Advel Application Note – AAN2022.1

Ghost-Voltage in industrial panels

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1. Introduction

In an industrial electrical panel, it may happen that "anomalous" voltages are detected in the most unexpected points: it is important to understand whether these are real voltages, or reading errors by the instrumentation used for the reading. In fact, sometimes digital meters, if used incorrectly (or just… cheap) can detect what are called "ghost-voltages" or "phantom-voltages".

2. Isolated Power Supplies

AC/DC switching power supplies are often used in industrial systems, where isolation between input and output is required: this is made possible thanks to the internal HF-transformer, which galvanically separates the input stage from the output stage, as well as any optoisolators, etc… as schematized in Figure 1.

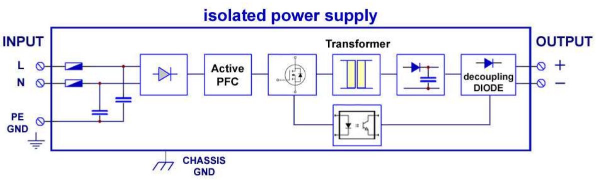

Figure1 *– The figure shows the diagram of a typical isolated AC/DC switching power supply.*

Sometimes it may happen that anomalous voltages are detected between two apparently isolated points, as shown in the example in Figure2, in which there is an AC/DC power supply that powers a load: the power supply is isolated, yet the voltmeter detects a voltage AC between output and GND.

The one in Figure2 could be a classic example of **ghost-voltage** reading.

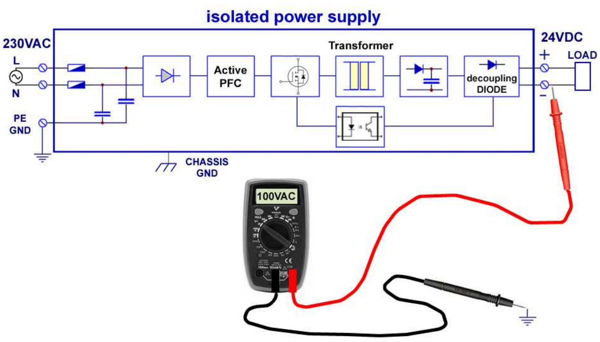

Figure2 *– Example of ghost-voltage.*

3. Ghost-voltages

Ghost voltages are generated by "capacitive/inductive coupling" phenomena, typically between an energized conductor and a nearby conductor connected to a high impedance, or even completely disconnected from it.

Often ghost voltages have a frequency of 50-60Hz (the mains frequency) and therefore do not depend on the switching frequency of a switching power supply, which is in the order of 30÷150kHz, nor on the EMI disturbances produced by the power supply.

In Figure3 the same example as Figure2 is schematized, but in addition the parasitic capacitances inevitably present in the system are highlighted.

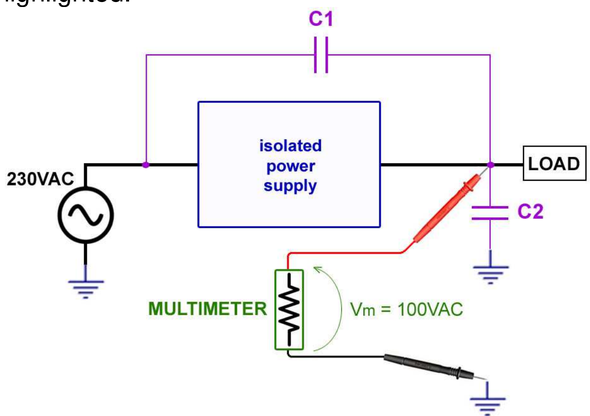

Figure3 *– The parasitic capacitances of a simple system composed of an isolated AC/DC power supply powering a load are highlighted.*

The digital multimeter has a very high input impedance (of the order of 5÷10MΩ) therefore the reading measured by the meter is given by:

$$V_m = 230VAC \cdot \left(\frac{C1}{C1 + C2} \right)$$

This formula explains very clearly why the multimeter can read a non-zero AC voltage between the output and input of the system.

The parasitic capacitances depend on the connection cables (both internal and external to the power supply), on a non-optimal ground connection, on the Y-caps used for the suppression of EMI disturbances and also on electromagnetic induction phenomena, which makes these capacities dependent on how much the power supply is loaded. In fact, it is not uncommon for the detected ghost-voltage to vary depending on how much the power supply is loaded.

4. Examples of industrial panels

Advel power supplies all feature galvanic isolation between input/output, with floating output and external mechanics in anodized aluminum and connected to the GND for protection from indirect contacts.

Figures4 show examples of electrical panels of industrial systems, containing various types of AC/DC power supplies produced by Advel (some mounted on DIN rails, others on 19" racks with plug-in modules), in various configurations (power supplies in parallel/redundancy or with separate output lines) and with various output voltages. As you can see, external wiring can be done in various ways, DC cables are often placed in the same raceway as AC cables and this, as already mentioned, can generate those capacitive couplings that generate ghost-voltages.

Figure4.1

Figure4.2

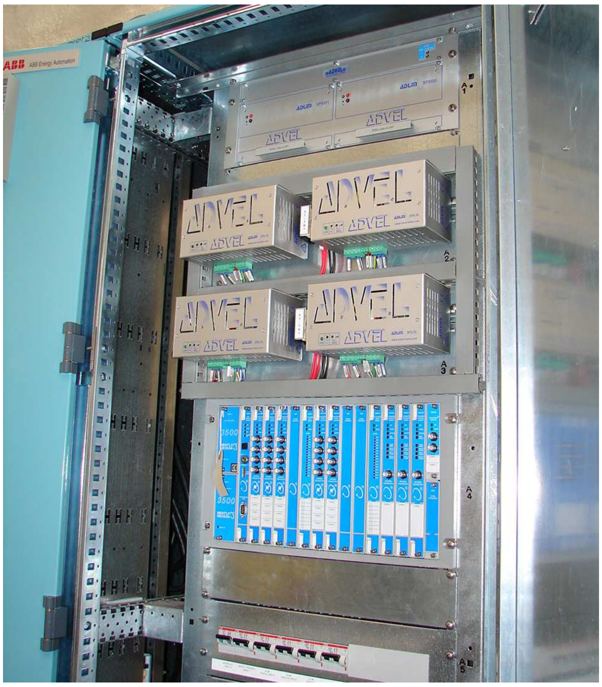

Figure4.3

Figure4.4

Predicting exactly the extent of capacitive-inductive couplings in any industrial panel is almost impossible, even if the system is wired to perfection.

5. Recognize ghost-voltages

Let's go back to the example in Figure3: how to understand if the voltage read by the multimeter is real (and therefore dangerous) or it is a ghost-voltage?

Digital multimeters can be used in “low-Z” mode (if this mode is not present, it means that the voltmeter is very cheap!). In this mode the voltmeter has a very low input impedance (2÷5kΩ) and therefore, if it is actually a ghost-voltage, the multimeter reads approximately 0V, as the capacitive voltage is discharged onto the low input resistance of the multimeter, as shown in Figure5.

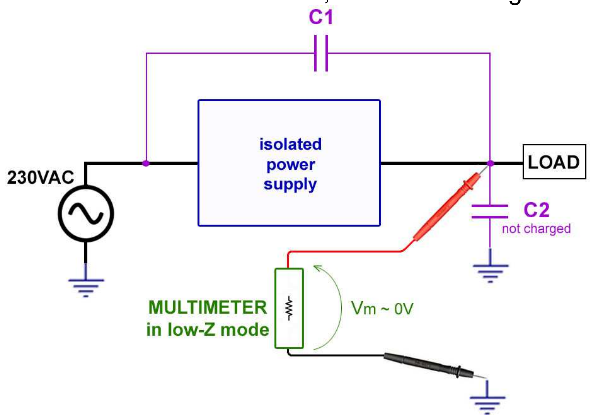

Figure5 *– If the digital multimeter, placed in low-Z mode, detects 0V it means that it was a ghost-voltage.*

Alternatively, an analog-meter can be used, given that the input impedance of these meters is typically very low (Figure 6).

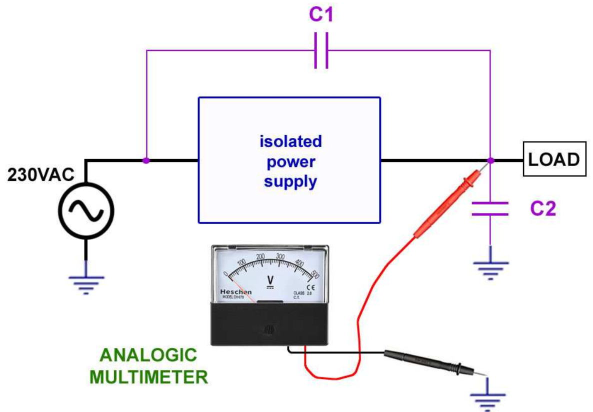

Figure6 *– Analog-meters, which typically have low input impedance, can identify ghost-voltages.*

Since neither an analogue- nor a digital-meter with low-Z option is available, a further, very practical method can be used.
In the initial example, a voltage of 100VAC was read between the power supply output and ground. By placing a 5KΩ_4W resistor between these points, a current i_R = 20mA should flow through it:
however, as already mentioned, ghost-voltages are due to capacitive couplings, and therefore are almost devoid of energy, i.e. they cannot support loads, so if the multimeter detects ~0V, it means that it was actually a ghost-voltage (Figure 7).

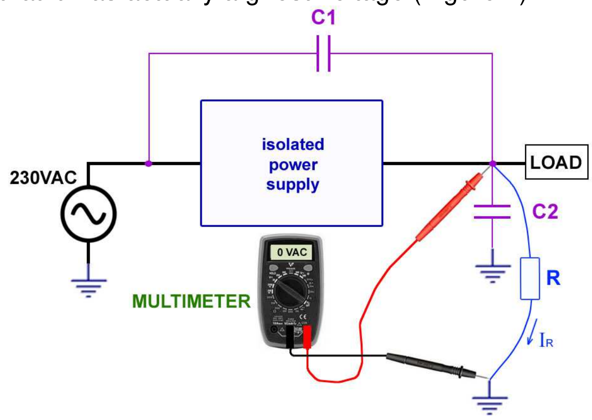

Figure7 *– After placing an appropriate resistor, if the multimeter detects 0V, it means that it was a ghost-voltage.*

6. Conclusions

The possible causes of the so-called ghost-voltages have been defined, which can be detected in an industrial system by a digital multimeter: basically these voltages are generated by capacitive coupling phenomena, and therefore are not considered dangerous (they cannot load a circuit, nor generate danger to people). However, it is useful to know how to recognize them, and therefore three useful methods have been described for this purpose.

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