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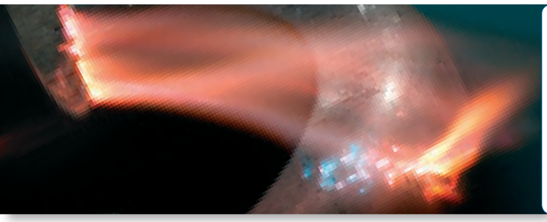
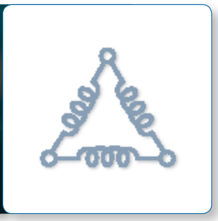
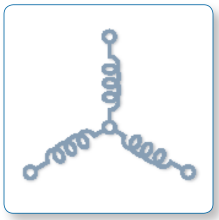
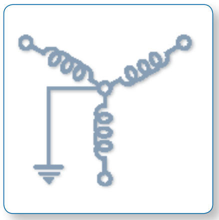
LOW AND MEDIUM VOLTAGE DISTRIBUTION SYSTEMS

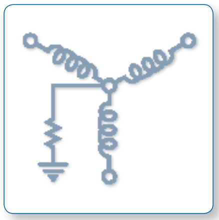
LOW &
MEDIUM











ASK THE EXPERTS, September 2018

LOW AND MEDIUM VOLTAGE DISTRIBUTION SYSTEMS

Electrical distribution systems can generally be classified as low voltage (208 volts to 4,160 volts) and medium voltage (4,160 volts to 13,800 volts) and high voltage (above 13,800 volts). You can broadly classify medium voltage (MV) grounding (earthing) systems into four categories: solidly grounded, low-resistance grounded (LRG); high-resistance grounded (HRG) and insulated neutral (ungrounded) systems.

With the solidly grounded system, there is no intentional impedance in the neutral–to-earth path. Instead, the neutral is solidly connected to earth. The phase-to-ground voltage remains constant during a ground fault, and there are very high fault current flows, resulting in extensive damage. The protective device closest to the fault must trip and isolate the circuit as fast as possible. The cost of repair is high due to extensive emergency repairs. If the fault is in a rotating machine, then there is a high possibility of core damage and replacement costs. Also, the cost associated with the down time can be enormous.

With LRG, the ground fault current is controlled and normally limited to between 25A and 1000A. The voltage-to-ground on the un-faulted phases increases to the phase-to-phase voltage level, so you must use adequately rated insulation systems and surge suppression devices. Also, the ground fault must be detected and isolated. Since the ground fault current is smaller and controlled, ground fault relaying still has the requirement of fast tripping. But, better time/current coordination can be achieved with this type of grounding system. Damage at the fault point is also reduced and thus the maintenance and repair costs are also reduced. The neutral grounding resistor needs to be short time rated (typically 10-30 seconds), as the fault will be cleared by the protective relay closest to the fault.

With HRG, the ground fault current is in the 10A range. The intention here is to allow the system to operate without tripping even with a phase-to-ground fault on one phase. When a ground fault does occur, only an alarm is raised. This permits time to locate the fault while power continuity is maintained. This also allows repairs to be done at a scheduled shut down of the faulty equipment. Damage at the fault location is small.

With the insulated neutral (ungrounded) system, there is no intentional connection of the system to ground. In effect, the three phases of the system float. When a ground fault occurs, the fault current is contributed by the system capacitance to earth on the un-faulted phases. This is usually small and the system can be operated without tripping. Since the system is floating, if the ground fault is an arcing or intermittent type, there is possibility of substantial transient overvoltages, which can be six to eight times the phase voltage. These transients often cause a subsequent failure elsewhere and thus raise the possibility of a phase-to-earth-to-phase fault, leading to high fault current and extensive damage.

For station service at distribution voltages of less than 15kV, power continuity is very important. Here, you would size the neutral grounding resistor so that the let through ground fault current is higher than the net current from the distributed capacitance. If the let-trough ground fault current is less than 10 A, then this would be high resistance grounding. If this current were more than 10A then it would be low resistance grounding.

It is rare to have station service voltage that is higher than 15kV. If the voltage is higher than this, then the same rule as noted above would apply, except the fault should be detected and isolated by tripping the faulted feeder at the closest protective device.

More recently hybrid grounding has been proposed. Here, a current limiting device is in parallel with a resistor, such as a resistor of low resistance and the other of high resistance (5A). In the event of an internal earth fault in the stator winding of the generator, a fast acting generator ground differential relay opens the current limiting device (in this case the low resistance grounding path) and thus allows the high-resistance (5A let-through) resistor) to control and lower the fault current, thus reducing the stator damage caused by the internal ground fault after the generator has been isolated and while it is slowing down. Without this reduction of current, the generator would continue to feed energy in to the fault while it is coming to a stop. The result would be extensive stator iron damage at the ground fault location.

NEUTRAL EARTHING RESISTOR

Q. What is your guidance in choosing resistance-neutral earthing when we have to use low or high resistance? Also, how do you define current protection of resistance earthing?

A. High resistance earthing is used on 3-phase, 3-wire distribution systems up to 5 kV (line-to-line), where:

(a) you want to maintain service continuity upon earth fault (i.e. do not trip faulted feeder on earth fault); and
(b) the system charging current is less than 6 A; and
(c) the neutral earthing resistor is sized for an amperage between 1-10 A. Typically, 2-5 A is used for system voltages up to 690 V; 5-10 A is used for system voltages above 690 V, up to 5 kV; and
(d) the neutral earthing resistor let-through current is equal to or higher than the system charging current.

Low-resistance earthing is used on medium voltage systems above 1 kV, where the system charging current is higher than 6A. Distribution systems above 5kV must not be high resistance earthed even if the charging current is less than 6A; the sole exception to this rule is a utility generator-transformer unit, where a 15kV generator generates utility power and feeds directly a step-up transformer for transmission – in this case the 15kV system charging current is so low that high resistance grounding with a 5-10A resistor may be used. Industrial distribution systems above 5kV must trip on earth fault, in order to avoid escalation of the earth fault into a phase-to-phase fault, at the point of fault. The system charging current and the voltage to ground are large enough that the risk of escalation is too high. So, low-resistance earthing is used to limit the earth fault current, typically within the range of 50-400A to allow for the earth fault to be sensed and selectively tripped offline by an earth fault relay. High current (400A) must be used if residually-connected CT's are used to sense the earth fault for the earth fault relay. Lower currents can be used (50-200 A) if a core-balance CT is used for input to a relay with sensitive earth-fault feature. Low-resistance earthing is better than solid earthing (TN) because is limits the earth fault current to a safe value, thereby reducing arc flash incidents and equipment damage on earth fault.

To protect star-connected motors, a feeder earth fault relay should be set to trip at 10-20% of resistor let-thru current. 10% is the minimum, but may lead to nuisance tripping, hence can be increased to 20% in case nuisance tripping occurs – this can be easily adjusted at commissioning time. This setting allows capture of earth fault that occur in the stator winding close to the neutral point (within 10-20%), where the voltage to drive the earth fault will only be 10-20% of rated, hence the current will be 10-20% of resistor let-thru rating. The trip setting should be equal to or higher than the system charging current to avoid nuisance tripping of unfaulted feeders, whose earth fault sensors will sense each of their own feeder's contribution to system charging current during earth faults elsewhere in the system. So if the system charging current on a 15kV system is 15A, then the minimum earth fault pickup setting could be 20 A, say, using a core-balance CT and sensitive earth fault relay. Then the resistor should be 10 times this, or 200 A.

To protect delta-connected transformers, the minimum fault current for a delta winding is 50%, because no matter where the earth fault is located in the winding, it will always be between 50-100% of the line-neutral voltage, hence the earth fault current will be at least 50% of resistor let-through current. Therefore, an earth fault pickup setting of 20-50% is acceptable. For selectivity, earth fault pickup settings over the range 20-60% of resistor let-through-current on feeders is acceptable. For backup protection, earth fault pickup settings over the range 50-80% of resistor let-through current on the earthing resistor are acceptable.

For high-resistance grounding, neutral earthing resistors must be continuous duty rated. For low resistance grounding, neutral earthing resistors are rated for 10 seconds duty. Earth faults are tripped off-line between 100 ms to 1 sec. On parallel generators, use a single neutral earthing resistor connected to the paralleling bus through a zig-zag earthing transformer.

GROUNDING FOR CO-GENERATION IN 13,8KV

Q. I would like to know about the concept of grounding for generators in 13,2 or 13,8 KV; in this case should the practice be neutral resistance rounding system, or may it be solidly grounded? The IEEE Std. 142-1991, the Green Book, "Recommended Practice for Grounding of Industrial and Commercial Power Systems," gives some information about this case; is this the formal and the final position?

A. Medium voltage industrial generators should be low-resistance grounded, not solidly grounded. See section 1.8 of in the IEEE Green Book (Std. 142-1991) for a good discussion of generator grounding. Another good source for medium voltage generator grounding and protection is Section 12.4 of the IEEE Buff Book, Std. 242-2001, and "Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems". Solidly grounded generators typically experience 20-50% higher fault current under ground faults than under three-phase faults.

The same is not true for transformers. Yet generators are normally braced only to withstand three-phase bolted faults, not ground faults. Generators should not be solidly grounded unless they are rated for solid grounding duty, regardless of voltage level. Medium voltage generators are quite expensive and have a long delivery time; their loads are always 3-wire, hence lending them to resistance grounding. To limit ground fault current, they are usually low-resistance grounded with a neutral grounding resistor rated 200-400 A, 10 seconds, avoid stator iron burning damage during a stator ground fault in a generator, a new technique of MV generator protection, called Hybrid Grounding, has been developed recently. In addition to the 200-400 A NGR, a 10-A continuous-duty NGR is connected to the generator neutral. Upon generator ground fault, the affected generator is immediately tripped off-line from the large NGR; the stored magnetic energy within the generator is safely discharged through the 10-A NGR without damaging the stator. This ground fault scheme requires a 51N ground fault relay on each feeder, and an 87GD directional ground differential relay on the generator. The 87GD relay distinguishes between internal and external ground faults. For external ground faults, the 51N feeder relay selectively trips the faulted feeder. For internal ground faults, the 87GD relay trips the faulted generator offline. Backup ground fault protection is provided with a 51G relay on the large NGR, coordinated to allow the primary 87GD and 51N relays to trip first. A failure of the primary relay causes the NGR 51G relay to trip the generator(s) off-line, de-energizing the distribution system.

For more details of the hybrid grounding scheme, refer to the following four-part article: IEEE Transactions on Industry Applications, Jan/Feb 2004, Vol. 40, No. 1, "Ground and Ground Fault Protection of Multiple Generator Installations on Medium-Voltage Industrial and Commercial Power Systems," by Prafulla Pillai et al.

HARMONICS

Q. How are harmonics produced in the HT system inside a plant? We use convertors and rectifiers on LT side only. How do these harmonics interact with the HT motors?

A. HT and LT stand for high-tension and low-tension, also known as medium-voltage (MV) and low-voltage (LV), respectively. Typically deltawye transformers provide power to the LV system from the MV system. Triplen harmonic currents on the LV side get trapped in the delta winding (at least the balanced portion of the triplen harmonics do) and do not flow in the MV side. Non-triplen harmonic currents (5th, 7th, 11th, 13th, etc) pass right through the transformers and flow in the MV side. These can interact with the MV motors in two ways: If there are power-factor-correction capacitors on the motors, then the harmonic currents can be attracted to the capacitors instead of the utility source.

Harmonic resonance can occur and the power factor correction capacitors can overheat, degrade, and lose their capacitance over time. Or, excessive harmonic currents can cause excessive harmonic voltage distortion through the impedance of the MV distribution system, causing the motors to overheat. This does not always occur, but when it does, solutions include adding harmonic filters at the main LV switchboards to keep the non-triplen harmonics from getting onto the MV system; using "anti-resonant" power factor correction capacitors, which have de-tuning reactors to prevent harmonic resonance between the capacitors and the power source impedance.

HIGH RESISTANCE GROUNDING

Q. Transient over-voltages on ungrounded electrical systems due to intermittent ground fault exist. The high resistance grounding reduces the potential overvoltage significantly. What about surge suppressors? Do they protect a medium voltage system from the over-voltage? Do they protect the system with high-resistance grounding when the grounding resistance is not selected correctly and a capacitive charging current is several times higher than the resistor current?

A. The transient over-voltage caused by intermittent ground fault on ungrounded system is due to the distributed capacitances to ground on the three phases. The magnitude can be 5 to 6 times phase to phase voltage. The neutral grounding resistor allows this charge to be dissipated and holds the neutral above ground at phase-to-neutral voltage thus allowing the voltage to ground on the unfaulted phases in order to increase from phase-to-neutral value to phase-to-phase value and this will exist continuously as long as the fault is present. So, there is no overvoltage beyond the phase-to-phase voltage magnitude. However, very short duration transients can still occur and exist on the three phases such as those caused by the lightning strikes and switching.

Surge suppressors are normally intended to clip and absorb very short duration (millisecond to microseconds) transient over-voltages such as those caused by lightning strike and switching. They cannot handle continuous excessive voltage. Their clipping voltage is also quite high. It could be more than 1.5 X the normal steady state peak voltage. So when TVSS's are applied on HRG systems they need to be rated for line-to-line voltage. They will then clip transients above their continuous rating.

NER ON MEDIUM VOLTAGE SYSTEMS

Q. This is related to sizing of a neutral earthing resistor for 33kV system. The main power transformer rating is 132/33kV, 25/31.5MVA YNd1. To introduce system earthing in 33kV side, an earthing transformer is introduced. Rating of the earthing transformer is 33/0.433kV, 315kVA, ZNy11. To have resistance-grounded earthing, NER is introduced in the neutral path of earthing transformer. We would like to restrict the earth fault current to 550A. The question is, while determining the resistance value of NER, should we consider total impedance in the circuit from source right up to the fault point in 33kV system. What will be the impact if we neglect the zero sequence impedance of power transformer and earthing transformer?

A. Yes, the total ground fault current is dependent upon lineto-neutral voltage and impedance of entire return path, which includes everything you mentioned. Experience shows that at medium voltage (and within an industrial setting), the voltage across the earthing resistor quickly rises to line-to-neutral voltage, indicating that the impedance of the return path and transformers are relatively small compared to impedance of earthing resistor. So yes, it should be considered but rarely does it have a large impact.

MULTIPLE TRANSFORMERS 415-7.5V

Q. I am currently faced with a delta-wired three-phase motor and need to connect a digital circuit to display the temperature of the windings. I have a display unit that runs off 240V mains fine but i only have access to the three actives (415V in Australia) and want to use a transformer to bring the voltage from 415 - 240V. Would this be safe considering there is no neutral in this setup? I have connected the "neutral" of the secondary winding of the 240-7.5V transformer to ground to ensure it is grounded properly. Is this safe, or will I get earthing problems and trip circuit breakers etc?

A. It is perfectly safe to connect a single-phase, double-wound isolation transformer rated 415V primary, 240V secondary, across two of the phases of the 415V delta power source. The secondary may be earthed as you have done (that is the preferred practice).

HYBRID GROUNDING

Q. For the Hybrid method, what equipment do you use to open the low resistance grounding resistor?

A. You can use a single pole vacuum contactor. We have seen these rated 15kV., 200A

SELECTION CRITERIA FOR MEDIUM-VOLTAGE NGR

Q. . I am sizing an NGR for a 132kV/11kV, Dyn11 40 MVA transformer. The biggest motor connected in the 11 kV system is 5.3MW slip-ring motor and the smallest one is 300kW. I am looking for a low resistance earthing system. What should be the current limiting value for the NGR? How it is arrived at? What are the criteria?

A. I recommend using low-resistance grounding (LRG) due to the voltage and capacity. At 11kV and 40MVA, the capacity (MVA) indicates the system is large (in terms of total length of all of the feeder cables, which are typically the greatest contributor to system capacitive charging current) and the voltage induces higher amounts of system capacitive charging current. The next largest contributor to system capacitive charging current is surge arrestors/capacitors on generators.

I would recommend 200A as this is becoming the industry standard. The NGR is determined by taking the line-to-neutral voltage (11kV/1.73 = 6.36kV) divided by desired current (200A) to get ohms (31.8ohms). Most people only allow the fault to be on the system for 10 seconds or less. So, the NGR would be rated for 200A / 10 seconds. Just make sure that the protective relaying scheme clears the fault within 10 seconds.

In general, lower the fault current; lower is the damage at the fault. Therefore, it is desirable to keep the fault current as low as possible. If MV motors are being protected then keeping the fault current low also helps in lowering the damage to the laminations at the fault point in the event of a fault in the stator winding. In wye connected motor windings the driving voltage for the ground fault reduces as the fault location moves closer to the star point hence ground fault relay must be set sensitive enough to detect the fault.

400KV/220KV INTERCONNECTING TRANSFORMERS

Q. In our project, we have three generators (11kV).The neutral of these generator are grounded separately thru NGR. These generators can run in parallel. Our client requires a means of disconnecting be fitted in the neutral earthing connection at each generator, so that generators may be disconnected for maintenance. My question is do we really require these disconnect switches? If we do not install these switches, what problems can we face?

A. If the neutrals are connected together and then run through a common NGR, then yes. A disconnect switch is required as the common neutral bus voltage rise with respect to ground during a ground-fault. This voltage could and will back feed into the generator windings. If each generator has its own NGR, then I would suggest that a disconnect switch is not needed. With the generator's MCB open, an open circuit is created. There is no potential rise. If your client still wants a disconnect switch, then I would install one on the ground side (save money by using a 600V disc SW) of the NGR and ONLY open when generator MCB is open.

ZIGZAG GROUNDING TRANSFORMER

Q. I have an application where I have a 75KVA dry-type lighting isolation transformer 480V three-phase delta to 480V three phase delta. The owner does not like the ungrounded delta since there is no reference to ground for lighting ground faults and wants a ground reference established in order to ensure a blown lighting fuse when a ground fault occurs. All the lighting is 480V single-phase with fuses in the fixtures. Rather than replace the transformer, I though it would be cheaper to install a 3kVA zigzag grounding transformer, three-phase grounded wye without a secondary and attach it to the delta secondary of the 75kVA transformer. This would in essence establish a ground and give lighting ground faults a direct path back to the source. I have found literature on these type of zigzag grounding transformers but I cannot find anyone who can sell me one in the 3kVA size range. Can you help? And to your knowledge is this a reasonable application?

A. I have seen 277V lighting applied on 277/480V three-phase four-wire systems and 347V lighting applied on 347V/600V three-phase four-wire system. Assuming that lighting is actually 480V, to blow a fuse on ground fault you will need substantial ground current, above 6-10 X fuse rating. 3kVA zigzag is a possible option if it can provide sufficient ground current to open the fuse. Two possible suppliers are Hammond and Rex Transformers.

Delta connected windings are often used so that nothing needs to be tripped on the first phase to ground fault. A small continuously rated zigzag with up to 5A grounding resistor will provide stability and allow ground current to flow which can be detected by ground fault relays. An alarm is raised indicating a ground fault. While nothing is tripped. The fixtures are connected to ground through the ground wire which carries the ground current continuously and keeps them safe to touch.

UNPARALLELED PROTECTION

A combination of NGR monitor and ground fault relay, it provides adjustable pick up level and adjustable definite time delay for the ground current. In resistance grounded systems, the neutral grounding resistor is constantly monitored to ensure that the 3-phase 3-wire distribution system remains fault free. The I-Gard SIGMA is designed for use on any resistance grounded system that requires continuous monitoring of the neutral grounding resistor. A separately mounted sensor measures the ground current and the voltage across the NGR.

Q. Is this an issue on smaller 12470 volt generator sets that are solidly grounded? We have several hospitals that have three 12470 volt generator sets (1.5 to 2.5MW) that can be paralleled with the utility.

A. This is very much an issue when you want to protect any kind of bus connected medium voltage generators. As stated in the presentation, “Most medium voltage generators are not rated to withstand a single phase to ground faults. “ The insurance companies requested IEEE to specifically look at why the normal mode of protection was not adequately protecting the generators. This is why the Hybrid system was developed.

Q. Can existing be upgraded?

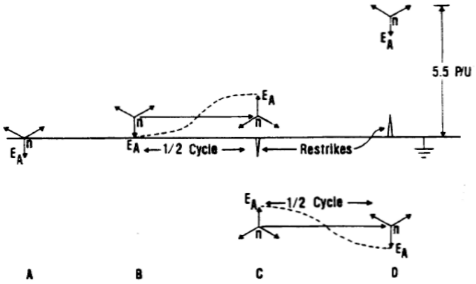
A. All generators can be upgraded. This upgrade can be very simple or very complexdue to existing infrastructure.

Q. You mention voltage escalating quickly at medium voltages and large systems (you said 4160, 13.8kV). What about a system of 2.4kV with 16 2-4MW generators in parallel, no utility? Would you still recommend LRG and HRG (hybrid)?

A. Voltage escalation is a threat in ungrounded systems and in poorly designed high-resistance grounded systems. As you can see from the figure below the voltage tends to escalate with every arcing fault. When a fault occurs within the stator winding of a generator, the arcing phenomena is very apparent. The problem is with the system capacitance. All electrical systems contain to component of distributed capacitance. The capacitance in the in the system charges with every restriking arc that occurs.

Q. How do you sell additional cost to the Layman who only wants to look at first cost issues? Can the Hybrid be installed in Phases over time?

A. The Layman will not be involved in determining whether or not the hybrid grounding system is applicable or affordable. This system will be used to protect generators that are of significant capital expense and will be protected with that capital cost in mind. The hybrid high-resistance grounding system is more expensive than the standard high-resistance grounding system and low-resistance grounding system. The important thing to keep in mind is that the hybrid high-resistance grounded system protects the generator at all times. The conventional low-resistance grounded system failed to adequately protect the generator.



Q. In industries, generators are normally running on essential power only. Do we still need to go for hybrid grounding, to protect it from the ground fault current?

A. Yes, The Hybrid grounding system is needed to protect the generator and electrical distribution system.

Q. I am still not sure what the purpose of hybrid is, why not just the HRG, why should we add LRG under normal circumstances?

A. The high-resistance grounding system will work under certain circumstances. Resistor will have to be designed to limit the ground fault current to a value that is larger than the system capacitive charging current. In large distribution system at medium voltage, the capacitive charging current will be too high. If the capacitive charging current is low enough and you have the necessary equipment to detect and isolate the faulted feeder in a reasonable manner, then the high-resistance grounding system will work.

Q. What will happen, if we use four-pole CB on transformer & generator on both?

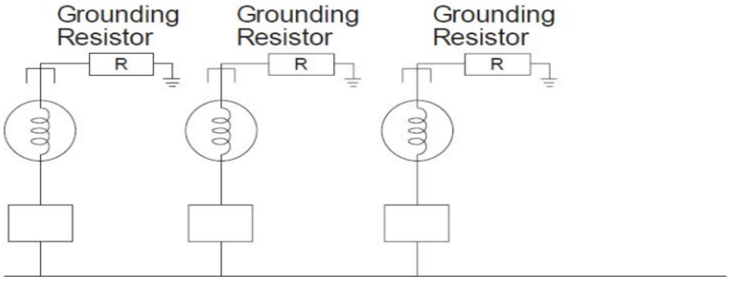
A. Four Pole breakers are used in solidly grounded systems and not in high or low-resistance grounded systems. The neutral is not distributed in these kinds of systems. If the 4th pole is used to isolate the resistor from the neutral, then the generator will be left in an ungrounded state and other problems will arise from that scenario.

Q. What size generators would benefit from the hybrid approach?

A. The Hybrid high-resistance grounding approach will work on all bus connected medium voltage generators. These generators are normally vital to the operation of a plant. The size of the generator is not that important.

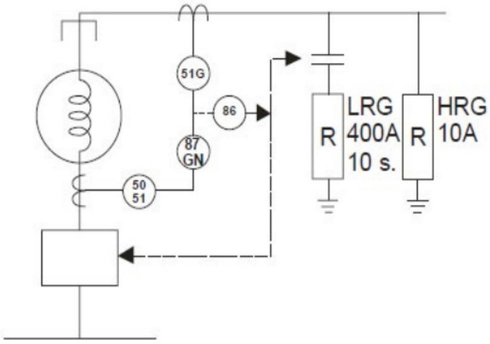
Q. What is the disadvantage of using low resistance neutral grounding (400A) for each of three 2500kW, 4.16kV generators operating in parallel?

A. When a ground fault occurs there will be 1200 A. flowing in the ground fault, 400 A though each resistor. This will occur no matter where the fault occurs. So if the ground fault occurs in the Stator winding, then the fault will remain in the generator even when the generator is off line, with 400 A. damaging the iron in the stator. The fault current has reduced from 1200 to 400 because the other 2 generators are electrically isolated from the fault. The Resistor connected to the generator that is faulted is still connected and completing the circuit. This is the damage we prevent with the Hybrid high-resistance grounded system.



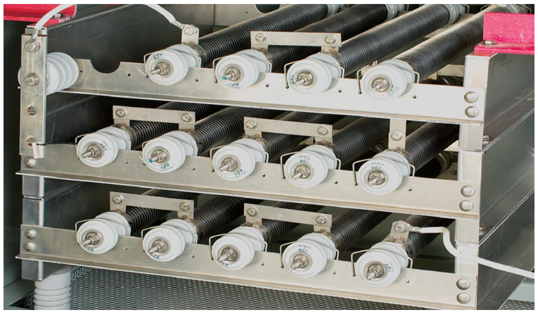
Q. How the overcurrent protective devices could be set to be adequate for systems that have both low resistance and high resistance grounded sources?

A. In a hybrid high-resistance grounded application the protective devices for the system are designed to be adequate with the low resistance grounded system. The presence of the high-resistance grounded system is only used to protect the generator should a fault occur within the stator winding. This condition is detected with the bus differential relay monitoring the generator and switching the grounding from low-resistance to high-resistance. All through faults are treated as low resistance faults.



Q. What is the physical size of the Hybrid in comparison to the HRG? Can it be installed indoors?

A. The Hybrid is a little larger than a low-resistance d system and much larger than a high-resistance system. It is difficult to compare sizes as the high-resistance may or may not be adequate for the purpose and a low-resistance will cause too much damage



HRG systems are the safest and least expensive system available today. IEEE supports this by saying, “A safety hazard exists for solidly grounded systems from the severe flash, arc burning, and blast hazard from any phase-to-ground fault.” (IEEE Std. 141-1993, The Red Book).

Ungrounded systems may experience damaging transient over-voltages and lack the ability to locate ground-faults, presenting another danger to personnel.

Please remember that in HRG systems, the neutral cannot be distributed. So, if you have loads requiring 277V, a small isolation transformer can be added to serve the 277V panel. The cost savings in not distributing the neutral, smaller ground wires, and no GF feature in the MCB will more than pay for the isolation transformer.

In summary, HRG saves money by using less copper (very expensive now-a-days) and makes systems safer by eliminating hazards mentioned above.

Q. I want to ask about the generator grounding point and why we use it?

A. IEEE Std. 142-1991 (Green Book- Recommended Practice for Grounding of Industrial and Commercial Power Systems) Section 1.4.2 states, “Numerous advantages are attributed to grounded systems, including greater safety, freedom from excessive system overvoltages that can occur on ungrounded systems during arcing, resonant or near-resonant ground-faults, and easier detection and location of ground faults when they do occur.”

OK, now that we have established why you need to ground the neutral, let’s discuss how to ground the neutral. If you effectively ground the neutral, you have just replaced the hazards with ungrounded systems with new hazards in the form of arc flash / blast hazards associated with solidly grounded systems.

IEEE Std. 141-1993 (Red Book- Recommended Practice for Grounding Industrial and Commercial Power Systems) Section 7.2.4 states, “A safety hazard exists for solidly grounded systems from the severe flash, arc burning, and blast hazard from any phase-to-ground fault.” For this reason, IEEE recommends resistance grounding.

IEEE Std. 142-1991 (Green Book) Section 1.4.3 states, “The reasons for limiting the current by resistance grounding may be one or more of the following:

1) To reduce burning and melting effects in faulted electric equipment, such as switchgear, transformers, cables, and rotating machines.
2) To reduce mechanical stresses in circuits and apparatus carrying fault currents.
3) To reduce electric-shock hazards to personnel caused by stray ground-fault currents in the ground return path.
4) To reduce the arc blast or flash hazard to personnel who may have accidentally caused or who happen to be in close proximity to the ground-fault.
5) To reduce the momentary line-voltage dip occasioned by the clearing of a ground-fault.
6) To secure control of transient over-voltages while at the same time avoiding the shutdown of a faulty circuit on the occurrence of the first ground-fault (high-resistance grounding).”

IEEE Std 141-1993 (Red Book) Section 7.2.2 states, “There is no arc flash hazard, as there is with solidly grounded systems, since the fault current is limited to approximately 5A.” As you can see, it is best to not only ground the neutral, but ground through high-resistance (typically 5A) for all systems < 600V and most systems > 600V to 5kV. For systems > 5kV, low-resistance grounding (typically 200A or 400A) is used.

Just a quick note about resonance grounding: resistance grounding is preferred in the US mostly due to economics and complexity. Resistance grounding is a passive device that performs independent of system topology and frequency, whereas resonance grounding must adapt to system capacitance. Resonance grounding uses an inductor to create an impedance to match the system capacitance impedance. In doing so, both components cancel and the result is a small resistive ground-fault current.

Disadvantages of resonance grounding: 1) Typically the inductance is slightly larger to avoid a true resonance condition (if not, an overvoltage condition will occur) 2) System capacitance continually changes as feeders are brought on- and off-line (so monitoring system must be installed and inductor must be variable) 3) Cost for monitoring and inductor variability are high 4) Physical size of inductor is significantly larger than resistor. Resistance grounding offers a fixed ground-fault current independent of system topology. However, the fixed current must be larger than the system capacitive charging current. So, a value of 200-400 is usually selected.

NEUTRAL GROUND RESISTOR VALUE FOR A POWER STATION

Q. We are in the process of installing a 3x5.5MW,11KV, 50hz gas turbine generator. The star point of the alternator is to be grounded via a neutral ground resistor (NGR). Can you determine the value of the resistor and the ratio of the neutral current transformer?

A. I recommend using low-resistance grounding (LRG) due to the voltage and capacity. At 11kV and 3 x 5.5MVA, the capacity (MVA) indicates the system is large (in terms of total length of all of the feeder cables, which are typically the greatest contributor to system capacitive charging current) and the voltage induces higher amounts of system capacitive charging current. The next largest contributor to system capacitive charging current is surge arrestors.

If this is a unit-connected generator, then I would recommend high-resistance grounded (10A-15A) to minimize fault damage only if there is very limited number of small feeders (resulting in a low system capacitive charging current).

I would recommend 200A as this is becoming the industry standard. The NGR is determined by taking the line-to-neutral voltage (11kV/ 1.73 = 6.36kV) divided by desired current (200A) to get ohms (31.8ohms). Most people only allow the fault to be on the system for 10 seconds or less. So, the NGR would be rated for 200A /10 seconds. Just make sure that the protective relaying scheme clears the fault within 10 seconds. You can either use a 200:5 or a 100:5 ratio CT.

In general, the lower the fault current, the lower is the damage at the fault. Therefore, it is desirable to keep the fault current as low as possible. If MV motors are being protected then keeping the fault current low also helps in lowering the damage to the laminations at the fault point in the event of a fault in the stator winding. In wye connected motor windings, the driving voltage for the ground-fault reduces as the fault location moves closer to the star point, hence, ground-fault relay must be set sensitive enough to detect the fault and sufficient amount of current must flow. This will also dictate how low you can go with the resistor let-through current.

GENERATOR SYSTEM GROUND CONNECTION

Q. I have a 750kW generator set in an industrial plant. My question is should I ground the neutral conductor at the generator terminals? If so, how should I size the GEC? I've heard sometimes this case is not considered a separately derived system, and the neutral should not be grounded.

A. Low-voltage generators should only be solidly grounded if the loads they feed are four-wire loads and must have a neutral. Generators that feed three-wire loads do not need to be solidly grounded. Instead they should be high-resistance grounded to limit ground-fault current. Generators are not braced for the ground fault current that can occur when solidly grounded. Generators have a higher ground fault current than three-phase fault current. Transformers do not experience this phenomenon.

At any rate, assuming you must solidly ground the generator neutral for your application, here are your rules:

1. If the automatic transfer switch (ATS) is three-pole type with a sold neutral terminal, then you must not ground the generator neutral at the generator; instead you must connect the generator neutral to the neutral terminal of the ATS, which is in turn connected to the neutral of the normal power source transformer. The neutral of the transformer will be solidly grounded at the transformer, and this will also be the grounding point for the neutral of your generator. When you have a three-pole ATS with a solid neutral, your four-wire generator is not a separately-derived source.
2. If your ATS is either a three-pole with an overlapping neutral type, or a four-pole type, then your generator will be a separatelyderived source. In this case, the neutrals of the transformer and generator will not be connected together, and you must ground the generator neutral at the generator.
3. If your ATS is a three-pole only with no neutral terminal and your load is three-wire, then your generator is a separately-derived source and you can ground the neutral at the generator. However, as above, standards such as NEMA MG 1-2003 Motors and Generators (Section 32.34), and the IEEE Green Book on grounding IEEE Std. 142 (Section 1.8), recommend that generators not be solidly grounded unless they are rated for such duty (which they rarely are).

Gemini

- Dual path current limiting resistor
- Redundant fail-safe resistor circuit
- Integral ground fault relay
- Integral ground monitoring relay
- Fault location through pulsing
- Harmonic filter and time / current adjustments to reduce false trips

STANDARD

DSP-OHMNi

- Monitors and protects up to 50 feeders on one relay
- 1st Fault Alarm, 1st Fault Trip or 1st Fault Time Delay Trip
- Resistor Monitoring Module
- Selective Instantaneous Feeder Trip on 2nd ground fault

STANDARD

Sentinel

- Current limiting resistor
- Voltage and current sensing
- Integral ground fault relay
- Integral ground monitoring relay
- Fault location through pulsing
- Harmonic filter and time / current adjustments to reduce false trips
- Inrush detection restraint
- Multi-feeder protection
- Second fault protection
- MODBUS for remote monitoring

PREMIUM

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HRG reduces the frequency of arc flash incidents and optical detection reducing impact, all in one.

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