SIEMENS

Totally Integrated Power

Technical Series Edition 3

Modeling of systems for Uninterruptible Power Supply (UPS) in SIMARIS® design for application in data centers

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1. Basics

Uninterruptible power supply to the servers is of fundamental importance for data centers in order to have those available 24 hours a day and 365 days a year. To achieve this goal, the power supply must be thoroughly planned. This includes the coordination between the components to be used, taking into account that the selection and integration of UPS systems in the power supply concept is essential in this process.

In accordance with the IEC 62040-3 standard (DIN EN 62040-3; VDE 0558 Part 530), UPS manufacturers can designate their devices according to the classification described therein. The assessment criteria are shown hereafter as an excerpt:

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 in normal operation in case of change of voltage and frequency at the input AC supply.

"VFD" (Voltage and Frequency Dependent):
UPS systems with VFD classification must protect the load against power failure.

In this case, the UPS output is influenced by changes of the input AC voltage and the frequency, and it is not suitable for assuming additional correction functions which may arise from the application of an autotransformer.

"VI" (Voltage Independent):
Like UPS systems with VFD, UPS systems with VI classification must protect the load against power failure, and also additionally ensure the supply in case of

- undervoltage permanently applied to the input
- overvoltage permanently applied to the input.

The output of a UPS with VI classification depends on the frequency of the AC voltage input, and the output voltage must remain within the prescribed limit voltage values.

"VFI" (Voltage and Frequency Dependent):
UPS systems with VFI classification are independent of (mains) supply voltage and frequency fluctuations, and must protect the load against negative effects of such fluctuations without discharging the energy storage system.

BB

Characteristic values dependent on the voltage curve. A difference is made between the following operating modes:

- Normal or bypass operation (first character)
- Energy storage operation (second character)

"S": The voltage curve is sinusoidal.
In case of linear and non-linear reference load (the exact specification can be found in IEC 62040-3), the total harmonic distortion is lower than 8 %. The curve shape is defined as sinusoidal.

"X": The curve shape is only sinusoidal in case of linear load. In case of non-linear reference load, the curve shape is no longer sinusoidal, as the total harmonic distortion exceeds the limit value of 8 %.

"Y": The voltage curve is not sinusoidal, neither for linear nor for non-linear reference loads. The limit value of 8 % is exceeded in both cases.

CCC

Characteristic values for the dynamic behavior of the UPS output voltage:

- First numeral: in case of change of the operating mode
- Second numeral: in case of linear load step in normal or battery operation (specification for the worst case)
- Third numeral: in case of non-linear load step in normal or battery operation (specification for the worst case)

"1": required operating behavior for sensitive, critical loads.
The UPS output voltage remains within the limit values of curve 1 (see IEC 62040-3) in this section.

"2": permissible operating behavior for most of the critical loads.
The UPS output voltage remains within the limit values of curve 2 (see IEC 62040-3) in this section.

"3": permissible operating behavior for most of the general IT loads, e.g. switched-mode power supplies.
The UPS output voltage remains within the limit values of curve 3 (see IEC 62040-3) in this section.

With SIMARIS design, electrical networks can be dimensioned with minimum input effort on the basis of real products – from the medium-voltage level down to the power consumer (which in the case of a data center means down to the rack where the ICT equipment (ICT: Information and Communication Technology) is supplied with power). This reduces your efforts for the overall planning of the power distribution a lot, and thus the time for selecting and dimensioning the electrical equipment – with a high level of planning security.

When UPS systems are integrated for planning the power distribution, the functionality is structured in SIMARIS design, both

- as a **load** for selecting the components of the infeed (transformers, generators, cables, busbars, switching devices)
- and as a **power source** to depict the effects on the downstream network regarding the maximum short-circuit currents in case of transformer infeed, as well as the minimum short-circuit currents in case of inverter operation mode.

Following the standard EN 50600-2-2, Clause 6.3.2, the functional elements of a power distribution system must be selected in accordance with the selectivity and short-circuit withstand strength requirements in all operating modes and during different operating phases.

To supply the connected loads, the

- supply via the UPS
- supply via a UPS bypass

must be considered. Infeed takes places either through a supply network (e.g. primary infeed for VFI operation and secondary supply in case of internal bypass operation of the UPS), or through an additional supply (e.g. generator).

With SIMARIS design it is possible to verify – for the downstream network – the compliance with the electrotechnical conditions according to the standard, such as the switch-off condition according to IEC 60364-4-41 (DIN VDE 0100 Part 410), as well as the selectivity.

2. Integration of UPS systems in power distribution networks

In power distribution networks, UPS systems are installed to protect critical consumers for which an interruption of the power supply or failures of the supply quality would lead to serious consequences such as data loss, production breakdown, or safety problems. The purpose of use usually determines the functionality of a UPS, and thus the associated UPS classification. When the UPS is integrated in the power distribution network, the functionality of the UPS must be observed in order to avoid malfunctioning and undesirable effects in case of fault or operational changes.

UPS systems with double instrument transformers (mostly with UPS classification VFI) offer the maximum safety by decoupling the load supply from the UPS input (see Fig. 1), and are taken as a basis for the following considerations.

The integration of a static UPS system in a concept for a power supply network will be shown in the following by means of a specific planning example, including the simulation of the UPS in SIMARIS design.

Based on the assumption that the input for the static bypass is supplied by the NPS busbar (transformer infeed, low-voltage main distribution LVMD of the normal power supply NPS) and the rectifier input is supplied by the SPS busbar (generator, LVMD of the safety power supply SPS), the resulting conditions from the perspective of the UPS output side (main distribution SD UPS) are shown in a simplified way in Fig. 2.

The static bypass is supplied by the LVMD NPS (transformer). This considers the high short-circuit currents of a transformer supply.

In double conversion operating mode, the UPS rectifier supply through the LVMD SPS (generator) is decoupled from the inverter output, which means that, in inverter operation, the fault currents at the UPS output are exclusively determined by the inverter, and must be taken into account in accordance with the manufacturer data.

Fig. 1: **Integration of UPS systems with DC link (double conversion)**

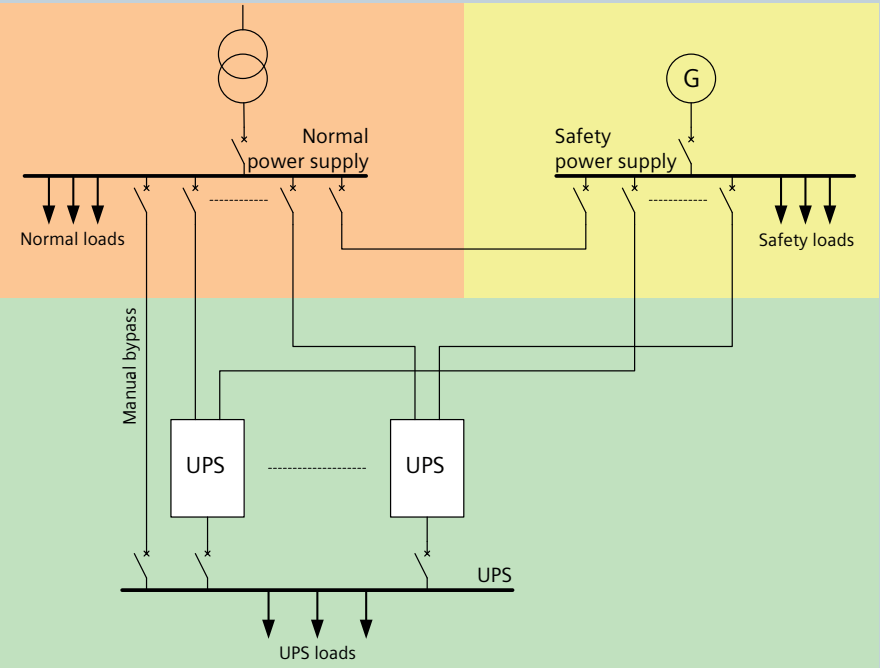
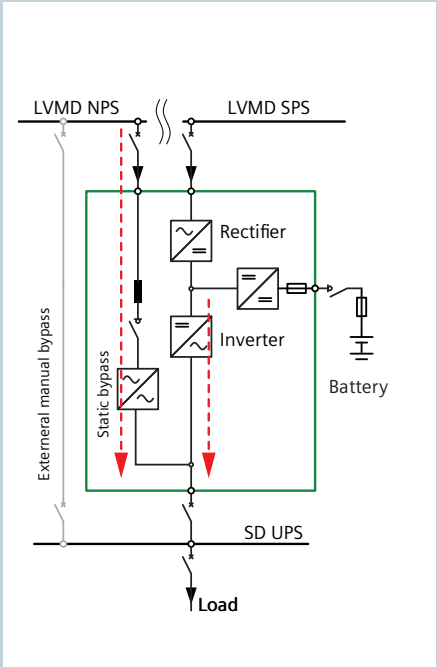


Fig. 2: **Supply of a short circuit on the output side by the transformer through the bypass or/and through the inverter**



3. Simulation of UPS systems in SIMARIS design

SIMARIS design offers various options for simulating UPS systems, of which only the detailed simulation according to Fig. 3 is represented. In this context, it must be observed that the UPS function modes are simulated together via SIMARIS design elements and the setting of various operating modes.

In Fig. 3, the essential components required for the functionality of the UPS are identified by means of color boxes. The red box marks the UPS as a symbol:

Yellow: **Internal, static UPS bypass** at one outgoing circuit-breaker from the LVMD NPS to the UPS output

Green: **Inverter** as power source connected to the UPS output

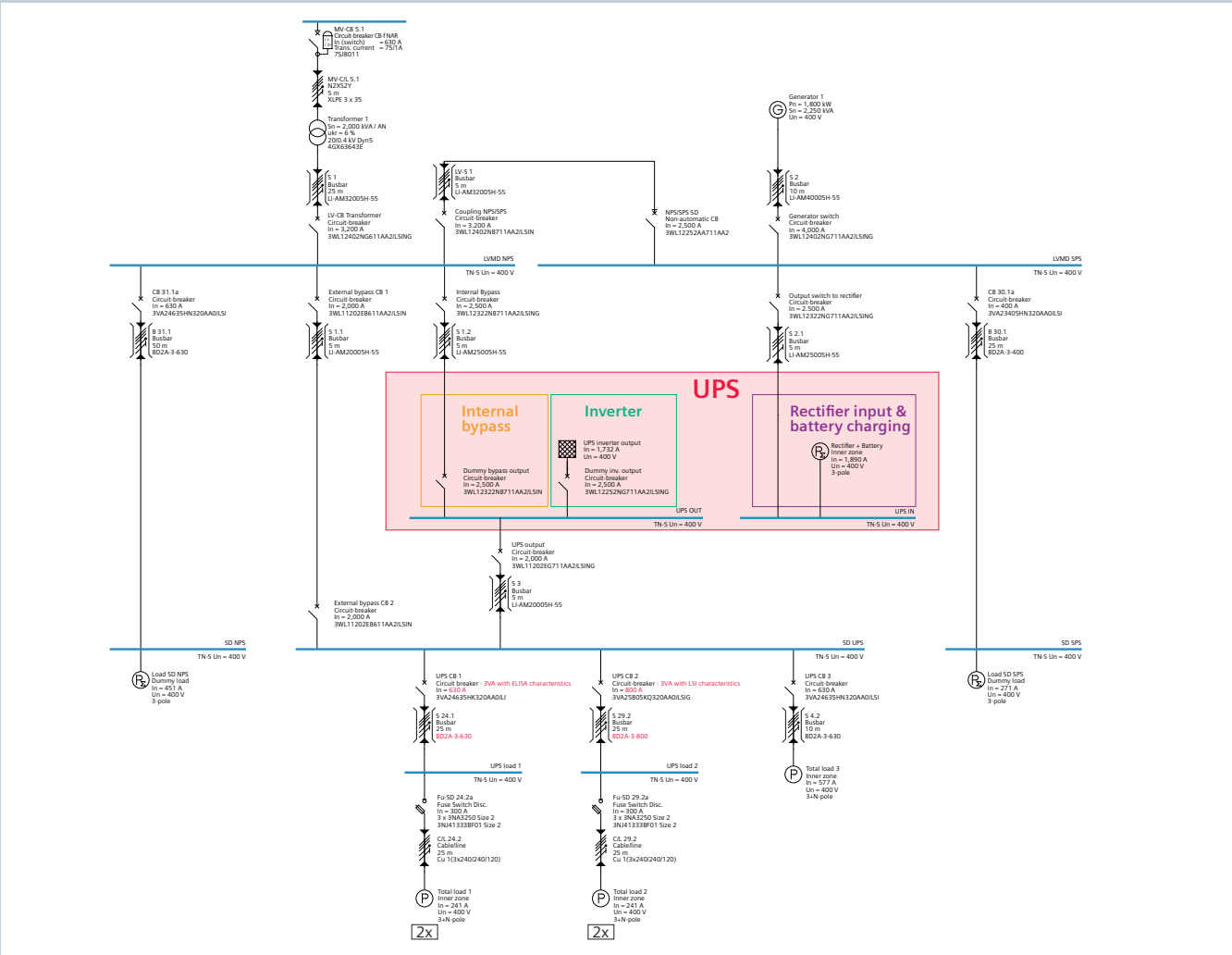
Dark red: **Rectifier** as load for rectifier supply and battery charging at the incoming distribution from the generator busbar

Remark: Regarding the rectifier requirements, not only the battery charging, but also the UPS losses in operation must be considered.

Moreover, Fig. 3 shows the three types of power supply via the corresponding sub-distributions:
- Normal power supply NPS (sub-distribution SD NPS)
- Safety power supply SPS (sub-distribution SD SPS)
- Uninterruptible power supply (sub-distribution SD UPS)

In addition, Fig. 3 shows a comparison between a molded-case circuit-breaker 3VA with the ELISA tripping unit and a 3VA circuit-breaker with an LSI tripping unit at the UPS sub-distribution. The advantages of adjusting the ELISA tripping characteristic to the one of a fuse are suggested. The example can also be found in the enclosed SIMARIS design file. Please contact your TIP partner at Siemens for more information.

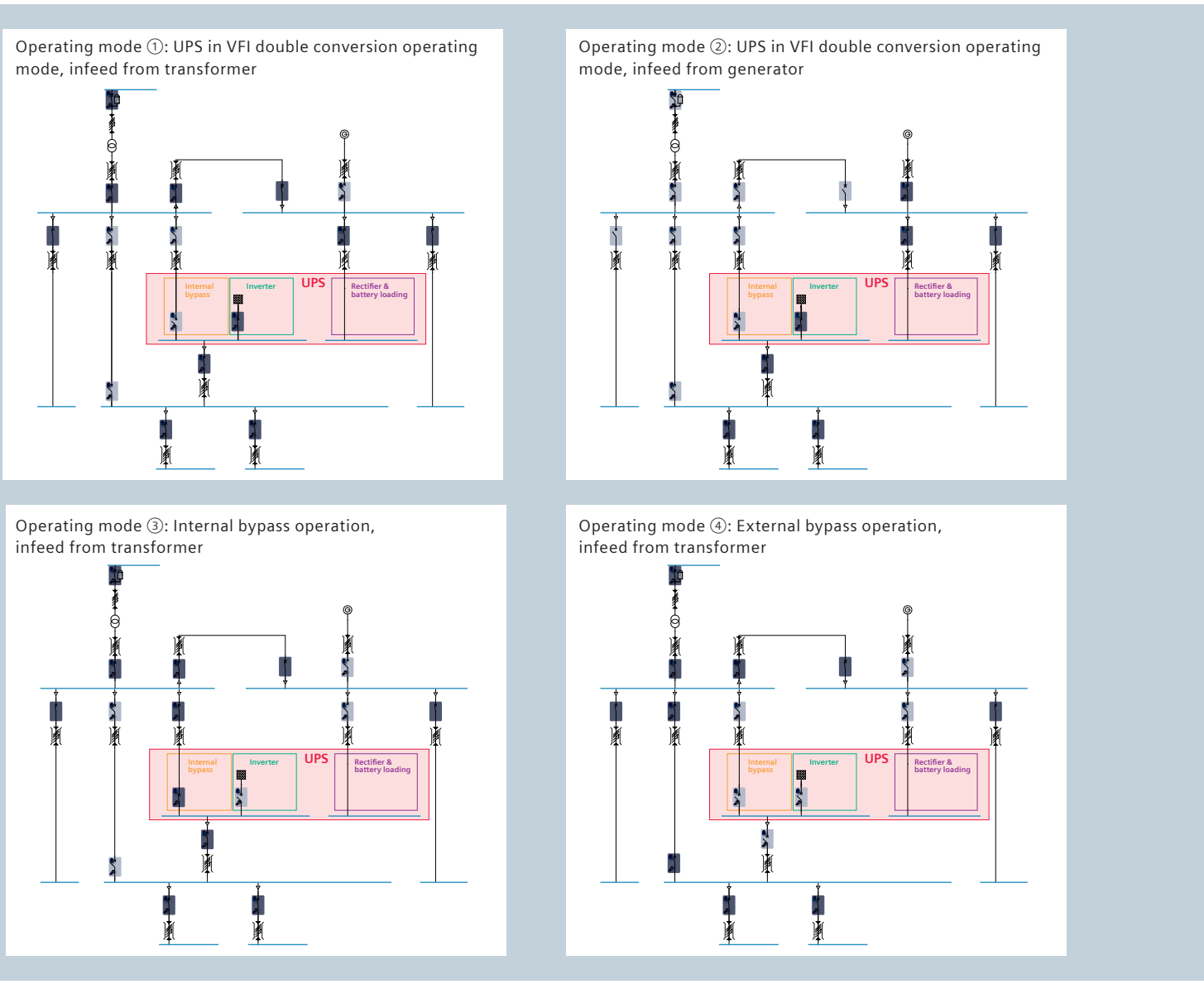
Fig. 3: **Detailed simulation of UPS systems in SIMARIS design**



For the different functionalities of the UPS, individual operating modes can be defined and calculated in SIMARIS design (Fig. 4):

- Normal UPS operation VFI ①:
  Double conversion operating mode of the UPS via rectifier and inverter fed by the transformer
- Normal UPS operation VFI via generator ②:
  Double conversion operating mode of the UPS via rectifier and inverter fed by the generator
- Internal bypass operation of the UPS ③:
  The rectifier and inverter of the UPS are bypassed; the UPS sub-distribution MD UPS is supplied through the transformer
- External bypass operation for UPS service purposes ④:
  The UPS is isolated and all loads are supplied through the transformer.

Fig. 4: **Functional UPS simulation by determination of operating modes in SIMARIS design**



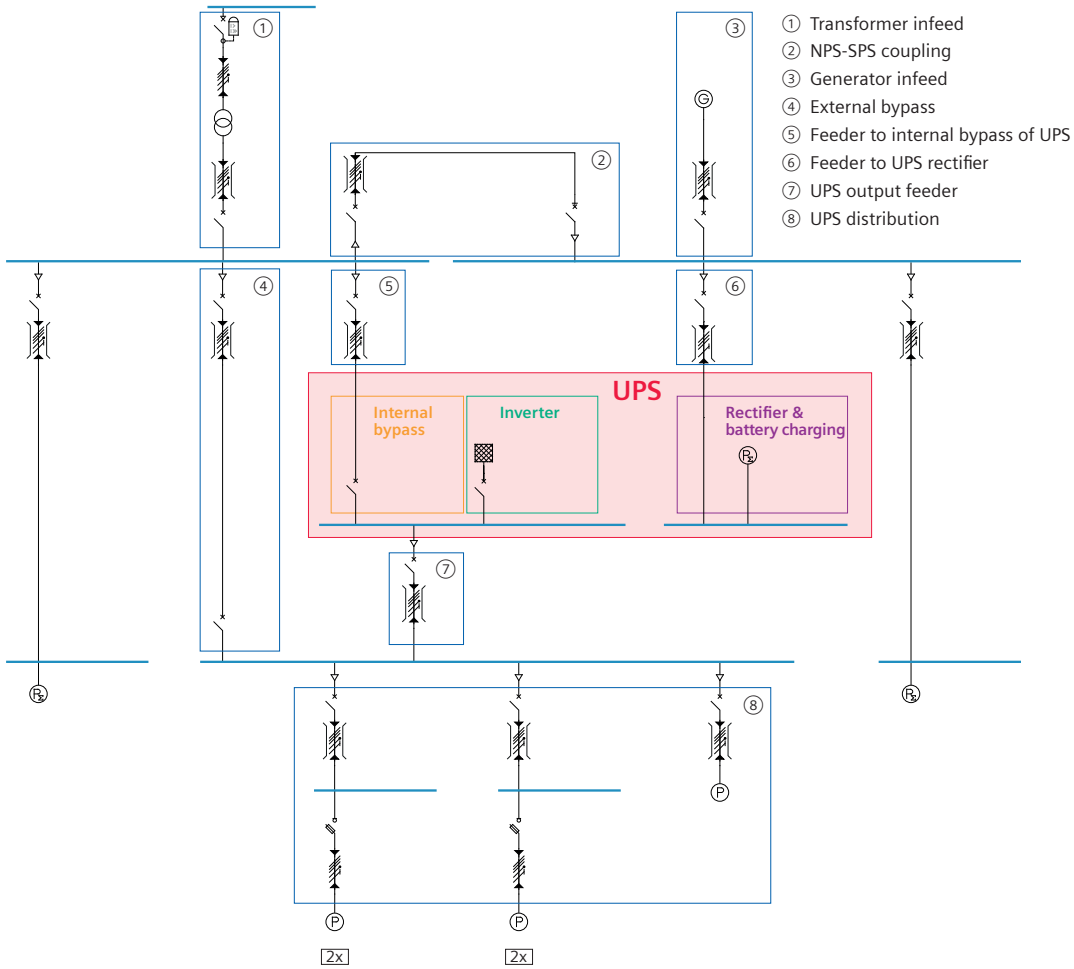
To illustrate the correlations between the operating modes and the calculations in SIMARIS design, the different operating modes are itemized in Tab. 1 and Tab. 2:

- Tab. 1 shows the relevant circuits for dimensioning in the respective operating mode (illustration in Fig. 5)
- Tab. 2 shows the current paths for determining the selectivity and the switch-off conditions, and assigns them to the respective operating modes (illustration in Fig. 6).

Tab. 1: **Observance of operating mode determination when dimensioning with SIMARIS design**

Dimensioning of products and systems (x identifies operating modes to be considered during dimensioning)									
		Circuit (see Fig. 5)							
		①	②	③	④	⑤	⑥	⑦	⑧
Operating mode	UPS VFI operation via transformer	x	x				x	x	x
	UPS VFI operation via generator			x			x	x	x
	Internal bypass operation	x	x			x		x	x
	External bypass operation	x	x		x				x

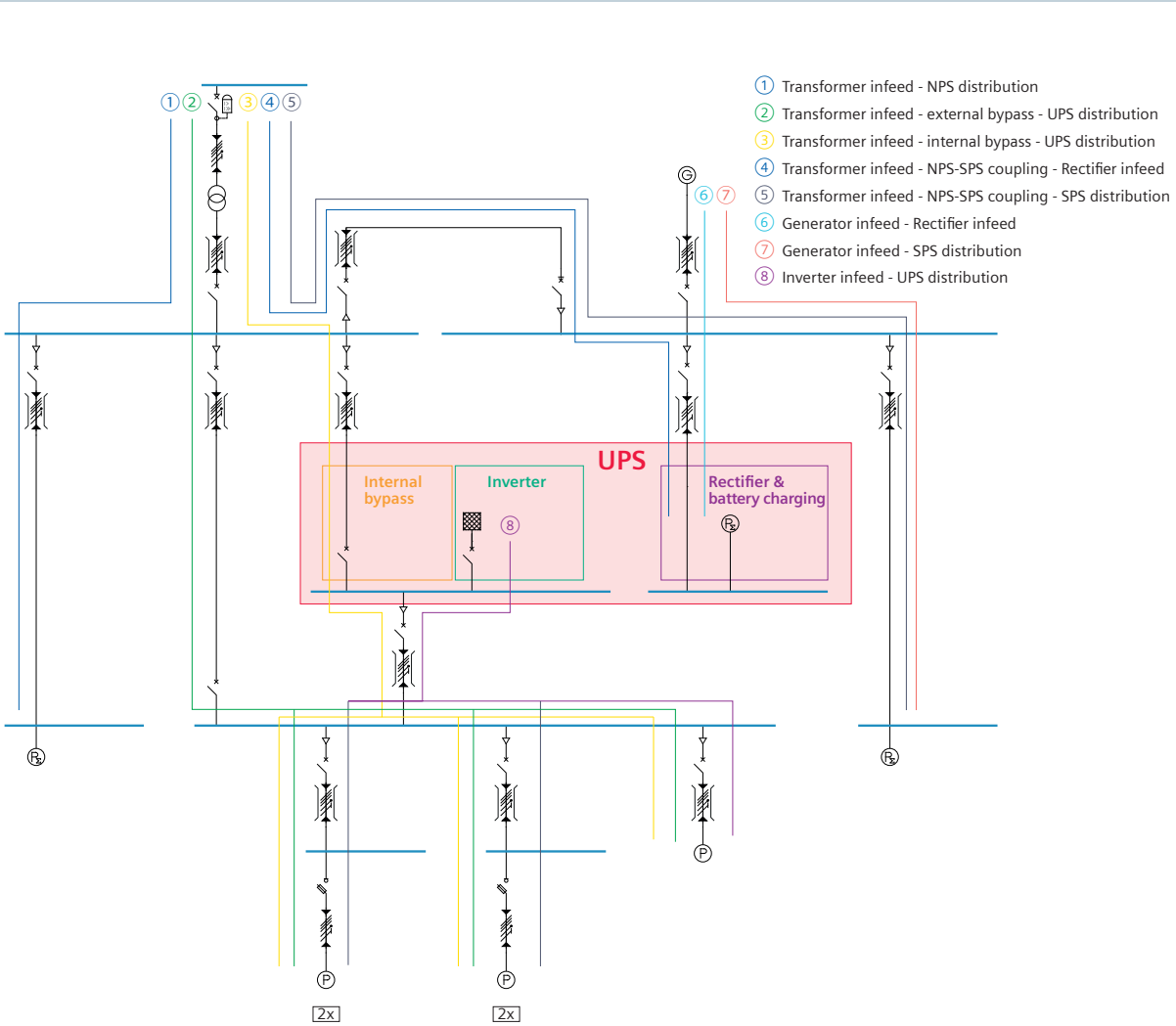
Fig. 5: **Illustration of circuits for dimensioning during UPS simulation**



Tab. 2: **Observance of operating mode determination for considerations of selectivity and switch-off conditions with SIMARIS design**

Selectivity and switch-off conditions (x identifies current paths to be observed)					
		UPS VFI operation via transformer	UPS VFI operation via generator	Internal bypass operation	External bypass operation
Current paths (see Fig. 6)	①	x		x	x
	②				x
	③			x	
	④	x			
	⑤	x		x	x
	⑥		x		
	⑦		x		
	⑧	x	x		

Fig. 6: **Illustration of current paths for considerations of selectivity and switch-off conditions during UPS simulation**



4. Technical UPS data for simulation in SIMARIS design

For the example shown in here, manufacturer information for a specific UPS with an apparent power of 1,200 kVA was taken as a basis (see Tab. 3).

Tab. 3: **Technical data for the example UPS[1] (used in the enclosed SIMARIS design file)**

Rated value of the apparent power in kVA	1,200
Rated active power in kW	1,200
Rated voltage in V	400 (380/415 selectable, 3ph + N)
Rated frequency in Hz	50 (60 selectable)
Rated output current in A	1,731
Maximum input current in A	1,890
Maximum short-circuit current (short-circuit withstand strength of the UPS) in A	3,877
Minimum short-circuit current (overload capability of the UPS[2]) in A	2,597

1) The UPS data corresponds to a Liebert® Trinergy™ Cube of Vertiv™ with an apparent power of 1,200 kVA
2) Information of Vertiv™: 150 % overload at rated output voltage for 1 min

5. Critical issues regarding the integration of UPS systems in power supply networks

Regardless of the simulation of a UPS in SIMARIS design, the following issues must be especially observed when integrating UPS systems in power supply networks:

- Faults on the SD UPS are critical and must be avoided preventively – using high-quality components (busbar trunking systems including design verified connection; SIVACON S8 in rootless design, ...)
- In inverter operation, faults on the SD UPS can be a problem for switching off according to IEC 60364-4-41 (DIN VDE 0100 Part 410) if the fault currents are almost as high as the rated currents. In case of 1-pole faults to earth, high-quality circuit-breakers with G releases (e.g. Siemens 3WL circuit-breakers with ETU45B, ETU76B and 3VA circuit-breakers with ETU550/560, ETU 850/860) can be the solution
- When switching off according to IEC 60364-4-43 (DIN VDE 0100 Part 430) and in order to implement selectivity, it is advisable – due to the UPS short-circuit behavior – to limit the rated currents of the switching devices in the outgoing feeders of the SD UPS to 30 % of the UPS rated output current
- For low-range UPS systems (< 100 kVA), RCDs can be used for 1-pole faults to earth. In case of unfavorable design of the SD UPS, an optimized calculation of the minimum short-circuit currents under consideration of the regular UPS behavior can be an advantage for the design
- In case of short circuit at the UPS output, the permissible load of the static bypass must be compared with the information of the UPS manufacturer
- If the UPS manufacturer uses a a semiconductor fuse for protecting the static bypass, this must be observed in the selectivity considerations
- When integrating the UPS systems in a TN-S system, the central earthing point and the number of poles of the switching devices (3- or 4-pole) must be defined, among others
- In case of UPS systems connected in parallel, a fault analysis in the downstream distribution network can reveal a possible additional protection requirement.

6. Sample file for SIMARIS design

Enclosed with the document you will find the SIMARIS design model network (.sdx) with a static UPS system for integration in your own projects. The file has been created with SIMARIS design 10.

Further information as well as the SIMARIS suite, which allows you to access planning tools such as SIMARIS design 10, can be found at **siemens.com/simaris**.

Imprint

Published by: Siemens AG

Smart Infrastructure
Distribution Systems
Mozartstr. 31 c
91052 Erlangen, Germany

E-mail: consultant-support.tip@siemens.com

For the U.S. published by
Siemens Industry Inc.

100 Technology Drive
Alpharetta, GA 30005
United States

Subject to change without prior notice • 10/20