Totally Integrated Power

# Technical Series, Edition 3

## Modelling uninterruptible power supply (UPS) in SIMARIS® design for use in data centres

Answers for infrastructure.

# 1. Basis

Uninterruptible power supply of servers is of vital importance for data centres to ensure 24/7 availability all year round. Careful power supply planning is indispensable to attain this goal. This includes dovetailing the components to be used. In this process it is of particular importance to integrate the UPS into the overall power supply concept.

In line with the IEC 62040-3 standard (DIN EN 62040-3; VDE 0558 Part 530) UPS manufacturers can mark their products according to the following classification. Criteria for assessment are outlined in excerpts (for details please refer to the above standard):

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Designation code: AAA BB CCC

e.g. VFI SS 111 (highest classification)

Meaning of the code elements:

| AAA |
|---|
| The characteristic value describes the dependency of the UPS output supply during normal operation if voltage and frequency of the input AC supply changes. |
| **VFD (Voltage and Frequency Dependent):**<br>VFD-classified UPS installations must protect the load against line failure.<br><br>In this case, the UPS output is influenced by changes in the input AC voltage and frequency. It is therefore not suitable for handling additional compensation tasks resulting from the use of a stepping transformer, for example.<br><br>**"VI" (Voltage Independent):**<br>VI-classified UPS installations, like VFD-classified ones, must protect loads against line failure, but they must also ensure supply in case of<br>• continuous undervoltage at the input<br>• continuous overvoltage at the input.<br><br>A UPS output classified as VI is dependent on the frequency of the AC voltage input, and the output voltage must remain within the specified limits.<br><br>**"VFI" (Voltage and Frequency Independent):**<br>VFI-classified UPS installations are independent of the (mains) supply voltage and frequency fluctuations. They must protects loads against harmful effects of such fluctuations without discharging the power storage device. |

| BB |
|---|
| Characteristic values dependent of the voltage curve progression with a differentiation of the following operating modes:<br>• Normal or bypass operation (1st character)<br>• Power save mode (2nd character) |
| **"S":** Sinusoidal voltage curve.<br>With linear and non-linear reference load (precise specification to be found in IEC 62040-3), the total harmonic distortion is less than 8%. The curve shape is called sinusoidal.<br><br>**"X":** The curve shape is only sinusoidal in case of linear loads. In case of non-linear reference loads, the curve shape is no longer sinusoidal, since the total harmonic distortion exceeds the limit of 8%.<br><br>**"Y":** The voltage curve is neither sinusoidal for linear, nor for non-linear reference loads. In both cases, the limit of 8% is exceeded. |

| CCC |
|---|
| Characteristic values for the dynamic response of the UPS output voltage:<br>• 1st number: required in case of operating mode change<br>• 2nd number: for linear step change in load during normal or battery-powered operation (given for the most unfavourable condition)<br>• 3rd number: for non-linear step change in load during normal or battery-powered operation (given for the most unfavourable condition) |
| **"1":** required response to sensitive critical loads<br>*The UPS output voltage remains within the limit values of curve 1 (cf. IEC 62040-3) in this section.*<br><br>**"2":** allowed response for most critical loads.<br>*The UPS output voltage remains within the limit values of curve 2 (cf. IEC 62040-3) in this section.*<br><br>**"3":** allowed response for most normal IT loads, e.g. switched-mode power supply units<br>*The UPS output voltage remains within the limit values of curve 3 (cf. IEC 62040-3) in this section.* |

SIMARIS design can be used to dimension electric networks based on real products with a minimum of input – from the medium-voltage level to the power consumers (in a data centre, this means down to the rack level, where the ICT equipment is power-supplied). This software helps reduce your overall planning expenses for power distribution systems and minimizes selection and dimensioning time for the necessary equipment enormously – and offers a high degree of planning reliability into the bargain.

Integrating UPS installations into power distribution concepts is possible in SIMARIS design with the aid of equivalent circuit mapping, both

- **as load** to select feed-in components (transformers, generators, cables, busbars, switching devices) and
- **as power source**, to map the influences on the lower-level network regarding maximum short-circuit currents when supplied from the transformer, and minimum short-circuit currents in inverter mode.

Here, the lower-level network can be checked for compliance with standard electro-technical conditions, such as the tripping condition in accordance with IEC 60364-4-41 (DIN VDE 0100 Part 410) and for compliance with selectivity conditions.

# 2. Integrating UPS Installations into Power Supply Systems

UPS installations are used in power supply systems to protect critical consumers against serious consequences of supply interruptions or bad supply quality, such as data loss, production loss or even safety problems. The intended application generally determines the functioning principle of a UPS and the corresponding UPS classification. When integrating a UPS into the power distribution network, its functioning principle must be considered, so that malfunctions and undesired effects in case of faults or in case of operational changes are avoided.

Double-conversion UPS installations (often classified as VFI) provide the utmost of safety owing to the fact that load supply is decoupled from the UPS input (see Figure 1). Therefore they are the basis of the following considerations.

The integration of a static UPS installation into the concept for a power supply system shall be demonstrated on the basis of a specific configuration example. This also includes UPS simulation in SIMARIS design.

Assuming that the input for the static bypass is supplied from the main power supply busbar (transformer supply, LVMD NPS) and the rectifier input is supplied from the safety power supply busbar (generator, LVMD SPS), the following conditions are present from the viewpoint of the UPS output (UPS main distribution) as shown in Figure 2.

- The static bypass is supplied from the LVMD NPS (transformer). This factors in the high short-circuit currents during transformer supply.
- In double-conversion mode, UPS rectifier supply through the LVMD SPS (generator) is decoupled from the the inverter output, which means that fault currents are solely determined by the inverter and must be factored in according to manufacturer specifications.

Figure 1: Integration of UPS installations with a DC link (double conversion)

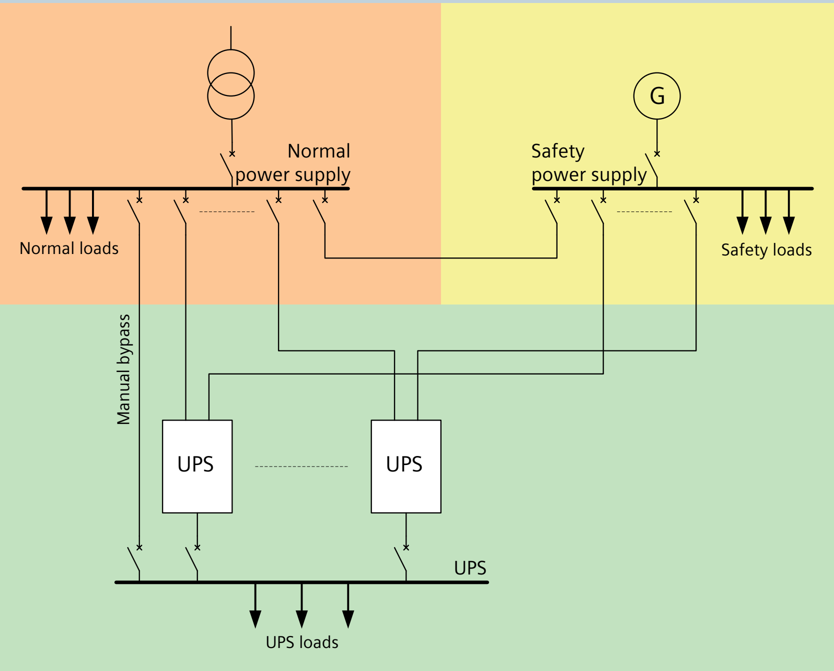
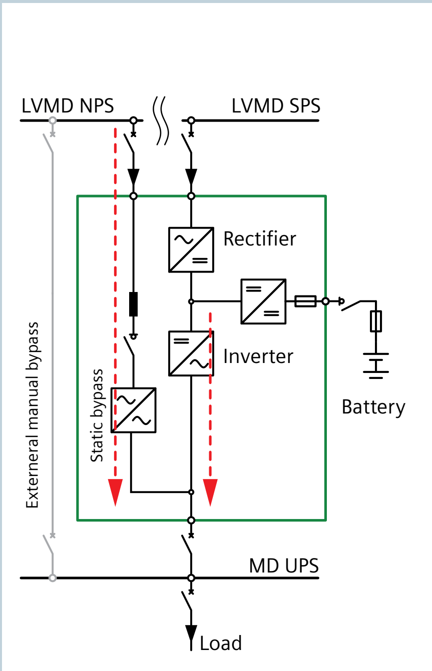



Figure 2: Feeding an output-side short-circuit from the transformer via the bypass and/or the inverter



# 3. Simulation of UPS Installations in SIMARIS design

SIMARIS design provides various options for simulating UPS installations, of which only the detailed simulation acc. to Figure 3 is described here.

The following components are created using a unidirectional coupling:

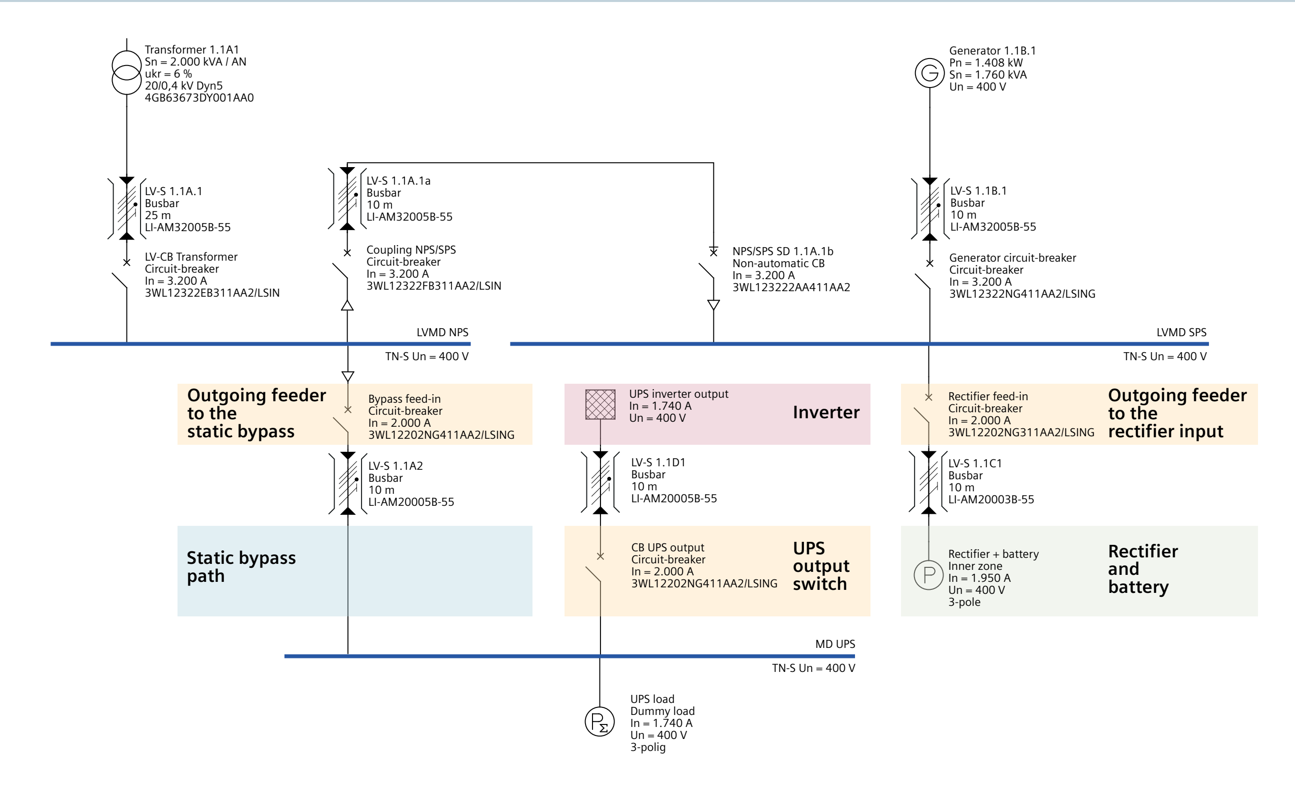
a) Outgoing-feeder from the LVMD NPS to the input of the static bypass of the UPS

b) Static bypass (connection between LVMD NPS and MD UPS, maximum short-circuit currents of transformer supply)

The inverter path of the UPS, the output switch of the UPS and the MD UPS (main distribution at the UPS output side) are simulated by the equivalent circuit diagram of neutral system infeed. The (minimum and maximum) short-circuit currents of the UPS are entered as technical data for the neutral system infeed acc. to manufacturer specifications (see Table 1).

The outgoing-feeder from the LVMD SPS and the rectifier input including the charging current for the battery are simulated by a load on the LVMD SPS.

Figure 3: Detailed simulation of UPS installations in SIMARIS design



## Technical data of the UPS

For our example, the following manufacturer data for a specific UPS was used as basic data.

Technical data can be seen in Table 1 (in excerpts)

Maximum input current at the rectifier input
$I_{(max)}$ = 1,950 A

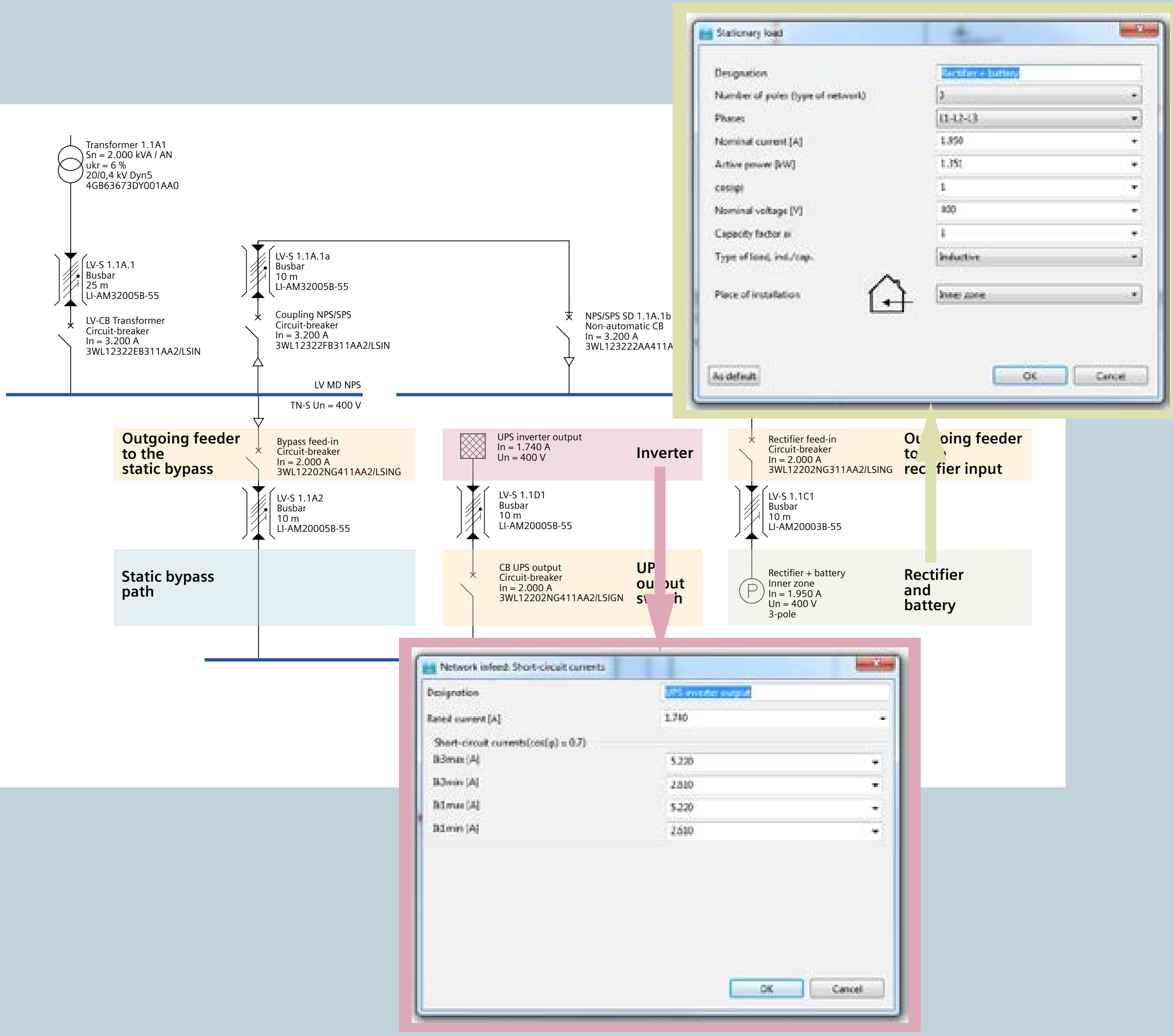
Rated output current = 1,740 A

Table 1: Excerpt from the technical data for a 1,200 kVA UPS

| Power output in kVA | | 200 | 400 | 600 | 800 | 1,000 | 1,200 |
|---|---|---|---|---|---|---|---|
| **Inverter output** | | | | | | | |
| Rated apparent power in kVA at 40°C ambient temperature, inductive or capacitive load factor | | 200 | 400 | 600 | 800 | 1,000 | 1,200 |
| Rated active power in kW | | 180 | 360 | 540 | 720 | 900 | 1,080 |
| Rated output current in A | | 290 | 580 | 870 | 1,160 | 1,450 | 1,740 |
| Maximum active power in kW | | 200 | 400 | 600 | 800 | 1,000 | 1,200 |
| Overload at rated output voltage for 10 min in % | | 125 | | | | | |
| Overload at rated output voltage for 1 min in % | | 150 | | | | | |
| Short-circuit strength for 10 ms / < 5 s in % | | 300/150 | | | | | |
| **Static bypass** | | | | | | | |
| Nominal voltage in V | | 400 (380/415 selectable, 3Ph + N) | | | | | |
| Nominal voltage range in % | | 10 (5 to 15 can be selected) | | | | | |
| Nominal frequency in Hz | | 50 (option: 60) | | | | | |
| Frequency range in % | | ± 1 (2, 3, 4 can be selected) | | | | | |
| Maximum overload capacity | for 10 min in % | 125 | | | | | |
| | for 1 min in % | 150 | | | | | |
| | for 600 ms in % | 700 | | | | | |
| | for 100 ms in % | 1,000 | | | | | |
| Thyristor | $I^2t$ @ Tvj=125 °C 8.3–10 ms in $kA^2s$ | 3,200 | 1,280 | 2,880 | 5,120 | 8,000 | 11,520 |
| | ITSM @ Tvj=125°C 10 ms in A | 800 | 12,700 | 16,640 | 20,160 | 23,390 | 26,415 |
| Rated power of the inverter fuse | $I^2t$ in $kA^2s$ | 67 | 268 | 603 | 1,072 | 1,675 | 2,412 |
| Switchover time, if the inverter is synchronous with the back-up system: inverter to back-up system and back-up system to inverter | | Non-interruptible | | | | | |

Figure 4 shows how to enter technical UPS data based on concrete manufacturer specifications (see Table 1) in SIMARIS design. This data is entered as technical data for the "dummies" used for simulation.

Figure 4: Entering technical data for the components used as substitutes (dummies) to simulate UPS installations in SIMARIS design



## Defining operating modes

To simulate operating modes for the calculation of maximum short-circuits currents (transformer supply) and minimum short-circuit currents (inverter mode), we suggest to set operating modes as follows (Figure 5).

To simulate the load conditions of the two UPS inputs – static bypass (transformer-supplied) and rectifier input (generator-supplied) – the following procedure is recommended:

1. The maximum UPS input load of 1,950 A, cos $\varphi = 1$, is connected to the generator distribution network (because cos $\varphi = 1$ is true for the UPS at the input). This simulates UPS feed-in ($I_n$ = 1,740 A) via rectifier including the UPS losses and battery charge (210 A) acc. to manufacturer specification. Since the network is decoupled towards the output by the semiconductor devices, it is sufficient to simulate the UPS and its associated outgoing feeder as a load on the LVMD SPS.

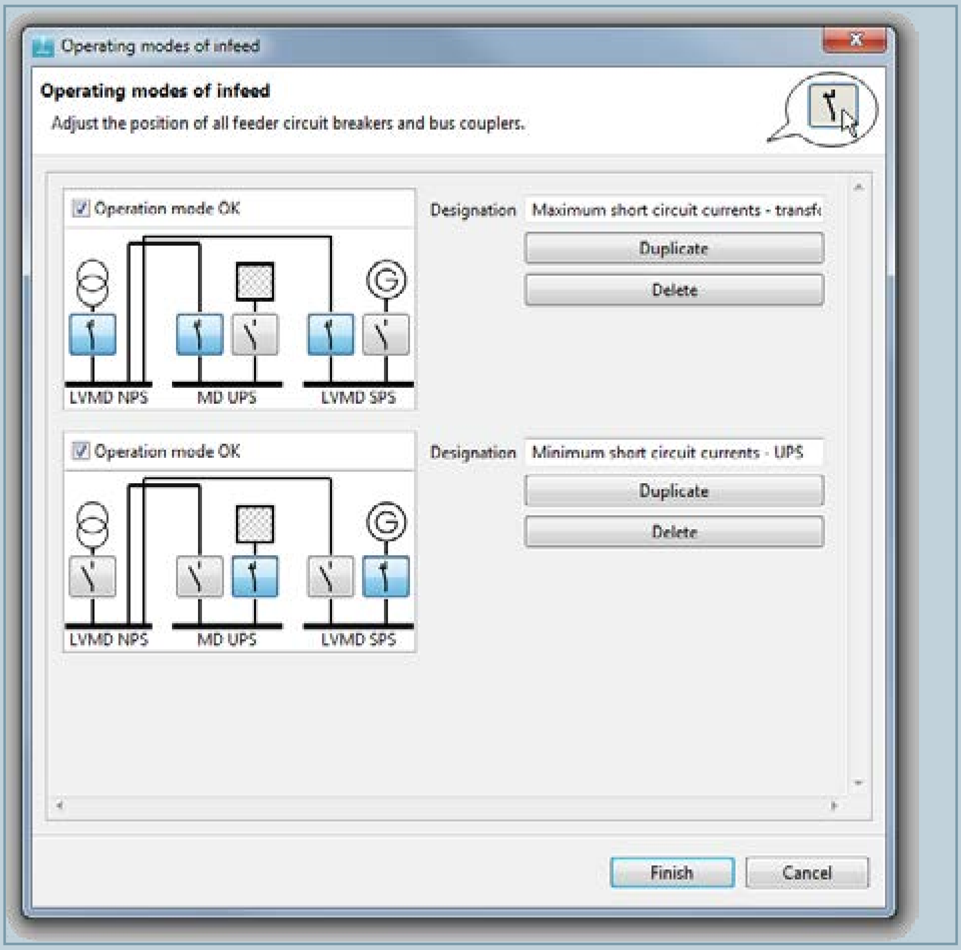
2. The MD UPS is loaded with the rated output current of 1,740 A, cos $\varphi = 1$ (for servers, cos $\varphi = 1$ generally is a very close approximation, but precise information must be obtained from the manufacturer in every single case).

3. Thus the LVMD SPS is loaded with the real UPS load (1,950 A) and the MD UPS with the rated UPS load (1,740 A). The LVMD NPS now carries a load of 1,950 A + 1,740 A. But only 1,950 A would be right. To compensate for this, the simultaneity factor ($g_i$) for the LVMD NPS is now determined as follows:
$g_i$ = 1,950 A / (1,950 A + 1,740 A) = 0.53

In this specific case, $g_i$ must be adjusted to the actual load conditions!

As soon as the operating modes have been defined and the technical data has been entered, the network calculation can be started, i.e. the equipment will be dimensioned.

Figure 5: Definition of operating modes to simulate transformer and inverter mode



## Simulation of short-circuit currents

The maximum short-circuit currents will flow through the static bypass, which is simulated in SIMARIS design as a unidirectional coupling from the LVMD NPS.

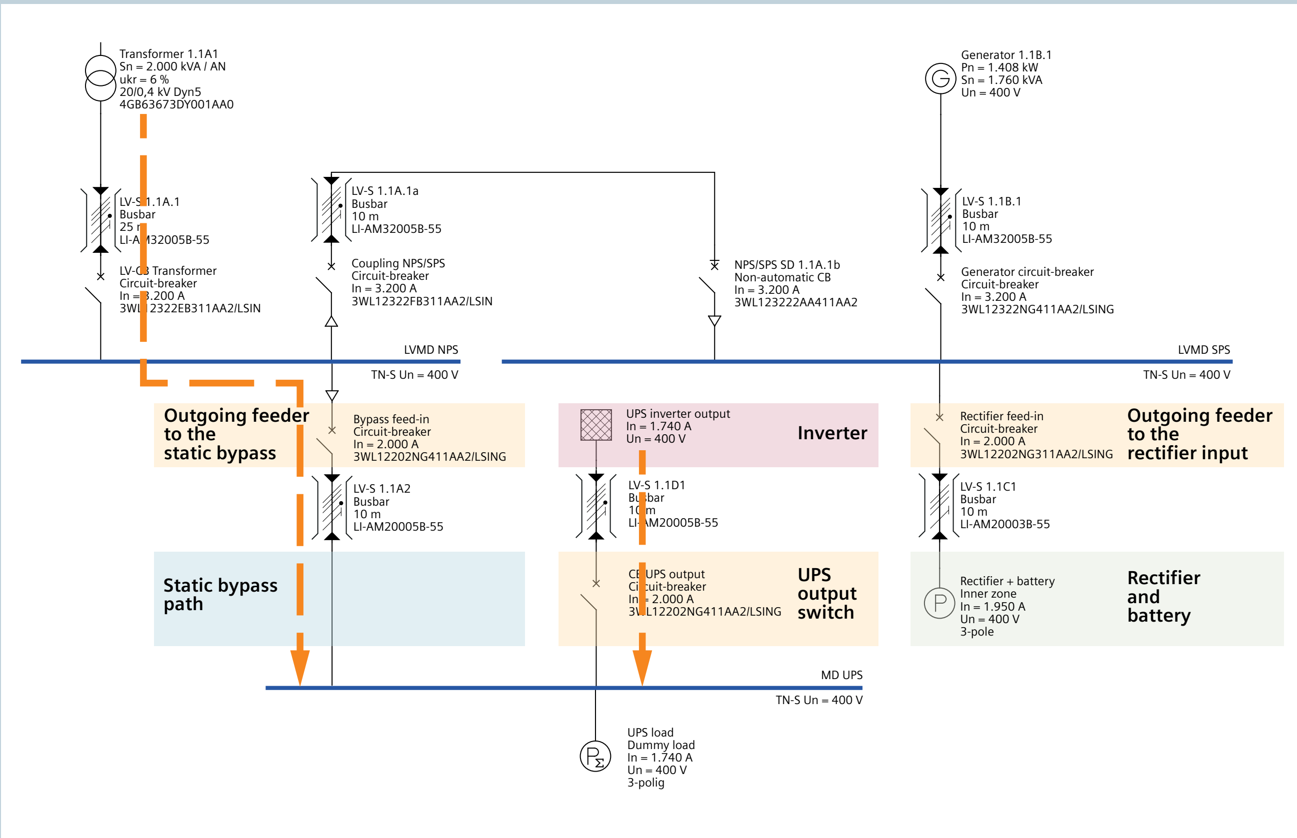
The inverter is simulated as a neutral system infeed, see Figure 4. The minimum (150% => 1.5 x $I_n$ = 2,610 A, 5 s) and maximum (300% => 3 x $I_n$ = 5,220 A, 10 ms) short-circuit currents of the inverter (see Table 1) are entered as technical data of neutral system infeed.

At the main distribution network of the UPS (MD UPS), this factors in the maximum short-circuit currents of transformer supply and the minimum short-circuit currents present during inverter supply.

The short-circuit strength of the outgoing feeder at the UPS must be the same as that of the outgoing feeder from the LVMD NPS to the static bypass (here 66 kA). This switch must be selected manually.

In accordance with IEC 60364-4-41 (DIN VDE0100 Part 410), the electronic tripping units ETU45B or ETU76B should be chosen as releases for 3WL circuit-breakers for reasons of selectivity (greater variability of setting options) and personal protection (G releases).

Figure 6: Simulation of short-circuit currents in networks including UPS installations in SIMARIS design



## UPS modules as Favourites

Individual components for modelling a UPS installation can be saved as Favourites in SIMARIS design. To do so, the LVMD NPS, LVMD SPS and MD UPS are saved as Favourites. These Favourites can now be read out using the menu item

**Tools > Favourites > Export Favourites**

Vice versa, existing collections of Favourites can be imported with the aid of the menu item

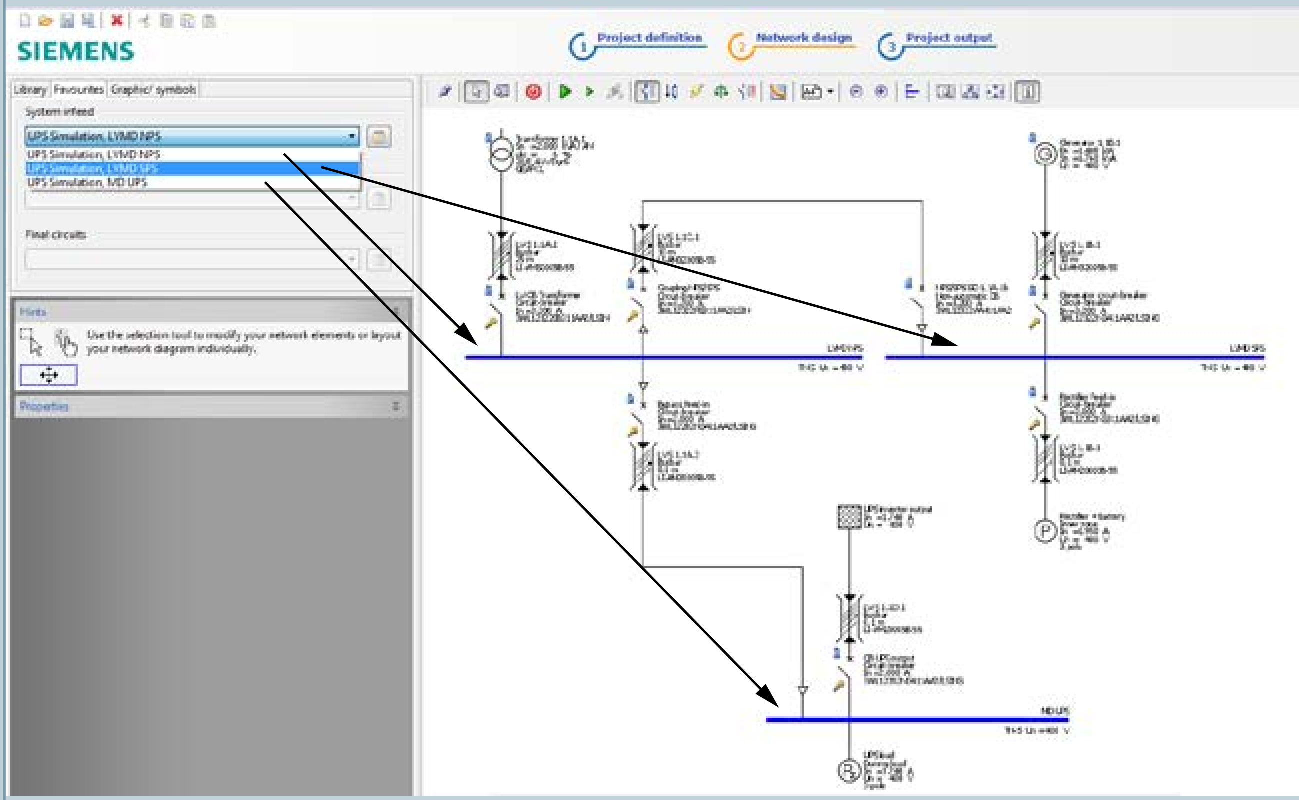
**Tools > Favourites > Import Favourites**

for use in a project dimensioned in SIMARIS design.

In the attachment to this document, you will find a SIMARIS design sample network (.sd) for a static UPS installation and the associated sample favourites (.sdt).

The files were created with SIMARIS design (**siemens.com/simaris**) .

Figure 7: Working with Favourites – to model a UPS, the unidirectional couplings between LVMD NPS => LVMD SPS and LVMD NPS => MD UPS must still be created.



# 4. Critical Issues of Integrating UPS Installations into Power Supply Systems

Independent of UPS simulation in SIMARIS design, the following issues must be paid special attention to when integrating UPS installations into power supply systems:

- Faults in the main distribution network for the UPS (MD UPS) are critical and must be prevented – by using high-quality components (busbar systems including type-tested connections, SIVACON S8 in a design that avoids earthing points which might provide a root for an accidental arc, ...)
- In inverter mode, faults in the MD UPS may become problematic concerning disconnection from supply in accordance with IEC 60364-4-41 (DIN VDE 0100 Part 410) if fault currents are almost as high as the rated currents. A remedy against 1-phase faults to earth could be high-quality circuit-breakers with G releases (e.g. Siemens 3WL circuit-breakers with ETU45B, ETU76B).
- Owing to the short-circuit response of the UPS, it is recommended for disconnection from supply in accordance with IEC 60364-4-43 (DIN VDE 0100 Part 430) to limit the rated currents of the switches in the outgoing feeder circuits of the MD UPS to 30% of the rated UPS output current.
- Low-performance UPS installations (< 100 kVA) may be equipped with RCDs to protect against 1-phase faults to earth. In case of an unfavourable MD UPS design, an optimized calculation of minimum short-circuit currents that takes the UPS control behaviour into account may be beneficial for equipment dimensioning.
- When analysing a possible short-circuit at the UPS output, the permissible load of the static bypass must be compared with the manufacturer data given for the UPS.
- If UPS installations shall be integrated into a TN-S system, some of the data to be defined, for instance, are the central earthing point and the pole numbers of the switching devices (3-pole or 4-pole).
- In case of parallel connection of UPS installations, a fault analysis of the lower-level distribution network may demonstrate that additional protection is required.

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Don't hesitate to get in touch with your regional Siemens contact in case of questions, or to obtain possible solutions for a specific application case:

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