A High Power Current Source with Arbitrary Current Waveforms for a HVDC Circuit Breaker Test Bench

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Why is a Test Bench for HVDC Circuit Breakers necessary?

- HVDC grids require possibility to disconnect parts of the grid
- First commercial, hybrid circuit breakers are available
- Further research necessary to improve circuit breakers
- One approach is the investigation of the DC arc
Required Current Waveforms

- Aim to describe the DC arc behavior
- Identify dependency of current and current gradient
- Required specifications:

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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Max Current</td>
<td>( I_{\text{out, max}} )</td>
<td>30 kA</td>
</tr>
<tr>
<td>Max Voltage</td>
<td>( V_{\text{out, max}} )</td>
<td>10 kV</td>
</tr>
<tr>
<td>Current Gradient</td>
<td>( \frac{dI}{dt} )</td>
<td>200 ( \frac{A}{\mu s} )</td>
</tr>
<tr>
<td>Pulse Length</td>
<td>( T_{\text{period}} )</td>
<td>100 ms</td>
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New Concept for the test bench: Unipolar Arbitrary Current Source (UnACuSo)

- 21 stacks, each with
  - 10 kV output voltage
  - 1.4 kA output current

- Combination of 2 converter Topologies:
  1. Low Voltage 3 Level Converter
     - High Switching Frequency
     - Enables Fast Dynamics
  2. Multi Level Converter
     - Generates High Output Voltages
     - Low Switching Frequency
Operation Principle of UnACuSo
3 Level Converter Prototype System
3 Level Converter Prototype System

Max Current: $I_{\text{out, max}} = 1.4 \text{ kA}$

Max Voltage: $V_{\text{out, max}} = 550 \text{ V}$
UnACuSo Prototype

- Proof of operation principle with prototype system
- Identification of the prototype’s limitations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Output Voltage</td>
<td>$V_{out,max}$</td>
</tr>
<tr>
<td>Output Current</td>
<td>$I_{out,max}$</td>
</tr>
<tr>
<td>Current Gradient</td>
<td>$\frac{dI}{dt}$</td>
</tr>
<tr>
<td>Operation period</td>
<td>$t_{Pulse}$</td>
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Measurement Results 3 Level Converter System

- Different resistive loads are employed
- Maximal output current of 1.4 kA
- Maximal current gradient of $3 \frac{A}{\mu s}$
- Typical test waveform
Measurement Results of UnACuSo

- Combination of 3 level converter system and modular multi level Marx type converter
- Special focus on output current ripple minimization
Summary

- 3 level converter system can be operated at full current, full voltage and maximal current gradient $\frac{dl}{dt}$.
- Proof of concept of UnACuSo performed
- Limitations of the prototype are indentified
Next Steps

- Enlarge the output voltage and current range
- Improve the EMI immunity

Phase II

- Build full scale test system
- Extension to a hardware-in-the-loop real time simulator
- Investigation of advanced control techniques
Thank you for your Attention

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