UPS and Battery Systems

IEEE Seminar Houston, October 20th – 21st, 2015

Tuesday, October 20th 2015
6:00 – 8:50 PM

Agenda

- Introduction
- Basic functions of UPS
- Industrial UPS markets
- Find the best UPS solution
- UPS configurations
- UPS solutions in detail - AC and DC
- Q&A and wrap-up

Wednesday, October 21st 2015
6:00 – 8:50 PM

Agenda

- Follow-up day 1
- UPS technology
- Operating and monitoring of UPS
- UPS for nuclear applications
- Batteries
- Standards
- Maintenance
- Q&A and wrap-up

Life Is On | Schneider Electric

Follow-up Day 1: Any questions?

Life Is On | Schneider Electric

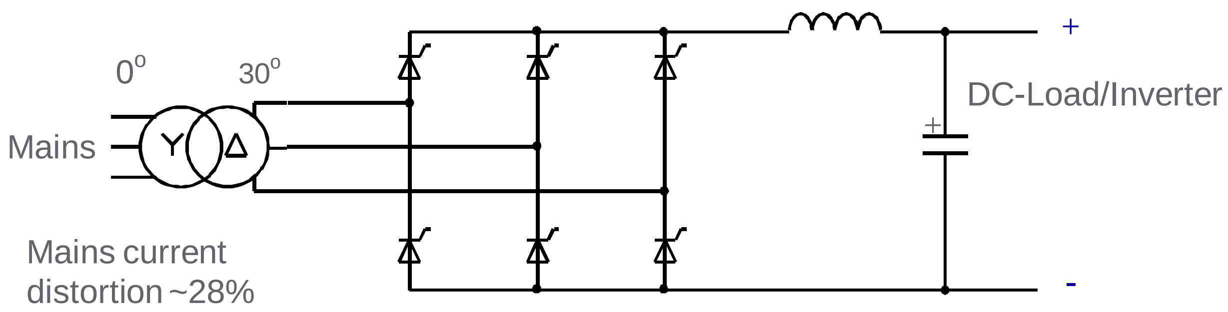
UPS technology

UPS technology

- Thyristor rectifier
  - 6-Pulse
  - 12-Pulse
- PFC Rectifier (Power Factor Corrected)
- Relation Harmonic Current and Voltage
- IEEE 519 Harmonic Considerations
- How can the Harmonic Current be reduced
- IGBT PWM Inverter
  - Inverter Performance
  - Inverter Short Circuit Considerations
- Heavy overload / short circuit on AC safe-bus / load

UPS and Battery Systems

Rectifier 6-Pulse Configuration



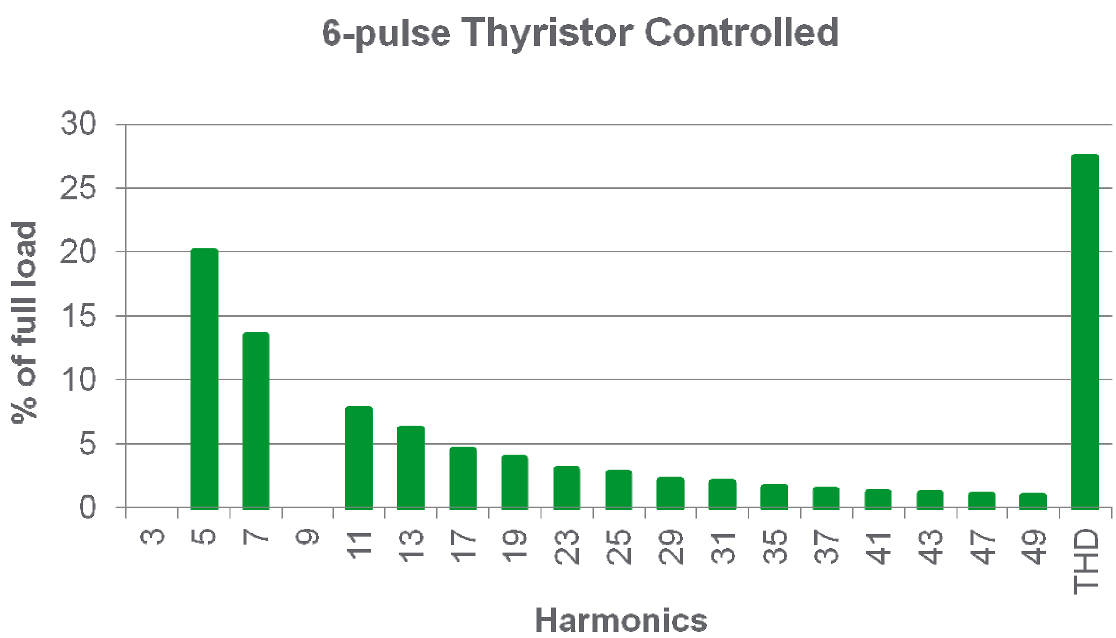
Characteristics

- Input isolation transformer with 30° phase shift
- Full wave 6-pulse thyristor bridge
- LC smoothing filter
- Up driven control loop

UPS and Battery Systems
Rectifier 6-Pulse Harmonics

Order of Harmonics	Harm. Current % of total load	Order of Harmonics	Harm. Current % of total load
1	100	25	2.7
3	0	29	2.2
5	20	31	2
7	13.5	35	1.6
9	0	37	1.4
11	7.7	41	1.2
13	6.2	43	1.1
17	4.5	47	1
19	3.9	49	0.9
23	3	**THD**	**27.4**

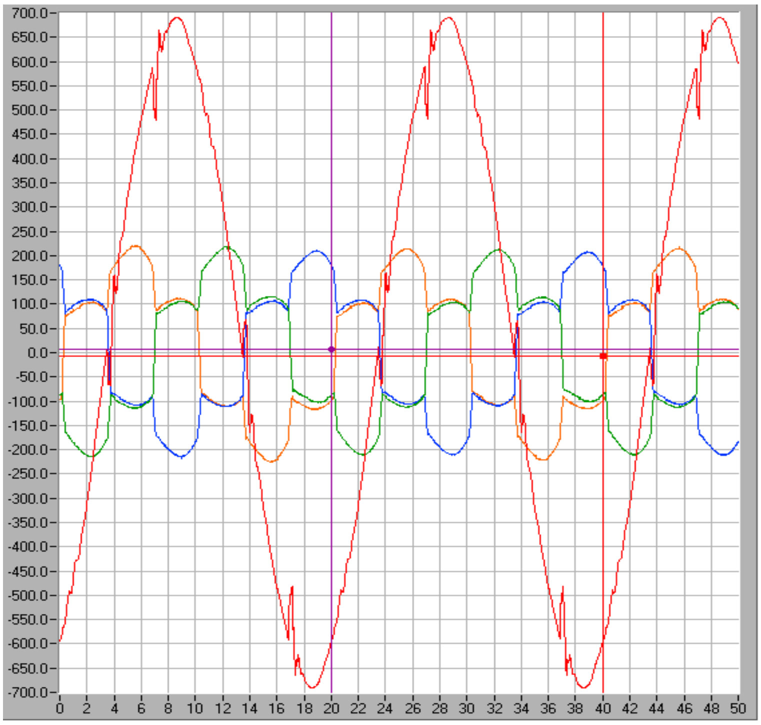
UPS and Battery Systems
Rectifier 6-Pulse Harmonics



UPS and Battery Systems

Rectifier 6-Pulse Harmonics

- Voltage L1 to L2
- Current L1
- Current L2
- Current L3



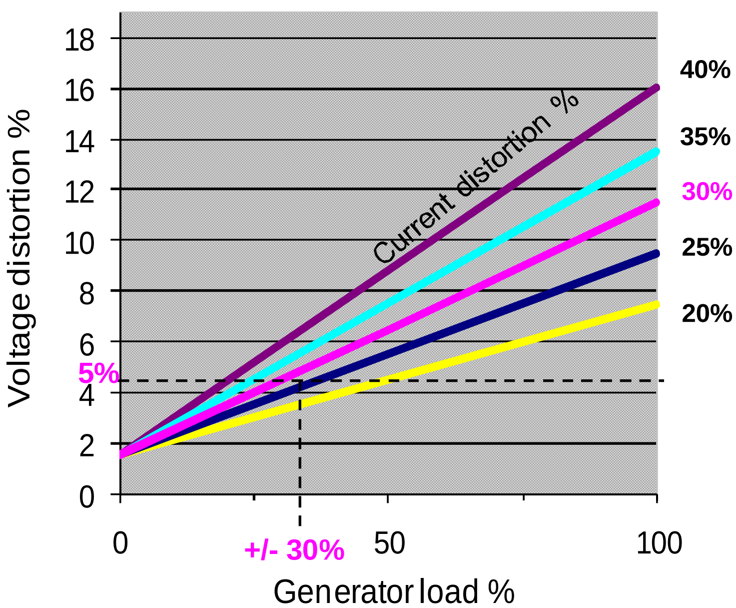
Mains current THD distortion ~28%

Check Generator rating:
approx. 3 x Rectifier rating

UPS and Battery Systems

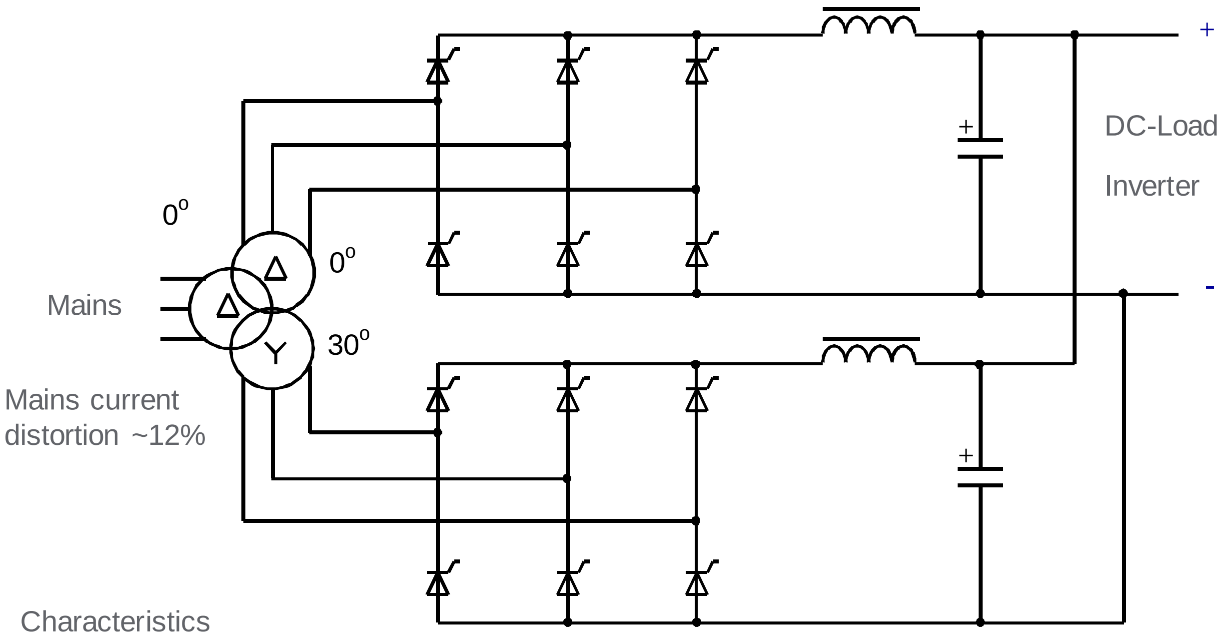
Rectifier 6-Pulse Diesel Generator Sizing

Load factor vs distortion for 6-pulse loads



UPS and Battery Systems

Rectifier 12-Pulse Configurator



Characteristics
- Input isolation transformer with 0° and 30° phase shi ft
- 2 x full wave 6-pulse thyristor bridges coupled with 30° phase shift
- LC smoothing filter
- Up driven control loop with active load sharing

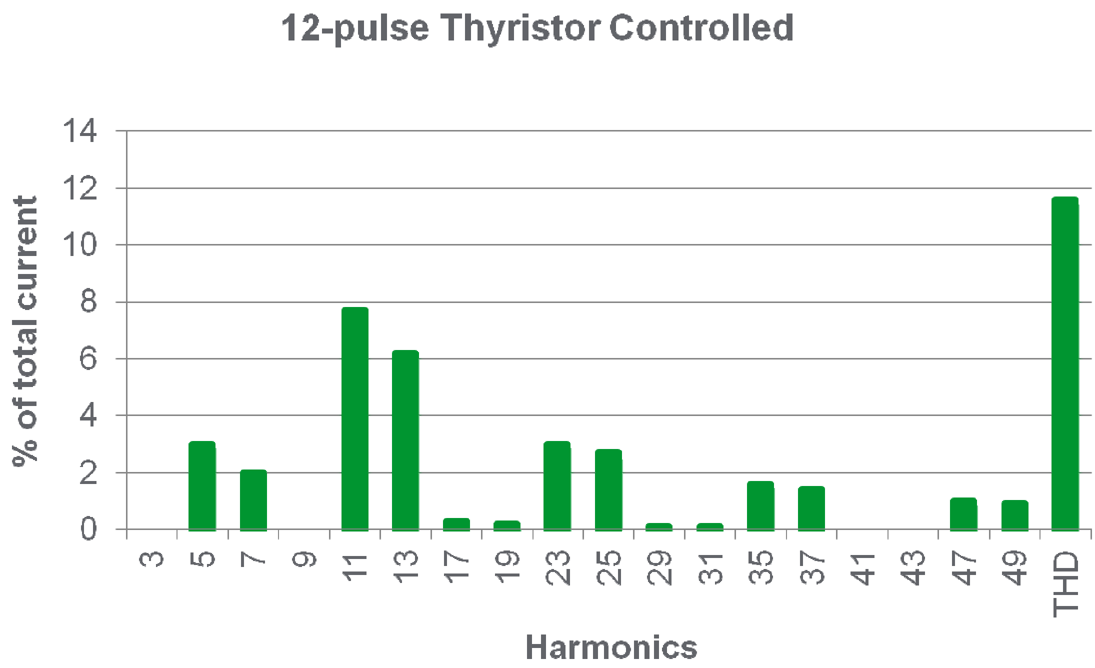
UPS and Battery Systems

Rectifier 12-Pulse Configurator

Order of Harmonics	Harm. Current % of total load	Order of Harmonics	Harm. Current % of total load
1	100	25	2.7
3	0	29	0.1
5	3	31	0.1
7	2	35	1.6
9	0	37	1.4
11	7.7	41	0
13	6.2	43	0
17	0.3	47	1
19	0.2	49	0.9
23	3	**THD**	**11.6**

UPS and Battery Systems

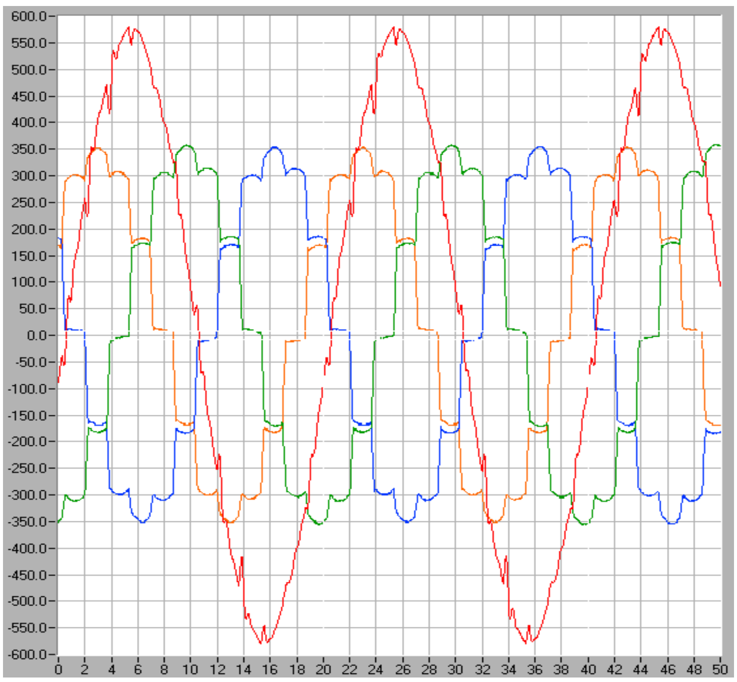
Rectifier 12-Pulse Harmonics



UPS and Battery Systems

Rectifier 12-Pulse Harmonics

- Voltage L1 to L2
- Current L1
- Current L2
- Current L3



Mains current THD distortion ~12%

Check Generator rating:
1,5 - 2,0 x Rectifier rating

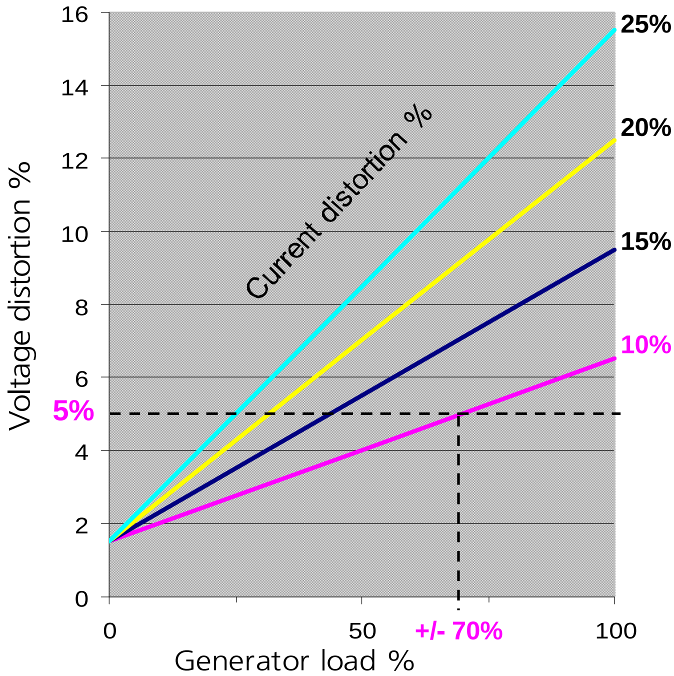
Preferred Solution for harmonic current reduction

Life Is On Schneider Electric

UPS and Battery Systems

Rectifier 12-Pulse Diesel Generatir Sizing

Load factor vs distortion for 12-pulse loads

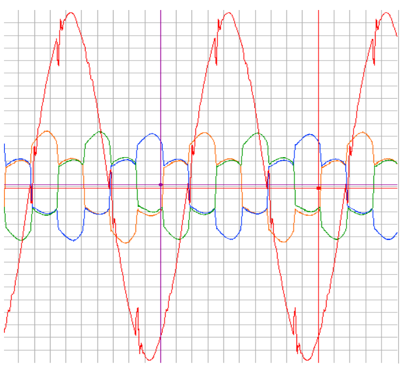


UPS and Battery Systems

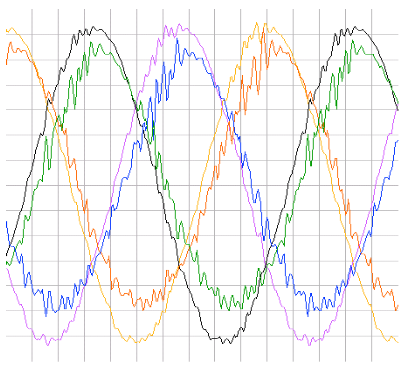
Rectifier with PFC

Reduction of harmonics

- PFC rectifier drastically reduces level of input harmonics (<5% THDi)
- No distortion of upstream equipment
- No need for 12-pulse thyristor bridge or additional harmonic filters



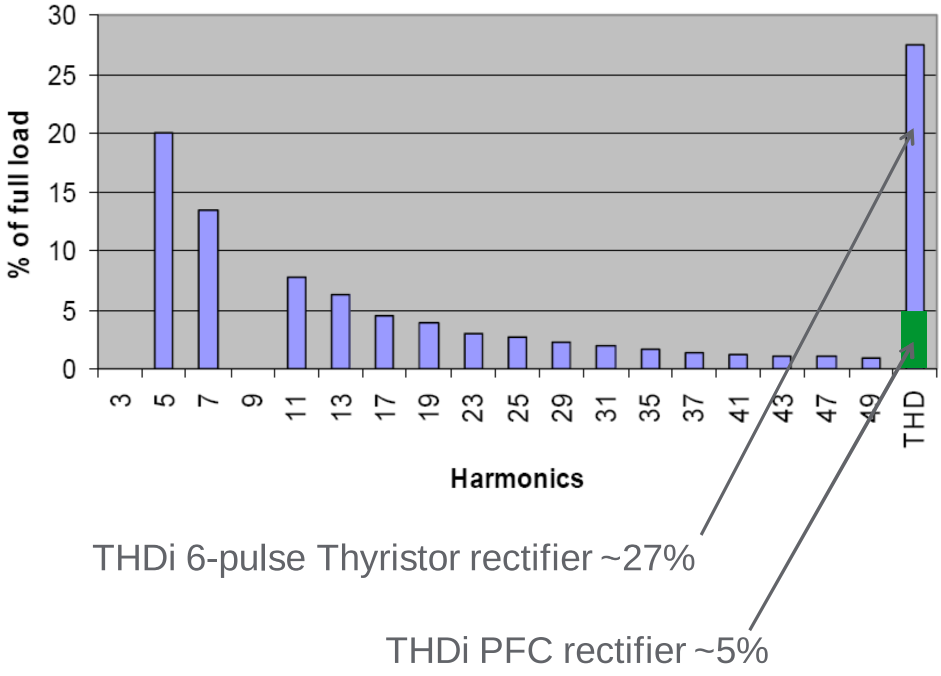
Thyristor-rectifier 6-Puls



PFC-rectifier

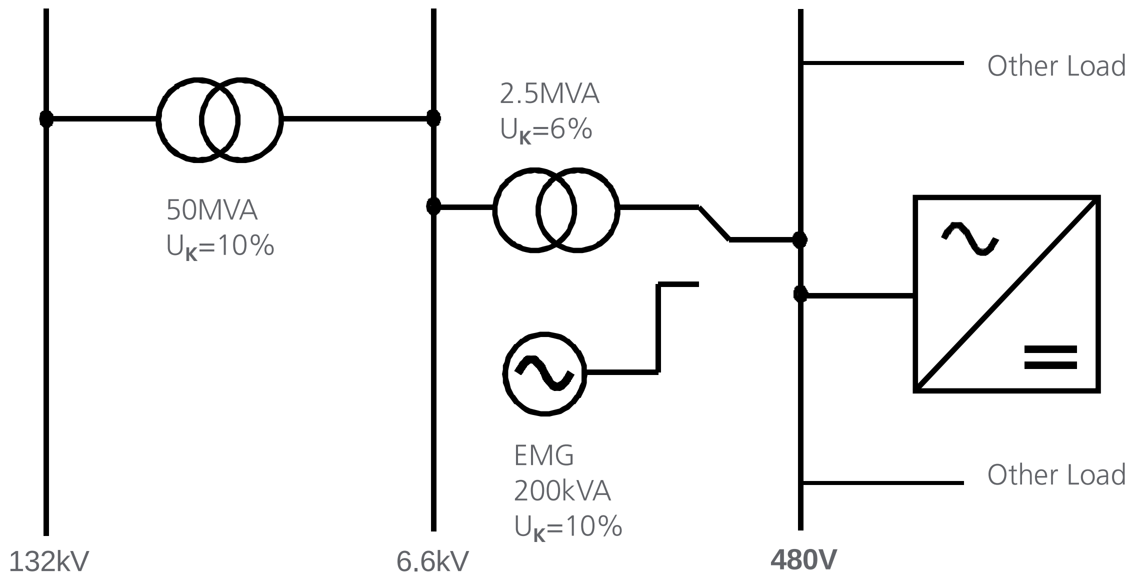
UPS and Battery Systems

THDi Thyristor rectifier compare with PFC rectifier



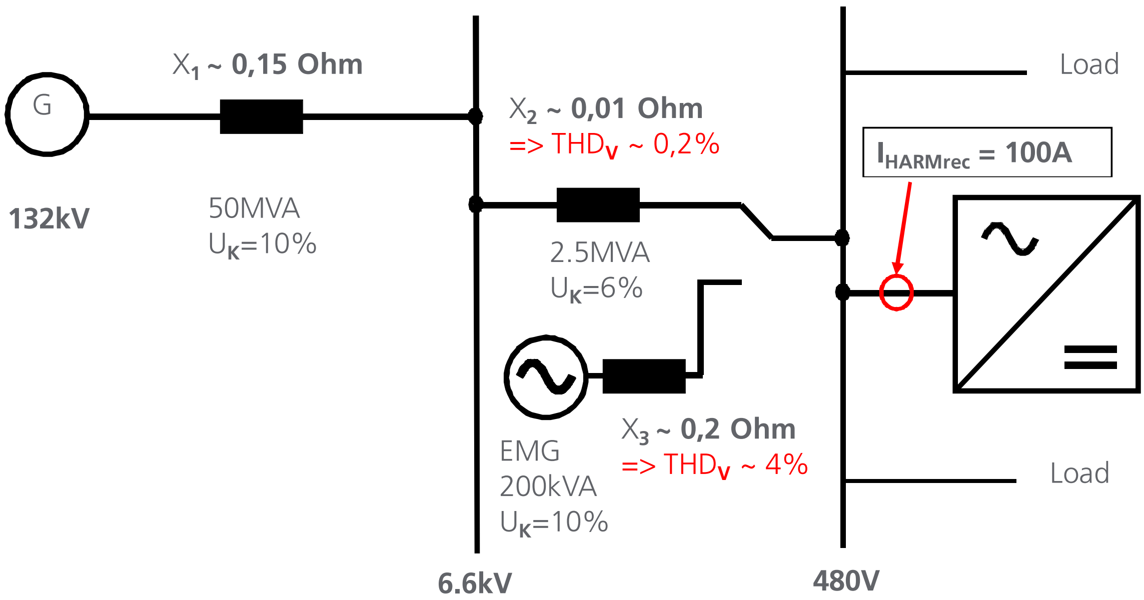
UPS and Battery Systems

Relation Harmonic Current and Voltage



UPS and Battery Systems

Relation Harmonic Current and Voltage



UPS and Battery Systems

IEEE 519 Harmonic Considerations

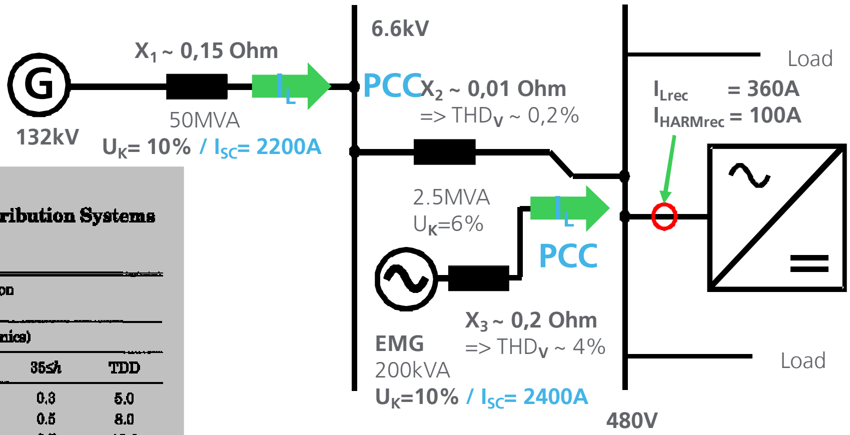


Table 10.3
Current Distortion Limits for General Distribution Systems (120 V Through 69 000 V)

	Maximum Harmonic Current Distortion in Percent of I_L					
	Individual Harmonic Order (Odd Harmonics)					
I_{sc}/I_L	<11	11≤h<17	17≤h<23	23≤h<35	35≤h	TDD
<20*	4.0	2.0	1.5	0.6	0.3	5.0
20<50	7.0	3.5	2.5	1.0	0.5	8.0
50<100	10.0	4.5	4.0	1.5	0.7	12.0
100<1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Even harmonics are limited to 25% of the odd harmonic limits above.

Current distortions that result in a dc offset, e.g., half-wave converters, are not allowed.

*All power generation equipment is limited to these values of current distortion, regardless of actual I_{sc}/I_L.

where

I_{sc} = maximum short-circuit current at PCC.
I_L = maximum demand load current (fundamental frequency component) at PCC.

Extract from IEEE 519-1992

Location of PCC (Point of Common Coupling) is difficult to determine and may vary depending on Power Generation topology.

IEEE 519 harmonic limits must be considered for the whole plant power distribution scheme.

UPS and Battery Systems

How can the Harmonic Current be reduced?

From 6-pulse to 12-pulse Rectifier → From 28% down to 10 -12%

Additional filter for the 11th and 13th harmonics for 12-pulse Rectifier → Down to ~5%

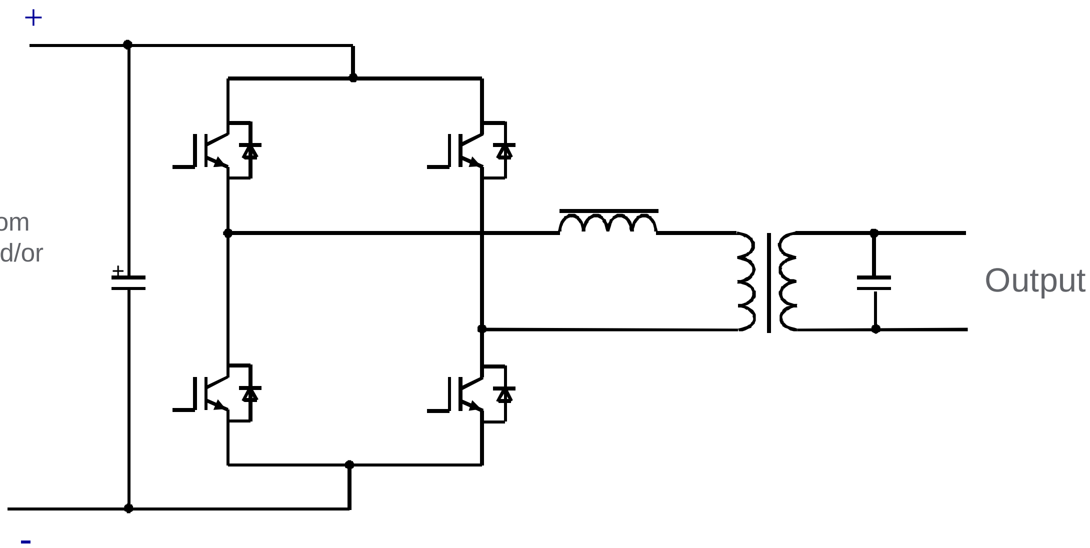
Additional active harmonic filters
or
Power Factor Corrected (PFC) Rectifiers with IGBT Transistors → Down below 5 %

Life Is On | Schneider Electric

UPS and Battery Systems

PWM IGBT Inverter

DC Input from Rectifier and/or Battery

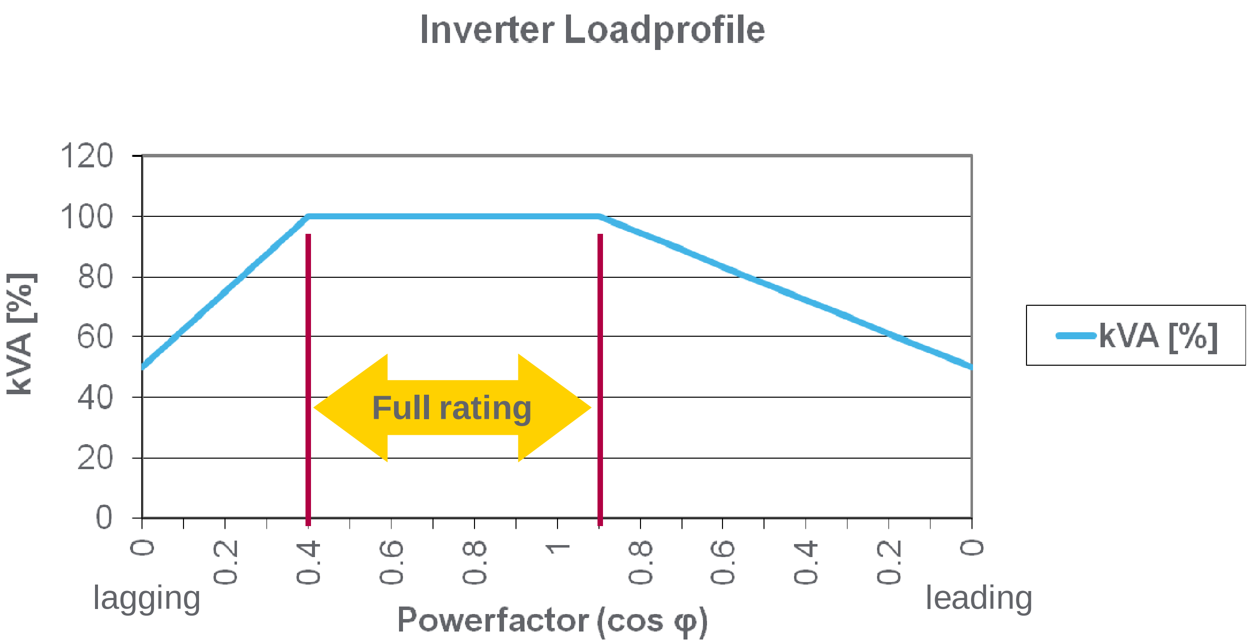


Characteristics

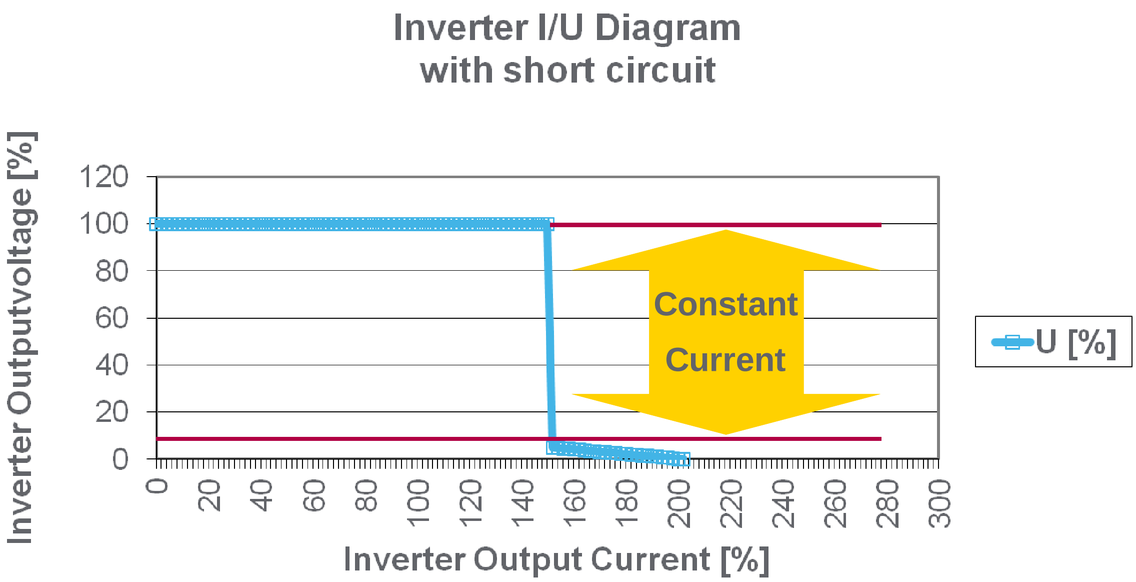
- Pulse Width Modulation (PWM) with >2kHz carrier frequency
- IGBT Insulated Gate Bipolar Transistor switching-bridges
- Linear inverter isolation transformer with connected sine wave filter
- Fast control loop and digital monitoring

Life Is On | Schneider Electric

UPS and Battery Systems
Inverter Performance

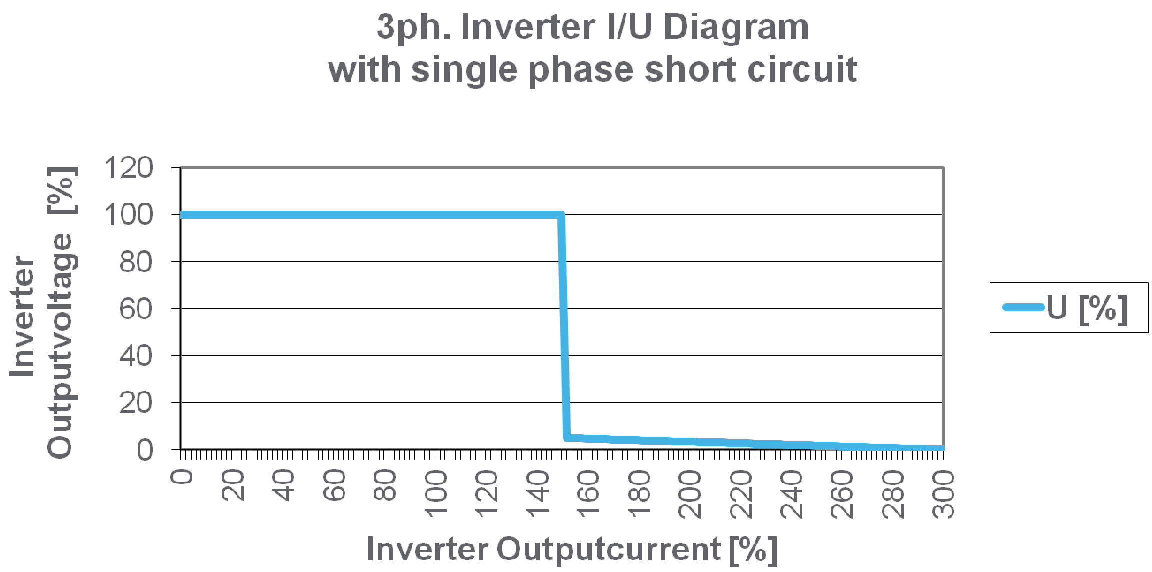


UPS and Battery Systems
Inverter Performance



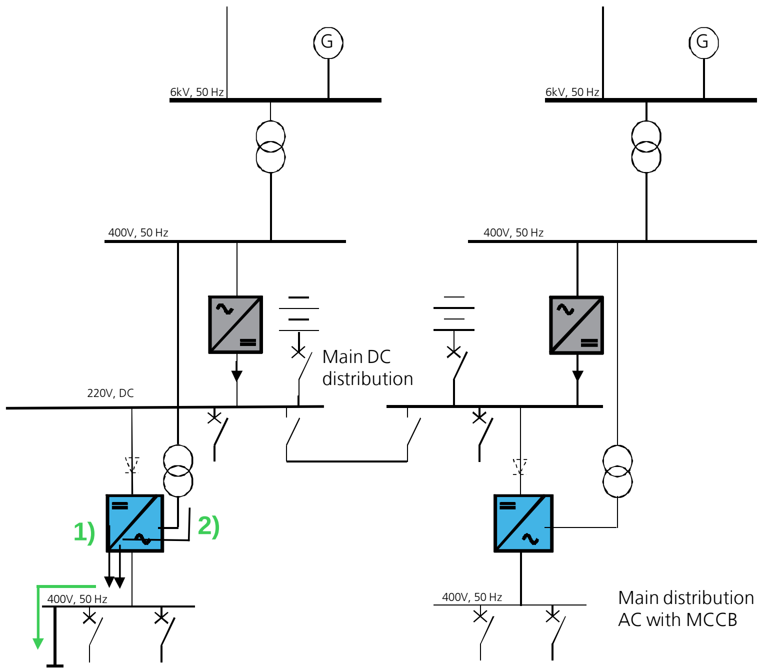
UPS and Battery Systems

Inverter Performance



AC-Systems

Heavy overload / short-circuit on AC safebus / load



Current source Inverter:

1) Current limitation current/time (for details see following slides)

Bypass:

2) Short-circuit current depending on upstream impedance and impedance of bypass transformer

AC-Systems
Inverter Short Circuit Considerations

Case 1:

Wire length = 2 x 100m
Rwire = 0.9Ohm
Ishort = 218A
= const. for 0.1 x Unom < Ushort < Unom
Ushort = Rwire x Ishort = 195V
Ushort = 85% of Unom

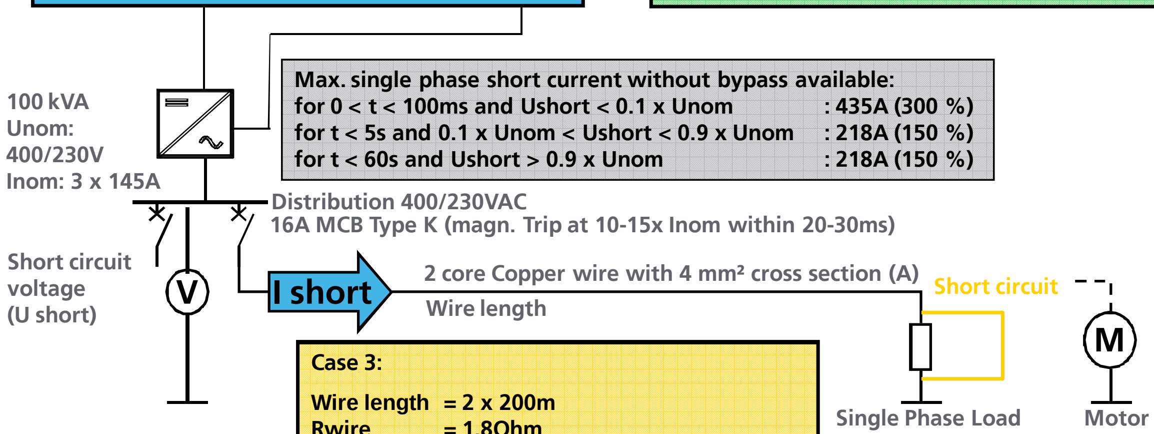
Conclusion: MCB will trip within 20-30ms

Case 2:

Wire length = 2 x 5m
Rwire = 0.045Ohm
Ishort = max. 435A = for Ushort < 0.1Unom
Ushort = Rwire x Ishort = 19.5V
Ushort = 8.5% of Unom

Conclusion: MCB will trip within 20-30ms

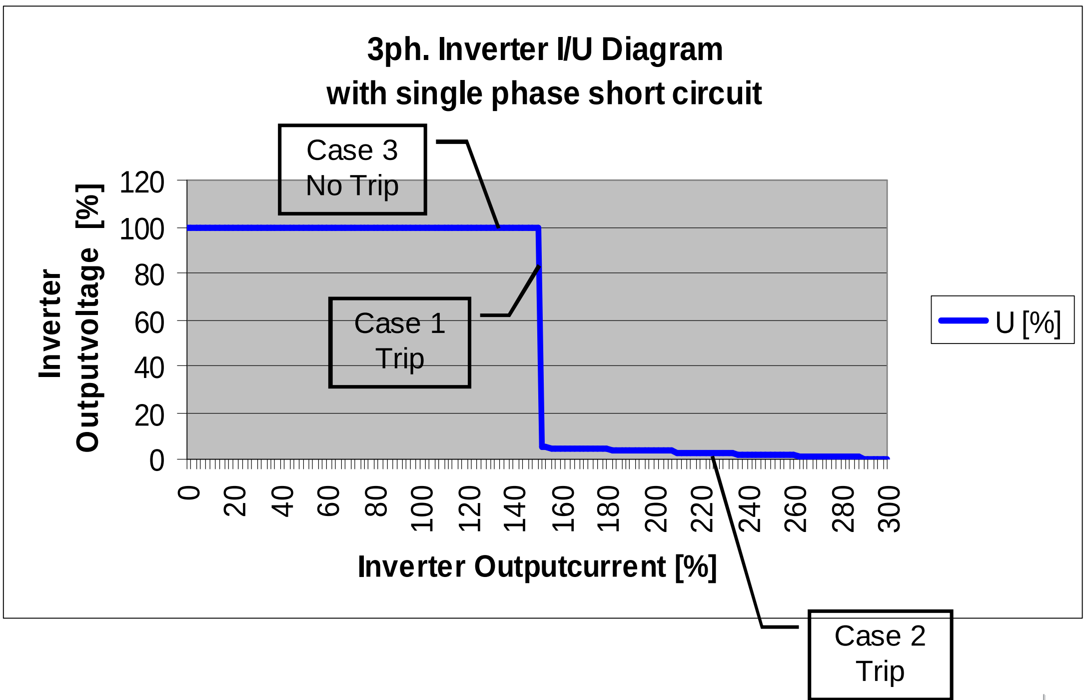
Max. single phase short current without bypass available:
for 0 < t < 100ms and Ushort < 0.1 x Unom : 435A (300 %)
for t < 5s and 0.1 x Unom < Ushort < 0.9 x Unom : 218A (150 %)
for t < 60s and Ushort > 0.9 x Unom : 218A (150 %)



Case 3:

Wire length = 2 x 200m
Rwire = 1.8Ohm
Ishort = Unom / Rwire = 129A
Ushort = Unom
Conclusion: MCB will not trip within 20-30ms

AC-Systems
Inverter Short Circuit Considerations



Operating and monitoring of UPS

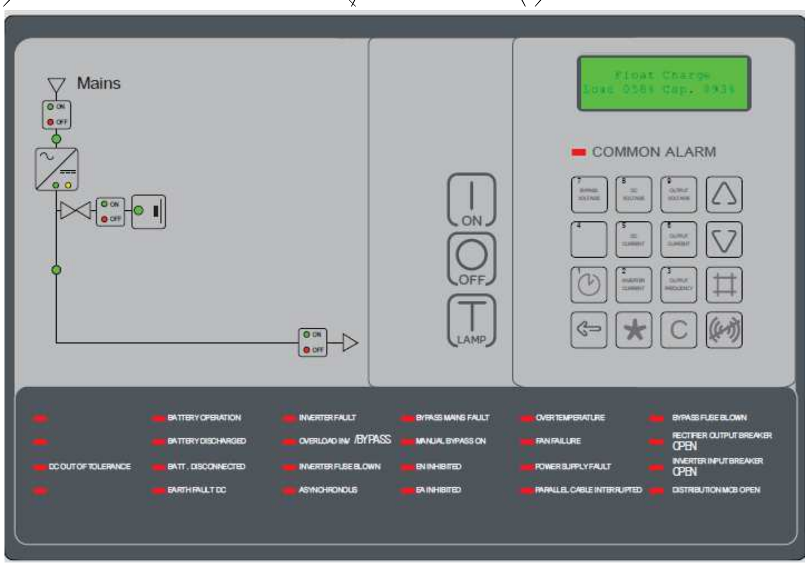
Human Machine Interface | Network / Remote monitoring

Operating and monitoring of UPS

Human Machine Interface

Gutor DC UPS

Operating Status indication | Operation | Display Unit



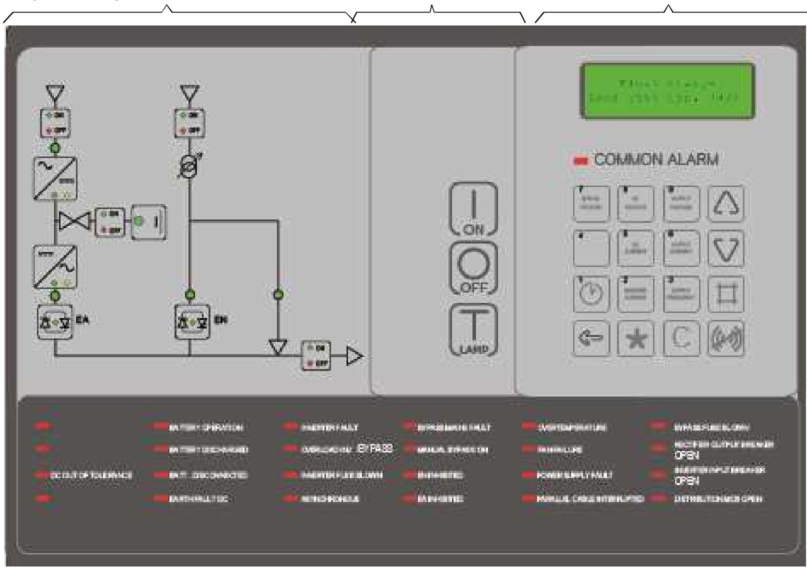
Alarm indication

Operating and monitoring of UPS

Human Machine Interface

Gutor AC UPS

Operating Status indication | Operation | Display Unit



Alarm indication

Operating and monitoring of UPS

Operator Access

"Operational" Section

1

2 INVERTER CURRENT

Pass-Word protected

"Genes" Section Settings

"Calibration" Section

Factory settings

"Operational Parameter" Section

User menu

0

"Alarm" Section

List of present alarms

0

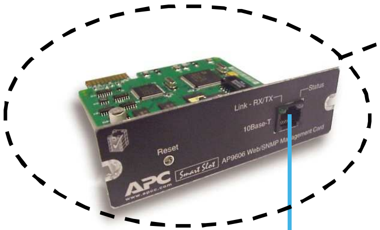
"Log-Alarm" Section

Event logger with Time Stamps

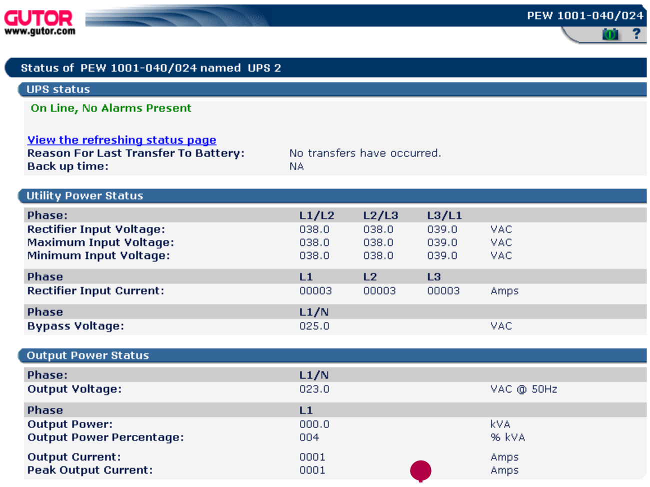
Operating and monitoring of UPS

Networking / Remote Monitoring

Web/SNMP /VMC
Management Card



UPS System



GUTOR www.gutor.com — PEW 1001-040/024

Status of PEW 1001-040/024 named UPS 2

UPS status

On Line, No Alarms Present

View the refreshing status page

Reason For Last Transfer To Battery: No transfers have occurred.

Back up time: NA

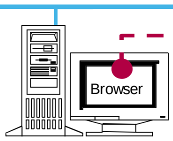
Utility Power Status

Phase:	L1/L2	L2/L3	L3/L1	
Rectifier Input Voltage:	038.0	038.0	039.0	VAC
Maximum Input Voltage:	038.0	038.0	039.0	VAC
Minimum Input Voltage:	038.0	038.0	039.0	VAC
Phase	**L1**	**L2**	**L3**	
Rectifier Input Current:	00003	00003	00003	Amps
Phase	**L1/N**			
Bypass Voltage:	025.0			VAC

Output Power Status

Phase:	L1/N			
Output Voltage:	023.0			VAC @ 50Hz
Phase	**L1**			
Output Power:	000.0			kVA
Output Power Percentage:	004			% kVA
Output Current:	0001			Amps
Peak Output Current:	0001			Amps

Ethernet, TCP/IP Network (10/100M, RJ45)



Network Client with
WEB Browser

Life Is On | Schneider Electric

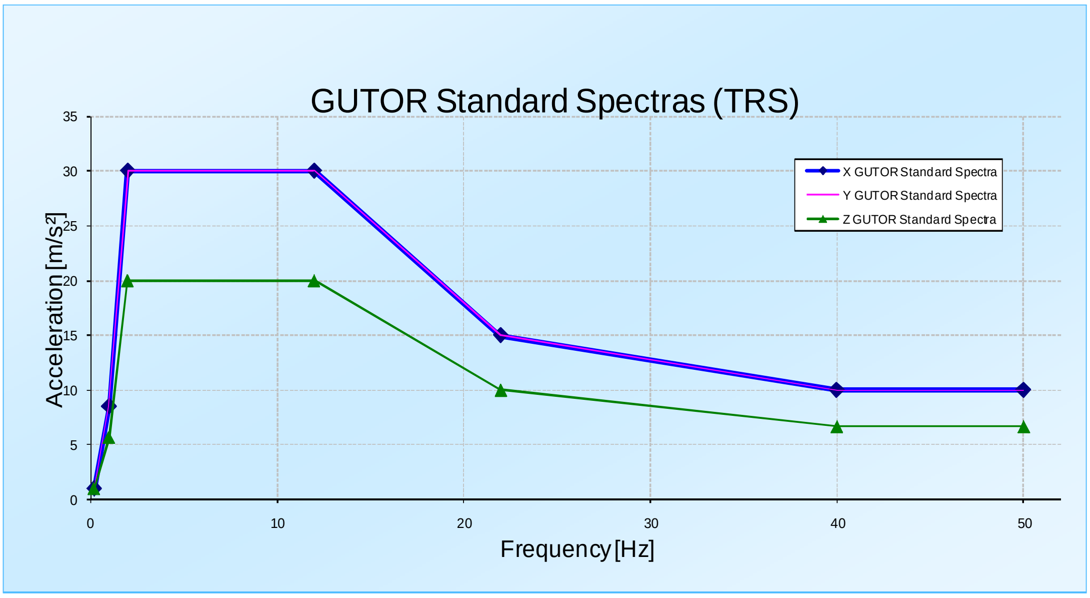
UPS for Nuclear Applications
Qualification

IEEE 650 (1E)

- Classify Components
  - Safety / Non-safety related
- Significant Aging
- Assemble Components in Equipment
- Testing before Seismic Test
- Seismic Test
  - Qualification by testing, full scale test according to IEEE344
  - Qualification by analogy
  - Qualification by combination of testing and analysis
- Testing after Seismic Test
- Conclusion

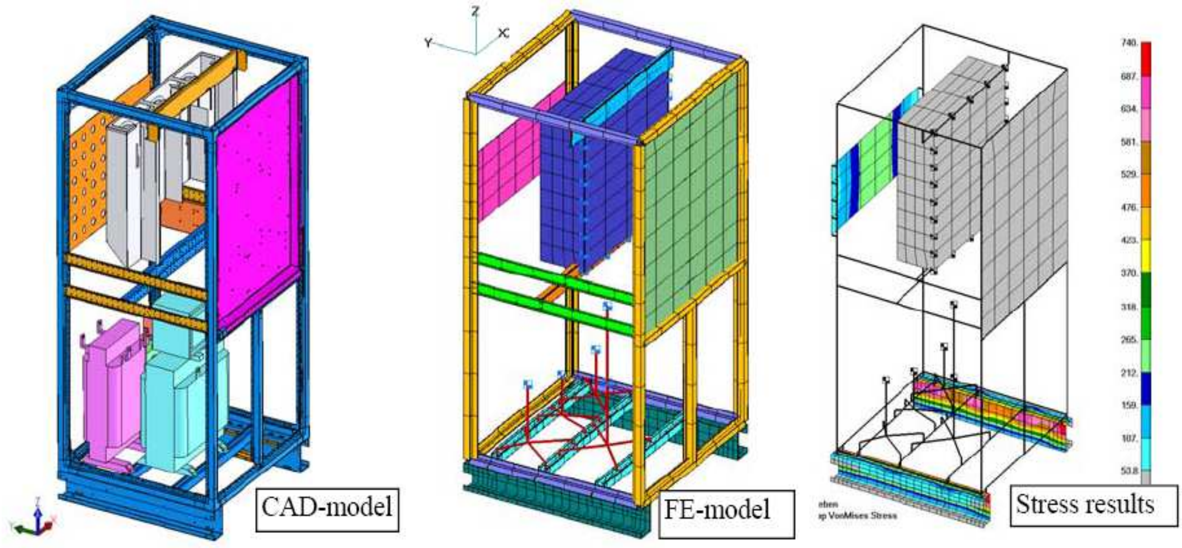
Life Is On | Schneider Electric

UPS for Nuclear Applications
Qualification



Life Is On | Schneider Electric

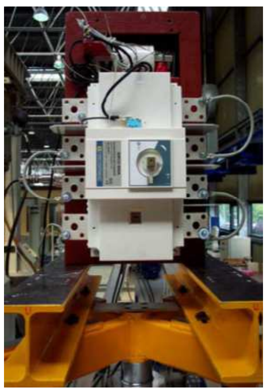
UPS for Nuclear Applications
UPS Seismic Design

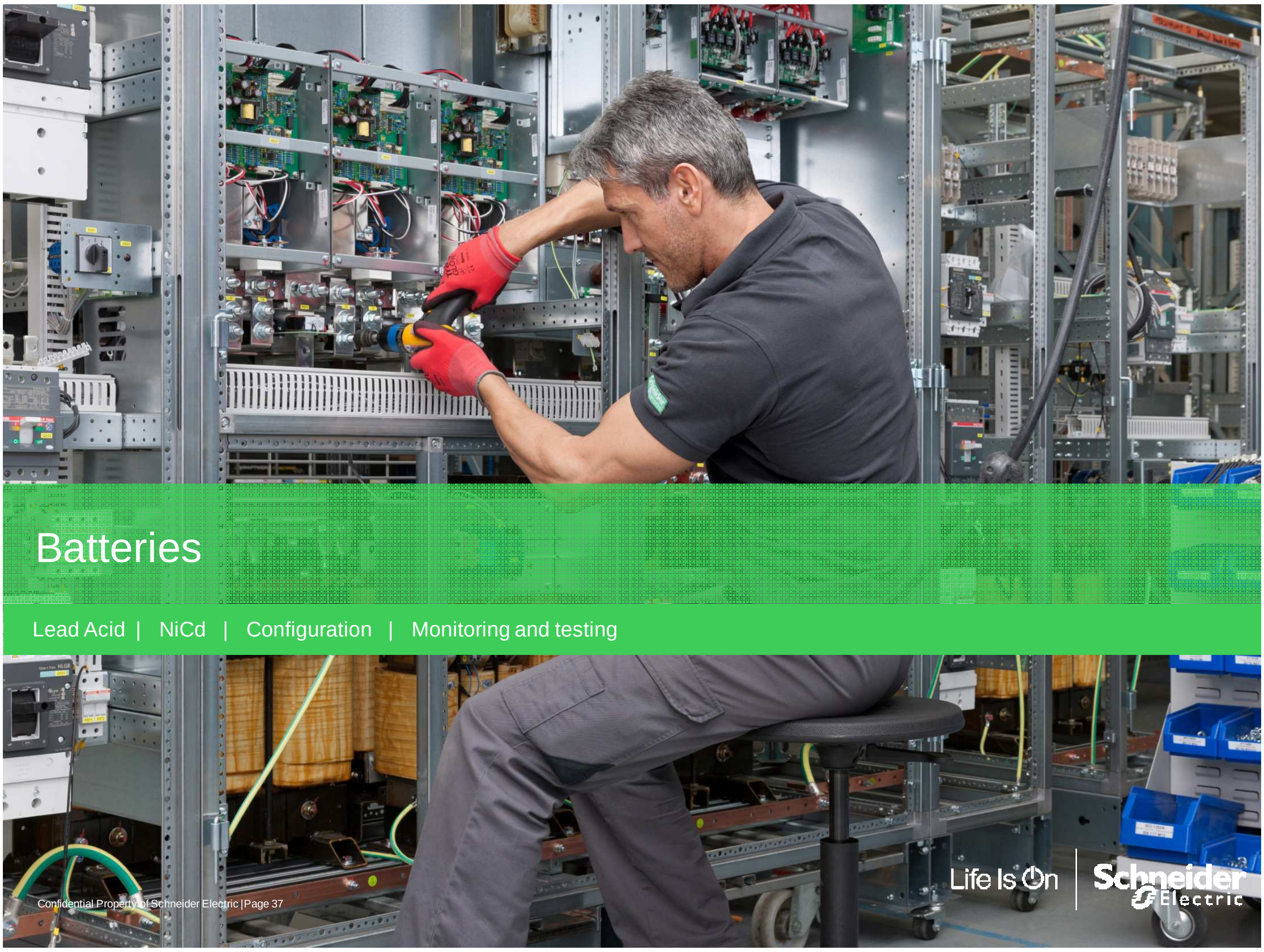


UPS for Nuclear Applications
Qualification

Seismic Qualification of systems and parts

- By Full System Test
- By Combined Method
  (structure analysis / parts tests)





Batteries

Lead Acid

Lead Acid

- VRLA (Valve Regulated Lead Acid)/Sealed
  - Medium Lifetime
  - No topping up
  - Low Maintenance

- VLA (Vented Lead Acid)
  - Long Lifetime
  - Topping up required
  - Low / Normal Maintenance

- Electrolyte (filled in liquid) for Lead Acid Batteries is Sulphuric Acid (caustic)
- Each cell has a nominal voltage of 2.0 VDC
- Cells must be connected in Series to achieve the required DC Level

Life Is On | Schneider Electric

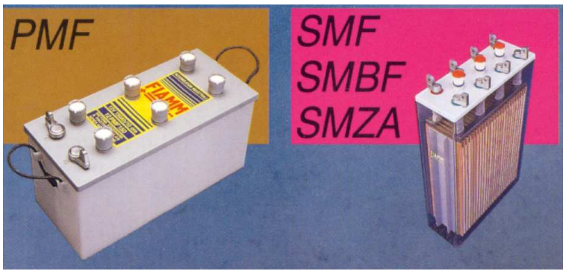
Batteries
Lead Acid

Batteries are used to store the energy that is required to feed the load, for example inverter, during a mains failure.

VRLA Lead Acid Batteries

Medium Lifetime
No topping up
Low Maintenance

Vented Lead Acid Batteries



Long Lifetime
Topping up required
Low / Normal Maintenance

Batteries
NiCd

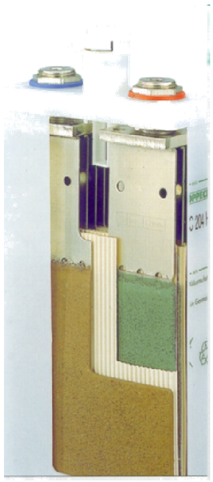
NiCd

- Vented Nickel Cadmium (Ni-Cd) Batteries
  - Long Lifetime
  - High Performance
  - Low / Normal Maintenance

- The alkaline Electrolyte for Ni-Cd Batteries is a solution of Potassium Hydroxide (KOH) and Lithium Hydroxide (LiOH) and is highly cuastic
- Each cell has a nominal voltage of 1.2 VDC
- Cells must be connected in Series to achieve the required DC Level

Batteries
NiCd

Vented Nickel Cadmium (NiCd) Batteries



Long Lifetime
Topping up required
Low / Normal Maintenance

Life Is On | Schneider Electric

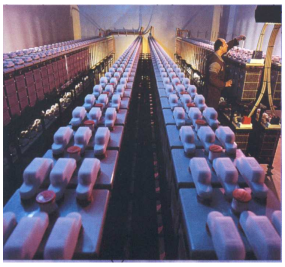
Batteries
Battery installation on rack

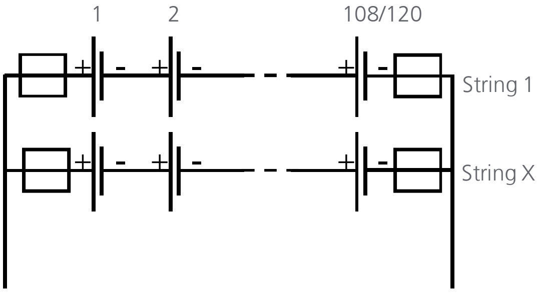
Typically Industrial Battery Installation on Racks, alternative in Battery Cubicles.

2 x 108cells x 2.0 V/cell = 216VDC

2 x 120cells x 2.0 V/cell = 240VDC

One or more strings parallel depending on capacity





Life Is On | Schneider Electric

Batteries
DC-Voltage Range & applicable number of cells (c)

Battery Nominal Voltage (VDC)	UPS Voltage Range for standard applications with AC output voltage in tolerance +/-1% (minimum values)	**Battery Type**		
		NiCd	**Lead-Acid**	**Sealed**
		max.V/c	**max. V/c**	**max. V/c**
		1.6	**2.4**	**2.33**
		Possible numbers of cells		
110 (125)	**93..145**	**86..90**	**54..60**	**54..62**
220	**187..280**	**170..176**	**108..120**	**108..124**
400	**316..495**	**288..300**	**180..204**	**180..210**

The voltage is limited on the downside due to the end-discharge voltage:
1.1V/c for NiCd & 1.75V/c for Lead Acid

The voltage is limited on the upside due to max. voltage range & boost charging:
1.6V/c (1.7V/c) for NiCd & 2.4V/c for Lead-Acid.

Batteries
Nominal Capacity 1/2

The nominal capacity is defined as follows

- Lead acid batteries
  - at 10 hours discharge time, a discharge end voltage of 1.80V/cell and at 20℃
- NiCd batteries
  - at 5 hours discharge time, a discharge end voltage of 1.00V/cell and at 20℃

Performance

- The battery capacity cannot be recalculated linear over the respective discharging time
- If the discharging time is lower, then the capacity to be drawn from a battery is also lower
- If the discharge end voltage is lower, then the capacity to be drawn from a battery is higher
- Higher temperatures on lead acid batteries will result in higher capacities to be available from the battery, but will significantly reduce the lifetime of lead acid batteries

Batteries

Nominal Capacity 2/2

Performance

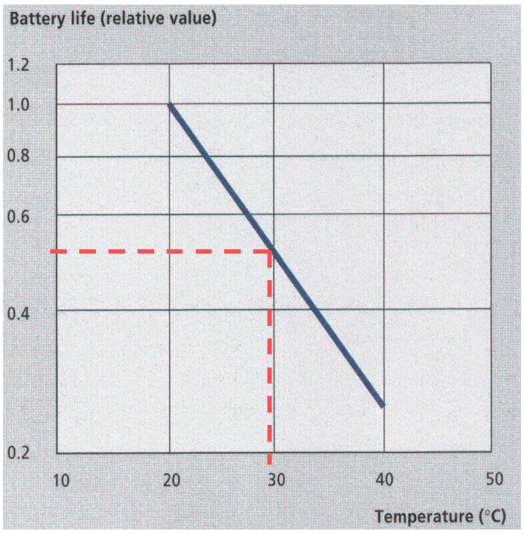
- The available capacity and the aging of a lead acid battery are mainly influenced by the battery temperature.
- Generally, the lifetime reduces by 50% if the battery temperature of lead acid batteries increases by 10℃ (taken from the referen ce temperature of 20℃).
- For lead acid batteries, the tested capacity must be at least 95% of the nominal capacity for the 1st cycle test and must be 100% after a maximum number of 5 cycle tests.
- For NiCd batteries, the tested capacity must be 95% of the nominal capacity after the 5th cycle test.
- The factory test procedures are given in the applicable standards IEC 60896 for lead acid batteries, and IEC 60623 for NiCd batteries.

Batteries

VRLA life / temperature

Valve Regulated Lead Acid Batteries (sealed) are very sensitive to temperature.

Temperature compensated charging helps to mon-mose the negative impact of elevated temperatures.

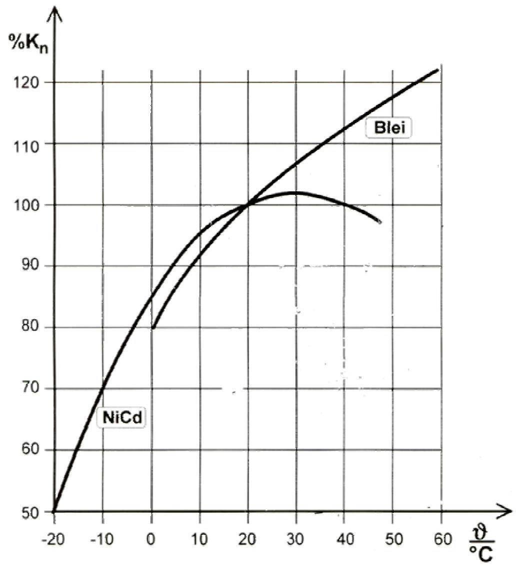


Batteries

Capacity of Lead-Acid and NiCd-Batteries in relationship to the temperature

NiCd-Batteries do have a higher capacity at lower temperatures in comparison to Lead-Acid batteries.

At higher temperatures, the capacity of NiCd-Batteries will decrease, and will also be lower than compared to Lead-Acid batteries.

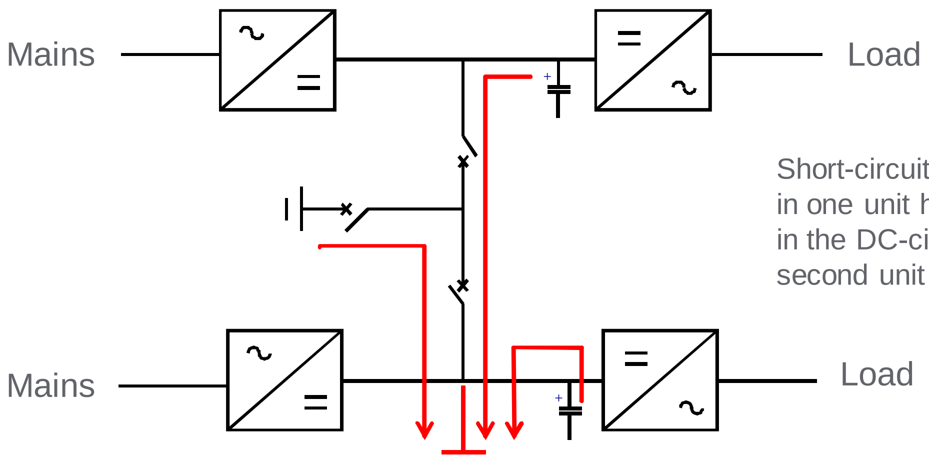


Life Is On | Schneider Electric

Batteries

Configuration

Common Batteries



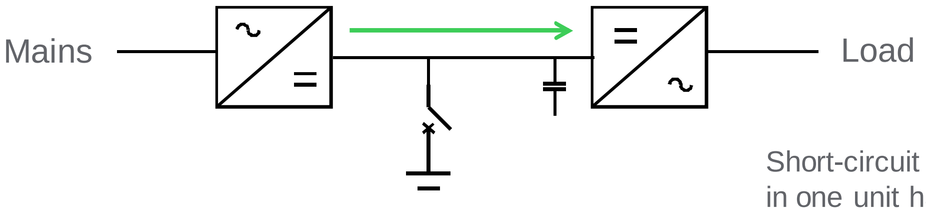
Short-circuit in the DC-circuit in one unit has an influence in the DC-circuit of the second unit

Short-circuit

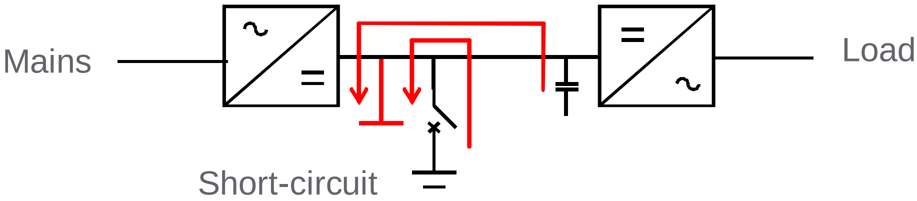
Life Is On | Schneider Electric

Batteries
Configuration

Individual Batteries

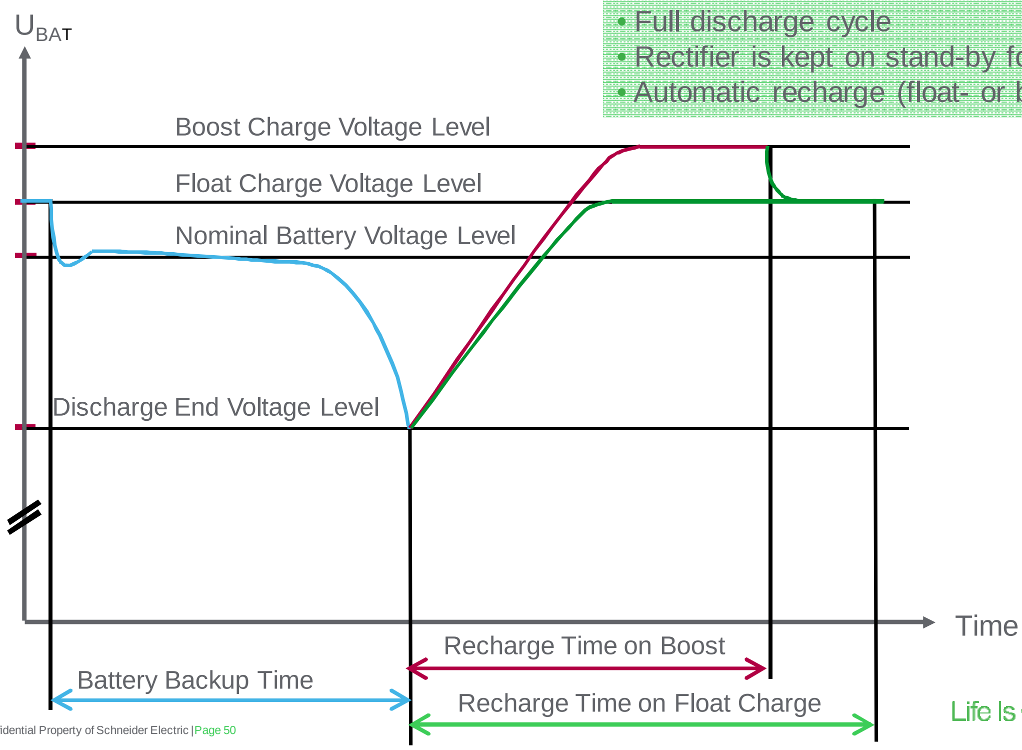


Short-circuit in the DC-circuit in one unit has no influence in the DC-circuit of the second unit



Batteries
Built-in Battery Capacity Test

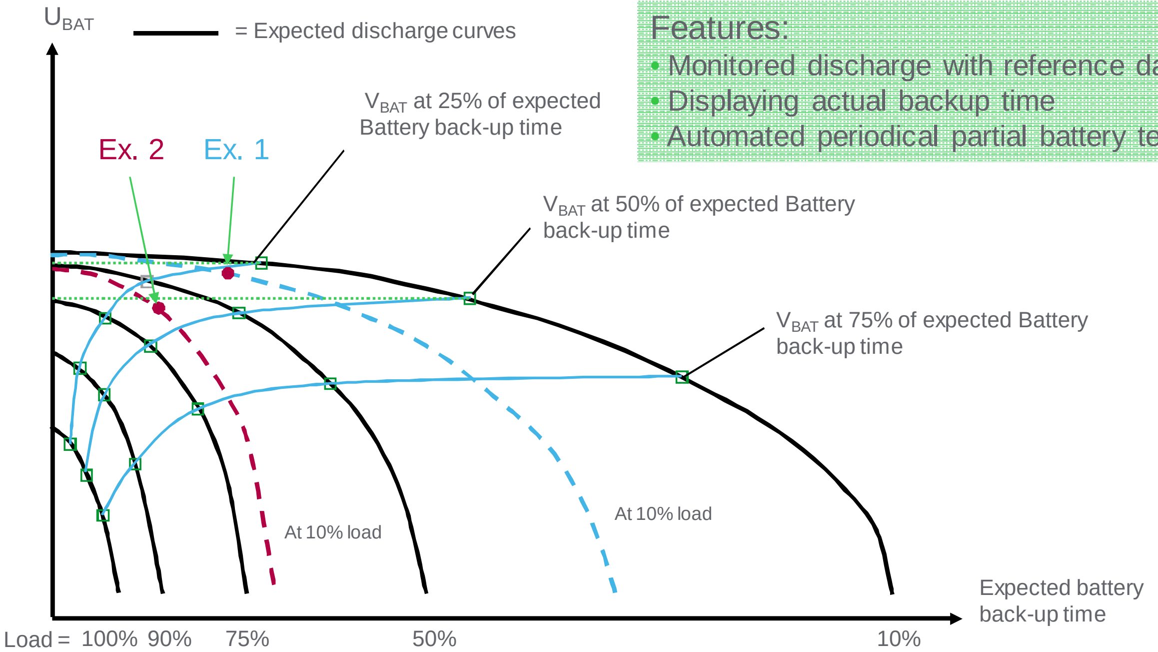
Features:
- Full discharge cycle
- Rectifier is kept on stand-by for safety reason
- Automatic recharge (float- or boost charge)



Batteries

Built-in Battery Monitoring and Testing Advances Battery Monitor

Features:
- Monitored discharge with reference data
- Displaying actual backup time
- Automated periodical partial battery test



Example 1.: Battery weak: V_{BAT} falls below „V_{BAT} 25%“ time before 25% of the time is reached

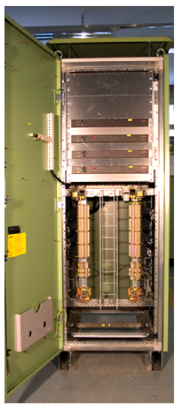
Example 2.: Battery defective: V_{BAT} falls below „V_{BAT} 50%“ time before 25% of the time is reached

Batteries

Single Cell Battery Management Sytsem GBMS

Features

- Single Cell Voltage / Resistance Monitoring and recording
- WEB Based Front End for remote monitoring
- Single Cell Equalize Charging
- Monitored Dirscharge Testing



Standards

Overview

Standards

- IEC
- UL

Quality

- ISO 9001

Conformity

- IEC - VFI

Standards

Certificates

Certificate	
ISO 9001	Quality System
IEC 62040 - 1	Uninterruptible Power Systems (UPS) - General and safety requirements
IEC 62040 – 2	Uninterruptible Power Systems (UPS) - EMC Requirements
IEC 62040 – 3	Uninterruptible Power Systems (UPS) - Method of specifying the performance and test requirements
IEC 60146	Semiconductor Convertors
IEC 60529	Degrees of Protection provided by Enclosures (IP Code)
IEC 60269	Low-Voltage Fuses
IEC 60076	Power Transformers
IEC 60950	Safety of Information Technology Equipment
IEC 60439	Low-Voltage Switchgear and Controlgear Assemblies
IEC 60617	Graphical Symbols for Diagrams

Standards

Standards for Industrial UPS UL / FCC

Certificate	
UL 1778	Uninterruptible Power Supply Equipment - UPS - Inverter - Battery Protection - (Rectifier)
UL 1012	Power Units Other Than Class 2 - Rectifier
UL 67	Panel boards - AC & DC Distribution
FCC	Part 15 Subpart B Class A - EMC Limits UPS / Rectifier

Standards

Standards for Industrial UPS IEEE / NEMA

Certificate	
IEEE 519	Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems
IEEE 315	Graphics Symbols for Electrical and Electronics Diagrams
NEMA PE1	Uninterruptible Power Systems - UPS Edition 2003 adopted to IEC 62040-3 Edition 1992: Input current total harmonic distortion -> 0 - 20kVA 30% THD -> 20 - 200kVA 15% THD -> >200kVA 10% THD
NEMA PE5	Utility Type Battery Chargers
NEMA ST20	Dry Type Transformers for General Applications
NEMA 250	Enclosures for Electrical Equipment

Standards

Conformity

IEC 62040 – 1	Uninterruptible Power Systems (UPS) - General and safety requirements → CE Label
IEC 62040 – 2	Uninterruptible Power Systems (UPS) – EMC Requirements → CE Label
IEC 62040 – 3	Uninterruptible Power Systems (UPS) - Method of specifying the performance and test requirements → Performance Code VFI-SS-111

Maintenance
Onshore and Offshore Installations

Onshore Installation

- Easy to get maintenance staff on site
- Availability of spare parts typically higher

Offshore Installation

- More difficult to get maintenance staff on site
  - Travel restriction
  - Certificates
- Consider
  - Remote monitoring
  - Single cell battery monitoring
  - Improve on site availability of spare parts

Life Is On | Schneider Electric

Maintenance
UPS

Maintenance is important; to secure long time reliable operation of the secured power system.

- UPS part
  - Visual inspection
  - IR check (Infrared camera)
  - Regular functionality check
  - Maintenance according to supplier specification
    - Components with limited lifetime
  - Parallel Redundant and Dual UPS; UPS power is available during maintenance
  - Single UPS; UPS power is not available during maintenance


Why preventive maintenance extends equipment life and helps you avoid downtime.

Let's face it: Critical power equipment can't last forever. But it can last a lot longer, if you perform regular preventive maintenance. Schneider Electric™ preventive maintenance service minimizes downtime, improves system performance, and extends your equipment's life span.

What we offer you
- Visual and functional check of your system
- Alarm and input/output measurement checks
- Visual check of the battery, with a battery-discharge test
- Replacement of fans, fan capacitors, AC and DC capacitors, power-supply unit (PSU) boards, RAM2 chips, and other parts with limited lifetimes

Which parts require preventive maintenance?
- **Fans** inevitably experience mechanical wear, and therefore need replacing every five years. Faulty fans can expose internal parts to extra heat, which can cause early equipment failure.
- **Electrolytic-type capacitors,** used in AC and DC filters, these need to be replaced every nine years. A capacitor failure threatens system availability and exposes the load to an unstable utility source.
- **RAM2 chips** have batteries that need replacing every nine years. If the batteries fail, you risk losing your system's event log and operational history.
- **DC Current Sensors** are vital for the system operation. They should be replaced every nine years of operation, to maintain proper regulation of battery and DC bus voltages according to the measured currents.
- **PSU boards** deliver power to your system's internal control electronics, and need to be replaced every ten years.
- **Batteries** are your system's safety net if grid power fails, and they need to be maintained and tested according to manufacturer recommendations.

Other factors worth considering
Your system's operating environment has a major effect on its performance. Extreme heat, humidity, dust, and other factors will decrease the lifetime of internal parts and shorten the replacement schedules outlined above.

1. Fan
2. Fan capacitors
3. DC capacitors
4. AC capacitors
5. Power-supply unit board
6. RAM2 chip

Extend the life of your equipment!
Contact your local service center to learn more or to schedule a maintenance visit.
> Europe, Russia, and Africa: gutor-service-ch@schneider-electric.com
> Americas: gutor-service-us@schneider-electric.com
> Asia Pacific: gutor-service-my@schneider-electric.com
> Middle East: gutor-service-ae@schneider-electric.com
> Saudi Arabia: gutor-service-sa@schneider-electric.com
> China: gutor-service-cn@schneider-electric.com

Gutor technology

Schneider Electric

Life Is On | Schneider Electric

Maintenance
Battery

Maintenance is important; to secure long time reliable operation of the secured power system.

- Battery
  - Visual inspection
  - Check connection/termination - IR check (infrared camera)
  - Cleaning and greasing
  - VLA and NiCd requires check of level of electrolyte, how often is depending on type of battery and temperature of electrolyte (not ambient temperature)
  - Further maintenance requirements are depending on type of batteries
  - Discharge test preferable; only a real discharge test can give evidence of healthiness of the battery

Life Is On | Schneider Electric

Maintenance
UPS Downstream distribution and loads

Maintenance is important; to secure long time reliable operation of the secured power system.

- UPS downstream distribution and loads
  - Dual configuration
    - If individual power supplies in the load is not monitored, it's important to check that both power supplies are working correct, other ways the duality of the DUAL system is not guarantee.

Life Is On | Schneider Electric

Questions?

Life Is On | Schneider Electric