Advel Application Note – AAN2010.2

Choice of power supplies according to the quality of the powerline

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1. Introduction

When designing an industrial plant, it's essential considering the quality of available AC power, and according to this should be selected the proper AC/DC power supplies.
Consider the single AC Low Voltage line: it's not "ideal" and can contain many diseases, such as: harmonics, flicker, voltage variations, unbalances, voltage dips, ...
Often the noise is produced by "disturbing" devices within the plant, for example:

- converters / power supplies, loads with non-linear behavior (ovens, welding machines, transformers, ...) → cause **HARMONICS**
- equipments with variations of active and reactive power exchanged with the powerline (motors, ...) → cause **VOLTAGE ALTERATION** and **FLICKER**
- loads with unbalanced between all three phases or single phase loads → **VOLTAGE IMBALANCE**
- inrush currents of transformers and capacitors, load rapidly varying and high inrush currents of motors → cause **VOLTAGE DROPS**

The subject is very vast, but it's worth here to analyze the characteristics required by a power supply for use in an industrial plant.

2. How to improve quality of powerline

Per contenere le emissioni dei disturbi bisogna:
It is essential to take all possible measures to minimize the adverse effects of noises for the user line.
To reduce the emission of noise:

- split the single phase load equally between the phases and put high loads in the three phase line (to limit VOLTAGE IMBALANCES),
- realyze a planned maintenance of the plant (to limit the VOLTAGE INTERRUPTIONS)
- use techniques to limit the inrush currents, and so a planned closure of the contactors, switching loads fast / slow (to limit the VOLTAGE DROPS)
- eliminate the resonance conditions (such as variations in power factor correction capacitors) and use passive filters (to limit the HARMONICS)
- start engines at low voltages (to limit voltage ALTERATIONS and FLICKER)

There are possible actions by the user on the plant to mitigate the propagating of noise:

- use of UPS (for VOLTAGE DROPS and other disturbances),
- Use of shielding suitable grounding, isolation, ... (for disturbances of the ground potential).

Again the discussion is quite articulate and widely described in literature.

3. Minimum requirements required by a power supply

As for AC/DC power supplies for use in an industrial plant, it's necessary of course that they meet the standards with regard to immunity and noise emission. The power supply must have the **CE** mark (regulated by the so called "low voltage" Directive) which implies the presence of:

- a declaration of conformity,
- an installation/operation/maintenance manual of the product
- a technical file (it is not given to the customer, but it must be stored on a file by the manufacturer).

In the Declaration of Conformity must be included in the rules and guidelines to which the product is compliant.
For a power supply it's required at least the meeting of the following standards

- **EN50178** (Electronic equipment for use in power installations),
- **EN61204-3** (Low voltage power supplies),
- **EN 60950** (Safety)

and the essential requirements of:

- **2004/108/CEE** (EMC Directive),
- **2006/95/CEE** (Low Voltage Directive).

This essentially means that the power supply complies the limits of immunity and noise emission.

4. Limitation of harmonics by a power supply

The effects of the presence of harmonics, even if not immediately visible, can have serious consequences in the medium-long term. These effects are mainly related to equipment operation voltages, currents and frequencies for which not had been designed and, in general, overheating, increased peak values of voltages, vibration, premature aging of equipment.

Switching power supplies AC/DC are sources of harmonics, and therefore must be designed to limit the emission in the network.
In particular, standards (**EN61000-3-11**) require that 75W (or more) power supplies (input single-phase 115-230VAC) must have inside a mechanism for the "correcting of the power factor", or **PFC** (Power Factor Corrector).
Without enter into technical details, completely unnecessary here, the PFC can be achieved in a passive way (PF value ~ 0.90 average) through the use of a coil (...) or actively (PF value ~ 0.99) by electronic circuits: the first method is less expensive but it makes the power factor PF load dependent, and the power supply less efficient. The active solution is more effective (the PF approaches unity), but the cost of the power supply is higher.

5. Hold-up time of a power supply to limit the effects of voltage drops

The Hold-Up time of a power supply defines how long the power supply can keep the nominal output voltage when V_{in} fails, and then gives an indication of how the power supply can support the network voltage drops.

5.1 Definition of voltage drops

"Voltage Drop" (usually due to faults in the powerline) is defined as the time interval ΔT in which the input RMS voltage has a sudden decrease below 90% of the nominal value. Voltage variations that don't reduce the voltage to less than 90% of the nominal voltage are not considered voltage drops.
Conventionally the duration of a voltage drops is between 10 msec and 1 minute.
The voltage drops is therefore defined by the duration ΔT and its depth, defined as the difference between the minimum voltage during the voltage drop and the nominal voltage of the powerline.

5.2 Hold-Up time in a power supply

Nel calcolo del tempo di Hold-UP di un alimentatore, naturalmente si deve considerare il caso peggiore, ovvero:
In calculating the Hold-Up time of a power supply, of course, we must consider the worst case, namely:

- input voltage drop with 100% depth (that is $V_{in} = 0V$) ,
- maximum output power provided by the power supply.

The rules (**EN60950**, **IEC1000-4-11**) impose for the power supply 115-230Vac single phase input an Hold-Up time equal to 20ms, that is the time equal to one cycle of sine wave voltage (that is $\Delta T = 1/_{50Hz} = 20m\sec$).

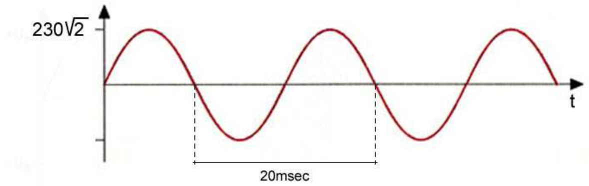

Figure1 *– The figure shows the sinusoidal mains voltage (230Vac) and the minimum Hold-Up time required by the rules.*

Of course if the voltage drop is longer than the Hold-Up time of the power supply, it turns off.

5.3 Frequency of the voltage drops

The CEI **EN50160** gives a rough indication of the expected voltage drops, that in a year can vary from a few dozen to a thousand. This is because it's an event largely random and an annual basis varies considerably depending on the type of power supply system and the observation point (for example in areas such as rural areas with weak grids, the voltage dips are more frequent than the average).

Considerando soltanto i buchi di tensione "profondi" (in cui si ha una riduzione del valore efficace della tensione al di sotto del 60% del valore nominale) secondo un'indagine UNIPEDE, in Europa si hanno i risultati riassunti in Tabella 1.
Considering only the "deep" voltage drips (in which there is a reduction in RMS voltage below 60% of nominal) according to an investigation of UNIPEDE, in Europe you have the results summarized in Table 1.

Width of the voltage Drop	Duration (ms)			
	10 ÷ 100	100 ÷ 500	500 ÷ 1s	1s ÷ 60s
>40%	26	70	25	14

Table1 *– Investigation of UNIPEDE (for 3 years) on the voltage drops in the european Middle Voltage: it's showed the annual frequency with 95% probability of not being exceeded.*

However, in the event of industrial processes or installations with loads sensitive to voltage drops, it's necessary to make a more detailed investigation in site.

6. Protections for voltage drops

Naturalmente la miglior protezione dai buchi di tensione in un impianto, è l'utilizzo di **gruppi di continuità**.

I gruppi di continuità sono dispositivi in grado di elevare la qualità dell'alimentazione della rete di distribuzione pubblica o dell'impianto elettrico dell'utente a monte del nodo di installazione dell'impianto, operando come un'interfaccia in grado di filtrare i disturbi provenienti dalla rete stessa e garantendo, per un tempo prestabilito, l'alimentazione dei carichi senza interruzione.

Of course the best protection for voltage drops in an industrial plant, is the use of **UPS**.

UPS devices are able to raise the quality of the powerline, operating as an interface to filter the noise from from the public powerline network and ensuring, for a preset time, the power for the loads without interruption

6.1 UPS types

A classification of UPS devices can be made: static UPS (based on the use of power electronic converters and storage system in DC, in general, but also electrochemical capacitance inductive or superconductors) and rotating UPS (based on the use of rotating machines, with storage flywheels made of high inertia). You may have "hybrid" UPS in which there are both static and rotating components.

The typical sizes for each type of UPS, are approximately:

- Static: 0 ÷ 1000 kVA;
- Rotating MT: 1000 kVA ÷ 5000 kVA;
- Rotating BT: 100 kVA ÷ 1500 kVA;
- Hybrid: 100 kVA ÷ 1000 kVA.

Higher power can be obtained by connecting in parallel more individual UPS units.

There are also several subtypes of UPS, but it's not important now: it's suffice to say that it is much more expensive devices, the higher the levels of power and "clean"of the powerline that they can provide.

In some plants of medium / large, high use of UPS leads to very considerable cost.

A possible solution, although less effective, is to build privileged lines "covered" by UPS, to be used only for the supply of critical equipment (eg. electronic control systems and data processing) whose disruption would cause economic damage or security issues.

In this case, especially in areas of the plant not supplied by the UPS lines, it is useful to use power supplies with high Hold-Up time, much higher than the minimum required by law (that is only 20msec, as seen in Figure 1).

6.2 Power supplies with high Hold-Up time available on the market

90% (or more) of AC/DC on the market, provide an Hold-Up time of just 20msec (the minimum required by regulations).

This time, as mentioned above, covers a voltage drop equal to a period of sinusoidal voltage provided by the powerline, and should be sufficient to cover the time needed for switching operations such as UPS-powerline or vice versa (typically equal to 10ms) but wholly insufficient to support most of the voltage drops.

However, as defined in the previous paragraph, it would be useful, in many cases, trying to cover much wider voltage drops, especially in areas of the plant not covered by UPS.

Some manufacturers of power supplies offer an optional "tool ", sold separately, to be connected to the power supply to increase the Hold-Up time (Figure 2).

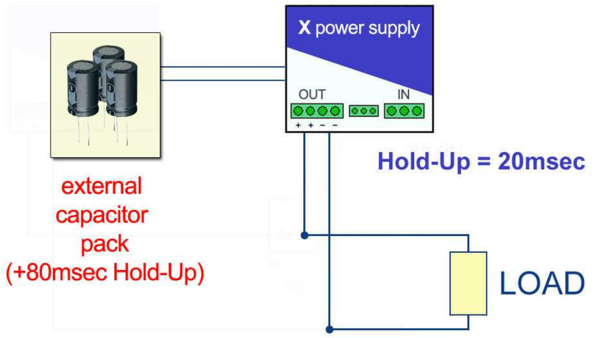

Figure2 *– Electrolytic capacitor pack to be connected to the power supply in order to increase the Hold-Up time.*

Infact it's a group of electrolytic capacitors (Figure 3).

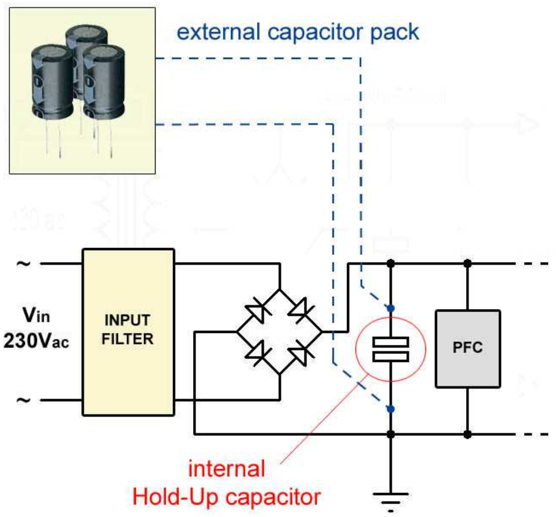

Figure3 *– Schematic diagram of the connection of external capacitor-pack in parallel to the Hold-Up capacitor inside the power supply*

This solution doesn't particularly like for the greater complexity of wiring and the increased encumbrance in the panel.

Moreover, with these systems, it's possible to get Hold-Up times of maximum 100 to 150msec, not more (because of Inrush current, which grows with the number of Hold-Up capacitors).

Advel instead offers, for all it's power supplies, an Hold-Up of 100ms, calculated in the condition of load 100% and maximum amplitude of the voltage drop (Figure 4).

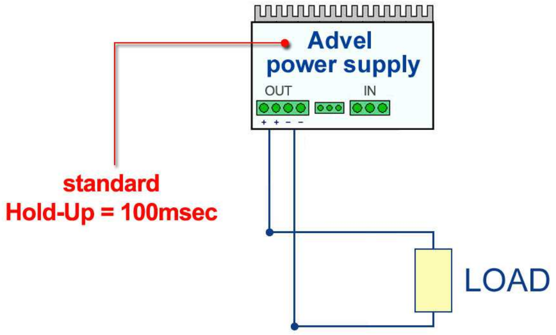

Figure4 *– Power supplies manufactured by Advel, with Hold-Up time = 100msec*

The solution offered by Advel implies a slight increase in size of the power supply (because the internal electrolytic capacitors are big) but has the advantage of having a product with an Hold-Up time significantly high.
Moreover, in the classical composition of a redundant system 1+1 (in which a single power supply, of the two in parallel, can support the entire load), the Hold-Up time of the system is certainly more than 200ms, as shown in Figure 5 (furthermore Advel power supplies can be paralleled without problem, having already inside the decoupling diode).

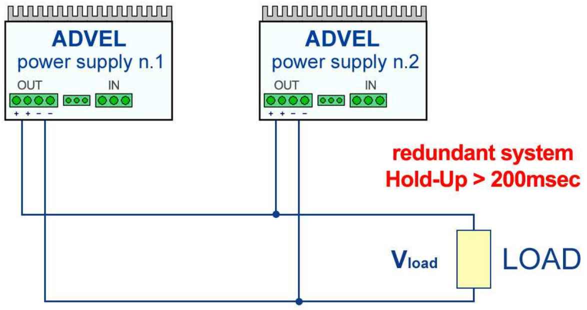

Figure5 *– Two Advel power supply system in the classical 1+1 redundancy: each power supply works at 50%, and the Hold-Up time the system exceeds 200msec.*

A system like the one shown in Figure 5, with an Hold-Up time greater than 200msec, can support well over 50% of voltage drops per year as estimated in Table 1.

7. Conclusions

In the design of an industrial plant is crucial to make a survey on the quality of powerline available.
It is also essential to classify the users (such as aggregates of individual consumers or users) in terms of consequences for the functioning of production processes and therefore performance of the powerline network. In particular, it's possible to define loads for which the input power failure has an insignificant impact on production and safety of personnel and equipment or loads for which, given the impact they have in terms of production and safety, it's necessary that the power is restored within a short time generally consistent with the needs of the production process or service performed. It 'also possible to define users or groups of users "privileged" (users typically extremely sensitive to noise in the input supply) and the proper functioning of which depends the safety of personnel, facilities, and the correct execution of processes whose arrest may cause significant losses production and therefore economic. All these elements are needed to define the power needs of the different types of users, leading to the definition of wiring diagrams of system most appropriate.
At this point we must use strategies to minimize the adverse effects of disruption for the user, and use UPS to create privileged lines for the most critical users.
AC/DC power supplies for use in industrial plants, have to be **CE** marked, because it provides noise immunity and low noise emission.
In particular it's better the power supplies are equipped with active PFC (to minimize the emission of harmonics in the network powerline), and which have a high Hold-Up time, especially if they must be installed in areas not covered by UPS.
Were taken as an example the power supplies produced by Advel, all with a standard Hold-Up time equal to 100 msec.

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