Controller Design and Implementation of a Medium Voltage (13.8 kV) Modular Multi-Level Converter for Asynchronous Microgrids

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Controller Design and Implementation of a Medium Voltage (13.8 kV) Modular Multi-Level Converter (MMC) for Asynchronous Microgrids (ASMGs)

Background and motivation:
• The ASMG with a back-to-back connected power conditioning system (PCS) is a future application area of medium voltage (MV) converters.
• A 10 kV SiC MOSFET based MMC is applied as the microgrid side PCS converter for a 13.8 kV ASMG.
• Controller is one of the key parts of the PCS converter
• The controller design needs to consider MV operation, noise immunity and full PCS compatibility.

Technical approach:
• The controller design follows IEEE standard 1676-2010.
• Modular design approach is applied.
• Fiber-optic cables are used to link controllers and submodules to improve the noise immunity capability.
• Extensible interface board is designed for future full PCS back-to-back operation.

Conclusion:
• A controller for ASMG PCS converter is designed and implemented.
• The controller is successfully tested with the PCS converter to 25 kV dc voltage and 13.8 kV ac voltage.
• The designed controller can achieve MV operation as well as noise immunity and is compatible with full PCS operation.
Central and Phase Controller Functions

- Central controller contains grid required and MMC operation functions
- Phase controllers realize modulation, voltage balancing and converter protection

**Controller Hardware**

**Central controller**
- Extensible interface
- FPGA
- Fault indicators

**Phase controllers**
- Gate signal output
- Fault indicators
- FPGA

**Controller Functions**

**Central controller functions**

**Phase controller functions**
Experimental Results

- PCS converter controls the ac output voltage and serial RC load is applied
- The PCS converter can operate to 25 kV dc voltage and 13.8 kV ac voltage
- The submodule voltage is well balanced in each phase leg

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values</th>
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<tbody>
<tr>
<td>DC-link voltage ($V_{dc}$)</td>
<td>25 kV</td>
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<tr>
<td>AC line to line voltage ($V_{ac}$, rms)</td>
<td>13.8 kV</td>
</tr>
<tr>
<td>Load condition (RC in series)</td>
<td>R=246 Ω, C=1.25 µF</td>
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<tr>
<td>Line frequency (f)</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Arm filter ($L_{arm}$)</td>
<td>$L_{arm}$=90 mH, $R_{Larm}$= 5 mΩ</td>
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<tr>
<td>Switching frequency ($f_s$)</td>
<td>10 kHz</td>
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</table>

Hardware setup

Voltage of 8 Submodules at 13.8 kV (Phase B)

Submodule voltage waveforms in phase b

Ac voltage and current waveforms
Acknowledgements

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