1. INTRODUCTION
The use of solid grounding for UPS-supplied power systems is currently a common practice in data centers. The use of conventional ground fault protection systems in this application often leads to circulating currents and nuisance tripping, resulting in the desire to defeat or exclude ground-fault protection altogether. This paper explores the nature of circulating currents in UPS-supplied power systems when solid system grounding is employed and the use of modified-differential ground fault protection to eliminate the effects of these circulating currents. In addition, the alternative of high-resistance grounding for this application is discussed, along with its advantages and disadvantages.

2. BACKGROUND

2.1. System Grounding Arrangements
There are three basic arrangements for system grounding: Solidly-Grounded, Ungrounded, and Impedance-Grounded. In a solidly-grounded system, there is an intentional connection to ground, providing a stable line-to-ground voltage reference. In an ungrounded system, there is no intentional connection to ground, and therefore no stable line-to-ground voltage reference. In an impedance-grounded system, there is a connection to ground through an impedance, providing characteristics which resemble both the solidly-grounded and ungrounded arrangements depending upon size and nature (resistive or inductive) of the impedance. Of the impedance-grounded systems, the High-Resistance Grounded (HRG) arrangement is the most popular for low-voltage systems. In the HRG arrangement, the system is grounded through a high resistance that typically limits the current to 1-10A.

Many references exist in the literature describing the principles of operation of these system grounding arrangements. A small selection of these is given in the references section below (see [1], [2]). The reader is encouraged to consult these references for more detailed information on the fundamentals of system grounding and the general advantages and disadvantages of each arrangement. For purposes of the discussion herein, the two grounding arrangements under consideration are the solidly-grounded and HRG arrangements. Table I gives a comparison of the distinguishing characteristics of solid- vs. HRG grounding arrangements in three-phase systems. To succinctly summarize these:

- The solidly-grounded system is the easiest to apply, as 4-wire loads are supported and the line-to-ground voltage is inherently stable. However, it has the disadvantage of high ground-fault currents and the need to trip when a ground fault occurs.
- The HRG system is harder to apply due to fact that the line-to-ground voltage can vary, and the resistance value should be chosen carefully to avoid transient line-to-ground overvoltages greater than ~2.5 pu. Utilization equipment must also be carefully chosen to insure that it can operate without damage on this type of system. However, it has the advantage of low ground-fault currents and the ability to run continuously should a ground fault occur, allowing location of the fault while the system is still energized.

In practice, both types of systems exist in critical power applications where UPS’s are employed, and both arrangements, if the system is designed properly, will function satisfactorily.
TABLE I.
CHARACTERISTICS OF THREE-PHASE SOLIDLY-GROUNDED AND HRG SYSTEMS

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Solidly-Grounded</th>
<th>HRG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Support for single-phase loads</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Stability of phase-to-ground voltages</td>
<td>Good – due to direct reference to ground. Phase-to-ground voltage is always 57.7% of phase-to-phase voltage</td>
<td>Good, but depends upon proper selection of resistor size in relation to the system charging current. Nominal phase-to-ground voltage is 57.7% of phase-to-phase voltage. With properly selected resistor, maximum transient line-to-ground voltage is typically ~2 – 2.5 x nominal. Maximum steady-state phase-to-ground voltage during a single ground fault is 173% of nominal.</td>
</tr>
<tr>
<td>Ground-fault current level</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Ground Fault Trip Required</td>
<td>Yes</td>
<td>No – single ground-fault can be maintained indefinitely</td>
</tr>
<tr>
<td>Ground detection</td>
<td>Via Tripping</td>
<td>Via Pulsing System that allows location of a single ground-fault</td>
</tr>
<tr>
<td>Use of TVSS</td>
<td>Yes – all modes of protection</td>
<td>Yes, but only with phase-to-phase protection modes. Suitable TVSS’s not available from all manufacturers.</td>
</tr>
</tbody>
</table>

For solidly-grounded systems, equipment protection for ground faults can be provided, and are mandated by the NEC [3] in several situations. The intent of this document is not to discuss where the NEC requires ground-fault protection; the NEC and the local Authority Having Jurisdiction should be consulted in this matter. For HRG systems, ground-fault protection is not required, however the NEC mandates ground-fault detection, which is easily achievable with this type of system.

2.2. The Parallel-Redundant UPS Arrangement

UPS’s are typically used in parallel-redundant arrangements in large data centers, in order to support the necessary system capacity and reliability. One version of this arrangement is as shown in Fig. 1. In Fig. 1, the UPS modules each consist of a rectifier that converts the incoming AC voltage to DC, a DC bus with connection to a stored energy source, an inverter that converts the DC bus voltage to controlled AC, and a delta-wye connected output transformer. Any circuit breakers contained within the UPS modules themselves are omitted for clarity. Circuit breaker CB-F represents the feeder circuit breaker immediately upstream of the UPS system. CB-1 and CB-1A provide power to their respective UPS rectifiers, and CB-2 and CB-2A connect their respective UPS output transformers to the rest of the system. CB-3 serves to connect the UPS output bus to the rest of the system. The static switch, in conjunction with CB-4, CB-5, and CB-6, allows rapid automatic wrap-around bypass of the UPS modules in the event of a module failure, overload, or fault condition, in order to maintain continuity of power to the load. CB-6 allows isolation of the static switch for maintenance. CB-7, CB-8, and CB-9 allow isolation of the UPS output bus from the loads for testing or maintenance, with wrap-around bypass to maintain continuity of power to the load while the UPS system is out of service. While only two UPS units are shown, configurations with more than two units are common and all of the information herein applies to those larger configurations also.

It should be noted that the secondary neutral connections for the UPS output transformers are not shown in Fig. 1. The performance of this system with different system grounding arrangements will be discussed herein.
2.3. Circulating Currents in Solidly-Grounded Systems

One key to understanding the performance of the system of Fig. 1 when the system is solidly-grounded is understanding that circulating currents can exist on paralleled solidly-grounded systems. Conceptually, this can be illustrated as shown in Fig. 2. In Fig. 2, two voltages from different sources are connected by an impedance. If the voltages are different, there will be a circulating current \( I_c \) which is equal to the difference between the voltages divided by the impedance between them. Note that the voltages and impedance are shown in phasor (vector) form; it is sufficient for either the magnitudes or phase angles, or both, to be different in order to cause the circulating current to flow. Further, if harmonic voltages are present on either source, these may contribute to the circulating current.

A three-phase representation of this for two 4-wire solidly-grounded wye systems is shown in Fig. 3. In Fig. 3, \( Z_p \) represents the phase impedance between the two sources, \( Z_N \) represents the neutral impedance, and \( Z_{G1} \) and \( Z_{G2} \) represent the ground impedances from the grounding points sources 1 and 2, respectively, to the “true” ground reference (including the equipment grounding conductors between the two sources). It can be shown that if there are magnitude or phase differences between the two source voltages that circulating currents will exist in each.
phase, the neutral, and the system grounding infrastructure, denoted here as $I_{ca}$, $I_{cb}$, $I_{cc}$, $I_{cn}$ and $I_{cg}$.

![Fig. 2 Conceptual Representation of Circulating Current](image_url)

![Fig. 3 Three-Phase Conceptual Representation of Circulating Currents for Solidly-Grounded Wye 4-Wire Systems](image_url)
If only three-wire loads are served, the neutral conductor is not required. Fig. 4 is a representation of the circulating currents that will exist on 3-wire solidly-grounded wye system without the neutral conductor, should there be a difference in voltage magnitude or phase (or difference in harmonic content) between the two sources. It should be noted here the parallel path between the neutral and equipment grounding system no longer exists, and circulating current flows on the ground path.

![Diagram of circulating currents in a 3-wire solidly-grounded wye system without neutral conductor.]

**Fig. 4** Three-Phase Conceptual Representation of Circulating Currents for Solidly-Grounded Wye 3-Wire Systems

In Fig. 5, the same representation is applied to two high-resistance grounded systems. There is a major difference in performance, however: The neutral ground resistors, which are each on the order of 250 times the other impedances shown, serve to limit the circulating currents in the ground path to a very low level.

A key to understanding the behavior of the system of Fig. 3 is that the sum of the circulating currents flowing into or out of either source is zero. Stated mathematically,

$$I_{ca} + I_{cb} + I_{cc} + I_{cn} + I_{cg} = 0 \quad \text{(Fig. 3 only)} \quad (1)$$

Take one of these currents away, and the sum is not zero, i.e.,

$$I_{ca} + I_{cb} + I_{cc} + I_{cn} \neq 0 \quad \text{(Fig. 3 only)} \quad (2)$$
Similarly, for Fig. 4 and Fig. 5:

\[ I_{ca} + I_{cb} + I_{cc} + I_{og} = 0 \]  \hspace{1cm} (3)

\[ I_{ca} + I_{cb} + I_{cc} \neq 0 \]  \hspace{1cm} (4)

This concept is vital to understanding the impact of circulating currents on conventional ground-fault detection systems.

2.4. Effect of Circulating Currents on Conventional Ground-Fault Detection Systems

Conventional, also known as radial, ground-fault detection methods for 4-wire systems generally consist of one of the schemes shown in Fig. 6. In Fig. 6 a.) four individual current sensors are used, and in Fig. 6 b.) a single zero-sequence current sensor is used. The goal of both arrangements is to produce a current that is equal to the sum of the phase currents plus the neutral current, which is assumed to the current which flows due to a ground fault. This current is used to provide fast tripping due to the ground fault. The device “GF” represents the ground-fault protective device, which can be the ground-fault function of an electronic circuit breaker or a dedicated ground-fault relay.
Fig. 6  Radial Ground-Fault Detection Schemes: a.) Individual Current Sensors b.) Zero-Sequence Current Sensor

Under many conditions this arrangement works quite well. However, if multiple source grounds exist, as shown in Fig. 3, this arrangement is not generally acceptable. To illustrate this, in Fig. 7 the circulating currents of Fig. 3 have been applied. If no ground fault is present, the current through the ground-fault protective device should be zero. However, from eq. (2) above it is not! The result is that the circulating currents “look” like a ground fault to the ground fault protection scheme, and if the resulting current seen by the ground-fault protective device exceeds the ground-fault pickup level, the device will trip.

Fig. 7  Radial Ground-Fault Detection Schemes of Fig. 6 with the circulating currents of Fig. 3 applied
Such nuisance tripping is not restricted to 4-wire systems. It can be shown that the 3-wire system of Fig. 4 is also susceptible. Ground-fault detection for this arrangement would not have a neutral sensor since no neutral exists, however this does not eliminate the problem.

For the HRG arrangement of Fig. 5, it has already been stated that the neutral ground resistors significantly reduce the level of the circulating currents in the ground path. Ground fault detection, rather than tripping, is used with HRG systems, and for this reason the low level of circulating currents that can exist on such systems are generally not an issue when HRG is used.

Do 4-pole devices solve the issue of circulating currents in power systems with multiple sources and multiple grounds? Because they separate the neutral the answer is “yes”, provided that the two sources are not paralleled. If the sources are paralleled, the effect of 4-pole devices is nullified. Thus, 4-pole devices are not a solution to the problem if sources with multiple grounds are paralleled.

The issues of ground-fault protection on multiply-grounded systems, including circulating currents and de-sensitization issues, are well-discussed in the literature (see [4], [5]). The reader is encouraged to refer to these sources for further information on this topic.

3. THE SOLIDLY-GROUNDED PARALLEL-REDUNDANT UPS SYSTEM ARRANGEMENT

3.1. Conditions for Circulating Currents

Solid system grounding is commonly employed on parallel-redundant UPS system arrangements such as the arrangement shown in Fig. 1. Three items must be noted regarding this arrangement:

1.) The UPS is designed so that its output “leads” the utility input by several electrical degrees. This is necessary to insure that when the UPS and utility are paralleled there is a net power flow is out of the UPS, which prevents damage to the UPS.

2.) The UPS output contains some level of harmonic content.

3.) The wrap-around bypass system, consisting of circuit breakers CB-4, CB-5, CB-6 and the static switch, may be called upon to parallel the utility source with the UPS in several different situations, such as overload of a UPS module or transfer of the UPS system to maintenance bypass mode.

Based upon the discussion above, conditions may therefore be present that force the existence of circulating currents, depending upon how the system is grounded.

3.2. Methods for Achieving Solid System Grounding

One method of achieving solid system grounding is as shown in Fig. 8. Here, the UPS internal details are not shown, and the utility/generator source is shown in a solidly-grounded wye configuration. The UPS output neutrals are connected to a common UPS neutral bus, which is grounded at a single point separate from the utility/generator source. In this configuration, the UPS output is a separately-derived system (note that the NEC definition of a separately-derived system requires that a separately-derived system have no direct connection, even the neutral, with the conductors in another system [3]).

In Fig. 9, the system is in bypass mode with CB-4 and the static switch closed. Such a condition would occur, for example, during automatic transfers to bypass mode due to UPS module overload. The connection between the utility/generator system ground and the UPS output system ground is shown in dotted lines, representing the equipment grounding conductors and grounding infrastructure connections between the two. The circulating current flows, which arise...
for the reasons outlined above, are shown, with $I_{cp}$ representing the sum of the A, B, and C phase circulating current flows. These divide into two parts, shown as $I_{cp1}$ and $I_{cp1A}$, at the two UPS’s, recombine at the UPS output neutral bus, and flow back to the utility/generator source over the grounding system. It can be seen that any ground-fault protection incorporated into CB-4 may experience a nuisance trip due to these circulating currents since the net sum of the phase and neutral currents sensed by the circuit breaker is not zero. The same applies to CB-F and any other circuit breakers upstream of it, which could result in a wider system outage.

Similarly, Fig. 10 shows the ground-fault current flows for a ground fault on the feeder circuit supplied by CB-10. The current $I_F$ represents the ground-fault current. It flows along the grounding system from the point of the fault and splits into two components: $I_{F1}$, which flows in the UPS output system, and $I_{F2}$, which flows to the utility/generator source. $I_{F1}$ further subdivides into $I_{F11}$ and $I_{F11A}$ at the UPS output neutral connections. $I_{F1}$ and $I_{F2}$ re-combine at the junction of the CB-3 and the static switch. In practice, a quantitative determination of just how much current flows in the UPS outputs ($I_{F1}$) vs. the utility/generator source ($I_{F2}$) is a function of the grounding system impedances and is generally not practical – any ratio between these two currents must be tolerated. It can be seen, then, that for this ground-fault scenario CB-10, if equipped with ground-fault protection, will trip, but CB-4, CB-6, CB-7, and CB-F (and any circuit breakers upstream from CB-F), if equipped with ground fault protection, may also trip since the sum of the phase and neutral currents sensed by these circuit breakers is not zero. A trip of any circuit breaker other than CB-10 would not be ideal. Indeed, if CB-F or circuit breakers upstream from it trip larger portions of the system could be subject to outage. It must be understood that the ground fault scenario of Fig. 10 is only one of several which must be considered.
Fig. 9  Circulating current flows for grounding arrangement of Fig. 8

Fig. 10  Ground fault current flows for ground fault as shown, grounding arrangement of Fig. 8
Clearly, the grounding arrangement of Fig. 8 not ideal, from the standpoint of the use of conventional radial ground-fault protection. One response to the ground-fault performance issues is to change the grounding system arrangement. One common arrangement, which is intended to reduce ground-fault nuisance tripping issues, is that of Fig. 11. In Fig. 11, the UPS output neutral bus is not separately grounded, but has a solid neutral connection back to the utility or standby generator system neutral. The UPS output in this arrangement, by definition, is not a separately-derived system.

The performance of the grounding arrangement of Fig. 11 when subjected to circulating currents is shown in Fig. 12. Here, it can be seen that circuit breakers equipped with ground-fault protection will not be sensitive to circulating current flow, since the neutral currents are such that the total current seen by the ground-fault protection on any circuit breaker is zero. So far, so good. However, consider the ground-fault depicted in Fig. 13. Here, the ground fault is located between circuit breakers CB-4 and CB-6. As can be seen, any ground-fault protection provided on CB-4 will sense the correct current (phase + neutral current = $I_{F1} + I_{F2} = I_F$) and trip. However, the fault is also supplied through CB-6, which will sense no ground-fault current (phase + neutral current = $I_{F1} - I_{F2} = 0$). Any ground-fault protection for CB-6 is therefore defeated for the fault location shown. Further, CB-F, and any other circuit breakers upstream from it, are subject to trip since the sum of the phase and neutral currents sensed by these circuit breakers is not equal to zero. As with the previous grounding arrangement, this is but one of many ground-fault scenarios which must be accommodated if ground-fault protection is supplied on the UPS system circuit breakers. Clearly, as with the previous arrangement, this arrangement is not optimal insofar as ground-fault protection is concerned, although it does have the advantage of desensitizing the ground-fault protection to circulating currents that occur during normal operating conditions.
System Grounding and Ground-Fault Protection Methods for UPS-Supplied Power Systems

![Diagram: Circulating current flows for grounding arrangement of Fig. 11]

**Fig. 12** Circulating current flows for grounding arrangement of Fig. 11

![Diagram: Ground fault current flows for ground fault as shown, grounding arrangement of Fig. 11]

**Fig. 13** Ground fault current flows for ground fault as shown, grounding arrangement of Fig. 11

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3.3. The Solution to the Ground-Fault Protection Problem

As stated previously, it is not the intent of this document to argue whether ground-fault protection is required for the UPS system output. It has been argued [4] that omitting such protection increases the risk of damage, increasing the mean time to repair (MTTR). However, even that argument is not the subject of this paper. The issue at hand is if the UPS system is solidly grounded, and if ground fault protection is desired (regardless of the justification), how can it be achieved?

The solution is a differential ground-fault protection scheme, popularly known as modified-differential ground-fault protection or MDGF. This type of ground-fault protection scheme divides the system into protective zones. Within each protective zone, the correct protective devices trip to isolate the ground-fault condition to the smallest possible part of the system. If properly designed, the MDGF scheme also makes the ground-fault protection immune to the effects of circulating currents. An example of the protective zones for such a scheme, as applied to the system of Fig. 8, is shown in Fig. 14:

![Diagram showing example MDGF protective zones for system of Fig. 8](image_url)

**Fig. 14 Example MDGF protective zones for system of Fig. 8**

In Fig. 14, the system has been divided into six protective zones. The devices that would trip for a ground fault in each zone are shown in Table II:

<table>
<thead>
<tr>
<th>Zone</th>
<th>CB-F</th>
<th>CB-2</th>
<th>CB-2A</th>
<th>CB-3</th>
<th>CB-4</th>
<th>CB-5</th>
<th>CB-6</th>
<th>CB-7</th>
<th>CB-8</th>
<th>CB-9</th>
<th>CB-10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
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<td>2</td>
<td></td>
<td>X</td>
<td>X</td>
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<tr>
<td>4</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td>X</td>
<td></td>
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<td></td>
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<tr>
<td>5</td>
<td></td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
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<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

TABLE II. DEVICES TO TRIP FOR A GROUND FAULT IN EACH PROTECTIVE ZONE OF FIG. 14
The protective zones shown give optimum isolation of a ground fault, i.e., the minimum part of the system is disturbed should a ground fault occur. Other arrangements are possible, depending upon the level of isolation desired. It should be noted that CB-1 and CB-1A do not appear in Table II; since there is no possibility of those two circuit breakers feeding a ground fault in the zones under consideration.

The hardware implementation of the MDGF scheme is generally accomplished with additional current sensors and auxiliary protection hardware that interfaces with the electronic circuit breaker trip units. For example, to accomplish the ground-fault protection for Zone 1 of Fig. 14, the arrangement of Fig. 15 would be used. Each of the current sensors shown represents either a zero-sequence current sensor or individual phase current sensors arranged similarly to Fig. 6. The devices “F”, “4”, and “8” represent the auxiliary protection hardware that interfaces with the electronic circuit breaker trip units for CB-F, CB-4, and CB-8, respectively. In practice, sensors are shared between zones, resulting in sensor interconnections that make the most effective use of the sensors.

More information regarding MDGF schemes may be found in the literature ([4], [5]). In practice, a custom design is often required to achieve the objectives above for the grounding arrangement desired. However, MDGF can usually be implemented in a cost-effective manner, allowing the use of ground-fault protection without the issue of nuisance tripping or de-sensitization.

Fig. 15 Arrangement for achieving MDGF protection of Zone 1 of Fig. 14
4. UTILIZING HRG WITH THE PARALLEL-REDUNDANT UPS ARRANGEMENT

4.1. Application of HRG to the Parallel-Redundant UPS Arrangement

One potential work-around to the issues which affect solidly-grounded system is to use HRG. Typical implementation of HRG to the parallel-redundant UPS arrangement is shown in Fig. 16:

![Fig. 16 Application of HRG to the parallel-redundant UPS arrangement](image)

In Fig. 16, the both the utility/generator source and the UPS outputs have HRG applied. This is to be expected, since the two could be paralleled via the static switch and CB-4, CB-5, and CB-6 as described previously; it is not desirable to parallel a solidly-grounded system with an HRG system. The UPS output neutral connections are brought to a common neutral bus in the output switchgear, where they are grounded through the HRG resistor. Ground-detection alarm and pulsing systems allow detection and location of ground faults, without the need to trip since the fault currents are at a very low level (1-10A).

The UPS output circuit breakers CB-2 and CB-2A are shown as 4-pole circuit breakers. The reason for this is that the voltage at neutral outputs during a ground-fault condition can have a voltage which is up to the nominal line-to-ground voltage (277V for a 480V system). Because a ground-fault condition can exist continuously on such a system, the neutral poles of these circuit breakers allow complete isolation of their respective UPS units for maintenance. Using 3-pole breakers would allow the exposure of maintenance personnel to hazardous voltage should a ground fault exist on the system.

As discussed previously, any circulating currents in the ground system which arise due to paralleling the UPS outputs with the utility or generator source are greatly reduced due to the ground resistors. Therefore, circulating ground currents during normal conditions are not normally a problem in these types of systems. Should a ground fault occur while the UPS output and the utility/generator sources are paralleled, the HRG resistors, because they are much larger...
than the other impedance elements in the ground path, cause the ground fault current to divide approximately equally between the two sources.

### 4.2. Is There a Down-Side to HRG?

Thus far, the description of the application of HRG to the parallel-redundant UPS arrangement has mentioned no negative aspects. In reality, there is no “perfect” solution and there are consequences to the use of HRG in this arrangement, namely:

- Added expense of pulsing systems and 4-pole circuit breakers where required
- Larger equipment size to accommodate HRG resistors, pulsing systems and 4-pole circuit breakers where required
- Limited use of TVSS (typically no phase-to-ground modes of protection)
- Care must be used in selecting load equipment to insure it is compatible with the HRG arrangement (phase-to-ground voltage can be up to 173% of its nominal value during a ground fault)
- A second phase-to-ground fault which occurs before the first is cleared will result in a phase-to-phase fault, with a trip required to clear it.
- The system cannot serve 4-wire loads without using transformers to establish solidly-grounded separately-derived system

The last limitation is usually not an issue in this application, since the UPS system usually supplies several Power Distribution Units (PDU’s) which contain delta-wye transformers. All of the load equipment (computers and IT equipment) is connected to the solidly-grounded system at the secondaries of these transformers (typically 208Y/120V).

The point regarding load equipment, however can be a significant limiting factor. Such “load equipment” includes the UPS modules themselves; it should always be confirmed that the UPS proposed for such an installation can coexist with the HRG system.

### 5. SUMMARY

In this paper, the various aspects of solidly-grounded systems when employed for the parallel-redundant UPS arrangement have been examined. In general,

- Solidly-grounded systems are the most common.
- Circulating currents that exist in the parallel-redundant UPS arrangement when solidly-grounded systems are used make the application of conventional ground-fault schemes impractical.
- If ground-fault protection is required for a solidly-grounded parallel-redundant UPS system, a modified-differential ground fault (MDGF) protection scheme must be employed.
- HRG is an alternative means to ground such systems, but is not a “perfect” solution, and trade-offs must be accepted if HRG is used.

The grounding scheme to be used must be given careful consideration for the resulting system to provide the required level of reliability. If designed properly, either a solidly-grounded or HRG system arrangement can provide reliable, stable systems which fulfill the expectations of high reliability and maintainability.
6. REFERENCES


