5,600 kVAR and is rated at 2.4kV. In the very unlikely event of a line fault simultaneously with a GIC event, a very fast MOV surge arrester assembly is employed to protect the RC combination.

Historical data shows that a ground current event of sufficient magnitude to need mitigation may occur once in 14 months on the average. During an event, when the SolidGround™ remediation was in place for 24 hours (a conservative time), it represents only 0.2% of the time. During mitigation, the capacitor blocks the DC and quasi-DC currents. While providing seamless AC grounding. Other blocking schemes that employ only resistors only reduce, but do not eliminate, the DC currents, which results in more significant harmonic and ferro-resonance remnants.

The SolidGround™ system is engineered and shipped pre-assembled from the factory, minimizing installation cost and effort. Typical installations involve concrete piers, the bolting of extension legs, completing the electrical connections, and commissioning. The system is designed to work on all HV class transformers.

The University of Manitoba, using one of the most powerful simulation tools in the world, has conducted a series of simulations to verify the performance of the SolidGround™ system to GIC remediation. Fig. 4 and 5 show how the SolidGround™ system with the MOV feature controls the neutral and phase voltages in the event that a fault occurs simultaneously with a GIC remediation switching period.
Variation of neutral voltage with and without MOV.

Variation of phase-C RMS voltage on bus-5 during the fault, with and without MOV.

Addition of properly located surge arresters gives protection to the E1 and E2 portion of the EMP spectrum.

View of maintenance disconnect switch.
Physical specifications

Dimensions

Physical data

<table>
<thead>
<tr>
<th>Dimensions and weights</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Height of upper equipment platform</td>
<td>9’ 6”</td>
</tr>
<tr>
<td>Height of platform extension legs</td>
<td>3’ 8”</td>
</tr>
<tr>
<td>Overall assembled height</td>
<td>13’ 2”</td>
</tr>
<tr>
<td>Width of platform</td>
<td>5’</td>
</tr>
<tr>
<td>Length of platform</td>
<td>14’ 6”</td>
</tr>
<tr>
<td>Length of optional disconnect switches</td>
<td>3’ 9”</td>
</tr>
<tr>
<td>Overall length with disconnect switches</td>
<td>18’ 3”</td>
</tr>
<tr>
<td>Shipping weight (lbs)</td>
<td>8,200</td>
</tr>
<tr>
<td>Minimum height to live parts</td>
<td>9’ 1”</td>
</tr>
</tbody>
</table>

Certifications

ISO 9001
ISO 14001
OHSAS 18001