

SolidGround™ grid stability and harmonics mitigation system

Geomagnetic Storm Induced Current (GIC) and Electromagnetic Pulse (EMP) protection

SolidGround™ GIC grid stability and harmonics mitigation system

The SolidGround™ system automatically blocks DC currents from flowing in the neutrals of large power transformers. The system protects the grid against effects of solar storm Geomagnetic Induced Currents (GIC) and Electromagnetic Pulse (EMP) induced currents.

Grid voltage collapse and component damage can occur during modest to severe solar storms. SolidGround™ installations will prevent this collapse and eliminate damage to power system components and customer equipment.

New insurance studies show that even low level solar storms cause damage to customer equipment of billions of dollars per year. SolidGround™ mitigates the effect of even these low level disturbances.

SolidGround™ as a GIC grid stability and harmonics mitigation system

Various solutions to remediate ground currents in HV and EHV transformer neutrals have been examined over several decades. All such solutions have the disadvantage of modifying the transformer neutral grounding impedance – which in turn modifies operating conditions, relay settings, and system reliability.

The SolidGround™ system grounds the transformer at all times. Under all operating conditions, the presence of GIC protection is completely transparent to grid operations as the transformer neutral has a complete metallic path to the ground when in its Solid Ground mode, and a very low AC impedance path to ground when in its GIC protective mode.

In addition, blocking transformer neutral GIC currents also prevents the generation of induced power line harmonics and power quality issues which can damage both power system components as well as customer equipment.



Protecting the grid against GIC and EMP currents

ABB is proud to offer the SolidGround™ for grid protection against geomagnetic induced currents.

Application

The SolidGround™ automatically senses the presence of GIC or induced harmonics, triggering the protective mode with AC grounding through a low impedance capacitor bank. This level of protection prevents:

- Transformer half wave saturation
- Generation of harmonics on power lines
- Unwanted extreme Reactive (MVAR) flows
- Power grid instability
- Thermal damage to transformers and SVCs
- Harmonic damage to generator rotors

Additionally, the system provides a metallic ground path which grounds a transformer neutral when geomagnetic induced currents (GIC) are not present – 99.8% of the time.

Transformer application

Transformer configuration	Two winding or Auto	Neutral of single or 3-phase transformers
Transformer rating	kV (rms)	115 to 765
Neutral quasi DC current attenuation	db	> 40 db below 0.6 Hz
Neutral GIC current sensing trigger	Amperes, selectable	6 to 100 (selectable)
GIC induced harmonic (THD) sensing trigger	%, selectable	1 to 10 (selectable)
Input power	Volts	125 DC

GIC: Geomagnetic Induced Current
 THD: Total Harmonic Distortion
 EMP: Electromagnetic Pulse
 IEMI: Intentional Electromagnetic Interference

Benefits of ABB's advanced technology

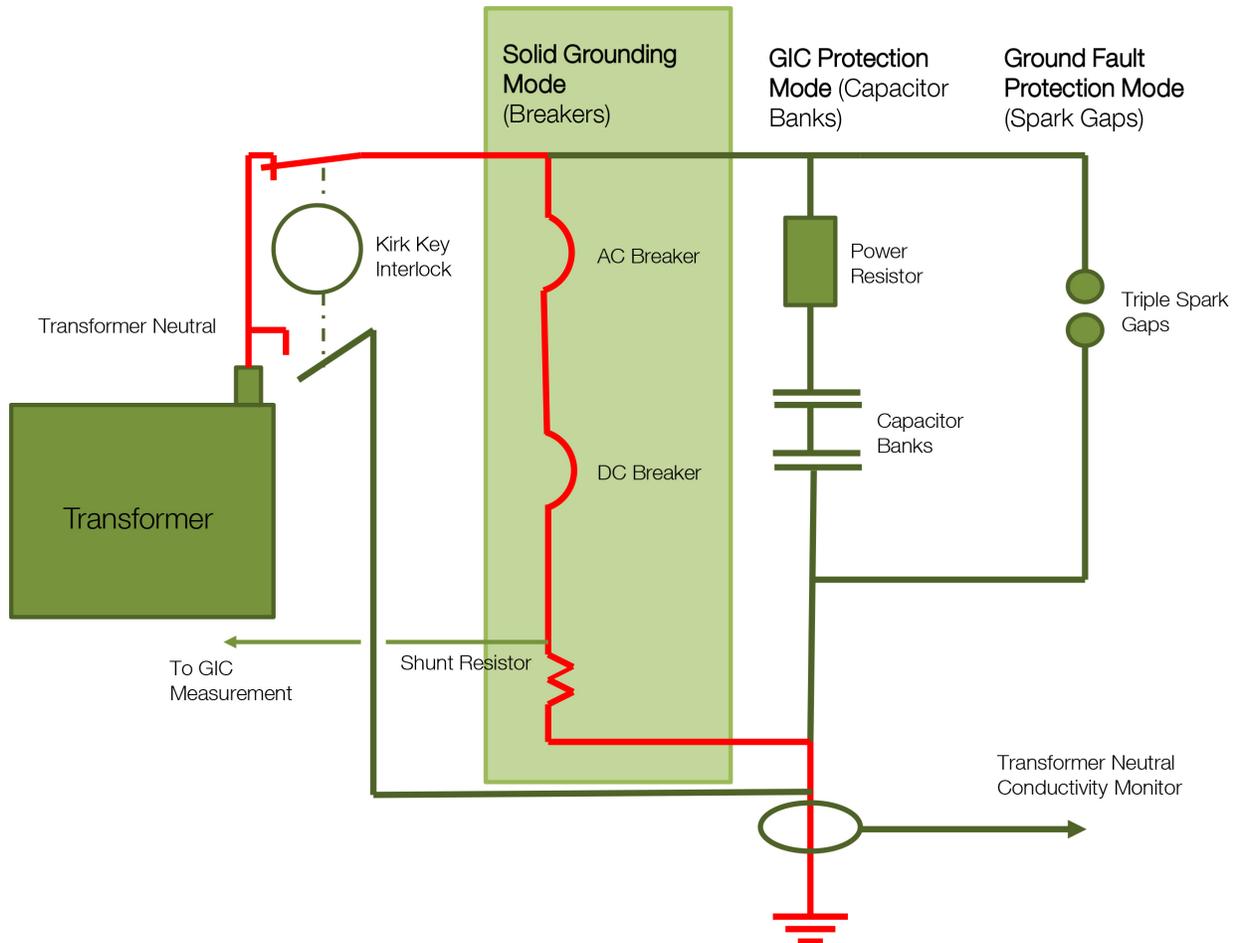
- The system is designed to work on HV and EHV class transformers
- The system has been extensively studied and modeled by the University of Manitoba
- The system has been fully fault tested at KEMA High Current and Voltage Laboratories in Pennsylvania
- The US Government has sponsored testing in a live power grid at the Idaho National Laboratory
- SEL control electronics provide SolidGround™ breaker controls, monitoring functions and communications with SCADA systems
- The system offers triple redundant fault protection when in the GIC protective mode, providing:
 - DuraGap™ spark gap voltage protection
 - Breaker reclose if spark gap should fire
- The 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.

SolidGround™ offers financial operating advantages

One means of managing the effects of GIC is to free-up capacity on long transmission lines. GIC flowing through HV transformer cores can cause large reactive power (VAR) demands when GMDs impact the earth. To make available more VARs during solar storm periods, utilities back down generation of base load (less expensive) and start up peaking (more expensive) generation. This temporary approach allows utilities to provide the same levels of service to end-users; but at a higher cost. Instead, the utilities could effectively block the GIC from entering the transformer core by implementing an ABB SolidGround™ solution.

Blocking GIC means reduced GIC effects in the system which means uneconomic dispatch can be avoided. In this scenario, SolidGround™ will offer a very compelling financial benefit. Additionally, SolidGround™ prevents GIC induced harmonics/power quality issues which can damage utility and customer equipment. By blocking GIC currents, damage caused by harmonics is avoided.

Operation



Sequence of operations

The breaker assembly is comprised of two separate breakers: a DC disconnect breaker and an AC vacuum breaker. The DC breaker is designed to break DC and quasi-DC currents. The AC breaker has a high voltage stand-off that is opened second and protects the DC breaker.

When a flow of GIC is detected, the control electronics opens the breaker assembly. Once both the breakers are opened, the DC disconnect breaker is reclosed but the AC breaker remains open until the control electronics sense that the GIC event is over. The unit then automatically closes the AC breaker and the system is then ready for the next GIC event.

When the AC break is open the system is in the GIC protective mode and the capacitor bank blocks the neutral quasi-DC currents in the transformer while providing a continuous AC ground connection. A low impedance, high power series resistor is utilized to effectively damp neutral voltage transients. In the unlikely event that a ground

fault should occur while in the GIC protection mode, a spark gap provides a grounding path to protect the transformer. If fault current through the spark gap is detected the AC breaker is reclosed to handle any repeated ground fault current events.

As back-up protection, a triple spark gap provides a grounding path for faults. If current through the spark gap is detected a relay is used to reclose the AC breaker which takes the SolidGround™ system out of the GIC protection mode and places it into its normal SolidGround™ operational mode.

Since the system will operate in its normal mode of operation (i.e. breaker assembly closed) most of the time (99.8% of the time), a SCADA system can be used to perform self-testing of SolidGround™ on a predetermined schedule e.g. once every month or once every week, to ensure all the components and the system continue to be operational.

Features

Triple DuraGap™ spark gap protection

A triple spark gap assembly provides transformer and system protection in the unlikely event of a simultaneous ground fault while the system is in its GIC protection mode. This spark gap assembly has been extensively tested at the KEMA laboratories in Pennsylvania and shown to provide highly redundant fault protection suitable for large numbers of faults.

Power resistor

A 50 kWatt, one (1) ohm power resistor effectively dampens neutral and phase transients while the system is in the GIC protection mode.

Maintenance/bypass switch

Maintenance/bypass switch is provided with Kirk Key Interlock, so the transformer ground connection is in place at all times.

Capacitor bank

During a GIC event, the capacitor bank effectively blocks the quasi-DC GIC currents in the transformer neutral while providing a continuous AC transformer grounding path. The standard SolidGround™ system comes with two series connected capacitor banks to provide full EMP stand-off voltage (8 kV) protection.

Sensing and control electronics

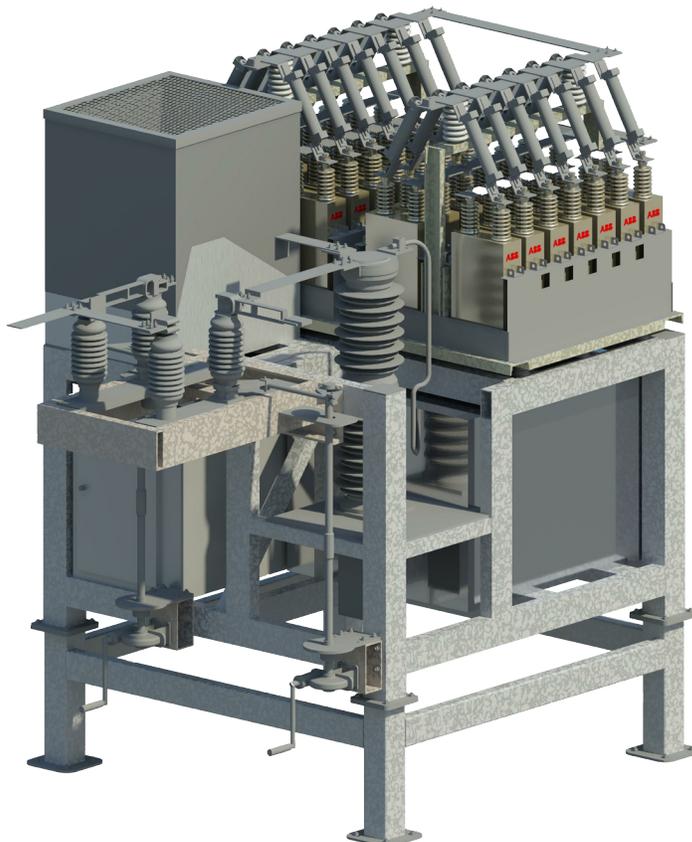
Electronics continuously monitor and measure for both DC currents and GIC induced harmonics. User settable thresholds allow for site-specific customization. System can be operated in automatic or manual modes. Shielding protection can be provided for IEMI and EMP E₁ as desired.

AC and DC breaker

Upon sensing either a quasi – DC GIC current or phase harmonics, the system DC and AC breakers are automatically opened to leave the transformer grounded through the power resistor and capacitor bank, maintaining a continuous effective grounding path while blocking the quasi – DC GIC currents. These breakers are highly reliable industry proven components used in numerous power equipment applications.

Transformer neutral conductivity monitor

An unique monitoring feature has been incorporated into the SolidGround™ system. A conductivity monitor now continuously assures operators that the neutral grounding connection has not been compromised.



Testing and conclusions

Live power grid testing

The system was tested at the KEMA high current testing facility in Chalfont, PA proving the robustness of the design and its readiness for live power grid testing.

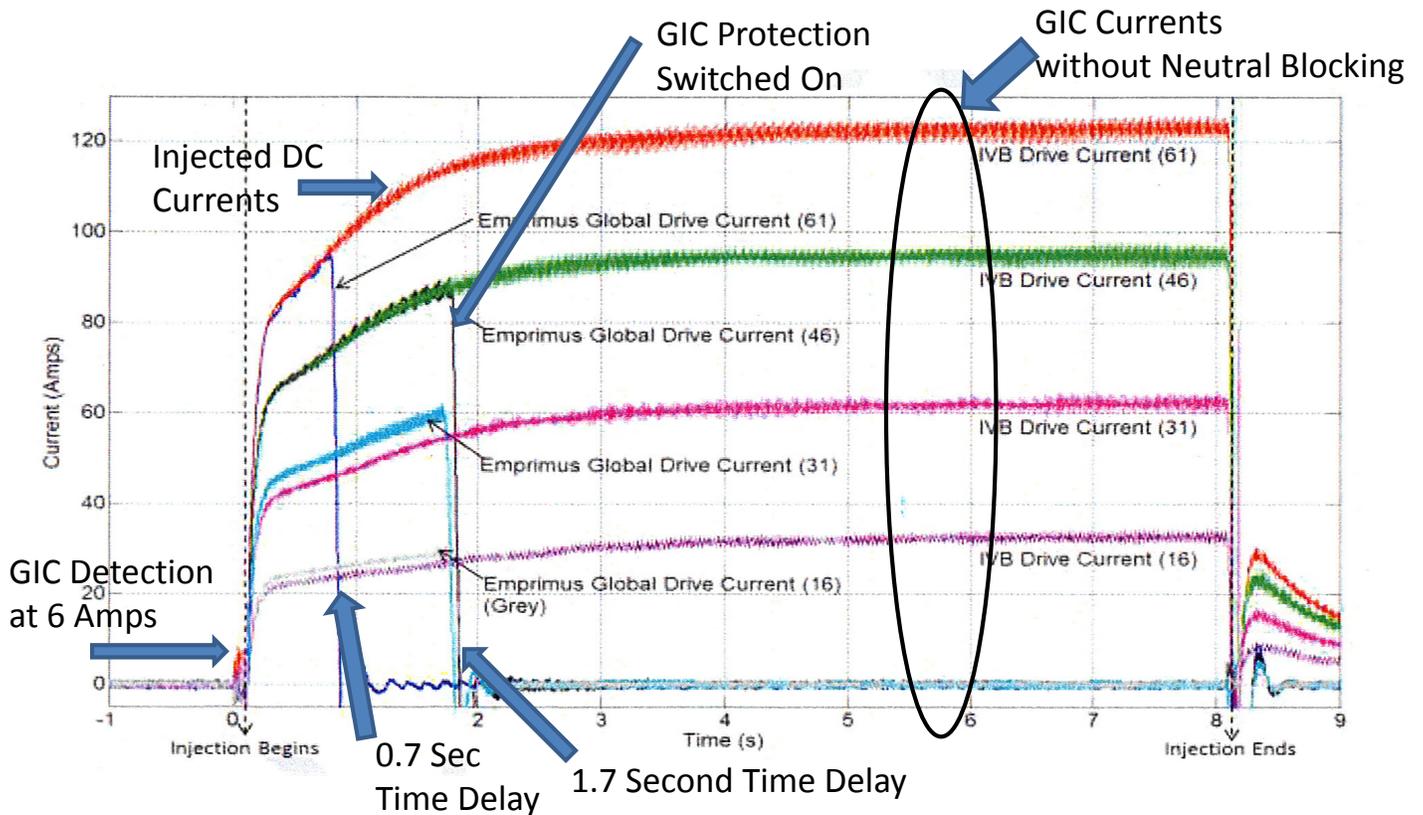
SolidGround™ was then inserted in live grid testing sponsored by the US Defense Threat Reduction Agency (DTRA). A snap shot of some of the data collected is shown in the adjacent figure. The system operated successfully in the live power grid under all testing scenarios conducted.

No neutral blocking unintended consequences

A question regarding the potential for neutral blocking to cause unintended power grid consequences has been raised by some individuals in the power industry. A NERC sponsored study performed by the Electric Power Research Institute (EPRI) in 2014 concluded that the SolidGround™ has no unintended consequences when introduced into a typical power grid network. The report is available to the public and can be found on the EPRI web site.



KEMA high ground fault current testing

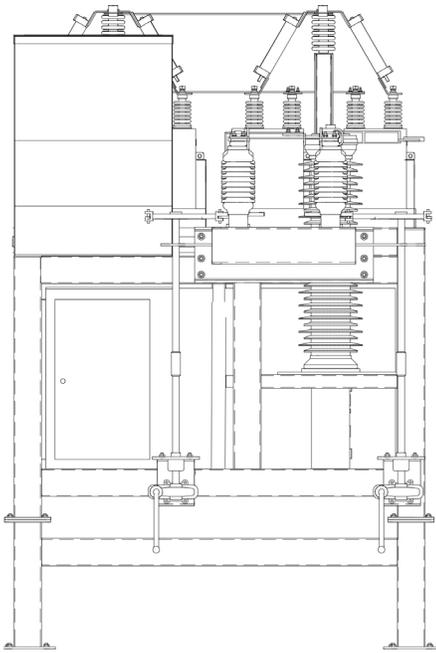


SolidGround™ testing results at the Idaho National Laboratories

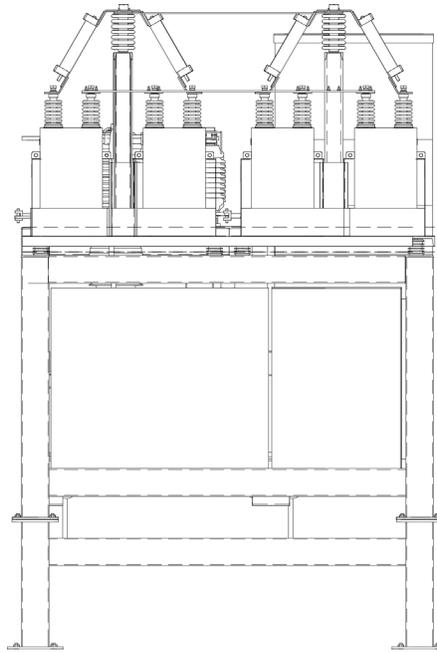
Drawings and dimensions

Physical data

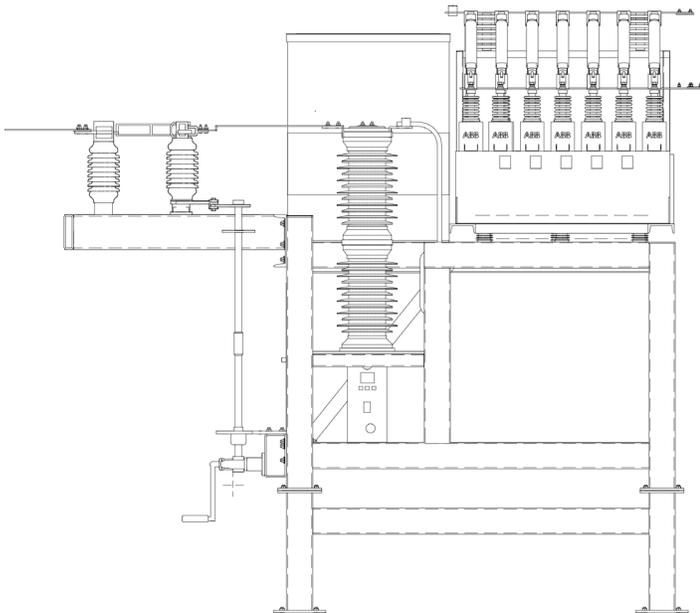
Dimensions and weights	
Height of upper equipment platform	9' 10"
Height of platform extension legs	2' 4"
Overall assembled height	12' 2"
Width of platform	7' 9"
Length of platform	7' 9"
Length of optional disconnect switches	3' 8"
Overall length with disconnect switches	11' 5"
Shipping weight (lbs)	8,200
Minimum height to unguarded parts	9' 0"



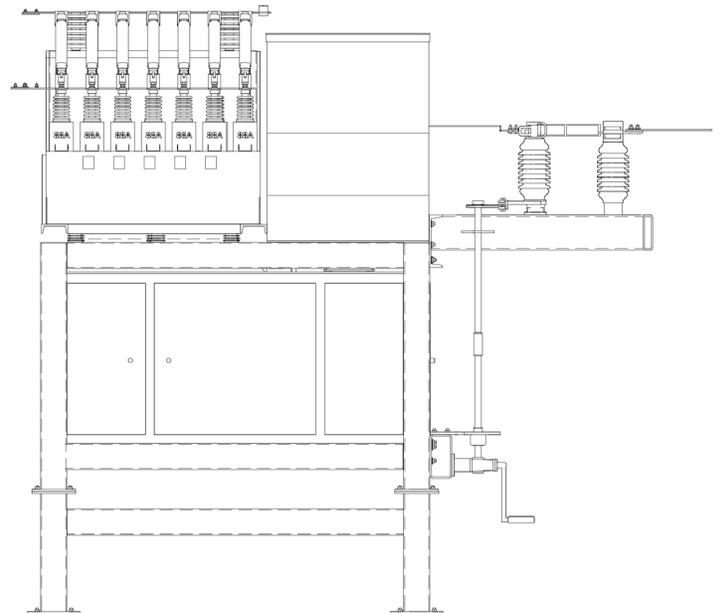
Left



Right



Front



Rear

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