IEEE Seminar Houston
October 20-21, 2015

Presented by: Gert Andersen, CTO Gutor UPS Product Line

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
Introduction
UPS in the Mid-Point between Utility and Critical Load

Introduction
Typical Mains Disturbances

3% of failures are related to direct power failures.
The rest is mainly due to fluctuations.
Basic functions of UPS

- Why do we need a UPS (Uninterruptible Power Systems)?

- Basic function of UPS
  - Secure electrical power for critical loads as long as power/energy is available from at least one of the UPS sources:
    - Rectifier mains – 1st Priority
    - Battery – 2nd Priority
    - Bypass mains – 3rd Priority and “high current” back-up
  - Protect critical load against upstream disturbances
    - All kinds of transients and blackouts
  - Technologies
    - UPS
    - Rectifier/Battery charger
    - Inverter

Basic functions of UPS

AC UPS System

- 3 Phase Input
- Voltage 3x200... 3x690V
- Frequency 50 or 60 Hz
- 6-pulse thyristor controlled rectifier
- Opt.: 12 pulse thyristor controlled rectifier
- Opt.: oversized for higher charge
- Float or boost charge
- Opt.: PFC

- 4 Standard DC
  - Volatages: 110, 125, 220 or 400 VDC
  - Lead Acid Type
  - Nickel Cadmium Type

- 1- or 3-Phase Output IGBT-PWM controlled inverter
- Short-circuit proof inverter
- Opt.: oversized for inverter module to interrupt bigger fuses

Online double Conversion System
Basic functions of UPS
DC UPS System

- 3 Phase Input
- Voltage 3x200...3x690V
- Frequency 50 or 60 Hz
- 6-pulse thyristor controlled rectifier
- Opt.: 12 pulse thyristor controlled rectifier
- Opt.: oversized for higher charge
- Float or boost charge
- Opt.: PFC - Modular

- 5 Standard DC Voltages:
  - 24, 48, 110 125 or 220 VDC
- Lead Acid Type
- Nickel Cadmium Type

Online System

Inverter System

- 4 Standard DC Voltages:
  - 110, 125, 220 or 400 VDC
- 1- or 3-Phase Output IGBT-PWM controlled inverter
- Short-circuit proof inverter
- Opt.: oversized for inverter module to interrupt bigger fuses

Online System
Industrial UPS Markets

Typically industrial markets

- Oil & Gas, Petrochemicals
- Nuclear Industry
- Power Generations
- Other industrial applications

- Mining
- Transport
- Desalination
- Chemical
## Industrial UPS Markets
### Industrial (ETO) vs. Commercial UPS

<table>
<thead>
<tr>
<th>Industrial ETO (Process and Power)</th>
<th>Engineering</th>
<th>Documentation</th>
<th>Service</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Customized solutions</td>
<td>Customized layout</td>
<td>Comprehensive</td>
</tr>
<tr>
<td></td>
<td>Flexible specifications</td>
<td>Approval procedure</td>
<td>20 years life</td>
</tr>
<tr>
<td></td>
<td>FAT / Type Testing</td>
<td>Project related</td>
<td>Spare parts</td>
</tr>
<tr>
<td></td>
<td>Many options</td>
<td></td>
<td>Upgrade packages</td>
</tr>
<tr>
<td></td>
<td>Upgradeable</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Harsh environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Commercial (IT)</td>
<td>Standard solutions</td>
<td>Standard</td>
<td>Limited</td>
</tr>
<tr>
<td></td>
<td>Fixed specifications</td>
<td>Limited</td>
<td>10 years life</td>
</tr>
<tr>
<td></td>
<td>Limited testing</td>
<td></td>
<td>Limited spare parts</td>
</tr>
<tr>
<td></td>
<td>Limited options</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No engineering</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Office environment</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>No options</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Power
- DC level typically 400 VDC or 2 x 400 VDC
- Given module sizes
- Mechanical Design
- Integrated disconnect- and incomer section
- Limited front access to major components
## Industrial UPS Markets
### Single vs. Three Phase Inverters

<table>
<thead>
<tr>
<th>Typical Applications</th>
<th>Single Phase</th>
<th>Three Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Higher short circuit current</td>
<td></td>
<td>· Total power shared by 3 phases</td>
</tr>
<tr>
<td>· Commercial, for ratings up to 30kVA</td>
<td></td>
<td>· Commercial, rating above 40 kVA</td>
</tr>
<tr>
<td>· Same cross section, Phase and Neutral Conductors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>· Better availability through less components</td>
<td></td>
<td></td>
</tr>
<tr>
<td>· No consideration concerning balancing the load on three phases required</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Typical Applications

- **Single Phase**
  - Single phase loads

- **Three Phase**
  - Three-and single phase loads

### Disadvantages

<table>
<thead>
<tr>
<th>Single Phase</th>
<th>Three Phase</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Disadvantages</strong></td>
<td></td>
</tr>
<tr>
<td>· Big conductor sizes</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Short circuit capabilities</th>
<th>Example: 30kVA / 230VAC</th>
<th>Example: 30kVA / 3x400/230VAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal current</td>
<td>130 AAC</td>
<td>3x44 AAC</td>
</tr>
<tr>
<td>Single Ph-N short circuit current</td>
<td>260 AAC</td>
<td>152 AAC</td>
</tr>
<tr>
<td>Three Ph short-circuit current</td>
<td></td>
<td>3x88 AAC</td>
</tr>
</tbody>
</table>
Find the best UPS solution

Decision-making

Find the best UPS Solution depending on

- Upstream supply
- Type of loads
- Environmental
- Maintenance
- Availability – in % or real hours?
  - MTBF (Mean Time Between Failure)
  - MTTR (Mean Time To Repair)
- Basic UPS
- UPS configurations
Find the best UPS solution

How to select the best UPS configuration

Find the best UPS solution

Upstream supply

Two upstream independent supplies, together with UPS with separate inputs for Rectifier and Bypass, results in overall higher reliability. Emergency generator will reduce required battery back-up time for UPS.
Find the best UPS solution

Type of loads

Single input loads (single-corded loads)
- Motors
- Valves
- Relays
- Heaters
- Switch Mode Power Supplies
- Other process equipment as for e.g. DCS, PLC,
- SCADA

Single or Parallel Redundant UPS preferred for loads with single inputs.

Find the best UPS solution

Type of loads

Dual input loads (dual-corded loads)
- DCS with dual Switch Mode Power Supplies
- Other process equipment with front end Static Transfer Switch (STS)

Dual UPS independent or synchronised preferred for loads with dual inputs. 100% redundancy including down stream distribution and cabling.
Find the best UPS solution
Environmental

Major environmental issues, which have an impact on reliability of UPS and Battery during storage, commissioning and operation

- Temperature
- Humidity
- Dust
- “Corrosive” e.g. “salty” air, H₂S

Environmental
Temperature

Temperature
- UPS part
  - Standard rating for industrial UPS up to 40°C/104°F
  - Option for temperature up to 55°C/131°F typically available for industrial UPS
- Battery
  - Average temperature 20 - 25°C/68 - 77°F
  - Lead Acid will be preferred type
  - Average temperature >25°C/77°F
  - NiCd to be considered
Environmental

Humidity

Humidity
- UPS part
  - Critical during installation and commissioning
  - Cubicle heating required during this period
  - During operation humidity up to ~95% acceptable
  - By risk of condensation above UPS IPX2 (Rain roof) required

- Battery
  - Critical during installation and commissioning
  - Depending on battery type vents needs to be protected
  - Terminal posts to be protected
  - Faster self discharge when not connected to Rectifier
  - Shorter time interval between refreshing charges needed

Environmental

Dust

Dust
- UPS part
  - Critical during installation and commissioning
  - Recommended to use air-filters in air-inlet of the UPS

- Battery
  - Critical in combination with humidity
Environmental Corrosives

“Corrosives” e.g. salty air, H₂S

- UPS part
  - Additional protection of metal parts may be required
  - PCB (Printed Circuit Board) may required conformal coating, depending on concentrations of corrosives

- Battery
  - May shorten maintenance interval (cleaning)
  - Check grease on terminal posts and connectors

Basic AC UPS configuration with 100% Galvanic isolation

• Basic UPS with 100% galvanic isolation (I) and Bypass section.
  The basic UPS configuration will be used in all Gutor AC-UPS solutions.
AC-UPS Product Line

AC-UPS configurations
• Single UPS (also available for DC)
• Parallel Redundant UPS (also available for DC)
• Dual UPS Independent (also available for DC)
• Dual UPS Synchronised

Dual UPS Indp/Synch • Option

Parallel Redundant UPS • Option

Single UPS • Option

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**AC-UPS Product Line**

**Single UPS**

Configuration
UPS consist of: Rectifier, Battery, Inverter, Static Switch Inverter, Static Switch Bypass, Bypass transformer

Operation modes
• Normal operation: Load is supplied from Rectifier => DC-link => Inverter => Static Switch Inverter => Load
• Battery operation: Rectifier or mains not available, load is supplied from Battery => Inverter => Static Switch Inverter => Load
• Bypass operation: Due to overload above available overload profile of the Inverter, or Inverter is not available. Load is supplied direct from Bypass => Static Switch Bypass => Load
AC-UPS Product Line

Parallel Redundant UPS

Configuration

- UPS A and B each: Rectifiers, Batteries, Inverter, Static Switch Inverter, Static Switch
  Bypass sharing one Bypass transformer*
- The Inverters are sharing the actual load by taking each 50% of the actual load
- System overload profiles are equal to two times the overload profile of each Inverter
- System stay in the highest possible operation modes, and in this way save battery
  capacity until really needed

Parallel Redundant UPS Operation modes: See following pages for details

- Normal operation; both inverters supplying the load
- Normal operation; one inverter supplying the load, second inverter in standby
- Battery operation; both inverters available
- Battery operation; one inverter supplying the load, second inverter in standby
- Bypass operation
### AC-UPS Product Line

**Parallel Redundant UPS: Normal Operation - load sharing**

<table>
<thead>
<tr>
<th>UPS A</th>
<th>UPS B</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectifier mains</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>Rectifier</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Battery</td>
<td>Charging/Float</td>
<td>Charging/Float</td>
</tr>
<tr>
<td>Inverter</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Static Switch EA (Inverter)</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Bypass Mains</td>
<td>Available</td>
<td></td>
</tr>
<tr>
<td>Static Switch EN (Bypass)</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Output voltage</td>
<td>Available</td>
<td></td>
</tr>
</tbody>
</table>

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**Parallel Redundant UPS: Normal Operation – One system part A or B out of service, example with Mains B out of service**

<table>
<thead>
<tr>
<th>UPS A</th>
<th>UPS B</th>
<th>Comments</th>
</tr>
</thead>
</table>
| Rectifier mains | Available | Not available | Mains A in tolerance  
Mains B out of tolerance |
| Rectifier | ON | OFF | Or not available |
| Battery | Charging/Float | Available | |
| Inverter | ON | Standby | Inverter A supply load 100%. Inverter B ready |
| Static Switch EA (Inverter) | ON | OFF | |
| Bypass Mains | Available | | In tolerance |
| Static Switch EN (Bypass) | OFF | OFF | Ready to takeover the load |
| Output voltage | Available | | In tolerance |
### AC-UPS Product Line

#### Parallel Redundant UPS: Battery Operation - load sharing

<table>
<thead>
<tr>
<th></th>
<th>UPS A</th>
<th>UPS B</th>
<th>Comments</th>
</tr>
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<tbody>
<tr>
<td>Rectifier mains</td>
<td>Not available</td>
<td>Not available</td>
<td>Mains A and B out of tolerance</td>
</tr>
<tr>
<td>Rectifier</td>
<td>OFF</td>
<td>OFF</td>
<td>Or not available</td>
</tr>
<tr>
<td>Battery</td>
<td>Discharging</td>
<td>Discharging</td>
<td></td>
</tr>
<tr>
<td>Inverter</td>
<td>ON</td>
<td>ON</td>
<td>Load sharing each 50% of the actual load</td>
</tr>
<tr>
<td>Static Switch EA</td>
<td>ON</td>
<td>ON</td>
<td></td>
</tr>
<tr>
<td>(Inverter)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bypass Mains</td>
<td>Available</td>
<td></td>
<td>In tolerance</td>
</tr>
<tr>
<td>Static Switch EN</td>
<td>OFF</td>
<td>OFF</td>
<td>Ready to take over the load</td>
</tr>
<tr>
<td>(Bypass)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage</td>
<td>Available</td>
<td></td>
<td>In tolerance</td>
</tr>
</tbody>
</table>

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### AC-UPS Product Line

#### Parallel Redundant UPS Operation – One battery discharged

<table>
<thead>
<tr>
<th></th>
<th>UPS A</th>
<th>UPS B</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectifier mains</td>
<td>Not available</td>
<td>Not available</td>
<td>Mains A and B out of tolerance</td>
</tr>
<tr>
<td>Rectifier</td>
<td>OFF</td>
<td>OFF</td>
<td>Or not available</td>
</tr>
<tr>
<td>Battery</td>
<td>Discharging</td>
<td>Discharged</td>
<td>Battery B has reach end of discharging stage</td>
</tr>
<tr>
<td>Inverter</td>
<td>ON</td>
<td>OFF</td>
<td>UPS A supply the load</td>
</tr>
<tr>
<td>Static Switch EA</td>
<td>ON</td>
<td>OFF</td>
<td></td>
</tr>
<tr>
<td>(Inverter)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bypass Mains</td>
<td>Available</td>
<td></td>
<td>In tolerance</td>
</tr>
<tr>
<td>Static Switch EN</td>
<td>OFF</td>
<td>OFF</td>
<td>Ready to take over the load</td>
</tr>
<tr>
<td>(Bypass)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Output voltage</td>
<td>Available</td>
<td></td>
<td>In tolerance</td>
</tr>
</tbody>
</table>
AC-UPS Product Line

Parallel Redundant UPS: Bypass operation

<table>
<thead>
<tr>
<th>UPS A</th>
<th>UPS B</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rectifier mains</td>
<td>Not available</td>
<td>Not available</td>
</tr>
<tr>
<td>Rectifier</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Battery</td>
<td>Discharging</td>
<td>Discharged</td>
</tr>
<tr>
<td>Inverter</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Static Switch EA (Inverter)</td>
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<td>Bypass Mains</td>
<td>Available</td>
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<tr>
<td>Static Switch EN (Bypass)</td>
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<td>ON</td>
</tr>
<tr>
<td>Output voltage</td>
<td>Available</td>
<td></td>
</tr>
</tbody>
</table>

May be in Hot-Standby

AC-UPS Product Line

Dual UPS Independent
AC-UPS Product Line
Dual UPS Independent

Configuration
UPS A and B consist of each: Rectifier, Battery, Inverter, Static Switch Inverter, Static Switch Bypass, Bypass transformer

Operation modes
• UPS A and B operates independently as two Single UPS
• Normal operation: Load is supplied from Rectifier => DC-link => Inverter => Static Switch Inverter => Load
• Battery operation: Rectifier or mains not available, load is supplied from Battery => Inverter => Static Switch Inverter => Load
• Bypass operation: Due to overload above overload profile of the Inverter, or Inverter is not available. Load is supplied direct from Bypass => Static Switch Bypass => Load

AC-UPS Product Line
Dual UPS Synchronised

Dual UPS Synchronised

3
Bypass Transformer*

1
UPS A incl SSW

2
UPS B incl SSW

Tie-breaker: NO

Dual UPS Synchronised

Single-corded loads

Dual-corded loads

Single-corded loads

Dual-corded loads

Single-corded loads

Dual-corded loads

Single-corded loads

Dual-corded loads

Single-corded loads

Dual-corded loads
AC-UPS Product Line
Dual UPS Synchronised

Configuration

- UPS A and B consist of each: Rectifiers, Batteries, Inverter, Static Switch Inverter, Static Switch Bypass, sharing one common Bypass transformer
- The inverters are synchronised to bypass as well as to each other
- Even during loss of bypass mains both inverters are synchronised
- Due to the synchronisation of the two inverters, it’s possible to feed a third distribution board by a no break STS unit (Static transfer switch), the change over from supply from UPS A to UPS B and vice worse will be without interruption.
- It’s even possible to operate the Dual Synchronised UPS with the tie-breaker closed, due to communication between the tie-breaker and the two UPS. In this mode the active load-sharing between Inverter A and B will be active as well as the operation mode control, securing that both Inverter will be in the same mode or if not possible one Inverter will be in standby.
- Operation of the two manual bypass switches, when the tie-breaker is closed, must be strictly according to manual.

AC-UPS Product Line
Dual UPS Synchronised

Operation modes

- Tie-breaker open
  - Each UPS A and B operates independently, as two Single UPS

- Tie-breaker closed
  - UPS A and B follow the same sequence of operations modes as for Parallel Redundant UPS