

## Top 10 “Transformer-based” vs. “Transformerless” questions and answers

Most other UPS manufacturers have not yet perfected transformerless designs for their large systems and as such, a transformer is required to make the UPS operate properly. Since they are reliant upon their transformers, some manufacturers cloud the issue by trying to make the case that the transformer benefits the user. Below are the top 10 statements Eaton has seen in competitive discussions.

### 1) The input and/or output transformer “protects” the rectifier and/or inverter SCRs from damage due to transients.

*Response:* In the past, transformers were needed to provide proper voltage and act as a series impedance for SCR-based power rectifiers or inverters. Eaton’s modern IGBT-based transistorized UPSs do not require either the voltage modification or the transient protection. In the past, SCRs and slower transistorized inverter controls were helped by the impedance of the transformers during a fault. This is no longer necessary since faster responding UPS controls act to protect the critical load by isolating the UPS within microseconds.

### 2) The input and output transformers in the UPS are required to “float” the rack-mounted battery, so it’s safer to service and safer for personnel who may accidentally touch a terminal.

*Response:* First, it is important to note that both an input and output transformer are required to “float” the battery. If the competitive UPS has only one transformer, the battery is NOT floating. It is Eaton's position, regardless of whether the battery is floating or not, that it is NEVER SAFE to touch an exposed battery terminal. A floating battery simply creates a FALSE SENSE of safety!

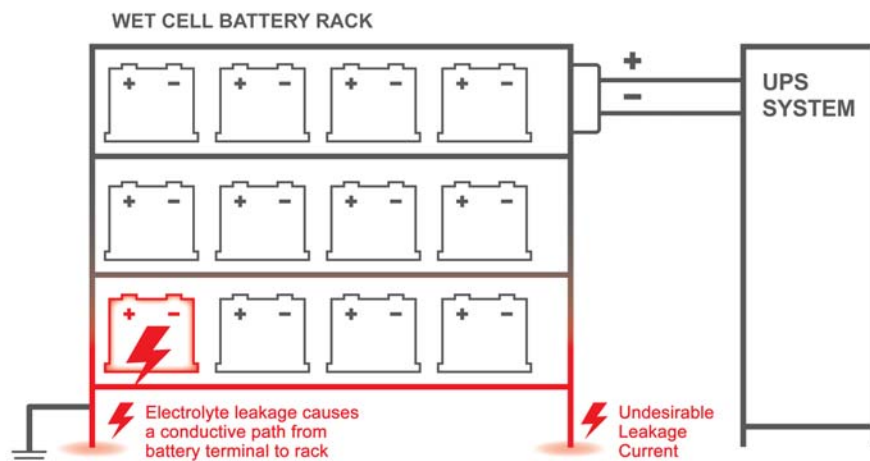


Figure 1. Example of leakage in a wet cell battery creating a path to ground

*Consider this:* A "floating battery" could easily electrocute a technician if, for example, there were a spilled electrolyte short between a terminal of battery #2 and the metal rack. If a technician, standing on the "ground," touched the terminal of battery #240, he/she would be exposed to 538 V! This is every bit as dangerous as a non-floating battery and UPS transformers do not prevent this! Even the input and output transformers in the UPS do not make the battery terminals safe to touch. Eaton believes that the battery terminals should be treated with the same respect as the AC input and output terminals in the UPS. Eaton UPSs do not require 4000 pounds of iron and copper to make the battery “seem” safe. We simply recommend battery terminal covers (much less expensive than transformers) and that all maintenance be completed with the battery breaker open. This is the careful way we treat our AC terminals in the UPS, because they are no less dangerous than battery terminals.

### 3) How can I detect a “battery ground fault” alarm if my battery is not “floating?”

*Response:* You easily can, with a third party ground fault detector devices, the cost of which is ~.05% of the cost of a pair transformers. It also weighs a lot less, and unlike transformers, doesn't penalize you on system efficiency!

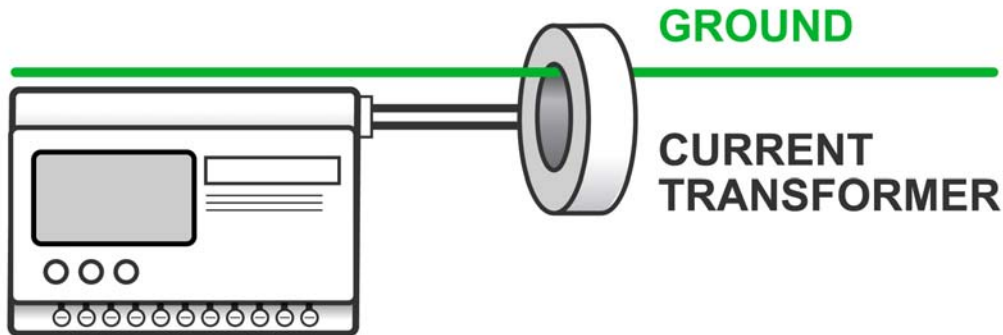


Figure 2. Third party ground fault detector installation

### 4) The lack of an output transformer means I can't bond neutral to ground in the UPS, so I might have neutral to ground, or common mode noise problems.

*Response:* You can, and should, bond the neutral to ground in the UPS unless a neutral has been brought to the UPS from the bypass source. In that case, the UPS neutral should be connected to the source neutral but not bonded to ground. That said, it is important to consider the following:

- If the facility transformer (with its N-G bond) that feeds the UPS is close to the UPS, then an additional transformer in the UPS is redundant.
- If there is a PDU transformer or distribution transformer between the UPS and the critical load, then an additional transformer in the UPS is redundant.
- Virtually all IT equipment manufactured in the last two decades has filtering that attenuates incoming common mode noise at a rate of about 10,000,000:1. Again, a UPS transformer to provide common mode noise is redundant. For more information on this topic, read competitor Schneider Electric's (APC) white paper #9 “Common Mode Susceptibility of Computers.”

### 5) A transformer in the UPS means it will be better able to handle internal and external faults or short circuits.

*Response:* This may have been true 20 years ago, but today's transformerless UPSs have internal circuitry, fusing and fast DSP controls that allow the machine to effectively handle internal shorts and external downstream and upstream faults, all while protecting the load and UPS internal components. Remember, there are hundreds of thousands of transformerless UPSs installed and operating worldwide. If fault handling was a real issue, it would be making headlines. Eaton has performed extensive fault testing — internal and external — on our transformerless products. We are happy to provide test results and waveforms on request.

### 6) A transformer in the UPS helps limit available fault currents and prevents arc flash issues.

*Response:* While statements that “the impedance produced by a UPS transformer will limit fault currents and arc flash energy levels” are true, it is important to ask a few additional questions.

*Is the UPS rated or marketed as an arc flash protection device?*

Answer: No. The facility should be designed properly to limit available fault current.

*Does either type UPS limit fault current when on bypass?*

Answer: No. There is no transformer in the UPSs internal bypass path.

*Do both types of UPS limit fault current when on inverter?*

Answer: Yes, it's called “electronic current limit.”

*What device feeds the UPS?*

Answer: A facility transformer.

*What device does the UPS typically feed?*

Answer: A PDU (containing a transformer).

*So if the UPS is already surrounded by transformers, why does the UPS need internal transformers to limit fault current?*

Answer: It doesn't; that's why Eaton eliminated them!

### **7) The output transformer of the UPS is necessary in order to prevent a “DC component” from appearing in the UPS output during an internal UPS failure.**

*Response:* Eaton transformerless UPSs (and the hundreds of thousands of transformerless units from other vendors that are operating successfully in the field) are designed with fast semiconductor fusing, and, in Eaton's case, with a rotating vector sensing algorithm that instantaneously isolates and protects the UPS and *will not allow a DC component to occur in the output under any operating or failure mode.* Eaton has performed extensive testing where an input rectifier short circuit fault is created, as well as an inverter IGBT fault, and both the positive and negative DC bus are faulted. In every case, the UPS is undamaged and the load remains protected. We have test results and waveforms to prove this, which are available on request and under non-disclosure agreement.

### **8) A transformerless UPS cannot protect the load in the event of a battery bus fault.**

*Response:* See above regarding DC fault tests.

### **9) A transformer based UPS is actually more efficient than a transformerless UPS.**

*Response:* The fact is that transformer-based UPSs are less efficient than transformerless designs. Transformers generate heat, and heat loss increases inefficiency — there's no way around it.

- Efficiency =  $P_{out} / (P_{in} + P_{loss})$ 
  - Ploss is comprised of:
    - IGBT switching losses and conduction losses
    - Magnetics copper and core losses → transformer losses

### **10) Reviewing the myths**

- *The lack of an output transformer decreases the overall reliability of the system.*
- *The transformer helps the inverter handle faults, protecting it from high fault currents.*
- *Similarly, the transformer protects loads from inverter faults, preventing them from having DC voltage applied to them when an inverter fails.*
- *The truth for the other guys:* Old, low-frequency inverters, driven by low-bandwidth analog or rudimentary microprocessor controls, do benefit from the increased impedance presented by either a large inductor or a transformer in the output of the inverter. Slow response controls require the current's rate of rise to be slowed down in the event of a fault.
- *Eaton's “mythbuster”:* Eaton transformerless topology is built on a foundation of:
  - High-frequency PWM power conversion
  - High-bandwidth advanced DSP controls, with sampling rates above 33 KHz (once every 30 microseconds)
- High-bandwidth controls do not get any benefit from additional impedance on the output of the inverter. On the contrary, they rely on instantaneous information to maintain best performance conditions.