HIGH POWER UPS SELECTION METHODOLOGY AND INSTALLATION GUIDELINE FOR HIGH RELIABILITY POWER SUPPLY

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Abstract.

This paper presents the most common UPS technologies for high power available on the market and compares their functional parameters. Also it presents the most important UPS parameters that must be considered to design the high reliability facility. Different configurations and the influence of the parameters on the UPS operation are discussed.
All steps of this selection process were put into practice in order to select UPS systems for installations of RETEVSION, one of the most important telecommunication companies in Spain.
The operation behavior of the installed UPS was confirmed by on site measurements.

Key words

UPS, Power Quality, Benchmarking, UPS technologies; Reliability

1. Introduction

Ideal power supply to a customer at low voltage is at 230/400V at 50 Hz. The local network operator cannot keep supply exactly at the ideal due to a range of disturbances outside its control and attempts to maintain its voltage within specified ranges.
In the case of some electrical loads even a short break in power supply may lead to enormous material losses or even cause hazard to people's lives. Examples include, protection and automatic circuits in power industry, control systems of automatic production lines in other industrial sectors (e.g. chemical, precise machining), some equipment in hospitals, airports, also in military sector.

First of all, the users with these critical applications have to assume investments to guarantee the required level of power quality. In order to achieve high reliability in power supply, the most common solution is uninterruptible power supplies (UPS). [1]

The electronic loads are highly vulnerable to voltage disturbances and therefore, a high reliability level is requested. That's why UPS are used in order to supply reliable power to those loads. Actually, UPS are indispensable in industrial producing processes, telecommunications, data-centers, financial business etc, where high power supply reliability is demanded. Moreover, they are easy to install, due to their compact design (apart from the batteries) and the output power can reach from some kW to WM.
But not all UPS technologies are similar. Although the purpose of this equipment is the same, each UPS manufacturer develops its own technology.

2. UPS Technologies

UPS available on the market can be classified into three groups, considering their structure and the operation modus. Two of them, the double conversion UPS (fig.1) and the stand-by UPS (fig. 2) are well known. The third technology, the delta conversion (fig. 3) is an evolution of the interactive UPS structure
All these technologies have a static switch by-pass (tyristors) in order to pass the load to an alternative power supply in the case of a malfunction of the UPS [2].

It is also well known that most UPS manufacturers are employing double conversion technology, which means

input power is rectified to dc voltage and supplied to a capacitor. To this cd bus, an inverter is connected and generates the output ac voltage. This UPS structure is the most reliable structure and is less vulnerable to disturbances coming from the power supply. The structure of rectifier - dc-bus and inverter separates the input ac power from the output power. Batteries are connected to the dc-bus in order to keep on supplying the output power during a mains failure. The autonomy of this type of UPS is dependent on the number of batteries and can be adapted to the customer's need. Hermetic lead batteries are the most used type for UPS systems.
Nowadays, the inverts of all manufacturer of high power UPS are designed with IGBT's, using PWM or SVPWM control algorithms at a commuting frequency between 4 kHz and 20 kHz.
The differences between UPS manufactures can be found in the type of rectifier, input and output filter and the output transformer.

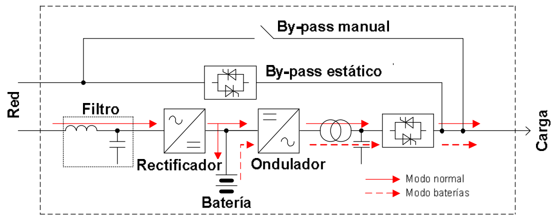


Fig. 1

The conventional input rectifier is a six or twelve pulse tyristor rectifier bridge, combined with a passive filter in order to lower the harmonic distortion at the UPS input. Six pulse tyristor rectifier and active filter combination and six pulse diode rectifiers with an IGBT boost step are other possible input rectifier structures. Active rectifiers are also applied because of the advantage of low harmonic distortion and input power factor near one.
The input harmonic distortion of an UPS is one of the most important input parameter because it is decisive for the electrical design of the input power circuit. Therefore, low harmonic distortions are requested by customers to UPS systems in order to avoid an over design of the electric installation. Thus UPS manufactures are trying to reduce harmonic distortion of the input currently by using different filter strategies.
The other important factor for the installation design is the input power factor of the UPS. Installations have to be designed to the total apparent power consumed by the UPS. If active rectifiers or active filters are applied, the input power has a power factor near the unity. Some manufacturers incorporate special control algorithm in order better the input power factor.
On the other hand, on the output we find the output filter. The purpose of this filter is to smooth the output voltage from the inverter and that's why low harmonic distortion in output voltage can be achieved. Consequently, high capacity is connected to the output and this capacity is also used in order compensate inductive reactive power from the load. Thus manufactures specify the output power of the UPS in apparent power with 0.8 inductive reactive power factor.
Conventional three phase power UPS structures need a transformer in order to reach the output voltage of 400 V.

A new architecture is adding an IGBT boost after the rectifier, so the output transformer can be removed.
If we compare the structure of the double conversion in Figure 1 with the stand by configuration in Figure 2 we can observe that the only difference is that the latter one is working in by-pass during the normal operation.
Most manufactures of double conversion UPS are offering an operation mode of their equipment, that permits them to operate the double conversion UPS as an off-line UPS.
In off-line UPS the rectifier unit is designed to rectify only the charging current; the output inverter is similar to the double conversion.
One of the main advantages is the high efficiency of off-line UPS and the low harmonic distortion that the UPS is injecting to the installation. The disadvantage of this type of UPS is that the commutation time can between the normal operation mode and the battery mode can be high.

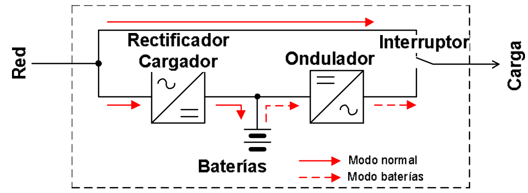


Fig 2

The delta conversion structure is a combination of the last two structures. The main inverter is watching continually that the output parameters are within defined tolerances and it goes into action when a mains failure is occurring. Meanwhile, this inverter charges the batteries and corrects the input power factor. The delta transformer is used to compensate small voltage variation between +15% and -15%. Both inverters are bi-directional converters.

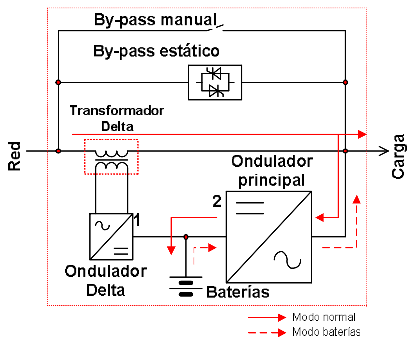


Fig.3

The main inverter is designed for the full output power, while the delta inverter and the delta transformer are designed for approximately 20% of the output power. Thus the efficiency of this UPS structure is in general higher than a double conversion UPS. The output power factor is near the unity because of the main inverter, which is operating during the normal operation as an active filter.

3. EN 62030-3 Standard

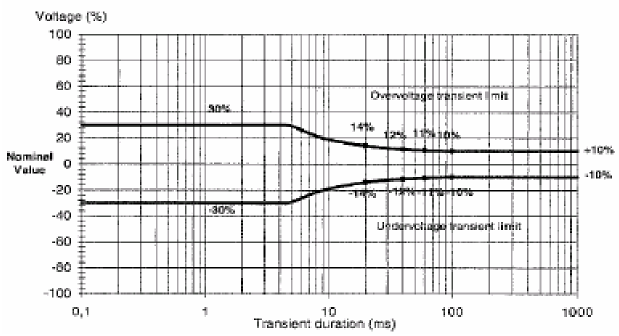
Comparing characteristics of high power UPS is not an easy task because there is a set of different structures on the market and the commercial names of these technologies can differ. In order to provide the user a clear and easy comparable criteria for the selection of UPS, the CENELEC standard EN 62040-3 (June, 2001) was created. [3]
This standard is establishing a classification for UPS without using the commercial terms like double conversion, off-line, on line, etc.
The following classification code was established:

VFI – SS – 111

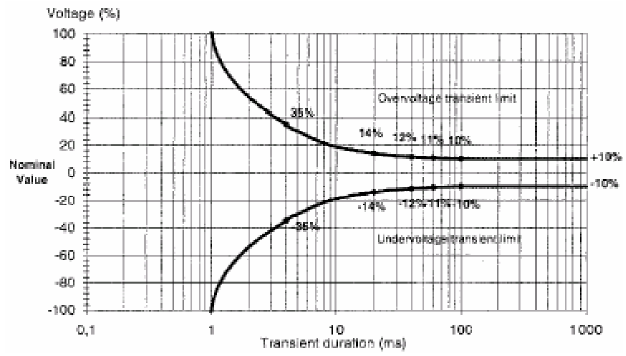
- Dependency of UPS output on the input power grid
  VFI: where the UPS output is independent of input supply voltage and frequency variations.
  VI: where the UPS output is dependent of input supply frequency variations, but supply voltage variations are conditioned.
  VFD: where the UPS output is dependent of input supply voltage and frequency variations
- The voltage waveform of the UPS output
  Two characters correlate the output voltage waveform into a simple structure, according to the two operational modes, the first is normal mode, and the second is stored energy mode.
  S: sinusoidal: total harmonics factor D<0.08 (IEC 61000-2-2) under all linear and under reference non-linear load
  X: non-sinusoidal: D>0.08 under reference non-linear load.
  Y: non-sinusoidal exceed the limits of IEC 61000-2-2.
- The dynamic tolerance curves of the UPS output
  Three characters describe maximum allowable dynamic deviations (from a clean sine wave). First is for change of operating mode performance, e.g. normal mode – stored energy mode – bypass mode. Second is for step linear load performance in normal or stored energy state (worst case). Second is for step non-linear load performance in normal or stored energy state (worst case).

Three tolerance curves describe the output voltage limits:

CLASSIFICATION 1



CLASSIFICATION 2



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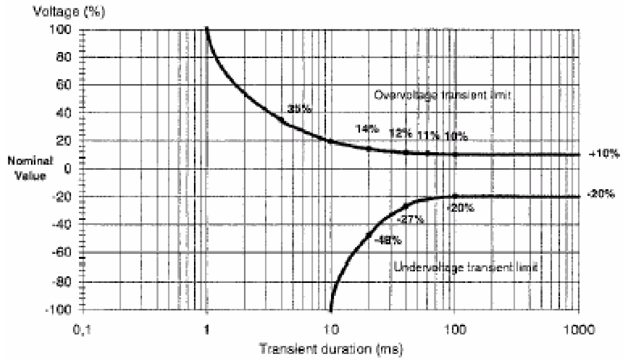

4. Characteristics to consider

After introducing the state of art of static UPS, present standards and technologies, it is important that customers can make an objective evaluation of the equipment which is more interesting to ensure the suitable power quality for the facility. [4]

The analysis of the installation must be the beginning. This must get all the expected parameters that UPS must carry out, so, UPS specifications are set.

The list of parameters can be very large. If the different equipment is compared, it's not possible to take them all into account. Then, the characteristics used to evaluate the UPS should only be the most important ones. These are listed next.

The UPS description is made with static and dynamic characteristics. The first reports normal performance mode without any quick variation. And the latter describes performance with transients and change between modes.

- **Static characteristics**

The whole group of static characteristics can be divided into three parts.
The first set consists of those whose value is practically independent from the load level.

  - Standard EN 62040-3 classification
  - Short Input filter
  - Acoustic noise

- Taken area for power
- Accessible
- Output transformer
- Feed-back protection
- Overload capacity
- Custom of batteries

Figure 4 can give a first idea of what kind of equipment is better to use to protect the loads.

	Voltage Phenomenon	Time	e. g.	IEC 62040-3	UPS-Solution
1.	Outage - blackouts ...	> 10 ms		VFD Voltage + Frequency Dependent	Classification 3 **Offline**
2.	Sags / brownouts	< 16 ms			
3.	dynamic overvoltage	< 16 ms			
4.	undervoltage	continuous		VI Voltage Independent	Classification 2 **LineInteractive**
5.	overvoltage	continuous			
6.	Lightning	sporadic		VFI Voltage + Frequency Independent	Classification 1 **Double Conversion**
7.	transients (Surge)	< 4 ms			
8.	frequency variations	sporadic			
9.	voltage distorsion Hf (Burst)	periodically			
10.	voltage harmonics	continuous			

Fig. 4. UPS solution accord to EN 62040-3. Published by ZVEI: UPS Guide

The second group includes those parameters whose value depends on load level. This is because the equipment is designed for 100% load. Figure 5 gives an example of this variation.
So when UPS works away from that point, the values are lower than expected. This situation is important if there is a parallel redundant configuration because UPS works under 50%.

- Input power factor
- Input THD_i
- Efficiency
- Output THD_u

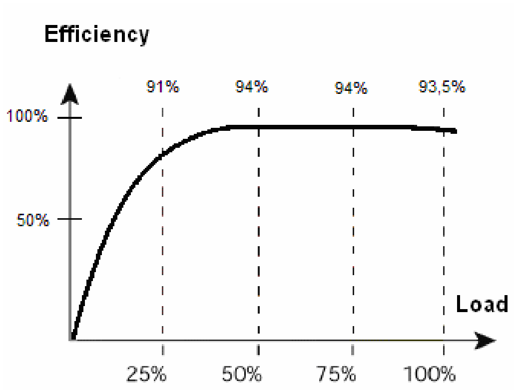

Fig. 5 Typical UPS efficiency curve

The last group is not exactly static characteristics. They present an idea of manufacture infrastructure.

- Technical assistant
- Delivery term

5. Installation recommendation

Once UPS is selected correctly, it is important to pay attention to the UPS installation. This helps to avoid problems with UPS performance. The more important points to be considered are the following [1]:

- UPS installation design
- Redundant configuration n+1
- Downstream earthing system: TN-S if transformer is in ownership and TT if it is not
- Neutral section equal or double to phases
- Different protection to UPS grid connection and by-pass connection
- Over voltage protections downstream and upstream UPS
- Disconnecting switch at UPS output to easy replacement
- Air conditioning system

6. Installation case of an UPS: Neutral commutation in UPS and generation set installations

A lot of the installations which use UPS systems, are supported by an alternative supply through a generation set. In these cases, the commutation between the grid connection and the generator is necessary for the case of long interruptions. Downstream of this commutation unit usually the UPS set is installed and supplies the critical load. In this section neutral schemes were analyzed in commutation installations with two or more different power supplies, supplying a UPS system with critical load downstream. The tests explained in this section were carried out in a telecommunications centre. An electrical scheme is shown in Figure 7.

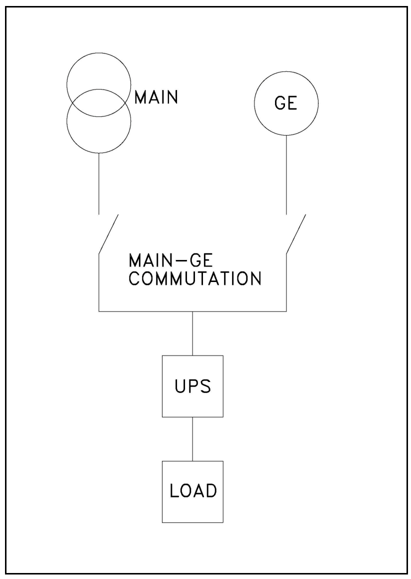

Fig. 7. Unifilar schema

In the tested cases, the selected neutral system was the TN-S for the whole installation. The commutation between grid and generator set is done by four-pole breaker and therefore, the neutral wire is also sectioned.

During the commutation time between the sources, when one breaker opens and the other closes, the neutral wire scheme downstream of the commutation is IT, because the neutral wire remains isolated from earth. These neutral wire commutations produce short duration over voltages and high voltage pulses with high frequency that can damage the load. In the tested case, each commutation caused a failure in the control logic in some of the telecommunication equipments connected to the UPS. Furthermore, the surges underwent dielectric stress and perturbations in each commutation that may affect the differential protections of the critical loads.
Fig. 8 shows the neutral vs. earth voltage downstream of the UPS during the commutation, in this specific case it was of three seconds.
Fig. 9 and 10 show the line voltage drop of the network and the starting of the generator set. During the tests important phase-earth over voltages appeared. The phase and neutral currents, and the line and line to neutral voltages (downstream of the UPS) do not show important variations.

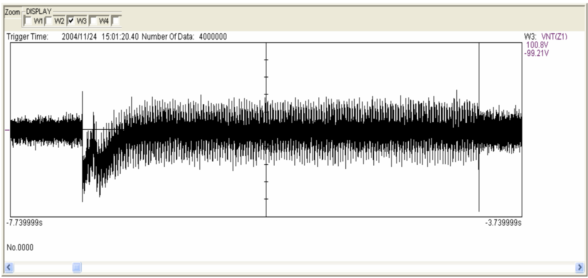

Fig. 8 Neutral to ground voltage during commutation

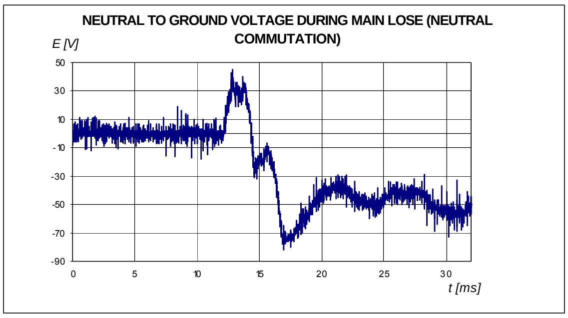

Fig. 9. Mains failure detail

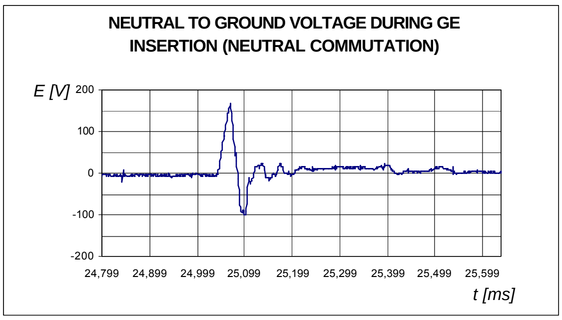

Fig. 10. GE insertion detail

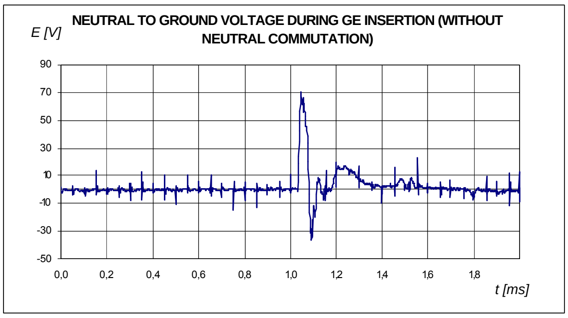

Fig. 11. Neutral to ground voltage during GE insertion without neutral commutation

The tests were repeated with the neutral wire connected to earth (downstream of the commutation), that means linking the commutation neutral wires. A substantial reduction of the over voltage peak was achieved. Figs. 11 and 12 show the results of those tests.

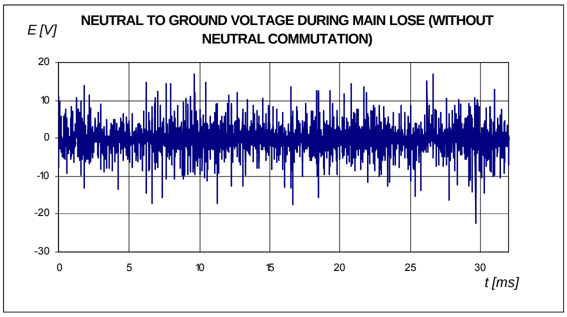

Fig. 12. Neutral to ground voltage during main loss without neutral commutation

To solve the problem of over voltage there are the following possibilities:

A. To change the neutral wire scheme by means of an isolator transformer.

If the UPS has the transformer in the output and it is possible to be fed without the neutral wire, adding a transformer in the by pass (static and dynamic) will provide a new neutral scheme downstream of the UPS, independent of the upstream scheme. This system is technically optimal, but expensive.

If the UPS needs a neutral wire in its connection at the network, the neutral wire in the UPS is not connected internally. If there is no isolation transformer in the inverter output, the transformer must be installed in the input or output of the UPS, including the manual and static by pass. (See fig. 13).

This scheme, although expensive, decreases the system's losses by 3 % and 8 %, depending on the quality of the transformer and the amount of the load.

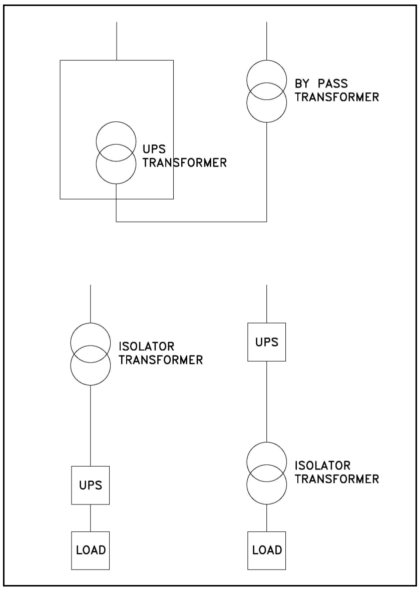

Fig. 13. Isolate transformer installation

If the transformer is installed upstream, the system losses are higher for the whole system, but the UPS better protected. The advantage of a downstream installation of the USP is that the losses of the UPS not included in the transformer power. The disadvantage is that the UPS is not protected in case of disturbances in the main supply.

B. Three-phase sectioning in the commutation.

If the commutation is in three phases, the UPS and the load will not be disconnected from neutral, and over voltages will be remarkably decreased as was verified during the tests. However, some difficulties were found:

a) Impedes the differential protection upstream of the commutation, because the unbalanced neutral currents will returns by the transformer branch as well as by the generator set. This is because both wye points are linked to earth, in the case of TNS- scheme.

b) In the TN-S scheme, both neutral points of the transformer and generator set are linked to earth, normally, in the transformer station. In this station is connected the ground protection conductor (see fig. 14) During the break an induced voltage in the load appears between neutral and earth because of the phase current variation and the coupling with the neutral wire and earth loop. These voltages may be low due to the means of over voltages protection connected between the neutral point and earth.

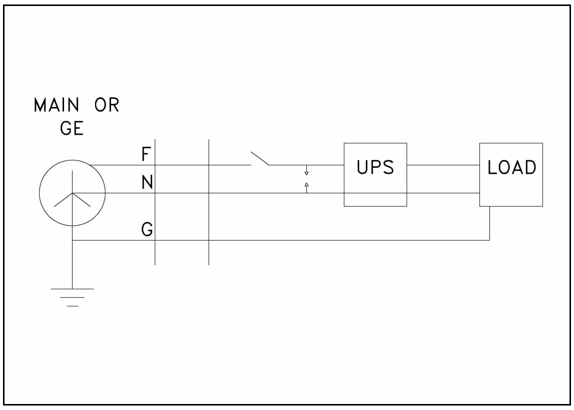

Fig. 14. Three phase commutation

C. Changing the neutral system.

TN-C system to the UPS and keeping (downstream) a scheme TN-S is an easy realizable solution. It can be done by means of the connection of the neutral wire in the UPS to earth. Disadvantages of this solution are the impossibility of the use of differential protections upstream from the UPS and, basically, the neutral currents will return to the transformer (or to the generator set) across all the earthing points of the installation causing interferences and potentials between those points.

UPS with transformer output and three phase connection a possible solution is the connection to earth of the neutral point of the UPS by means of a switch in such a way so that when the by pass is connected, the switch must open. The result is to have an independent neutral scheme while the UPS works on line (most of the time) and being unified with the others when the systems works in by pass or static. This requires more complex maneuver procedures and changes between neutral schemes during the maneuver (see fig. 15).

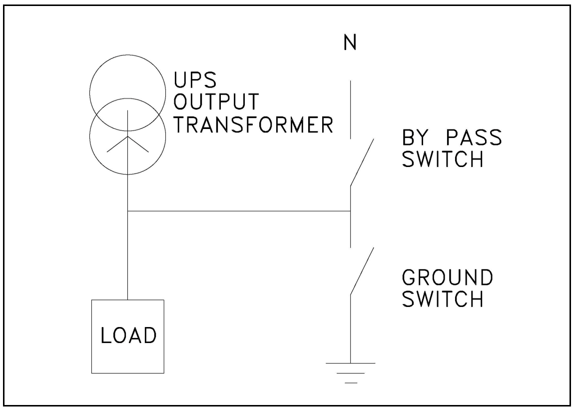

Fig. 15.- Changing the neutral system by switches

7. Conclusion

Selection and installation of UPS for highly reliable installation require a good knowledge of UPS structures and technologies. Thus manufactures are applying their own technical terms and technical parameters, which are not easy to compare, an evaluation of the best suitable technology for the application is a complex task. Therefore, the standard EN-62040-3 should be applied in order to compare the characteristics of UPS from different manufactures.
On the other hand, the installation of an UPS combined with a generator set implies that over voltages can occur. In order to aviod these over voltages, three solutions were presented: changing the neutral wire scheme by means of an isolator transformer, changing the neutral system and using three-phase sectioning in the commutation.

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