FASTER AND MORE ACCURATE CONTROL OF SWITCHED RELUCTANCE ELECTRIC MOTORS USING ZYNQ SOC

IR. STEVEN BERVOETS
CONTROLS ENGINEER
MATLAB EXPO
28/06/2016
Punch Powertrain

ARMEVA

Design workflow

SR motor technology

Matlab workflow

Results
Punch Powertrain

intends to become the leading independent provider of innovative clean powertrain technologies for car manufacturers.
In 2015 the domestic Chinese OEMs adopt:
• 71% of all their CVTs from Punch
• 11% of all their ATs as Punch CVTs

Demand rises also from other regions
• Wider spread of applications
• Design for global market coverage

2006: few apps/30 kupa VT2
2016: 60 apps/400 kupa VT2/3
### Market requirements and solutions

<table>
<thead>
<tr>
<th>Electric Drives</th>
<th>Electric hybrids</th>
<th>Flywheel based</th>
<th>DCT Transmissions</th>
<th>CVT Transmissions</th>
</tr>
</thead>
</table>

#### Conventional ICE
- Stop-start
- 48V
- Mild hybrid
- Full hybrid
- Plug-in hybrid
- Range Extender
- EV
Goal:
To develop a new generation of rare-earth free electric motors based on magnetic reluctance.

<table>
<thead>
<tr>
<th></th>
<th>Company</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Punch Powertrain N.V.</td>
<td>Belgium</td>
</tr>
<tr>
<td></td>
<td>Siemens SISW</td>
<td>Belgium</td>
</tr>
<tr>
<td></td>
<td>Technische Universiteit Eindhoven</td>
<td>Netherlands</td>
</tr>
<tr>
<td></td>
<td>Prodrive B.V.</td>
<td>Netherlands</td>
</tr>
<tr>
<td></td>
<td>TeKshift GmbH</td>
<td>Germany</td>
</tr>
<tr>
<td></td>
<td>Universitatea Tehnica din Cluj-Napoca</td>
<td>Romania</td>
</tr>
<tr>
<td></td>
<td>Siemens SISW</td>
<td>France</td>
</tr>
</tbody>
</table>
Content
Electric Drive System including:
• Motors
• Power Electronics
• Controls

Focus
• power density increase
• Increased efficiency
• Smart packaging

Impact
• EV with increased efficiency at lower cost
- Optimize 3 motors
- Sensitivity analyses
ARMEVA research scope

- Cost
- Efficiency drive cycle
- Noise

Rotating motors

Synchronous machines

- AC motors
- Asynchronous machines (ASM)

Reluctance motors

- Switched reluctance motors (SRM)
- Variable reluctance synchronous motors (VRSM)
- DC excited flux switching machines (DCEFSM)
Basic Principle: Magnetic Reluctance

Advantages
- Simple, robust construction
- No permanent magnets
- High efficiency
- High speed capability
- Low cost
- Safe Operation

Challenges:
- Torque Ripple
- Controls
- Electronics
- Acoustics
Challenges SR in ARMEVA

- Higher speed: 20 000rpm
- Less inductance: 8000A/ms
- Delay of 1µs -> error of 8A
- Interrupt based current hysteresis control in processor 14µs minimum
- New closed loop control strategies with fast and heavy calculations
- -> SoC device: Zynq 7045 device
- No FPGA knowledge within Punch
**MATLAB workflow**

- **Zynq 7045 device**
- **Fixed point workflow**
- **Embedded coder / HDL coder**
- **Vivado**

---

**Diagram:**
- **Simulation System:**
  - Algorithm C Model
  - Algorithm HDL Model
  - Motor Model
- **Implement Algorithm:**
  - Algorithm C Code
  - Algorithm HDL Code
  - FPGA Reference Design
  - Motor Hardware
- **Integrate with Reference Design:**
  - ARM Reference Design
  - Algorithm C Code
  - Algorithm HDL Code

**3ph asymmetric bridge:**
- $I_{M1}$
- $I_{M2}$
- $I_{M3}$
- $I_{BO}$
- $V_{DC}$
- $V_{HV}$

**Boost converter**

---

© 2016 Punch Powertrain

Strictly confidential. All rights such as copying and passing on to third parties reserved by Punch Powertrain.
• Easy to split SW architecture for µproc and FPGA
• Reuse of legacy code
• Automatic communication HW-SW
• Ecosystem Zynq for more specialized drivers not available: CAN
• Fixed point conversion not yet push button
• Vivado workflow fully automated
Development workflow part 2

Vehicle requirements

E-drive requirements

Architecture Design

Module Design

Implementation

Vehicle

Test bench

Final board HIL test

Eval Board HIL test

Eval board desk test

MIL

Reuse models from left leg for validation
• Integrated E-drive:
  – motor, PE and SW
• 4 different control strategies
  – 1.5 years with 2FTE’s
• Models reusable for production
• Smooth integration and validation due to development process
  – Validation before electronics are produced
  – Do not lose critical test bench time
Future

• Growth in:
  – Products
  – Staff

• Time to market
• Quality
• Cost
Thank you for your attention!

For more info about us, please visit our website www.punchpowertrain.com

steven.bervoets@punchpowertrain.com