A New Paradigm for Online Education and Research in "Power" Worldwide

Using ONR-funded Low-cost Rapid Real-time Platform
Consortium of Universities for Sustainable Power (CUSP)

235 U.S. Universities as members (over 450 faculty)
Increasing course adoption

• Cost of laboratory infrastructure major impediment

• Software such as MATLAB are essential but inaccessible
  1. Costs around $4,500 for educational purpose
  2. Upwards of $21,000 for commercial use
  3. Unaffordable to community colleges, universities in developing countries and startups

• Real-time prototyping hardware such as dSpace are equally expensive and not best suited for power electronics
Sciamble Workbench

- Numerical simulation software.
- Model based drag and drop.
- Advanced coding environment.
- Supports matrix operations.

Public kpi As Native Double ! current loop proportional gain
Public kii As Native Double ! current loop integral gain

! Parameter initialization function
Public Function Init()

! local variables, just for the purpose of computation and
Local Ardqθ As Native Double = \sqrt{(\lambda Ardq^2 + \lambda Arqθ^2)}
Local Asdqθ As Native Double = \sqrt{(\lambda Asdq^2 + \lambda Asqθ^2)}
Local @Isdq As Native Double = Math:ATan2(Isqθ, Isdqθ)
Local @Vsdq As Native Double = Math:ATan2(Vsqθ, Vsdq)
Local Isdqθ As Native Double = \sqrt{(Isqθ^2 + Isdqθ^2)}
Local Vsdqθ As Native Double = \sqrt{(Vsqθ^2 + Vsdqθ^2)}
Workbench – Model based numerical simulation and real-time code generation
Workbench Features – Script Editor

- Language designed from scratch to support dynamic compilation.
- Extremely easy to use.
- Inbuilt matrix operation support.
Workbench Features – Real-time Code Gen
Workbench Features – Real-time Code Gen
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<th>Academic</th>
<th>Non-academic</th>
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<td>Total: &gt; $20,500</td>
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<td>Total: &gt; $47,500</td>
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Previously used system in electric drives lab (Spring 2017)
Currently used system in electric drives lab (Spring 2018)

<table>
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<tr>
<th>Academic/Non-academic</th>
<th>Cost: FREE!</th>
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<th>Cost: $3,300</th>
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Total: $3,300
Electric Drives Lab
List of Experiments

Basic drives lab (undergraduate level)

1. Switched-mode DC-DC converter
2. Characterization of DC motor
3. DC motor closed-loop speed control
4. Four-quadrant operation of DC motor
5. Torque-load angle characteristics and speed control of PMAC motor
6. Determination of Induction motor parameters
7. Torque-speed characteristics and speed control of Induction motor

Advanced drives lab (graduate level)

1. Characterization of Induction motor
2. Induction motor V/f control
3. Vector control of induction motor
4. Encoder-less vector control of induction motor
5. Direct torque control of induction motor
6. Space vector Pulse width modulation of two level three-phase inverter
7. Vector control of surface PMAC motor
Workbench Induction motor vector control
Workbench Induction motor vector control
Induction motor real-time vector control results
Induction motor real-time vector control results

Induction motor 3φ stator current

Induction motor 3φ stator current (zoomed in)
Induction motor real-time vector control results

Induction motor stator dq currents

![Graph showing stator d-axis and q-axis currents with Time (s) on the x-axis and Current (A) on the y-axis.]

Induction motor torque and load torque

![Graph showing motor torque and load torque with Time (s) on the x-axis and Torque (Nm) on the y-axis.]

Torque (Nm)

Current (A)

Time (s)
Electric drives lab adoption - Worldwide
WBG based Digitally controlled Power Electronics Lab
List of Experiments

Power electronics lab (undergraduate level)
1. Si and GaN power-device characteristics
2. Buck converter
3. Boost converter
4. Buck-boost converter
5. Digital voltage mode control
6. Digital current mode control
7. Flyback converter
8. Forward converter
9. Full-bridge converter
10. Single-phase DC-AC inverter
11. Three-phase DC-AC inverter
Low-cost general purpose prototyping platform

- Code-free model based design enabled rapid prototyping platform.
- Cost $25 and has similar capability as $9000 dSpace platform.
- Measures 1 x 1 in and can be easily plugged into any real-world control application.
- 100 MHz clock, 16 PWMs, 14 ADCs, 33 GPIOs, 1 SPI/SCI/CAN COM.
- On-board datalogger and programmer that interfaces directly with Workbench.
Emulated Power Systems Lab

Emulated micro-grid

$\frac{1}{2}$ kW GaN 3-phase inverters

3-phase Voltages & currents

Emulated grid connected PV system

Emulated grid fault
Acknowledgement

We are greatly indebted for the three grants to the University of Minnesota from the Office of Naval Research (ONR):

a. N00014-22-1-2491 “A Low-Cost Scalable Tabletop Emulator for Shipboard Power System”


These grants allowed the development of the Workbench simulation platform, which is available free-of-cost for educational purposes. These grants also allowed the development of a low-cost hardware laboratory, available from Sciamble Corp (https://sciamble.com) – a University of Minnesota startup.
Thank you