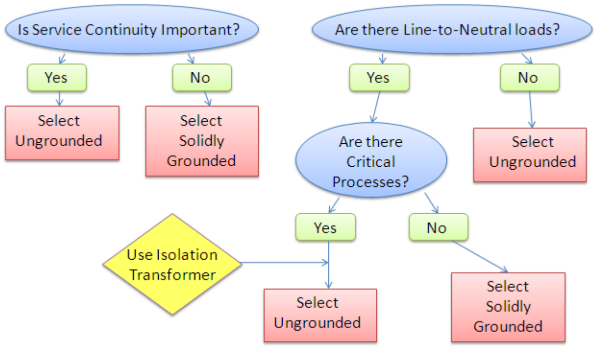
Common Misconceptions
About High Resistance Grounding

----------------------------BY ANDREW COCHRAN------------------------

When designing the grounding system for industrial facilities, the two most common questions asked were with respect to service continuity and single phase loads and this often determined the decision on which grounding system to choose.

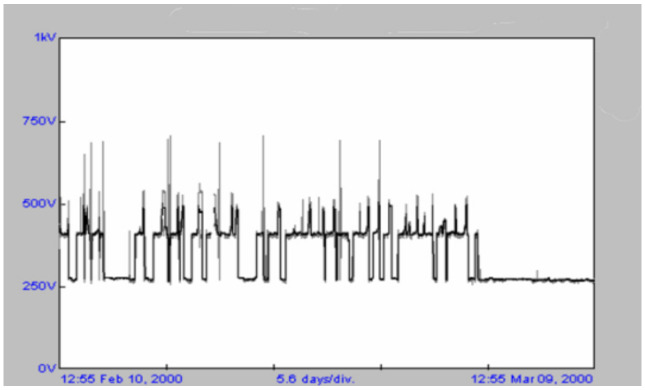
If service continuity was a key factor then the decision was often made to operate an ungrounded system, since service continuity was permitted under single ground fault conditions.
If there were a significant number of neutral loads to be serviced, then the typical decision was to select a solidly grounded system.



However, both of these choices contain inherent risks. With respect to ungrounded systems it was discovered that intermittent arcing ground faults on ungrounded systems could experience line-to-ground voltage excursions up to six times above normal, leading to multiple simultaneous motor insulation failures.

In section 8.2.5 of the IEEE Buff Book, "If this ground fault is intermittent or allowed to continue, the system could be subjected to possible severe over-voltages to ground, which can be as high as six to eight times phase voltage. Such over-voltages can puncture insulation and result in additional ground faults. These over-voltages are caused by repetitive charging of the system capacitance or by resonance between the system capacitance and the inductance of equipment in the system."

Section 7.2.1 of the IEEE Red Book states: "Accumulated operating experience indicates that, in general-purpose industrial power distribution systems, the overvoltage incidents associated with ungrounded operation reduce the useful life of insulation so that electric current and machine failures occur more frequently than they do on grounded power systems."



The graph shows the phase voltage readings from a 347/600V ungrounded automotive facility with high level of transients, peak voltage of 1050V and 485 events over 700V.

For many industrial plants it was deemed less risky to trip a faulted circuit using the high ground fault current of a solidly grounded system, than to maintain service continuity with an ungrounded system.

However, solid grounding of 480V and 600V systems created a new challenge – low level arcing ground faults and their consequent damage.

In IEEE 141-1993, Recommended Practice for Electrical Power Distribution for Industrial Plants section 7.2.4, it states that, *"The solidly grounded system has the highest probability of escalating into a phase-to-phase or three-phase arcing fault, particularly for the 480 and 600V systems. A safety hazard exists for solidly grounded systems from the severe flash, arc burning, and blast hazard from any phase-to-ground fault.*

The answer to service continuity without the concern over transient over-voltages and without damaged equipment due to a second ground fault is High Resistance Grounding as referenced by several IEEE Standards:

1. IEEE 242-1986 Recommended Practice for the Protection and Coordination of Industrial and Commercial Power Systems

   7.2.5. Ungrounded systems offer no advantage over high-resistance grounded systems in terms of continuity of service and have the disadvantages of transient overvoltages, locating the first fault and burn downs from a second ground fault. For these reasons, they are being used less frequently today than high-resistance grounded systems"

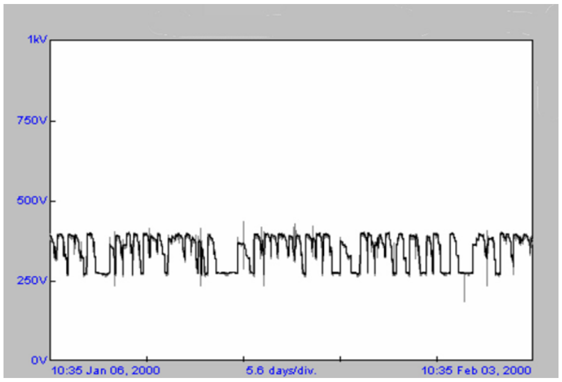
2. IEEE Standard 141-1993 (Red Book)

   7.2.2. High-resistance grounding provides the same advantages as ungrounded systems yet limits the steady state and severe transient over-voltages associated with ungrounded systems.

This graph is for the same automotive facility but the grounding system was converted to High Resistance Grounded from Ungrounded.

The phase voltage readings show that transient are under control, that peak voltage was held to 660V and most importantly there were 0 peak events over 700V.

High Resistance Grounding has proven to provide excellent protection from low-level arcing grounds and is supported by NFPA 70E -2009 Standard for Electrical Safety in the Workplace which states in section 130.2 FPN No.3 "Proven designs such as arc-resistant switchgear,…high-resistance grounding and current limitation….are techniques available to reduce the hazard of the system". OSHA subpart S issued on February 14 2007, and effective on August 13, 2007 is based on NFPA 70E.



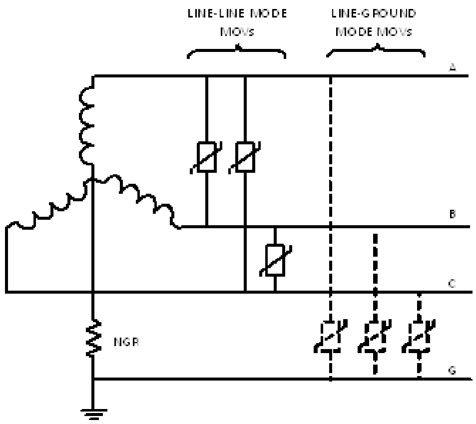
So if High Resistance Grounding is preferable to ungrounded given that it provides the same level of service continuity but without the risks associated with transient over-voltages and High Resistance Grounding is recognized as a technology that reduces the arc flash hazard, then why has this not become the default choice of consulting engineers and facility engineers?

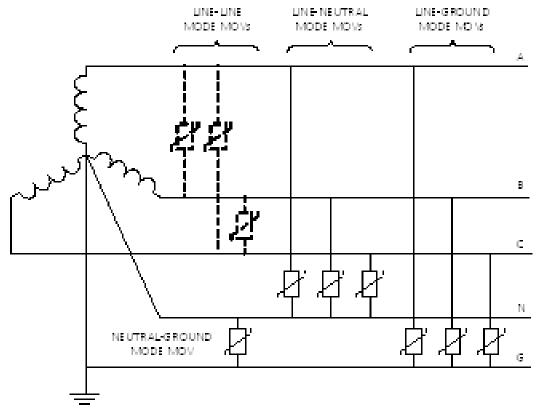
8 Commonly Held Misconceptions about HRG Technology.

1. HRG Technology is not compatible with my installed TVSS

In the late-1990's a transient voltage surge suppressor (TVSS) ruptured in a new 600V switchboard at a data center in southern Ontario, Canada. The 600V distribution system was high resistance grounded through a 5A, 347V, 69Ω neutral grounding resistor. Investigation revealed that the TVSS, rated for a 3-phase, 4-wire, 347/600V wye system, failed during a ground fault when the metal oxide varistors (MOVs) connected between line-to-ground (L-G), were exposed to excessive continuous voltage on the two unfaulted phases during the ground fault. The applied voltage exceeded the rated maximum continuous operating voltage (MCOV) of the MOVs.

The TVSS was designed for use on a solidly grounded system. It had been misapplied on the HRG system. The diagram on the left represents a TVSS on a solidly grounded system while that on the right is for a TVSS applied on a high resistance grounded system.





In a typical 3-phase 4-wire system a MCOV of 420V is sufficient for MOV's connected Line-to-Ground on a 347/600V system as the actual voltage does not exceed 347V and the TVSS is manufactured with this rating in mind.

However in North America, HRG systems are 3-phase 3-wire, the neutral is not distributed because it becomes energized during a ground fault and during this fault, the Line-to-Ground voltage will rise to 600V. The NEC article 285.3(2) states that an SPD shall not be installed on impedance grounded systems unless listed specifically for use on these systems.

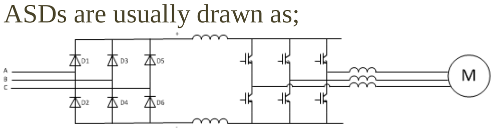
2. The UPS Manufacturer said the UPS is not for use with an HRG system.

UPS systems designed for use on solidly grounded systems often employ MOV surge suppressors at the rectifier input. The phase-to-ground MCOV is typically insufficient for application on a HRG source as previously explained. A typical UPS will include either a rectifier input autotransformer, or possibly no transformer at all. When purchasing a 3-phase UPS System, the UPS manufacturer should be informed whenever the UPS is to be fed from a HRG power source. The UPS manufacturer can make the simple design change to provide the UPS with a rectifier input isolation transformer to prevent the rectifier MOVs from being exposed to high phase-to-ground voltages during a ground fault on the upstream power source.

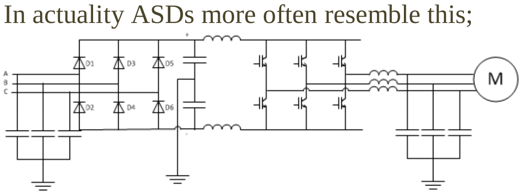
3. Variable Frequency Drives Fool the HRG and the Unit Alarms Erroneously or There's Something on ASD and HRG.

It is extremely important to communicate with your suppliers the type of grounding system employed.

ASDs are usually drawn as;

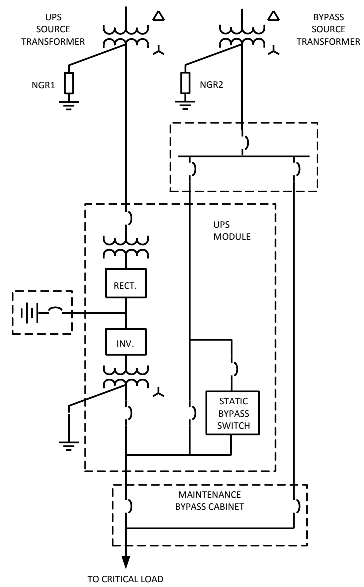


In actuality ASDs more often resemble this;



The additional capacitors are used to filter all undesired frequencies. What these additional capacitors do is provide alternate paths for ground fault currents to return. It may seem like a trivial amount but when you multiply the quantity of ASDs in a facility with a small amount of leakage current contribution by every ASD, it becomes a considerable amount of current. Most manufacturers of ASDs have products to suit high resistance grounded systems.

4. I have an HRG Bypass and a Solidly Grounded Inverter and they are Incompatible.



Applying a three-phase input/output UPS module with separate bypass input to a 480V or 600V HRG power source, both the UPS inverter output transformer and the bypass transformer should be high resistance grounded. If the UPS output is solidly grounded while the bypass is HRG, the critical load could be compromised during an UPS output ground fault. If a ground fault occurs on the solidly grounded system that supplies the critical load, the UPS, as designed, would instantly transfer the load to bypass via the static bypass switch, in order to clear the fault.

The bypass source, being HRG, would then reduce the ground fault current to 5A or less, as per the amperage rating of the NGR. The bypass neutral voltage would rise to 347V above ground. Meanwhile, the inverter output, being disconnected from the faulted critical load after transfer, would have its neutral voltage at ground potential.

The UPS static bypass transfer logic prevents the critical load from being transferred back to inverter because of the difference between the neutral-to-ground voltages. As a result, the critical load remains in bypass mode whenever a ground fault occurred in the solidly grounded system of the critical load, posing an unacceptable risk of downtime.

It is recommended that the bypass and inverter output sources be grounded same way, either solidly grounded or HRG. Typically, if the building distribution system is HRG, then the UPS inverter output should also be high resistance grounded. In this way, a ground fault in the critical load would not result in a transfer to bypass, but merely produce an alarm.

5. High Resistance Grounding does not protect Against Arc Flash.

While High Resistance Grounding as a technology was originally applied to industries as diverse as food processing, mining, petrochemical and even commercial installations such as airports, data centers etc. to enhance the reliability and uptime of power distribution equipment it is also proven effective in significantly reducing the frequency and severity of arc flash accidents.

With the correct application of High Resistance Grounding limiting the fault current to between 5amps and 10amps, there is insufficient fault energy for the arc to re-strike and it self-extinguishes and the hazard frequency is reduced. At the same time the process is allowed to continue to operate with a single ground fault that is limited and controlled to a safe level.

The choice of High Resistance Grounding directly impacts the arc flash hazard both in terms of frequency and impact. This technology can be applied on any electrical distribution system up to 5kV and in some cases 15kv where there are no line-to-neutral loads to be serviced. The effective deployment of HRG technology will reduce the number of arc flash incidences some 90% or more.

The choice of High Resistance Grounding directly impacts the arc flash hazard both in terms of frequency and impact. Section 7.2.2 of the IEEE Red Book states that when using high resistance grounding, “There is no arc flash hazard, as there is with solidly grounded systems, since the fault current is limited to approximately 5A.” The Red Book is referring here to phase-to-ground faults.

I read once a statement in a competitor’s advertisement that High Resistance Grounding should be considered when reliability is important and there is concern about arc flash. I can’t think of any application or industry where reliability is not important and where arc flash is not a concern.

As noted earlier High Resistance Grounding does not offer any protection or reduction in phase-to-phase or 3-phase faults that can result in arcing and for these issues alternative technology must be considered. Technology such as optical arc detection (which is the quickest) and arc pressure sensing (which is not prone to nuisance tripping and therefore the most reliable) protect against the arc flash and lower the incident energy to safer levels. While there is place for labels, warning signs and PPE as protection and awareness, these options should be implemented only after steps are taken to reduce the frequency and impact of a hazard.

NFPA 70E credits high impedance grounding as an arc flash mitigating technique. This is due to the fact that it reduces the risk of a single phase to ground fault propagating to 3-phase fault due to the limited energy and destruction at the point of the fault.

6. With High Resistance Grounding the Ground Fault is left on the System indefinitely and this is dangerous?

It is not an uncommon procedure (though not recommended) to ignore the first ground fault on HRG systems rated 600V and below as there is no immediate effect to production or plant operation. When there is a ground fault on a High Resistance Grounded system the un-faulted phase is subject to full line-to-line voltage and there is a concern that this could lead to insulation degradation and a phase-to-phase fault. The first line of defence in this regard is insulation ratings and typically 600V systems are protected by 1000V rated cables and therefore there is no issue. The second factor to consider is the time required to actually locate the ground fault. With pulsing technology this is typically a matter of only a few hours. It is worth noting that the more advanced HRG systems available today also include phase and feeder indication. With this knowledge it not only takes significantly less time to find the fault, but given that the search starts at the feeder level, it is a safer option as the available fault current at the feeder level is much lower than at the main branch, resulting in the incident energy level to be lower and safer.

Another benefit with advanced HRG systems is feeder time delay trip functionality. The user can select the timeframe from 1 minute to 99 hours that they are willing to accept the process operating with an active ground fault on the system before the want to isolate the faulted feeder. In this case only the faulted feeder is isolated, not the entire system and this functionality ensures that maintenance personnel must locate the fault within the timeframe mandated or the feeder will isolate.

7. Using a Hand Held Ammeter to Trace a Fault puts my Employees at Risk.

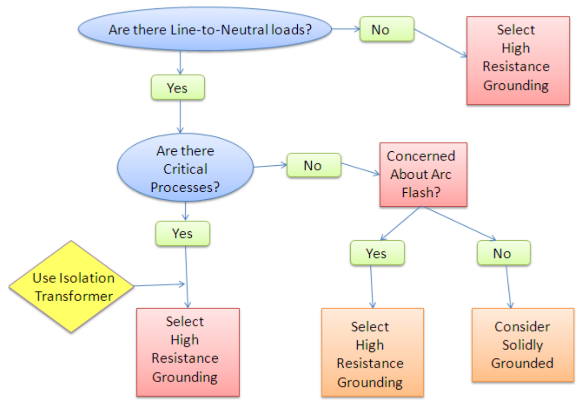
Whether a HRG system is implemented in a new facility, or is introduced as a change to an existing facility, education and training of applicable personnel are required for safe operation and maintenance, which contributes to increased reliability of the facility. HRG systems can greatly contribute to the reliability of a production facility by providing a window-of-time for personnel to locate and isolate faulted equipment prior to a unit or plant trip. With the aid of a logical alarm system, operating procedures, and ground fault locating equipment, personnel can navigate towards the faulted device and remove it from service.
With feeder indication technology, the maintenance personnel can start the search for the fault without ever having to open the main switchgear compartment and far away from the equipment with the highest incident energy levels ensuring the search for the fault is not only fast but safer.

Navigation to the faulted device can be assisted by the use of fault tracking equipment (tracking signals or pulses impressed on the ground system and the use of hand held sensing equipment).

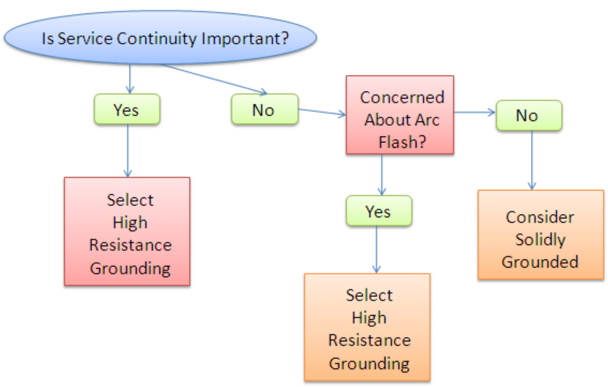
8. I am Concerned over a Second Ground Fault before the First Fault is Cleared

With the basic or industry standard HRG technology, a second ground fault on a different phase from the first will result in a phase-to-phase fault and the over-current protection on the main circuit will trip and the entire system will isolate.

With advanced HRG technology there is the option to pre-select up to 50 feeders with priority from the lowest to highest (16 different settings are available) so that in the event of a second ground fault the least important feeder will trip within 100ms. This allows process continuity of the more important feeder. With this feature the most important process in your facility will remain operational at all times.



There are numerous examples of facilities where service continuity is paramount and where the conversion from ungrounded to HRG technology has not only provided the same level of process continuity (or in the case of Advanced HRG increased continuity of critical processes) but eliminated the concern of transient over-voltages. There is no credible justification for designing or operating a facility today with an ungrounded electrical distribution system.



At the same time, the concern over the arc flash hazard which is more evident with solidly grounded systems, has designers and safety executives questioning whether the time has arrived to consider changing to High Resistance Grounding.

Care must be taken to understand and take into account any operational consideration such as TVSS, UPS supply etc. but these are all manageable and the need for a safe and reliable electrical system can best be served through the proper application of High Resistance Grounding.

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