Open-source software for HVDC control and protection

-- enabling interoperability and reducing technical risks

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AC vs DC

AC grid key component – Transformer

- Copper and steel
- Predictable, easy to model
- Grid expansion made by TSO

HVDC key component – Converter

- Behavior is software-defined
- Software is proprietary and closed
- System verification relies on detailed computer simulations
The HVDC software dilemma
HVDC control and protection with partly open-source software

Existing paradigm

DC voltage / active power
AC voltage / reactive power
AC current, PLL, external protection

Circulating current, arm energies, modulation, capacitor balancing, internal protection

Valve controllers, MMC cells, sensors

Added paradigm

Upper Level Control

Interface

Lower Level Control

Interface

Converter hardware

Non-OEM/open source

Closed source

See also CIGRE TB 604: Guide for the Development of Models for HVDC Converters in a HVDC Grid
Why open-source HVDC Control and Protection?

Widen the ecosystem – reduce technical risks
Open issues...

- **Interfaces** between open and closed software parts
- Choice of open-source **software licenses**
- **System verification** in an open-source context
- **Responsibility** for system performance
- **Guarantees**
Ongoing activities this far

- Cigre Workgroup – B4.85 (Interoperability in HVDC systems based on partially open-source software)
- Research project to be started at KTH with support from Svk and RTE
- Paper at ISGT 2019, Paper at CIGRE session 2020 to be presented

Your participation is welcome!

- Cigre WG B4.85 – contact your Cigre B4 regular member
- Open-source C&P codebase for HVDC
- Contact me:

  norrga@kth.se
Impact of control on converter behavior

MMC AC-side admittance at different current control elements employed

- fixed references
- ac-side current proportional controller
- circulating current controller
- ac-side current resonant controller
- ac-side voltage feedforward
# Blackbox Control Problems

<table>
<thead>
<tr>
<th>Problem</th>
<th>Setup</th>
<th>Party</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switching in AC grid → Resonant current → Converter trip</td>
<td><img src="image1.png" alt="Diagram 1" /></td>
<td>TenneT (from field)</td>
</tr>
<tr>
<td>Generic model HVDC 1 → Study power sharing → Relevance of results?</td>
<td><img src="image2.png" alt="Diagram 2" /></td>
<td>Equinor (simulation)</td>
</tr>
<tr>
<td>Blackbox (existing projects), generic (future projects) → Assess risk of interactions → Solution?</td>
<td><img src="image3.png" alt="Diagram 3" /></td>
<td>RTE (simulation)</td>
</tr>
<tr>
<td>Blackbox, multivendor HVDC → 15% interoperability problems</td>
<td><img src="image4.png" alt="Diagram 4" /></td>
<td>BestPaths (simulation)</td>
</tr>
</tbody>
</table>
Proposal for Open-Source Control Design

- For specific control scheme: circulating current (control) does not impact MMC ac-side admittance

- Proposal:

  - CIGRE guide 604:

  - Similar in IEEE 1676-2100
Existing Control with Proposal

- Chinese multiterminal HVDC system Nan’ao
  - Several higher-level layers
  - Vendor-specific valve and submodule control
# Licensing, Patents, Business models

<table>
<thead>
<tr>
<th>License</th>
<th>Type</th>
<th>Free Distribution</th>
<th>Derivative Works (new ext. control)</th>
<th>Patenting</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIT, BSD</td>
<td>All</td>
<td>Yes</td>
<td>No restrictions</td>
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<tr>
<td>Apache 2.0</td>
<td>permissive</td>
<td>Yes</td>
<td>Apache name cannot be used for marketing</td>
<td>Patent grant required</td>
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<tr>
<td>MPL v2</td>
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<td>Yes</td>
<td>GPL or MPL</td>
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<tr>
<td>LGPL</td>
<td>Restrictive</td>
<td>Yes</td>
<td>GPL or LGPL</td>
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<tr>
<td>GPL</td>
<td>Restrictive and viral</td>
<td>Yes</td>
<td>GPL</td>
<td></td>
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<tr>
<td>Commercial</td>
<td>All restrictive</td>
<td>No</td>
<td>Not allowed</td>
<td>Okay</td>
</tr>
</tbody>
</table>

- Less restrictive licenses
- Patent grant seems to be a requirement
- Option: tailor HVDC-specific license

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Parties in HVDC

- Academia
- End-user
- Consultants
- Vendor B
- Vendor A

Knowledge flow:
- Open-Source external control
- Blackbox internal control
- All except vendor A

Relationships:
- Service-based pricing?
- Responsible
- Knowledge
- Incomplete knowledge
Implementation and Expected Impact

1) Separation: black-boxed internal - open external controls
   - 1 physical unit vs. 2 physical units
   - Communication delay, might be acceptable
   - Interface (software / hardware)

2) Requirement: defined interface
   Expected impact
   - Easier implementation of external input, (e.g. research results)
   - Better studies with actual external controller
   - Standard development
   - Interoperability
   - Multivendor development

3) Accelerate multivendor framework
   - End-user responsible for system stability
   - Less requirements on vendors to solve system-related problems
   - Easier to solve problems touching on other vendors’ equipment (with certain conditions)
Licensing, patents, business models

• Restrictive licenses:
  – Require that alterations published back into the community
  – Risk that this is not done
  – Risk that material is used in closed IP for competitive product (forking)
  – Difficult to re-use in other platforms (e.g. RTDS, PSCAD etc.)
  – Discourage vendors from joining the open-source community and should be avoided

• Permissive licenses:
  – Distribution for derivative work is permitted, but not obligatory
  – Dynamic open-source community has strong incentive to contribute back
  – Better for maintenance in the long term

• Derivative work:
  – Work that has sufficient changes compared to the original work so that the derivative work becomes independent, e.g. a new external control method.
References


References


