UPS Technologies, Developments and Applications

Presented by Julian Gobey to CIBSE
Agenda

- Overview of Piller
- Data Centre Evolution & Power Systems
- User key requirements
- Solutions
- UPS & Energy storage system types
- What is Isolated Parallel Bus Configuration?
- Summary
Agenda

- Overview of Piller
About Us

Piller - The Company

- Uniquely the only manufacturer of
  - Static
  - Diesel Rotary and
  - Hybrid Rotary UPS technologies
- R&D for all technologies
- Purpose-built development, test and manufacturing facilities
- Trading for over 100 years
- Revenues of €196.6 m (2012) with 764 employees and offices in Germany UK USA France Spain Italy Singapore and Australia
- Worldwide Service
- High Quality manufacturing
- UK privately owned
Overview of Piller Group
UPS Technologies

- Static
- Energy Storage
  - Batteries
  - Kinetic Energy Storage
  - Diesel Engine
- Diesel Rotary (DRUPS)
Agenda

- Data Centre Evolution & Power Systems
Data Centre Evolution

As Data Centres have become increasingly more critical, the resilience of the infrastructure has become paramount.

Down time is absolutely unacceptable.

Service level agreements (SLA’s) and penalties necessitate close scrutiny of all critical infrastructure and scheme design.
Rising Data Centre capacity requires increased demands on the power supply.

Data Centre Evolution
Growing Power Demand

2 MW  5 MW  10 MW  20 MW
By example, “The Uptime Institute” has defined standards for Data Centres known as “Tier Classification” covering many areas, including:

- Electrical Infrastructure
- Cooling Infrastructure
- Site physical security
A key system of classifying scheme design is in accordance with the Uptime Institute’s Tier 1 – 4 criteria demanding various levels of redundancy and resilience for key subsystems. Some electrical redundancy options include:

- **Parallel Redundant Tier 2**
  - UPS 1
  - UPS 2
  - Load

- **System Redundant Tier 3**
  - UPS A1
  - UPS B1
  - Load

- **Distributed Redundant Tier 3**
  - UPS A1
  - UPS B1
  - UPS C1
  - Load

- **Parallel System Redundant Tier 4**
  - UPS A1
  - UPS A2
  - UPS B1
  - UPS B2
  - Load
Unfortunately, as is often the case, there is a price to pay for incorporating redundancy/resilience within a scheme:

- Increased cost:
- Increased plant space:
- Reduced efficiency:
User Key Requirements
Survey of Key Client Requirements

- From a recent survey of major Blue Chip organisations asking their key concerns in relation to IT provision revealed:

  - No 1 concern: Integrity
    - Biggest worry is risk of IT site failure
  
  - Also listed but of lesser importance:
    - Energy efficiency
    - Regulatory compliance
    - Cost
    - Strong after sales support
From a recent survey of 67 Datacentres, the following were recorded as the primary route cause of unplanned outage:

- UPS System failure
- Accidental/human error
- Cyber Crime
- Weather related
- Heat or CRAC failure
- Generator Failure
- IT equipment failure

Source: Ponemon Institute © Research Report
Agenda

- Power Solutions
# Types of UPS Technologies

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**Energy Store**
## Types of UPS Technologies

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- **Parallel on line**
  - Static
  - Rotating

- **Series on line**
  - Energy Store
## Types of UPS Technologies

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**Note:** The diagrams represent the flow of electrical power in different UPS technologies.
Types of UPS Technologies

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<td><img src="parallel_on_line_static.png" alt="Diagram" /></td>
<td><img src="series_on_line_rotary.png" alt="Diagram" /></td>
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- **Parallel on line**
  - Static
    - Energy Store
  - Rotary

- **Series on line**
  - Static
  - Rotary
## UPS Technologies

<table>
<thead>
<tr>
<th>Parallel Online</th>
<th>Series Online</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Control Only VI</td>
<td>Voltage &amp; Frequency Control VFI</td>
</tr>
<tr>
<td>Potentially Very High</td>
<td>High Operating efficiency</td>
</tr>
<tr>
<td>operating efficiency</td>
<td></td>
</tr>
<tr>
<td><strong>Static</strong></td>
<td>Static Inverter Feeding the Load</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td><strong>Rotary</strong></td>
<td>Rotating Machine Feeding the Load</td>
</tr>
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</table>
UPS Technologies

- A rotating machine feeding the load – ROTARY
- A static inverter feeding the load – STATIC
- Battery – an energy store
- Flywheels – an energy store
- Any UPS can be with or without Diesel

“In a Rotary UPS, during all modes of operation, the load is fed directly from a synchronous generator or motor generator .......Hence, the distinction between a static and a Rotary does not lie in the use of batteries or flywheels as a short-term emergency power source; rather it is based on the method through which the output power is derived”

2008 Frost and Sullivan
### Energy Storage Options

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<th>Series Online</th>
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<tr>
<td><strong>Static</strong></td>
<td>Any energy store can be used with any type of UPS</td>
<td></td>
</tr>
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<td></td>
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**A Langley Holdings Company**
Energy Storage Options

- By far the most common Energy Store in the market today is:
  - Batteries

- Other options include:
  - Kinetic Energy Storage
    - Flywheel - electrically coupled Kinetic Store
    - Induction coupling - mechanically coupled energy store
  - Compressed Gas
  - Fuel Cells
Energy Storage Options
Chemical Energy - Batteries

Advantages
- Flexible for life span, autonomy and power rating
- Silent
- Multiple strings can provide redundancy
- Minutes of autonomy

Disadvantages
- Require valuable space
- Temperature control required. (Air conditioning)
- Capacity degradation with ageing.
- Degradation through cycling
- Maintenance and increasing H&S issues
Energy Storage Options
Kinetic Energy Storage

Advantages

- Simple installation and maintenance
- No air conditioning requirements
- Small footprint (Potentially large space saving)
- Infinite Duty cycles
- Fast recharge
- Long life (20 years plus)
  Easy to maintain

Disadvantages

- Only seconds of autonomy
**Performance Data for PB16.5:**

- Net. energy content: 16.5 MWs
- Input/output power: 1650 kW
- Speed range: 1800 to 3300 rpm
- Total weight: 6000 kg
- Rotor weight: 2900 kg
- Idling losses: 10 kW
- Automatic greasing device
- Typical Bearing service life: 10 years

**Features:**
- Helium filled
- Magnetic support
- Redundant bearings

**AC output with:**
- Constant voltage
- Constant frequency
- Independent from the flywheel speed

---

**Diagram:**

- Magnetic Support
- Top Bearing
- Top Guard Bearing
- Rotating Rectifier
- Excitation Generator
- Main Machine
- Flywheel
- Bottom Bearing
- Bottom Guard Bearing

**Energy Storage Options**

- Kinetic - The Powerbridge
Energy Storage Options

Kinetic Energy systems available

**Induction Coupling**
- Coupled: Mechanical
- Energy: 4.4 – 6.2 MJ
- Outer speed: 1500 min⁻¹
- Inner speed: up to 4500 min⁻¹
- Mounting: Horizontal
- Bearings: up to 6
- Bearing not always changed in situ

**Piller Powerbridge**
- Coupled: Electrical
- Speed: 1800 – 3600 min⁻¹
- Mounting: Vertical
- Bearings: up to 2
- Bearing changed in situ
## Energy Storage Options Comparison

<table>
<thead>
<tr>
<th></th>
<th>Chemical energy storage</th>
<th>Kinetic energy storage</th>
</tr>
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<tbody>
<tr>
<td><strong>Ambient temperature</strong></td>
<td>20°C</td>
<td>0-40°C</td>
</tr>
<tr>
<td><strong>Foot print</strong></td>
<td>$n \times m^2$</td>
<td>very low</td>
</tr>
<tr>
<td><strong>Life time</strong></td>
<td>10 years</td>
<td>20+ years</td>
</tr>
<tr>
<td><strong>Standby losses</strong></td>
<td>extremely low</td>
<td>low</td>
</tr>
<tr>
<td><strong>Recycleable</strong></td>
<td>yes (&gt;98%)</td>
<td>yes (&gt;99 %)</td>
</tr>
<tr>
<td><strong>Autonomy</strong></td>
<td>Minutes</td>
<td>Seconds</td>
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Energy Storage Options
Typical Mains Failure Statistics

Facts:
- Up to 99% of all Mains Disturbances can be compensated for with a Kinetic Energy storage system
Agenda

- Static Series on Line UPS
# Types of UPS Technologies

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SERIES ON-LINE STATIC UPS

- Filter
- Rectifier
- Inverter
- Filter

Static Bypass Switch

UPS OUTPUT (Synthesized Waveform)
Inside a Static UPS

- **Input Filter**
- **Rectifier controller**
- **Battery**
- **DC Bus Filtering**
- **IGBT Inverter controller and Snubber circuits.**
- **Isolation & Filter**
STATIC UPS
IGBT Rectifier/Inverter

High number of components reduces MTBF
Agenda

- Static Parallel on Line UPS
### Types of UPS Technologies

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| **Rotary**           |                  |                |

*Diagram showing types of UPS technologies.*
Types of UPS Technologies
Typical Static UPS Parallel on Line
Agenda

- Hybrid Rotary UPS – Series on line rotary UPS
## Types of UPS Technologies

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### Static

#### Parallel on line

#### Series on line

![Diagram](#)
UNIBLOCK Evolution

Standard technology up to the 1980's

Hybrid machine developed in 1981 by PILLER

Unique and highly reliable system including motor and generator
UNIBLOCK
The Machine

System Fan
Thrust Bearing
Brushless Excitation
Motor and Generator Windings
in a common Stator
Common Rotor
with Damper winding
Vertical Arrangement
for low Bearing Load
Start motor

Unloaded Guide Bearing

Motor winding  Generator winding

Load current

Generator Voltage

Exciter winding
Damper cage
UNIBLOCK R Hybrid Rotary UPS

- Two fully conditioned power paths.
- 15-times short circuit current.
- Practically unlimited crest factor.
- Large overload capacity.
- Reduced air conditioning.
- Reduced plant room space

- ~Unity input power factor.
- No input distortion.
- Naturally generated sinusoidal output.
- Galvanic isolation.
- High efficiency up to 95%.
- High reliability - MTBF 70+ years.
- Dual mains input capability.
Hybrid Rotary: Normal Operating Mode

- Normal operating mode via Static Switch: power factor >0.96 and THD< 2%
- No double conversion, reducing losses: efficiency up to 95%
- Battery charging via rectifier
- Redundant path (Inverter) in standby mode

Mains 1
+10% -15% V
+/- 5% Hz

Mains 2
+/- 8% V
+/- 1% Hz

Load
+/- 1% V
+/- 1% Hz
Hybrid Rotary: Redundant Operating Mode

- Failure of grid supply on Mains 2
- Load Supplied via rectifier, inverter and Uniblock
- Full load supplied even in the event of a failure
- No restrictions on performance
Hybrid Rotary:
Mains Failure Operating Mode

- Battery mode: no connection to the grid
- Conversion of battery power via inverter and Uniblock
- Battery discharging until 1.6V/cell
- Constant and uninterrupted load supply under all conditions
Hybrid Rotary Scheme: Normal Operating Mode

Dual Inputs increase the reliability of each UBR module to approximately 900,000 hours MTBF
Hybrid Rotary Scheme: Input Tx and switchboard Failure

- **Dual Inputs** increase the reliability of each UBR module to approximately 900,000 hours MTBF
UNIBLOCK R Hybrid Rotary UPS Technology

The UNIBLOCK is a combination of high power machine construction and the latest power electronics and micro-electronics.

- 14 times short circuit current thanks to extremely low source impedance
- High efficiency
- 100% unbalanced load capacity
- Microprocessor control and regulation
- Electrical isolation from battery
- Very easy operation
- SNMP capability
- Power shut down
- Remote control, Remote monitoring, Remote diagnostics
- Paralleling capability
Agenda

- Rotary UPS – Parallel on line rotary UPS.
## Types of UPS Technologies

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UNIBLOCK T
50Hz Filter

- UNIBLOCK characteristics at the heart of the parallel on line system:-
- High fault clearing
- High Crest Factor handling
- Low input harmonics
- Isolation input to output via choke (no galvanic isolation)
- Leading Power Factor tolerance
- Bypass not required for fault clearing
- Battery / Kinetic flywheel / Diesel option

500 kVA – 2500 kVA
UNIBLOCK T Rotary and Diesel UPS with Battery

Without Diesel

With Diesel
UNIBLOCK T Rotary and Diesel UPS with Powerbridge

Without Diesel

With Diesel
UNIBLOCK UBT range

Frequency: 50 Hz
Voltage: 380 V up to 25kV
Ratings: 400 kVA – 1.67 MVA

Frequency: 60 Hz
Voltage: 380 V up to 25kV
Ratings: 400 kVA - 2 MVA

- **Bypass**
- **Coupling Choke**
- **Battery**
- **PowerBridge**
- **alternatively**
- **UNIBLOCK**
Agenda

- Diesel Rotary UPS - DRUPS
UNIBLOCK T Diesel UPS
Typical Electrical Scheme: Standby Generator Only

Normal Mains Supply

Reserve Standby Generator

LOAD
Typical Electrical Scheme: Separate standby generator and separate UPS system only or DeRUPS

- Normal Mains Supply
- Reserve Standby Generator
- UPS System
- LOAD
Typical Electrical Scheme: Combined Generator and UPS = Drups System
Piller UBTD Diesel UPS – Main Components.

3 basic elements that can be distributed to suit any installation.
Variants

- All Diesel UPS are made up of engine, clutch, alternator and choke/switchgear control panel.

- The differences are in the type of clutch, storage system and electrical performance specification.

- The manufacturer with the deepest infrastructure and service support is Piller.
# The Energy Store

**Piller PowerBridge**
- **Technology**: Electrically coupled bi-directional storage.
- **Storage Energy**: 16.5 MJ
- **Rotational Speed**: 3300rpm - adjustable
- **Recharge time**: < 1 minute
- **Bearings**: up to 2
- **Squarefoot**: 18.94

**Induction Coupling**
- **Technology**: Mechanical coupled uni-directional storage.
- **Storage Energy**: 6.2MJ
- **Rotational Speed**: 4500rpm
- **Recharge time**: > 7 minutes
- **Bearings**: up to 6
- **Squarefoot**: 35.09
False Starting

Number of Mains Failures per year

- Voltage Dips from 10% to 100%

Duration of Mains Failure

- 10ms - 100ms
- 100ms - 0.5s
- 0.5s - 1s
- 1s - 3s
- 3s - 20s
- 20s - 60s

Other Diesel UPS

- 40% of all mains disturbances compensated without engine start

UNIBLOCK UBTD

- Up to 99% of all mains disturbances compensated without engine start

Piller – Protecting business and the environment.
Effects of False starting

- Increased risk of failure to support the load when needed.
- Reduced reliability.
- Increased running costs.
- Shorter maintenance interval.
- Air and Noise pollution.
UBTD Electrical Schematic Diagram

Dual Output
Common Bus
UPS up to 3000kVA
(2500kW) per module.
Single Output

UPS up to 3000kVA (2500kW) per module.

Dual Output

Isolated Bus

Up to 3000kVA (2500kW) per module.
UBTD Electrical Schematic Diagram - LV or MV?

- Bypass
- Coupling Choke
- BATTERY or Powerbridge
- UNIBLOCK Machine
- Diesel Genset

MV

LV

Piller Group GmbH
A Langley Holdings Company
UBTD Integration within client Switchgear

Integration can save significant costs and space.
Medium Voltage

UPS

Powerbridge Kinetic energy store and controls

Coupling Choke

Transformer

Diesel Engine & Uniblock
Example Distribution (Data Center 1600/800kW)

Redundant Mechanical Load

Dual fed Critical Load
Space comparison with Separate (Static UPS) & Batteries

GenSet
54.8m²
589.86ft²
Air Condition:
max. 50°C
Max. 122°F
Day tank

Static UPS
27.8m²
299.129ft²
Air Condition:
max. 40°C
Max. 104°F

Battery
42.2m²
454.12ft²
Air Condition:
max. 25°C
Max. 77°F

UBTD
54.8m²
589.86ft²
Air Condition:
max. 40°C
Max. 104°F
Day tank

56% less space with UBTD
Working Example
Agenda

- Isolated Parallel Bus Power Systems
A key system of classifying scheme design is in accordance with the Uptime Institute’s Tier 1 – 4 criteria demanding various levels of redundancy and resilience for key subsystems. Some electrical redundancy options include:

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  - UPS B1
  - UPS C1
  - Load

- **Parallel System Redundant Tier 4**
  - UPS A1
  - UPS A2
  - UPS B1
  - UPS B2
  - Load
Unfortunately, as is often the case, there is a price to pay for incorporating redundancy/resilience within a scheme:

- Increased cost:

- Increased plant space:

- Reduced efficiency:
Typical Conventional Schemes to achieve resilience

- More Resilience =
- More hardware = more cost £
- Lower operating efficiency.

Parallel Redundant

Parallel System Redundant
Isolated Parallel Bus (IP-Bus) Power System

- Developed initially by Piller in the 2005 in conjunction with Piller Inc and design partners for the US Data Centre Market

- System utilises Rotary UPS Modules coupled with chokes to provide a highly resilient, high efficiency power solution

- System provides a flexible, modular concept, available in Low and medium voltage, with choice of energy store, eg. Kinetic Flywheel, battery and / or diesel engine.
Scheme Design: IP Bus – what is it?

UPS 1 → Load 1
UPS 2 → Load 2
UPS 3 → Load 3
UPS 16 → Load n

IP-Bus

IP-Choke
Scheme Design
Additional breakers increase the flexibility
Modes of Operation

- How does it operate?
Worked Examples
Load Sharing: Balanced Loads

IP-Bus

UPS 1  UPS 2  UPS 3  UPS 16
80% → 80% → 80% → 80%
0% → 0% → 0% → 0%
80% → 80% → 80% → 80%
Worked Examples
Load Sharing: Unbalanced Loads

UPS 1 78% 2%
UPS 2 70% 30%
UPS 3 78% 2%
UPS 16 78% 2%

IP-Bus

80% 40% 80% 80%
How can system be maintained whilst retaining integrity to load?
Worked Examples
Power Flow During UPS Isolation/Shut-Down

Load 1

Load 2

Load 3

Load n

UPS 1

UPS 2

UPS 3

UPS 16
Modes of Operation
Isolating an IP-Choke for maintenance

Load 1
Load 2
Load 3
Load n
Modes of Operation

- Fault Conditions
Modes of Operation
Design criteria: Short Circuit

- Short circuits need to be dealt with quickly in any part of the system.
- IP-Choke
  - Needs to be short circuit proof and current limiting
- IP-Bus
  - Needs to be able to withstand the concurrent short circuit currents of all IP-Chokes for a short time.
Worked Examples
Current Flow: Short Circuit Downstream

UPS 1

UPS 2

UPS 3

UPS 16

IP-Bus

Load 1

Load 3

Load n

400 V

0 V

400 V

400 V

700 A

23 kA

11 kA

700 A

34 kA

(40ms)
Benefits
IP-Bus UPS
Key Benefits

- High level electrical resilience with reduced hardware, compared with conventional schemes.

- Typically a Tier 3 resilience can be achieved with a conventional Tier 2 Infrastructure

- Highly maintainable with no disruption to load

- Very high operating efficiency is achieved

- Full time continuous on-line protection
IP-Bus UPS
Additional Benefits

- Reduced plantroom space
- Suited to rotary or diesel rotary UPS types.
- Can be provided as Low or Medium voltage (LV or MV)
- High power capacity even at low voltage
- Proven operation with an increasing number of schemes being implemented.
IP-Bus UPS
Example of Benefits

- A 20MW IP Bus System with modules highly loaded (90% plus) whilst offering reliability similar to a system redundant scheme where the maximum loading would be 50% = an improvement in system operating efficiency of 3 – 4%.

- Remember, for every 1MegaWatt of load 1% losses = £10,000 per year.

- So for a 20 MegaWatt data centre load with 3% losses = £600,000 per year!!
Agenda

- Summary
Summary

There are many potential solutions to meet power protection requirements!

The choice will depend upon the specifics of the application.

Remember:

No 1 concern is: Integrity

Highest root cause of unplanned outages:

Power system failure and human error!
Summary

- High reliability = low component count
- Generally static UPS systems are an ideal solution for lower power requirements, where component count is within reasonable limits.
- Rotary UPS systems are ideal for higher power applications where component count is very low.
- Diesel Rotary UPS Systems (DRUPS) are ideal where high power is required and reduced plant space is preferred.
THANKYOU – ANY QUESTIONS?
In 2012 the total installed capacity of our rotary UPS systems in major data centres and elsewhere was over 2,350,000 kVA. During the year we maintained over 3,000 UPS units up to 3,000 kVA with 280 technicians for over 400 data centre clients in over 40 countries, speaking more than 20 different languages.

We are Piller. We are No.1 in high-end UPS for data centres*.

Time after time, leading banks and financial institutions, broadcasters, telecoms operators, government departments, hosting and other major data centre operators around the world choose Piller UPS over all others.

[* Source IMS Research]

Nothing protects quite like Piller – www.Piller.com