Modeling Power Electronics Components Using SimElectronics and SimPowerSystems

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Modeling Power Electronics Components Using SimElectronics and SimPowerSystems helps you in understanding:

- System level and detailed modeling of power electronics systems.
- Different ways to parameterize devices like IGBT from a datasheet and visualizing the characteristics.
- How to bring thermal effects into the power electronics convertor.
Applications of Power Electronics using IGBT.

- AC/DC power supplies
- Electric machine drives
  - Electric vehicle
  - Wind turbine
- Flexible power transmission in power systems
  - HVDC (High Voltage DC) transmission
  - FACTS (Flexible AC Transmission Systems)
What are the challenges in designing the Power Electronics Convertors?

**Challenge 1:**
- System level simulation of power electronics applications.

**Challenge 2:**
- Detailed modeling of power electronics with non linear switching characteristics

**Challenge 3:**
- Calculating the switching loss of the power converter from a datasheet to design an appropriate control logic

**Challenge 4:**
- Bring thermal effects to the power electronics convertor.

**Challenge 5:**
- Control system design and PWM waveform generation.
Agenda

- **Big Picture demo** – 6-Switch 2-Level Converter

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6-Switch 2-Level Converter
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Power Circuits:

Switching loss:

Thermal Model:

Controls:

Select a specific PWM mode by typing:
1. (SPWM: sinusoidal PWM)
2. (SVM: space vector modulation)
3. (60 DPMW: 60 degree discontinuous PWM)
4. (+30 degree shift from 60 DPWM)
5. (-30 degree shift from 60 DPWM)
6. (30 DPMW: 30 degree discontinuous PWM)
7. (120 DPWM: positive dc component)
8. (120 DPWM: negative dc component)
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System level simulation of Power Electronics

Model:

Problem: Model a system level simulation of a power electronics convertor

Solution: Use inbuilt blocks from SimPowerSystems to model the convertor.
Agenda

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Problem: Model a detailed power electronics convertor with non linear characteristics.

Solution: Use semiconductor blocks from SimElectronics to model the convertor.
SimElectronics AND/OR SimPowerSystems

**SimElectronics**
- Simultaneous nonlinear equations solution
- SPICE level switching device models
  - Include switching losses
  - Include parasitic current effects
  - Include temperature effects
  - Higher fidelity simulation

**SimPowerSystems**
- Piecewise linear systems solution
- Multiphase bridges and pulse generators
- Detailed and average voltage models
- Transient and harmonic analysis
- Faster simulation
SimElectronics and SimPowerSystems

**SimElectronics**

**SimPowerSystems**

PNP Bipolar Transistor

Model PNP bipolar transistor using enhanced Ebers-Moll equations

Library
Semiconductor Devices

Description

The PNP Bipolar Transistor block uses a variant of the Ebers-Moll equations to represent an PNP bipolar transistor. The Ebers-Moll equations are based on two exponential models plus two current-controlled current sources. The PNP Bipolar Transistor block provides the following enhancements to that model:

- Early voltage effects
- Optional base, collector, and emitter resistances.
- Optional fixed base-emitter and base-collector capacitances

\[
I_C = -IS \left( e^{-\frac{V_{ce}}{V_A}} - e^{-\frac{V_{ce} + V_{be}}{V_A}} \right) \left( \frac{1}{\beta_R} e^{-\frac{V_{be}}{V_A}} - 1 \right)
\]

\[
I_B = -IS \left( e^{-\frac{V_{be}}{V_A}} - e^{-\frac{V_{be} + V_{bc}}{V_A}} \right) \left( \frac{1}{\beta_F} e^{-\frac{V_{bc}}{V_A}} - 1 \right)
\]

IGBT

Implement insulated-gate bipolar transistor (IGBT)

Library
Power Electronics

Description

The IGBT is modeled as a series connection of a combination of layers. The IGBT turns on when gate driver input (g > 0), and the IGBT turns off when the gate driver input (g = 0).
6-Switch 2-Level Converter

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Switching loss:

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Modeling the characteristics of IGBT using SimElectronics

**Problem:** Model an IGBT and visualize different characteristics from datasheet

**Solution:** Use SimElectronics to model the Semiconductor device by parameterizing from datasheet
Steady-state Characteristics (I-V curves)

- Control Circuit
  - $I_C$
- Power Circuit
  - $V_{CE}$
  - $V_G$

Graphs showing $V_{CE}$ vs. $I_C$ for different voltages ($17V$, $15V$, $13V$, $11V$, $9V$) with $T_0 = 25^\circ C$ and $T_0 = 125^\circ C$. 
Switching Characteristics
(Switching Energies vs. Collector Current)

Test circuit parameters
Generate switching loss graph

V_{CC} = 2800 V
V_{GE} = \pm 15 V
R_G = 1.5 \text{ ohm}
C_{GE} = 220 \text{ nF}
T_J = 125 \text{ °C}
L_C = 150 \text{ nH}

\[ E_{sw} [J] = 1.2 \times 10^{-6} \times I_C^2 + 6.1 \times 10^{-3} \times I_C + 1.08 \]
Modeling the characteristics of IGBT using SimElectronics

**Model:**

**Device Blocks**

- IGBT
- Diode
- Collector
- Emitter
- Gate

**Problem:** Model an IGBT and visualize different characteristics from Spice netlist

**Solution:** Use SimElectronics to model the Semiconductor device by parameterizing from Spice netlist
Parameter Estimation of IGBT using Simulink Design Optimization

Model:

Problem: Match the result of the simulation with the datasheet.

Solution: Use Simulink Design Optimization to match the results between the simulation and the datasheet.
6-Switch 2-Level Converter

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Switch 2

Level Converter

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**Problem:** Model thermal effects in IGBT

**Solution:** Use thermal block sets from Simscape and do the multi-domain modeling.
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- System level simulation of power electronics applications.
  - **SimPowerSystems**

**Challenge 2:**
- Detailed modeling of power electronics with non linear switching characteristics
  - **SimElectronics**

**Challenge 3:**
- Calculating the switching loss of the power converter from a datasheet to design an appropriate control logic
  - **SimElectronics**

**Challenge 4:**
- Bring thermal effects to the power electronics convertor.
  - **Simscape**
Key Takeaway

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Thank you