COMPISO

P-HIL

200kVA to MVA

CAPS

Nov 6th 2015
ENJOY ....
COMPISO P-HIL Solutions

Grid Transformer
COMPISO P-HIL Solutions

- Grid Transformer
- Grid Inverter
COMPISO P-HIL Solutions

Grid Transformer

Grid Inverter

Output Matrix

Power Amplifier
COMPISO P-HIL Solutions

Grid Transformer

Grid Inverter

Power Amplifier

Output Matrix

Measurement
COMPISO P-HIL Solutions
COMPISO P-HIL Solutions

P-HIL Turn Key Solution Provider
COMPISO
GRID CONVERTER BLOCK
COMPISO Grid Converter Block
COMPISO Grid Converter Block

- Power: 100kVA up to 1MVA
- Bidirectional Energy Flow
- Galvanic Isolation (Grid Transformer)
- $V_{DC\text{-}LINK} = 770V$
- Supply Grid: 50/60 Hz; $V_{AC\text{ }}400 – 690V$
- Perfectly balanced with Power Amplifier Block
COMPISO
DIGITAL AMPLIFIER
COMPISO Digital Amplifier
Inverter Technology

- 6-leg step-up / step down converter with coupled inductors
- $f_{PWM} = 6 \times 20.833 \text{ Hz} = 125 \text{ kHz}$
COMPISO Digital Amplifier

RT-Link → \[\begin{array}{c}
\text{4Q}
\end{array}\] → Vout

WORLDWIDE AUSTRIAN POWER
COMPISO Digital Amplifier

Digital Input Signal

RT-Link

...0010100101010...

4Q

Vout
COMPISO Digital Amplifier

- Digital Input Signal
  ...0010100101010...

RT-Link

4 Quadrant Output

4Q

Vout

Analogue Output Signal

Sinusoidal Output with Distortion

Voltage

Time

WORLDWIDE AUSTRIAN POWER
COMPISO Digital Amplifier

Digital Input Signal

RT-Link

...0010100101010...

Transport Delay

HIL → PWM

4 µs

4 Quadrant Output

Vout

Analogue Output Signal

Sinusoidal Output with Distortion

Voltage

Time
Full Span Bandwidth

Output Voltage 3-Phase System

- Full span up to 5 kHz
Transfer Function – Low Signal (Harmonics)

Amplitude as a function of frequency (no load)

Amplitude [dB]

Frequency [Hz]

Phase as a function of frequency (no load)

Phase [°]

Frequency [Hz]
Transfer Function – Low Signal (Harmonics)

Amplitude as a function of frequency (no load)

Phase as a function of frequency (no load)

-1 dB

10 kHz
Transfer Function – Low Signal (Harmonics)

Amplitude as a function of frequency (no load)

-1 dB at 10 kHz

Phase as a function of frequency (no load)

-25° at 10 kHz
## CDA Specification

<table>
<thead>
<tr>
<th>CDA SPECIFICATION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Digital Amplifier DC &amp; AC ratings</strong></td>
</tr>
<tr>
<td>Input voltage range</td>
</tr>
<tr>
<td>Output voltage range – DC</td>
</tr>
<tr>
<td>Output voltage range - AC</td>
</tr>
<tr>
<td>Output voltage range - AC</td>
</tr>
<tr>
<td>Current range - DC</td>
</tr>
<tr>
<td>Current range - AC</td>
</tr>
<tr>
<td>Current overload capability</td>
</tr>
<tr>
<td>Power – DC</td>
</tr>
<tr>
<td>S- AC Single Phase</td>
</tr>
<tr>
<td>S- AC 3 Phase</td>
</tr>
<tr>
<td>Full Span Output Voltage</td>
</tr>
</tbody>
</table>

### Signal Quality

| **Output ripple voltage** | $V_{PEAK} < 0,25 \% \ V_{IN}$ |
| **Switching frequency** | 20.833 Hz x 6 = 125 kHz |
| **Efficiency** | 98,5 % (at step down operation, $V_{IN} = 800 \ V$, $V_{OUT} = 400 \ V$, $I_{OUT} = 100 \ A$, $f_{PWM} = 125 \ kHz$) |

### Operating modes

| **DC operation** | 2 quadrant - source / sink operation |
| **AC operation** | 4 quadrant operation |
| **Load regulation** | < ± 1% of $V_{IN}$ (steady state) |
COMPISO
MEASUREMENT
Measurement
CDA Measurement Processing

CDA Controller

Set Points
CDA Measurement Processing

Control Loop
Level 1

CDA Controller
Set Points
CDA Measurement Processing

Control Loop
Level 1

CDA Controller

Set Points

V-Source
I-Source
(250 kHz)
CDA Measurement Processing

Loop Level 1:
- Fast sampling (MHz)
- low latency
- medium accuracy
- active damping
CDA Measurement Processing

Loop Level 1:
- Fast sampling (MHz)
- low latency
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<th>ADC Resolution</th>
<th>Max. Value</th>
</tr>
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<tbody>
<tr>
<td>Current</td>
<td>5 %</td>
<td>12 Bit</td>
<td>± 200 A</td>
</tr>
<tr>
<td>Voltage</td>
<td>1 %</td>
<td>12 Bit</td>
<td>± 1.000 V</td>
</tr>
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V-Source
I-Source
(250 kHz)

Set Points
Cabinet Measurement
Cabinet Measurement

COMPISO System Unit

RT-Link

CDA

CCM

V/I Measurement

HiL-Application

HiL-RT Processor

HiL PC
Cabinet Measurement

Control Loop
Level 2
Cabinet Measurement

COMPISO System Unit

Control Loop
Level 2

V-Source
I-Source

HiL-Application
HiL-RT Processor

HiL PC
Cabinet Measurement

Loop Level 2:
- Slower sampling (250kHz)
- Longer latency (2+4µs)
- High accuracy
Cabinet Measurement

Loop Level 2:
- Slower sampling (250kHz)
- Longer latency (2+4µs)
- High accuracy

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<tr>
<td>Current</td>
<td>1,1%</td>
<td>15 Bit</td>
<td>± 200 A</td>
</tr>
<tr>
<td>Voltage</td>
<td>0,3%</td>
<td>16 Bit</td>
<td>± 1.000 V</td>
</tr>
</tbody>
</table>
Cabinet Measurement – Data Tracking

- Data Tracking
  - Digital: SFP (2 – 8 Gbps Optical Interface)
  - Analogue Output Channels (3 Chan, 0..5V or +/- 5V)
HIL
HARDWARE IN THE LOOP
Power Amplifier / HIL Architecture
Power Amplifier / HIL Architecture

Amplifier Block

HIL- Block (Application)

COMPISO System Unit

RT-Link

V./I. Measurement

HIL-Application
Power Amplifier / HIL Architecture

Amplifier Block

HIL-Block (Application)

Interface
Power Amplifier / HIL Architecture

f_{SET\_POINT} = 250kHz
Power Amplifier / HIL Architecture

Amplifier Block

COMPISO System Unit

CDA

CCM

RT-Link

V/ I Measurement

Interface

f_{SET\_POINT} = 250kHz

V-Source I-Source

V-Measurement l-Measurement

f_{SAMPLE} = 250kHz

HIL- Block (Application)

HIL-Application

HIL-RT Processor

HIL PC
CDA (Amplifier) Parallel Driver
CDA (Amplifier) Parallel Driver

Loop Level 3:
- CDA Parallel Driver
- 2 .. 20 Amps
- Balancing parallel amplifiers
CDA (Amplifier) Parallel Driver

Loop Level 3:
- CDA Parallel Driver
- 2 .. 20 Amps
- Balancing parallel amplifiers
CSU (Cabinet) Parallel Driver

COMPISO System Unit

Cabinet Control and Measurement Board

CDA Parallel Driver

CSU Parallel Driver

HIL-Application
Loop Level 4:
- CSU Parallel Driver
- 2 .. 6 Cabinets
- Balancing several cabinet
CSU (Cabinet) Parallel Driver

Loop Level 4:
- CSU Parallel Driver
- 2 .. 6 Cabinets
- Balancing several cabinet
P-HIL 1 MVA System

- Single 1 MVA Block
P-HIL 1 MVA System

- Single 1 MVA Block
P-HIL 1 MVA System

- Single 1 MVA Block
• Split System
  • 3 x // für AC
  • 2 x // für DC
P-HIL 1 MVA System – Split Op Mode

- Split System
  - 3 x // für AC
  - 2 x // für DC
P-HIL 1 MVA System – Split Op Mode

- Split System
  - 3 x // für AC
  - 2 x // für DC
P-HIL 1 MVA System – Split Op Mode

- Split System
  - 3 x // für AC
  - 2 x // für DC
P-HIL 1 MVA System – Split Op Mode

- Split System
- 5 Individual Systems
Supported HILs – Fibre optic interface

- OPAL-RT
  - OP4510 (currently integrated in the cabinet)
  - OP5600 over SFP
- In preparation (via SFP Interface)
  - RTDS
  - National Instruments
  - Plexim
COMPISO
SCADA
SCADA

EGSTON Compiso SCADA v3.5

System Unit 1:
- CDA 1: 10.32.254.120: 8300
- CDA 2: 10.32.254.129: 8301
- CDA 3: 10.32.254.130: 8302
- CDA 4: 10.32.254.131: 8303
- CDA 5: 10.32.254.132: 8304
- CDA 6: 10.32.254.133: 8305

System Unit 2: Not Deployed

System Unit 3: Not Deployed

System Unit 4: Not Deployed

System Unit 5: Not Deployed

Source IP: 10.32.254.226

Cyclic pollute (s): 1

Connect

Disconnect

Start System

Stop System

AC Grid

AC Bus

Main Switch

GRID Converter

CGCR 200

AC-DC Converter

15.06 VDC

CDA

1.48

CDA

2.20

Output Matrix

6

Emergency Stop

Main switch OFF

CDA fault config

Cooling fan

Lamp power

CDA

0.00

CDA

0.00

CDA

0.00

CDA

0.00

CDA

0.00

CDA

0.00
COMPISO P-HIL
200 KVA SYSTEM
OP-Mode: Single Phase

- CSU 200 kVA
  - \( V_{LN} = 0 \ldots 500 \, V_{RMS} \)
  - \( I_L = 0 \ldots 378 \, A_{RMS} \)
  - \( S = 70 \ldots 180 \, kVA \)
OP-Mode: 3-Phase - symmetrical

- 2 CDAs drive 1 phase

- CSU 200 kVA
  - $V_{LL} = 0 \ldots 480\, V_{\text{RMS}}$
  - $I_L = 0 \ldots 250\, A_{\text{RMS}}$
  - $S = 0 \ldots 200\, \text{kVA}$
Op-Mode: 3 Phase with N

- 1 CDA per Phase
- 3 CDAs for N

CSU 200 kVA
- $V_{LL} = 0 \ldots 480 \, V_{RMS}$
- $I_L = 0 \ldots 125 \, A_{RMS}$
- $I_N = 0 \ldots 375 \, A_{RMS}$
- $S = 0 \ldots 100 \, kVA$
OP-Mode: DC

- 6 CDAs parallel
- CSU 200 kVA
  - $V_{DC} = 0 .. 750 \text{ V}$
  - $I_{DC} = 0 .. 900 \text{ A}$
  - $P = 0 .. 200 \text{ kW}$
OP-Mode: Independent Digital Amplifier

- For every Digital Amplifier
  - \( V_{\text{DC}} = 0 \ldots 750\text{V} \)
  - \( V_{\text{LL}} = 0 \ldots 480\text{V}_{\text{RMS}} \)
  - \( I_{\text{DC}} = 150\text{A} \)
  - \( I_{\text{AC}} = 125\text{A}_{\text{RMS}} \)
  - \( P = 120\text{kW} \)
  - \( S = 33\text{kVA} \)
OP-Mode: Output Transformer (additional)

- Output configurations:
  - $V_{LL} = 690 \ldots 3.300 \; V_{RMS}$
Serial Operation Mode

- 2 Blocks in Serial
- $V_{\text{OUT}} = 0 \ldots 1.500\text{V}_{\text{DC}}$

- Important
  - Middle Point $\Rightarrow$ Ground
  - $-1.000\text{V} < V_{\text{OUT}} < 1.000\text{V}$
COMPISO
HIL APPS
HIL Application Strategy

- We provide the sources (Matlab / Simulink) to the customers
- Customer is invited to adapt sources
- Customers are invited to develop own applications

→ no additional costs for adaptations
HIL Grid Applications

• Arbitrary Wave Form Generator
  • Grid Fault Simulations
    • LVRT (Low Voltage Ride Through) Test Sequence
    • HVRT (High Voltage Ride Through) Test Sequence
  • Frequency Drift Sequence
  • Phase Jump Sequence
  • Harmonics Measurement
    • Perfect Sine Voltage Wave form
    • Background Harmonic Voltage Distortion

• Photovoltaic Generator Simulator
• Virtual AC Load
• Grid Impedance Emulation
P-HIL

TARGET MARKETS
Potential Applications

• **Grid Applications**
  - Grid Emulator (50, 60, 400 Hz)
  - Grid Load
  - PV-Inverter Emulation
  - Wind-Generator Emulation
  - UPS (Uninterruptible Power Supply) Emulation
  - Grid Inverter Emulation
  - Grid Motor / Generator Emulation

• **Motor Applications**
  - Motor / Generator Emulator
  - Drive Inverter Emulator
  - Frequency Inverter Emulator

• **Aerospace / Military**
  - 400 Hz Supply Grid Emulator
  - DC-Supply emulation
  - 400 Hz Aerospace device emulator
  - AC-DC Coupling Emulator
  - Generator / Motor Emulator
  - 400 Hz Inverter Emulator

• **Automotive Applications**
  - **Electrical drive train emulation**
    - Battery Emulator
    - Drive Inverter Emulator
    - Motor Emulator
  - **eVehicle Applications**
    - eVehicle charging station emulator
    - Test Bench for charging
  - **Test Benches for combustion engine drive train**
    - Drive Inverter for electrical machines connected to combustion machines, wheel, gear boxes

• **Transportation**
  - Supply Grid Emulator
  - Machine Emulator
  - Inverter Emulator
  - Electrical drive train emulation
Thank you…
…for your Attention

G. Pammer Oct. 2015