MATLAB EXPO

Implementing and Real-Time Testing of a Grid-Tied Solar Inverter Controller

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MathWorks®

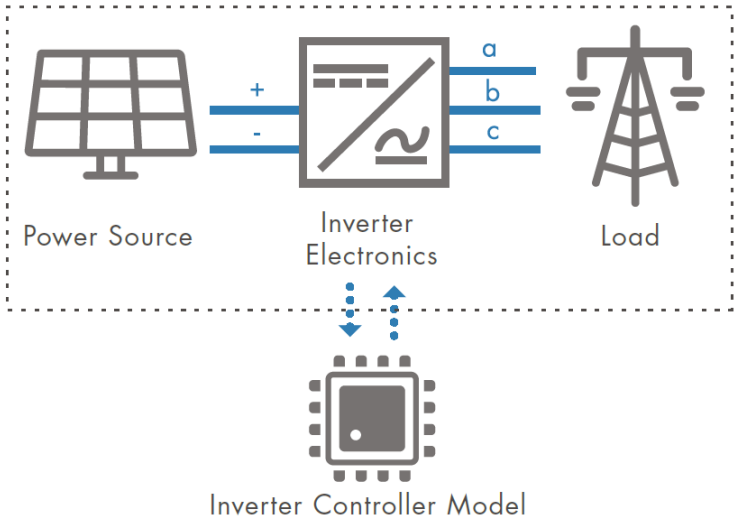
speedgoat
real-time simulation and testing

Key Takeaways

- Simplify control development for power electronics using Simscape Electrical and Speedgoat hardware
- Automatically generate C and HDL code for plant simulations and production code from Simulink and Simscape Electrical
- Use hardware-in-the-loop to test normal operation and fault conditions such as Fault-Ride Through

Simulink and Speedgoat are a common platform fo control design and testing

Design and optimize controls using electrical systems simulation



Generate code for the plant

and the controller

About Speedgoat

- A MathWorks associate company, incorporated in 2006 by former MathWorks employees. Headquarters in Switzerland, with subsidiaries in the USA and Germany

- Provider of real-time target computers, expressly designed for use with Simulink

- Real-time core team of around 200 people within MathWorks and Speedgoat. Closely working with the entire MathWorks organization employing around 5,000 people worldwide

What is Our Goal?

- Primary goal is to design power electronics hardware and controllers

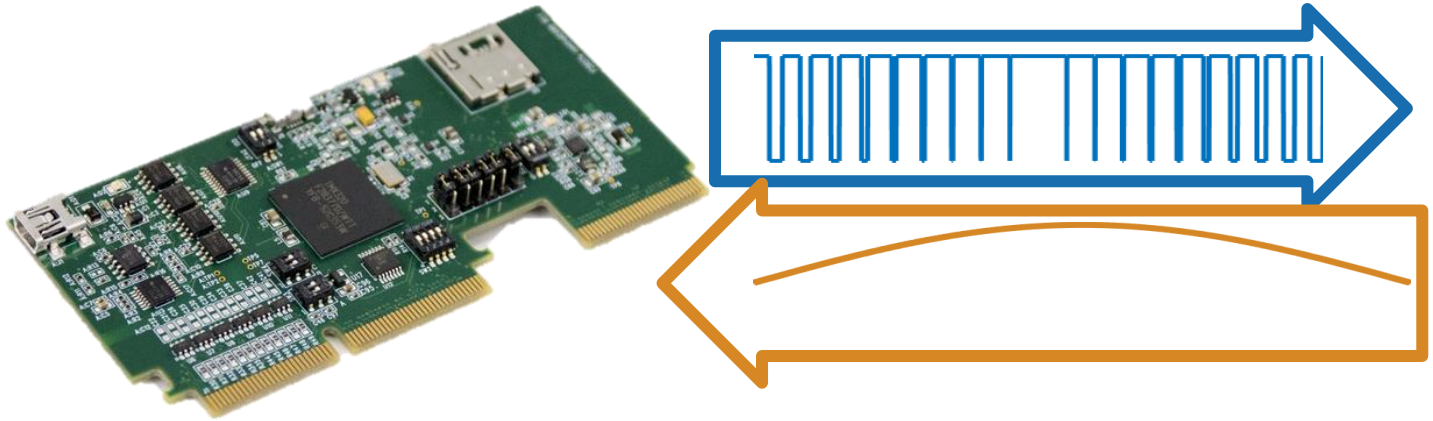
Controller

Hardware (Plant)

What is Our Goal?

- Primary goal is to design power electronics hardware and controllers
  - Hardware in the loop (HIL) testing can improve this process

Controller

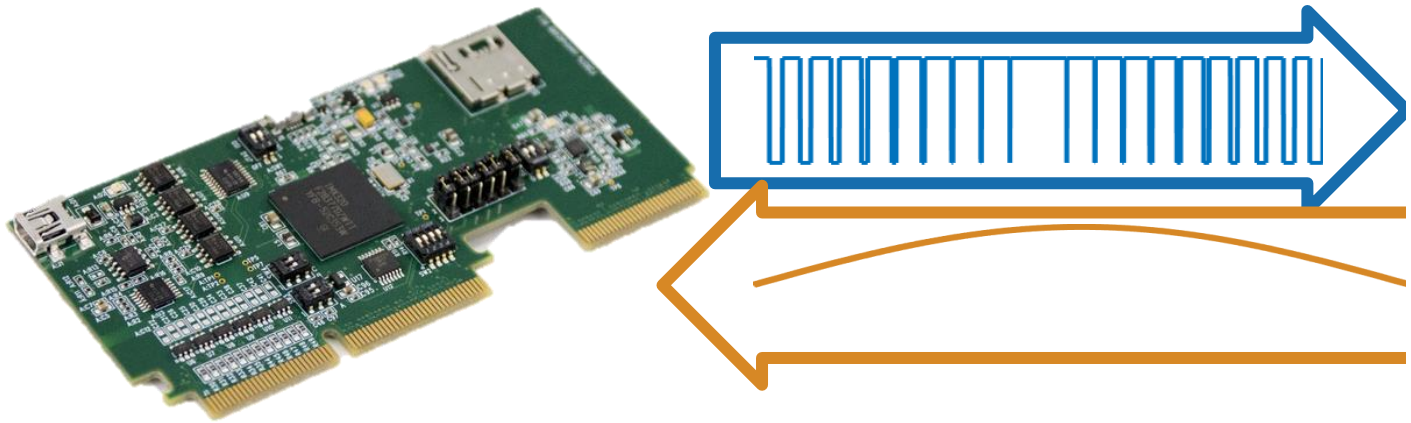


Hardware (Plant)

What is Hardware in the Loop (HIL) Testing

- HIL replaces the power electronics hardware with a virtual simulation

Controller

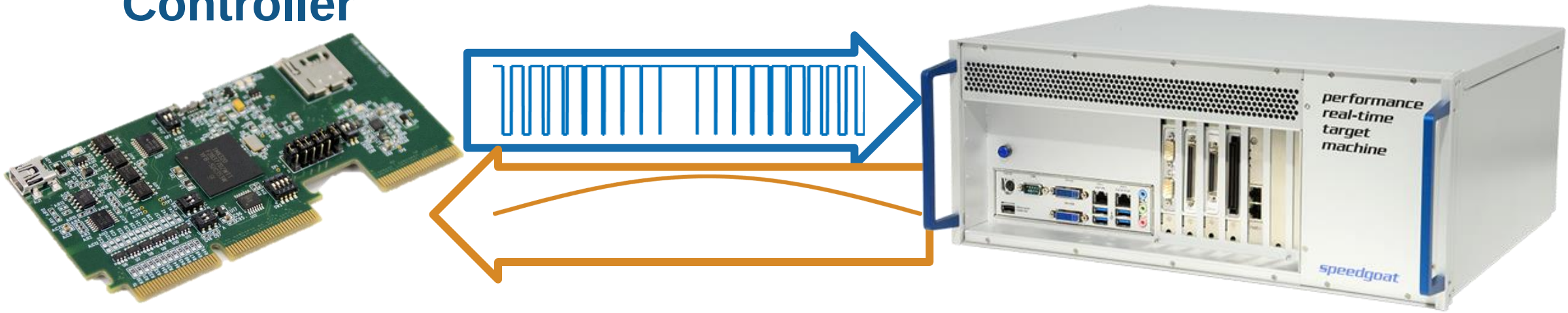


What is Hardware in the Loop (HIL) Testing

- HIL replaces the power electronics hardware with a virtual simulation
  - Controller can operate as if in the real system

Controller

Virtual Simulation (Plant)

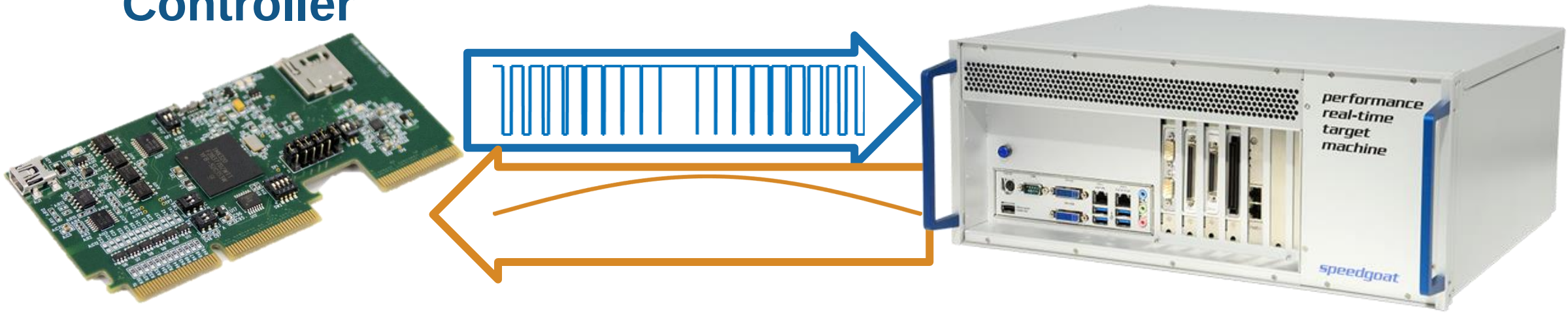


Advantages of Hardware in the Loop (HIL) Testing

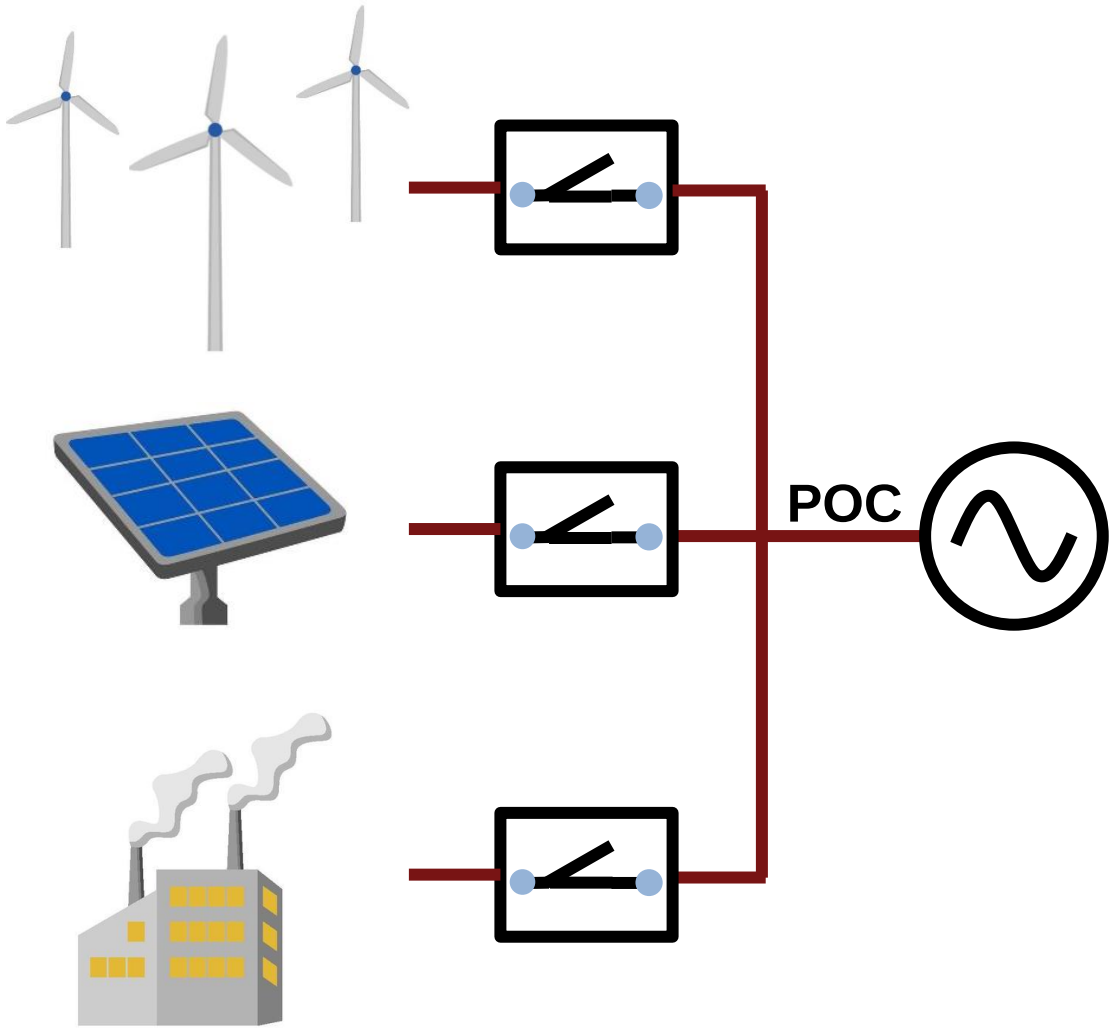
- Can replace prototypes or production hardware with a real-time system
- Easier to automate testing and **test grid code fault scenarios**
- Safer than most power electronics hardware
- Start many design/test tasks earlier

Virtual Simulation (Plant)

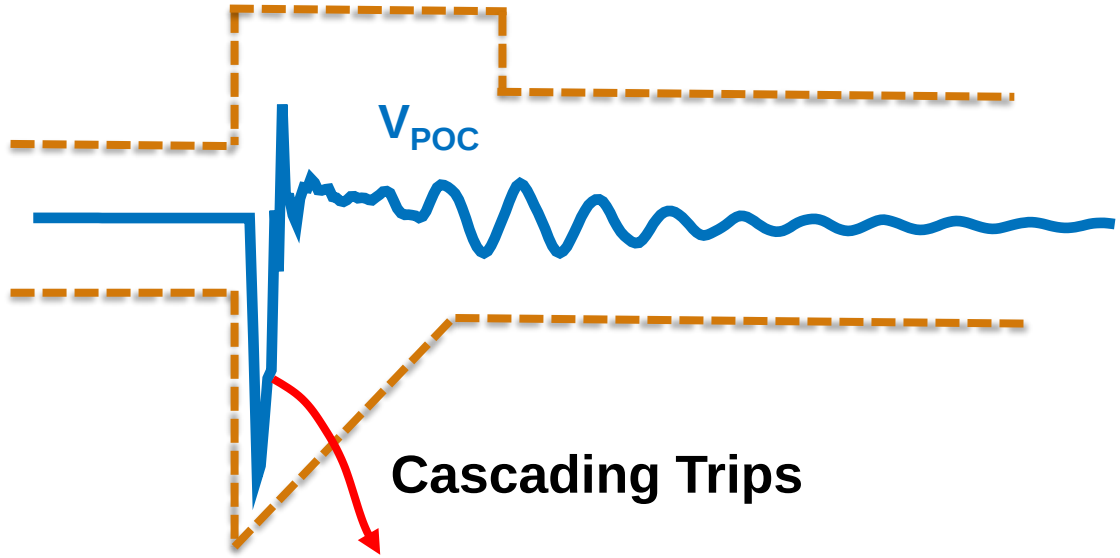
Controller



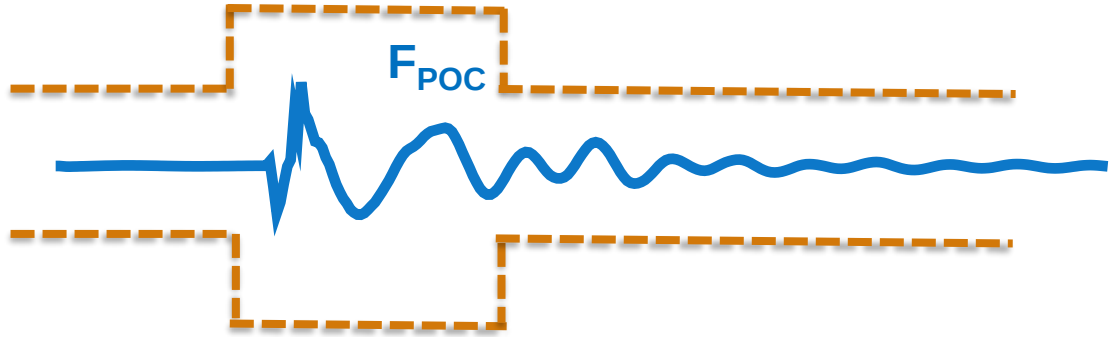
Protecting the Utility Grid



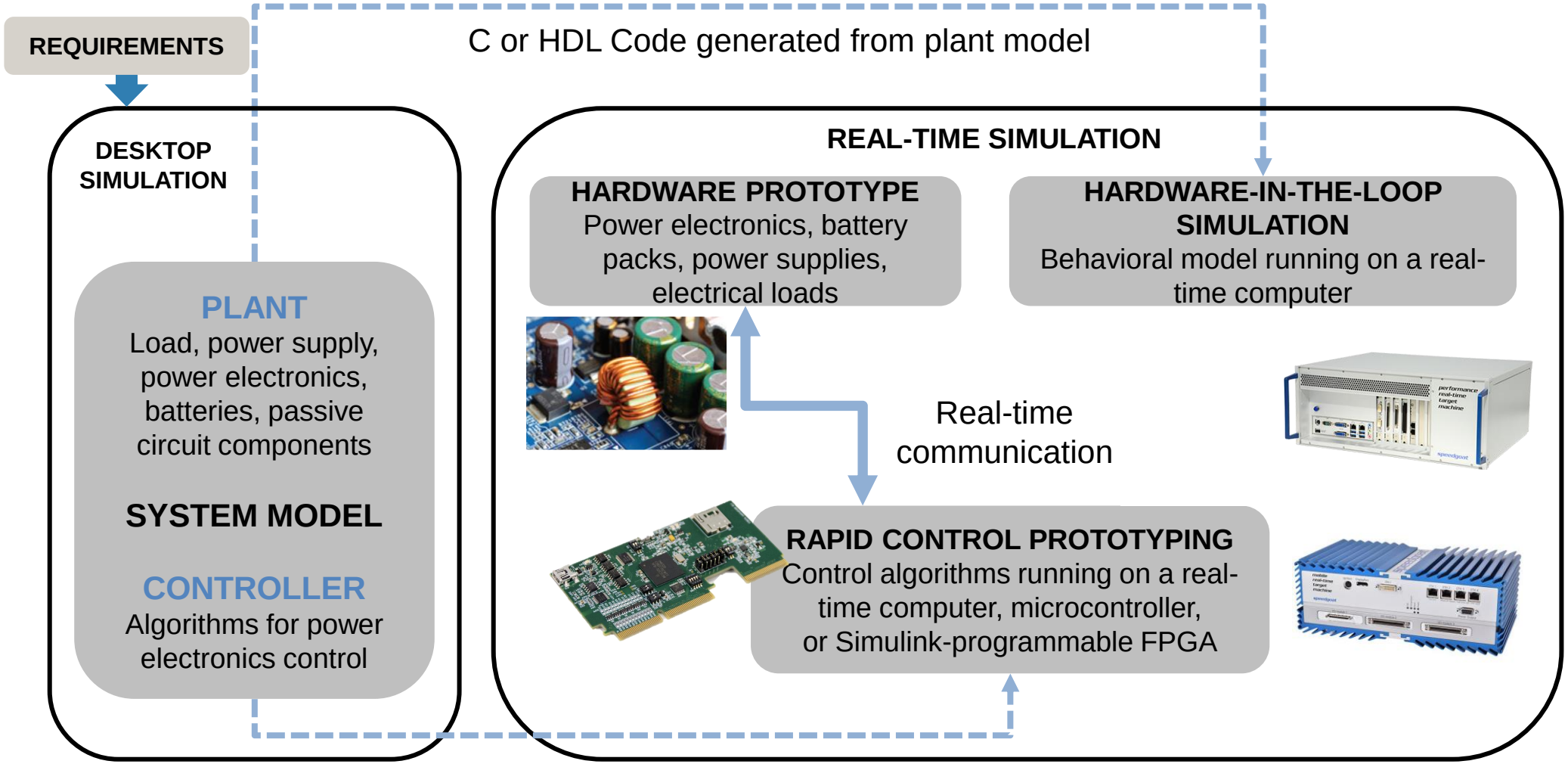
Voltage Grid Codes



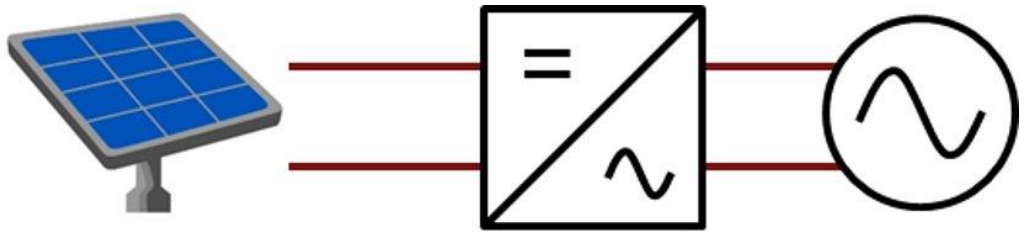
Frequency Grid Codes

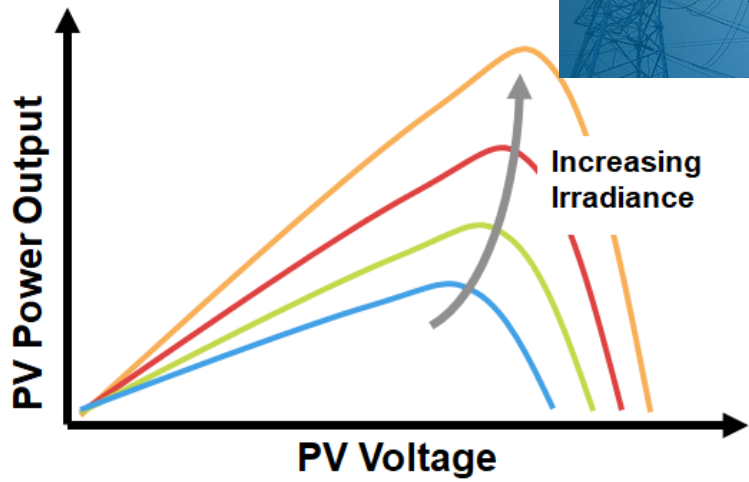


Model Based Design for Power Electronics



Overview of Solar Inverter Control Development

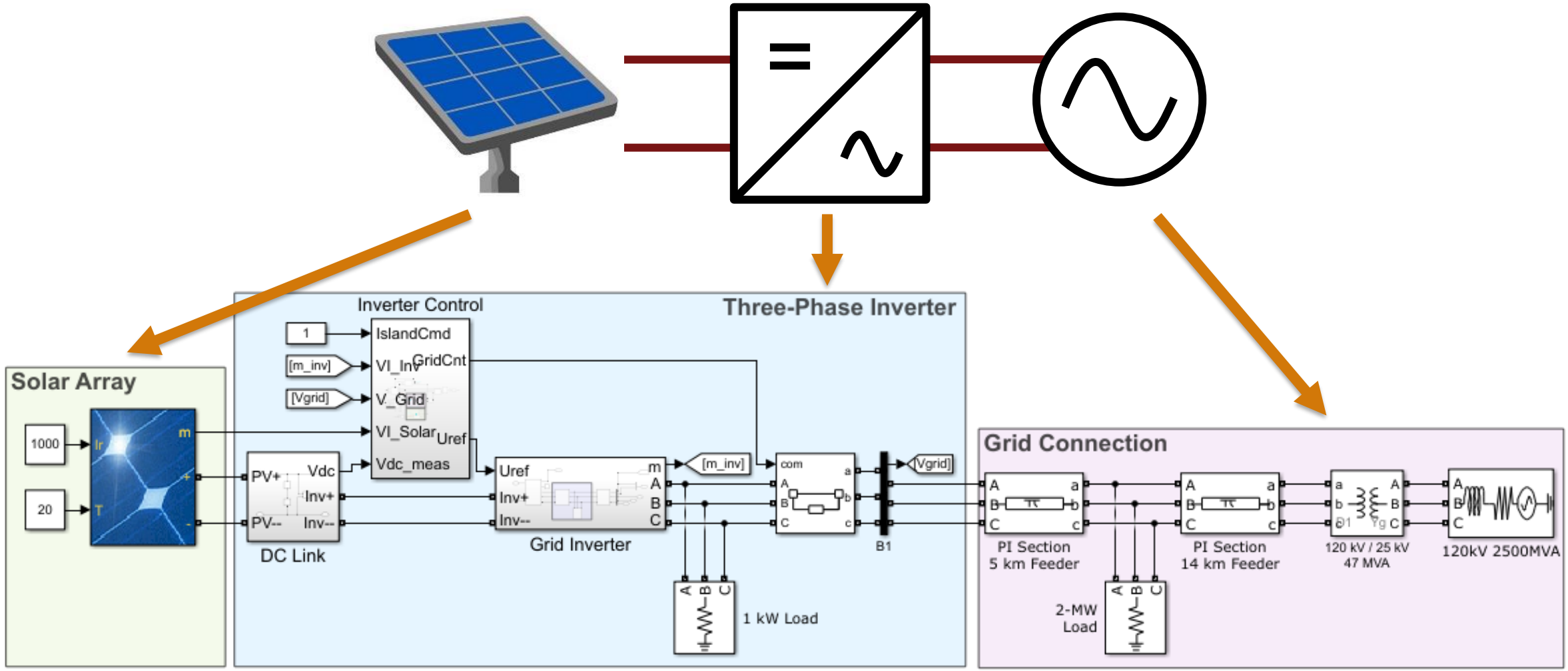




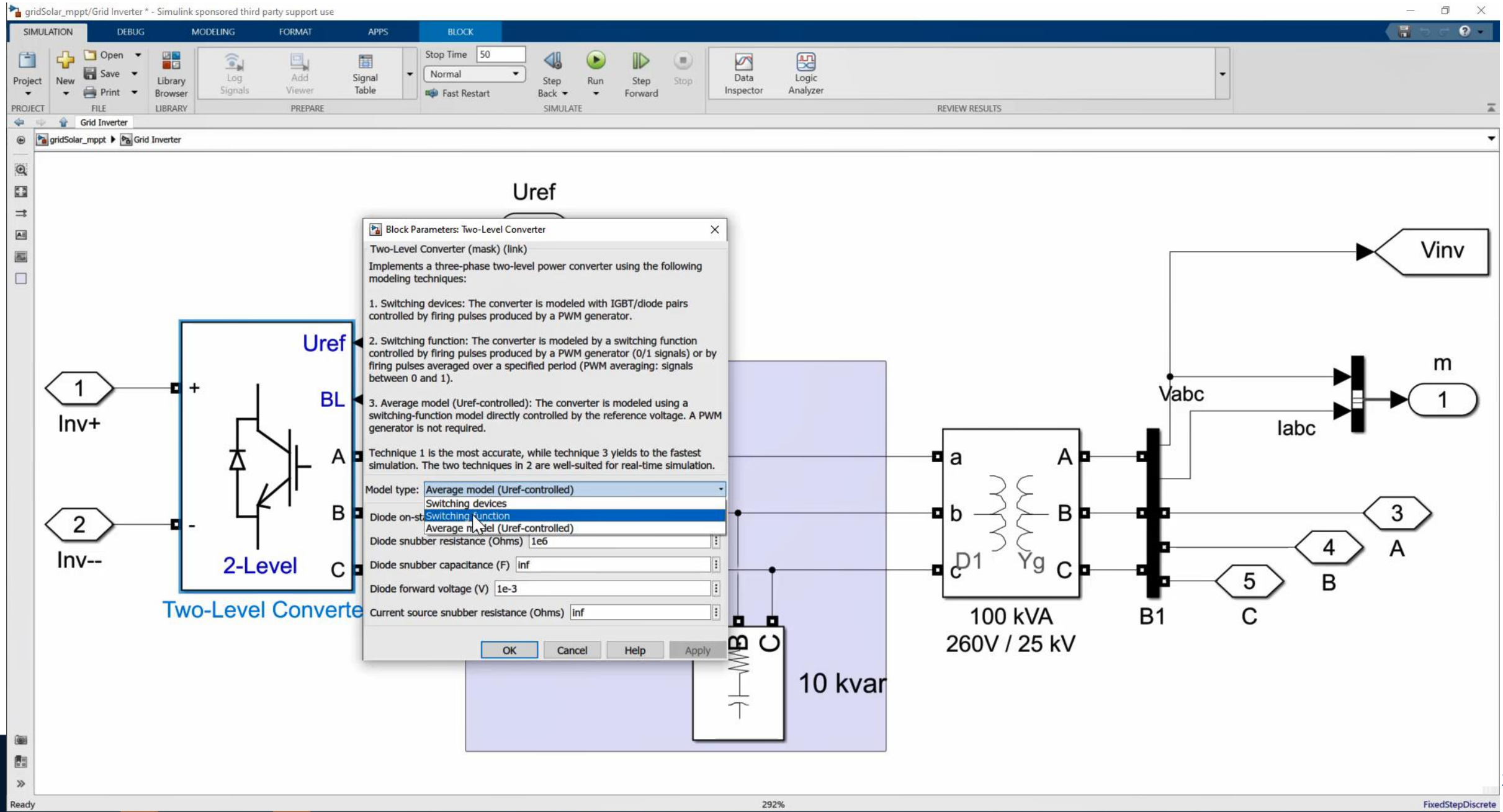
1. **Plant Modeling**
   (Photovoltaic plant, Inverter, Grid)
2. **Control Design**
   (Grid synchronization, MPPT algorithm)
3. **Automatic Code Generation**
   (Deploy code to TI C2000 and Speedgoat hardware)
4. **Hardware-in-the-Loop Testing**
   (Controller verification with Speedgoat hardware)

1 Plant Modelling

Schematic-based modeling with common power electronics topology

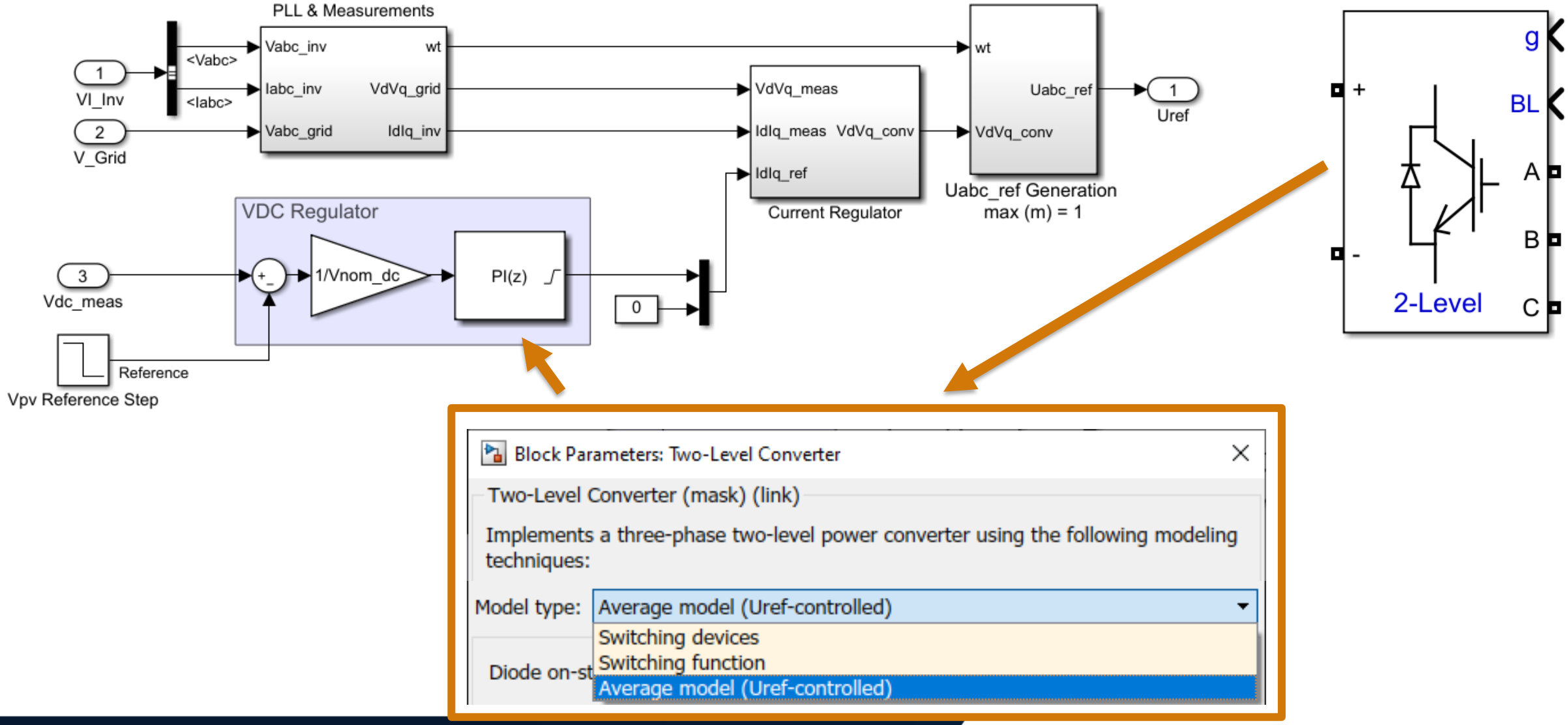


1 Plant Modelling



2 Control Design

PID Tuning of Power Electronics – Leverage Average-Value Models



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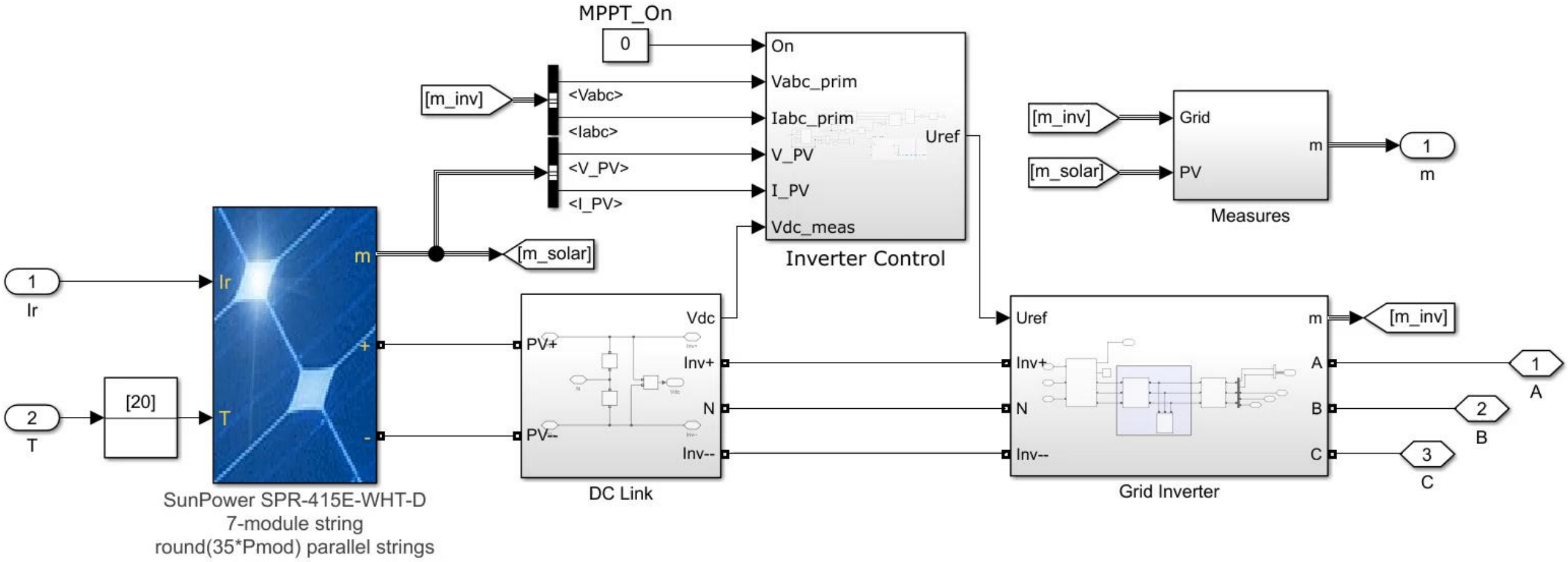

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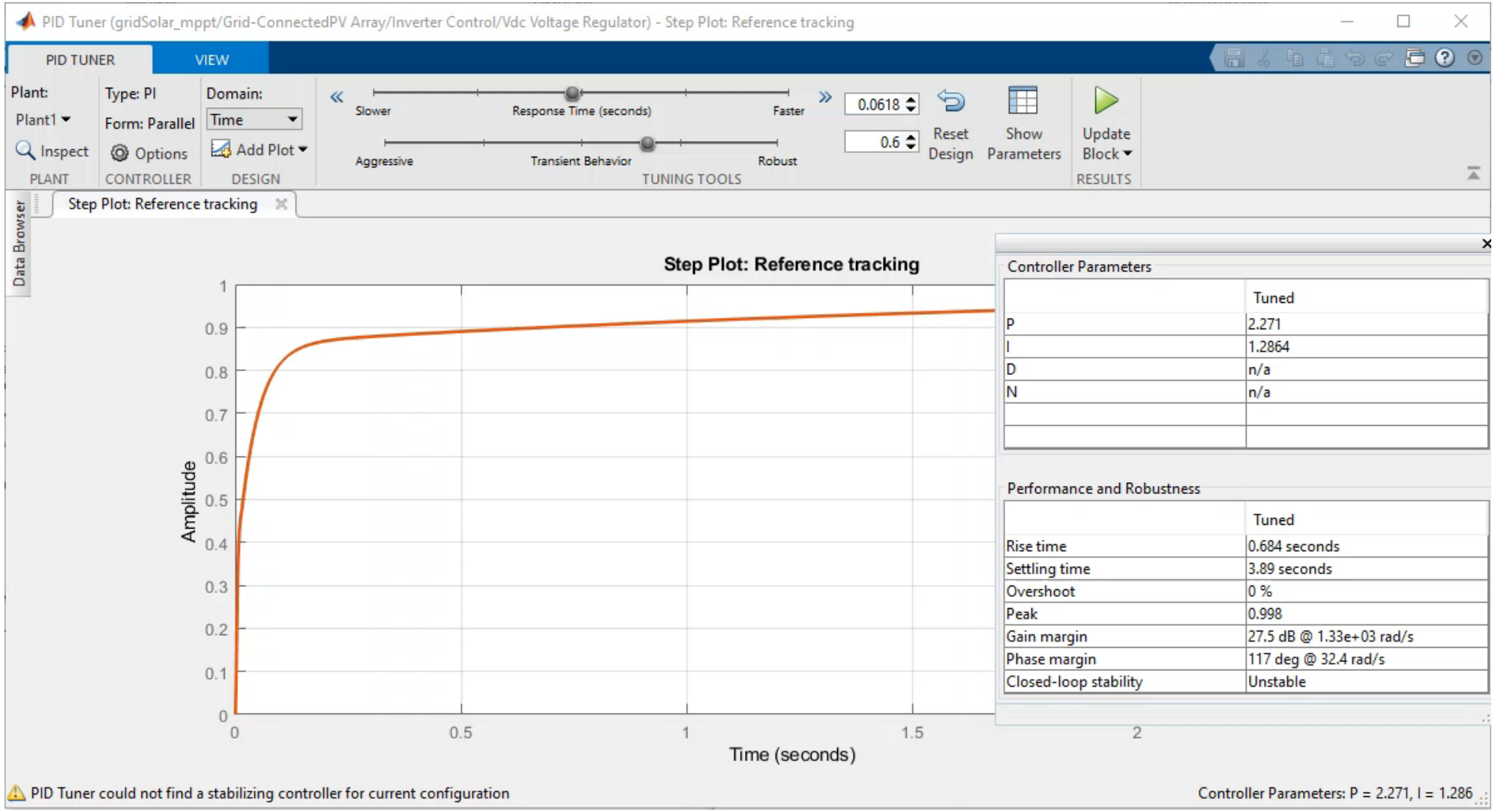

2 Control Design

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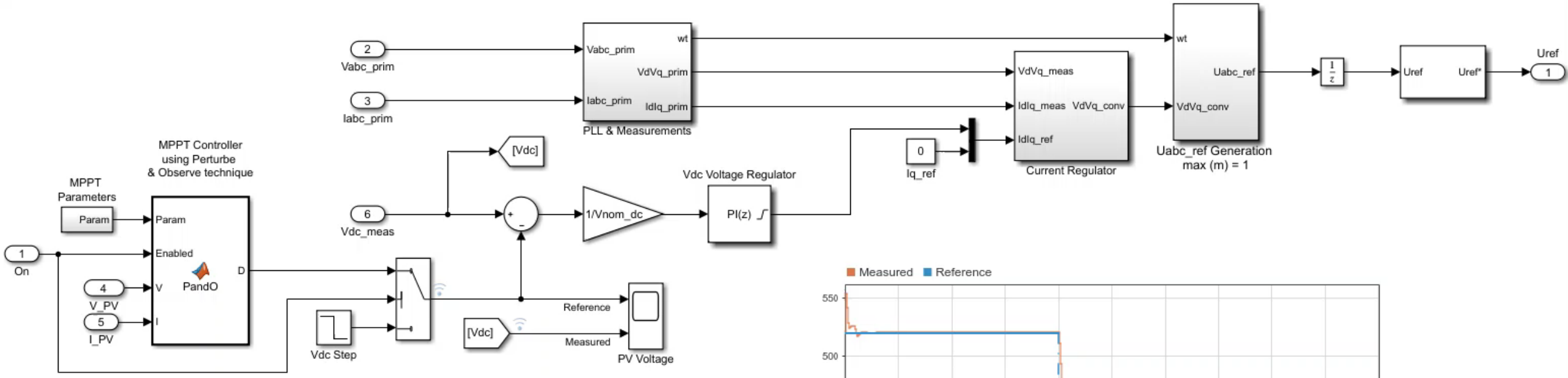
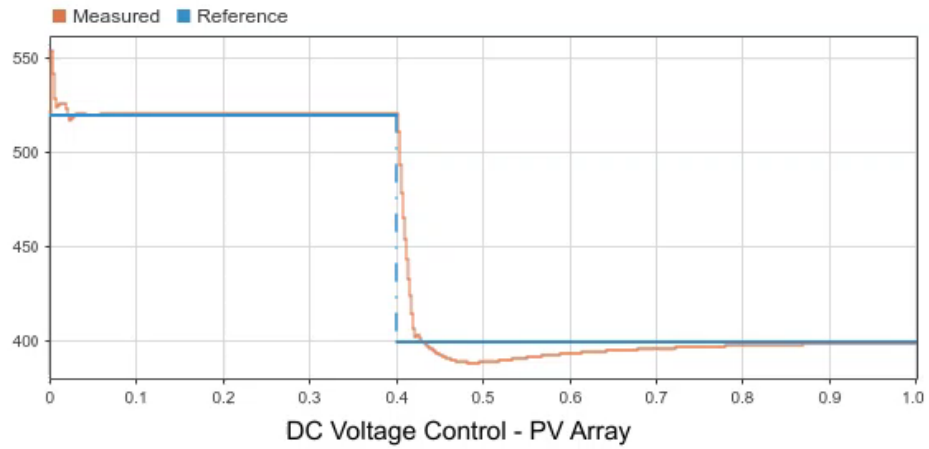
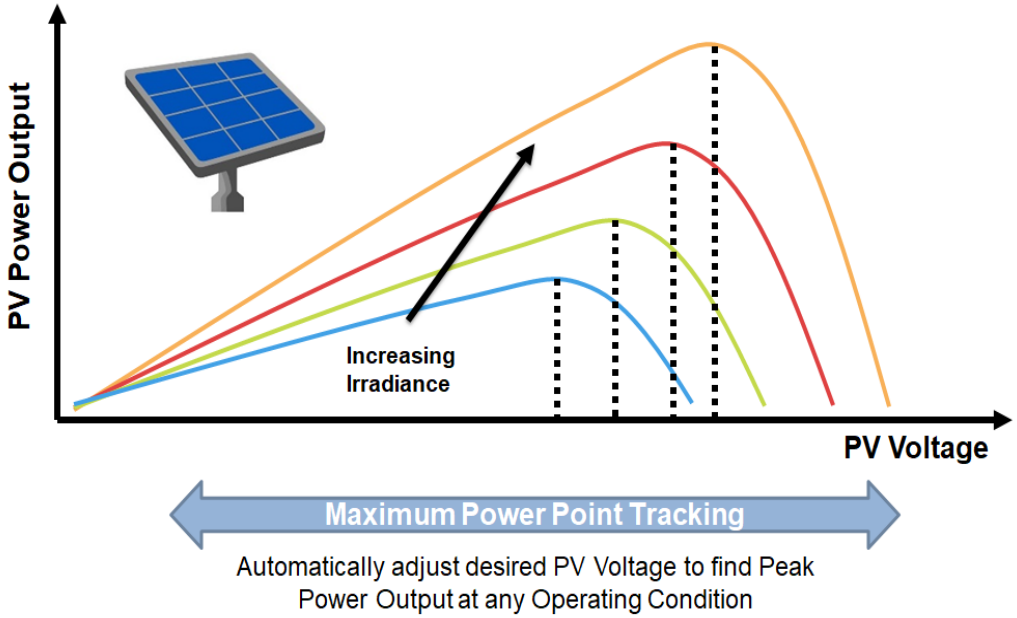
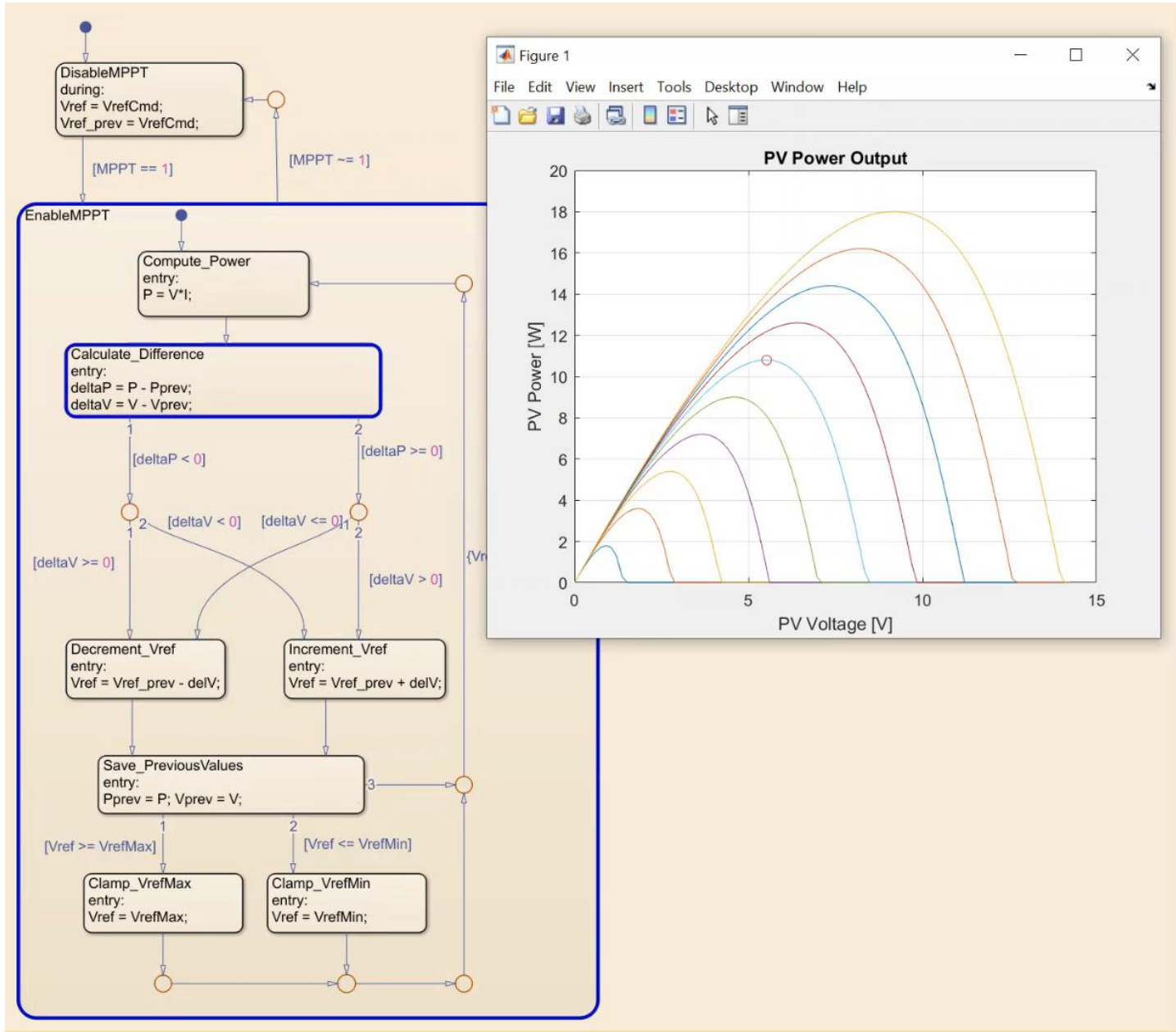




2 Control Design - MPPT

- **Using inverter control to track maximum power point**



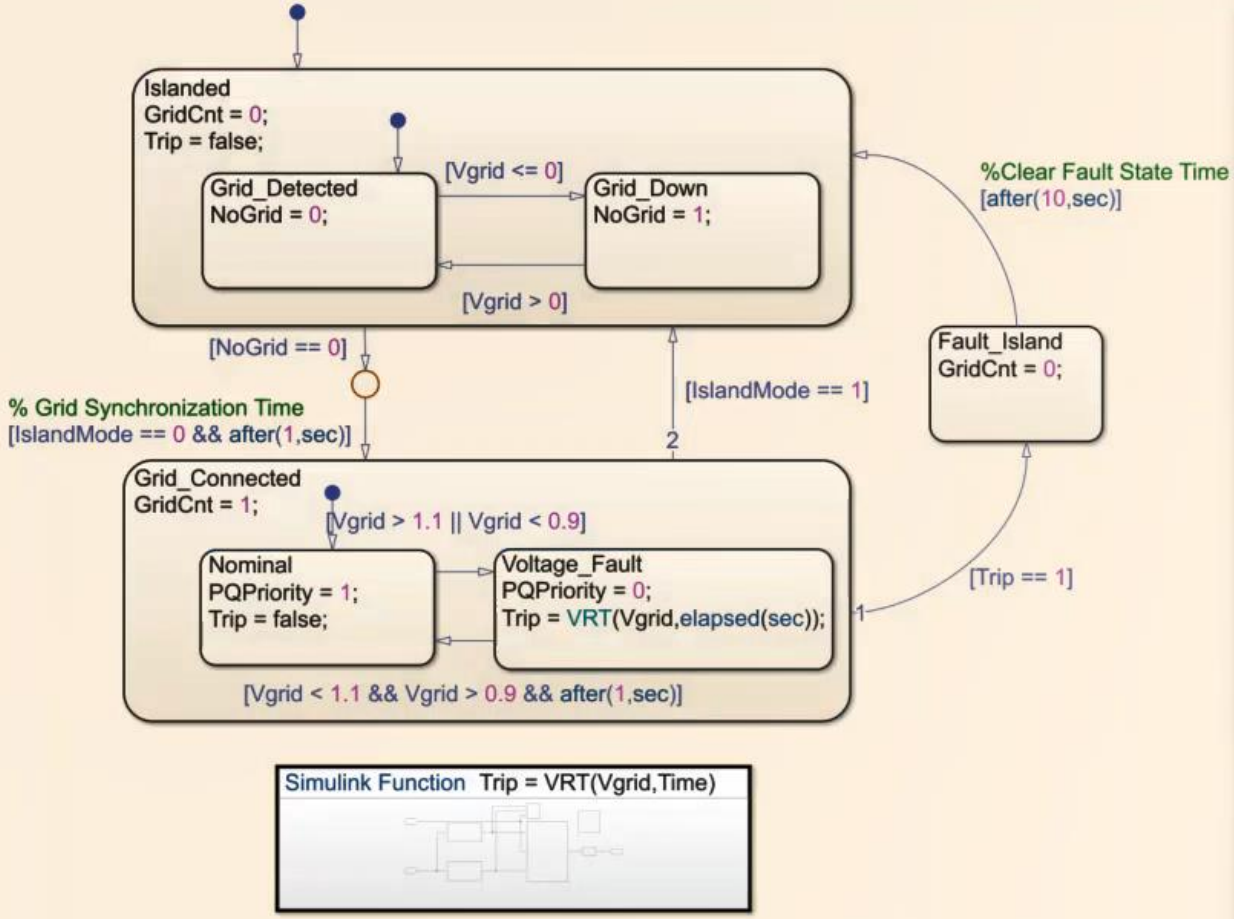


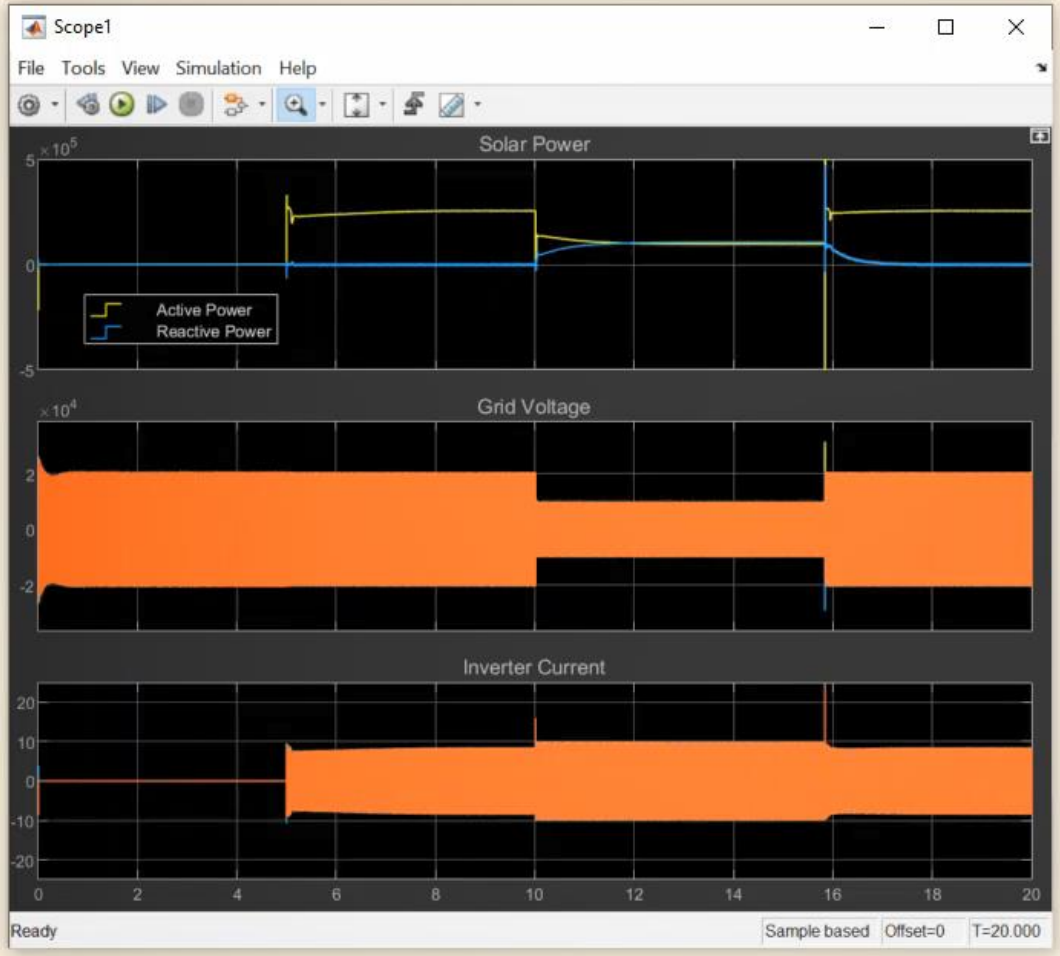
Learn more: [Webinar on Modeling, Simulating, and Generating Code for a Solar Inverter]

2 Control Design

Designing Fault-Ride Through Algorithms

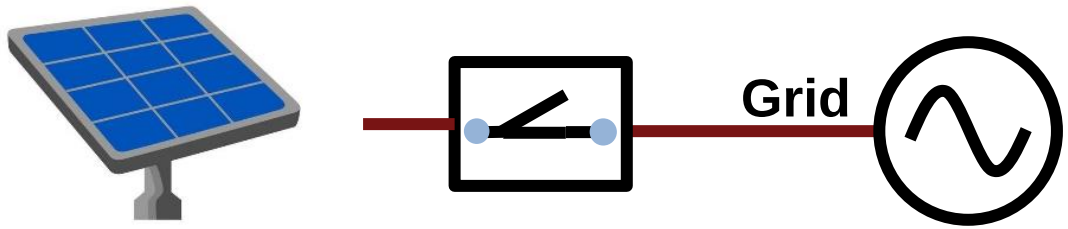
- **Reactive power support during low voltage fault**

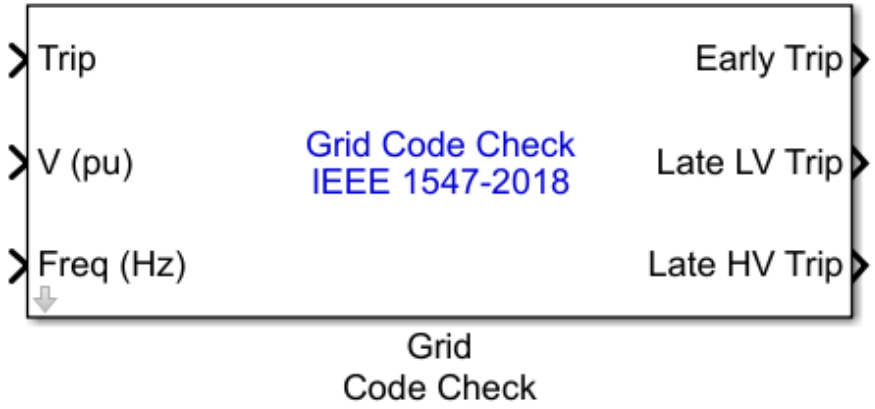


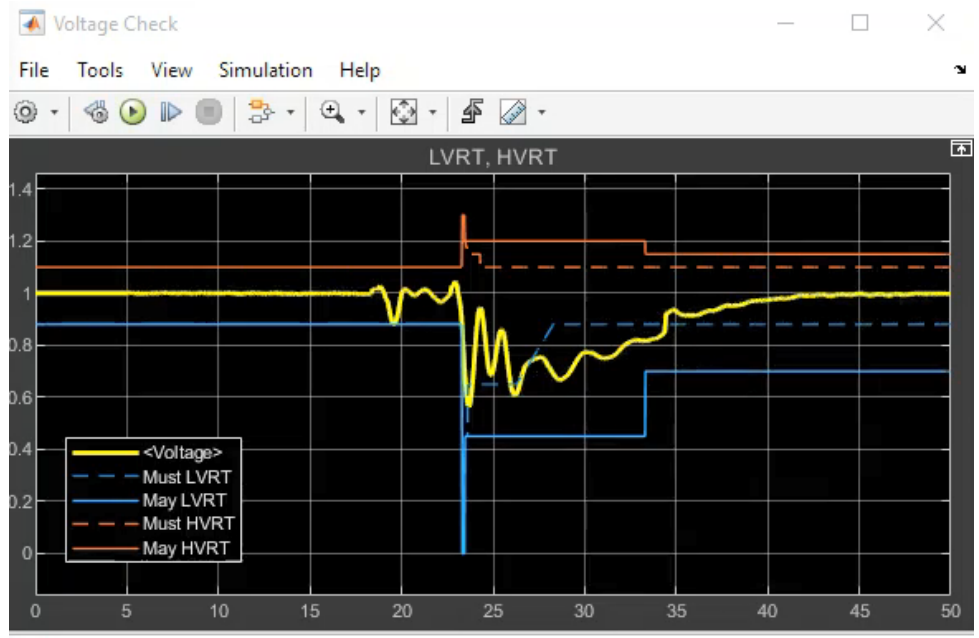


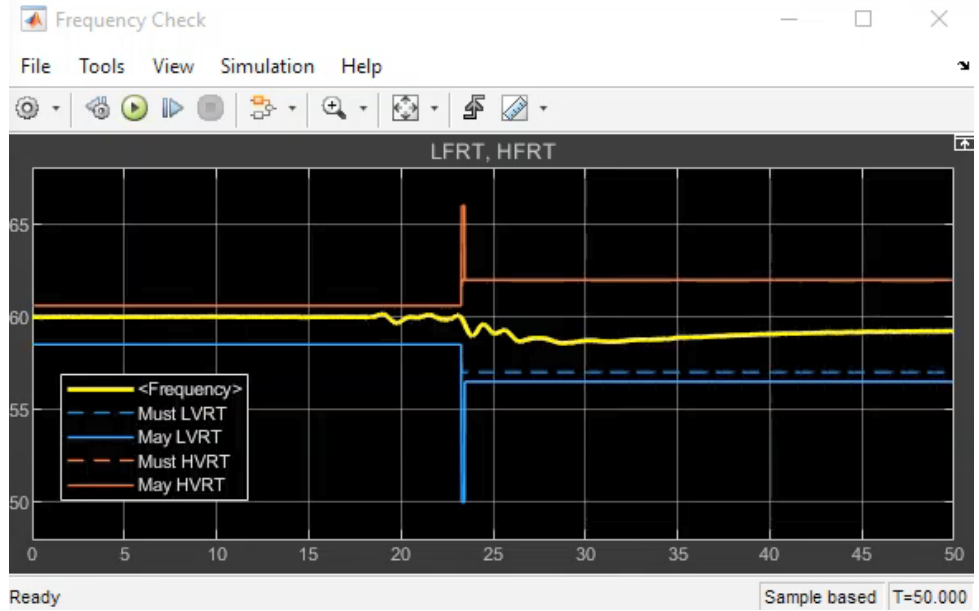
2 Control Design
Fault-Ride Through

- **Testing Fault-Ride Through against Grid Codes such as IEEE 1547-2018**





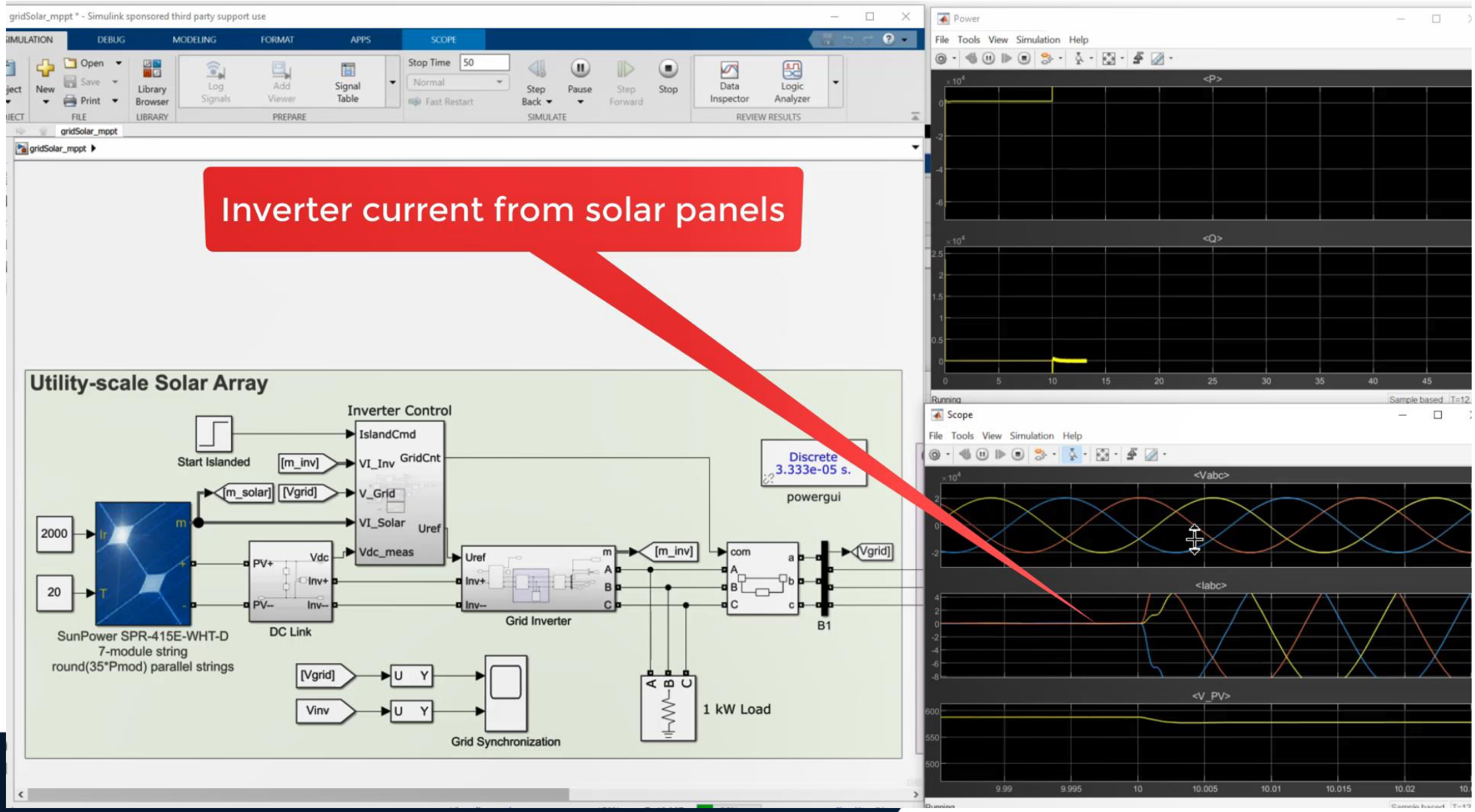




Learn more: Webinar on Renewable Grid Integration Studies

2 Control Design

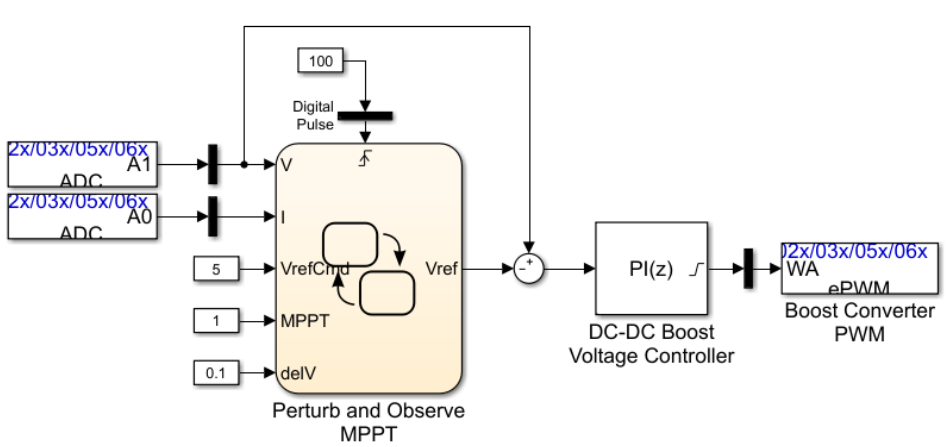
Simulation Results



3 Automatic Code Generation
Microcontroller

- **Use Embedded Coder and C2000 hardware support package**

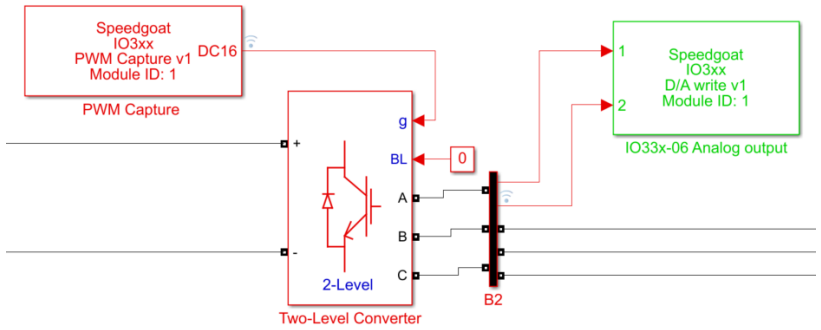
Combine Simulink Algorithms with C2000 IO Blocks	Auto-generate C code	Build and Implement using CCS	Operation Check with TI C2000

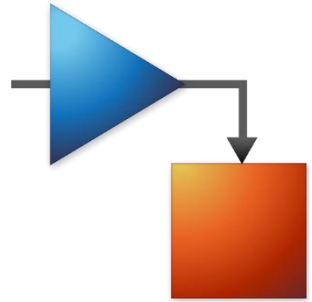


3 Automatic Code Generation
Speedgoat Real-Time Simulator

- **Use Simulink Real-Time and HDL Coder for C and HDL code generation**
- **Deploy to multi-core CPUs or multiple FPGAs**
- **Wide range of I/O connectivity, communication protocols and I/O functionality**

Combine Simulink Model with Speedgoat Driver Blocks	Auto-generate C code or HDL Code	Build using Simulink Real-Time	Operation with Speedgoat Target Computer

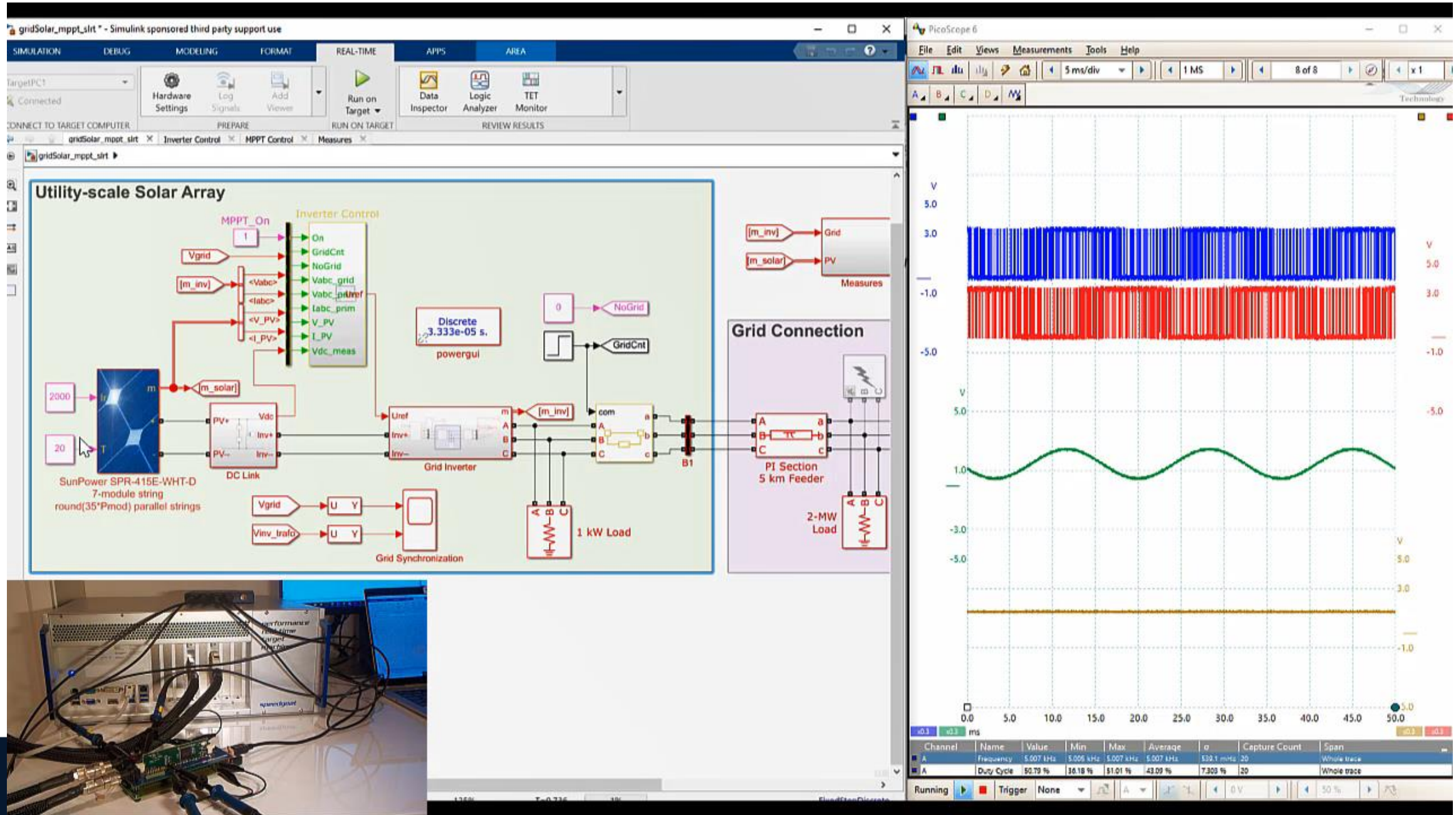




4 Hardware-in-the-Loop Testing

- **Reuse models at different levels of fidelity in CPUs and FPGAs**
- **Automatic code generation**
  - **Multi-core CPUs using Simulink Real-Time**
  - **Simulink-programmable FPGAs using HDL Coder**
- **Compatibility of Simulink, V&V tools and Speedgoat hardware**
- **HIL simulation with switching dynamics**
  - CPU workflow up to around 5 KHz switching
  - FPGA workflow up to around 100 kHz switching

4 Hardware-in-the-Loop Testing



Conclusion

- Simplify control development for power electronics using Simscape Electrical and Speedgoat hardware
- Automatically generate C and HDL code for plant simulations and production code from Simulink and Simscape Electrical
- Use hardware-in-the-loop to test normal operation and fault conditions like Fault-Ride Through

Learn More

- www.speedgoat.com – Speedgoat real-time solutions
- Developing Solar Inverter Control with Simulink – video series
- HIL for Power Electronics -whitepaper
- Detailed Model of 100 kW Grid-Connected PV Array - example
- MPPT Algorithm - webpage