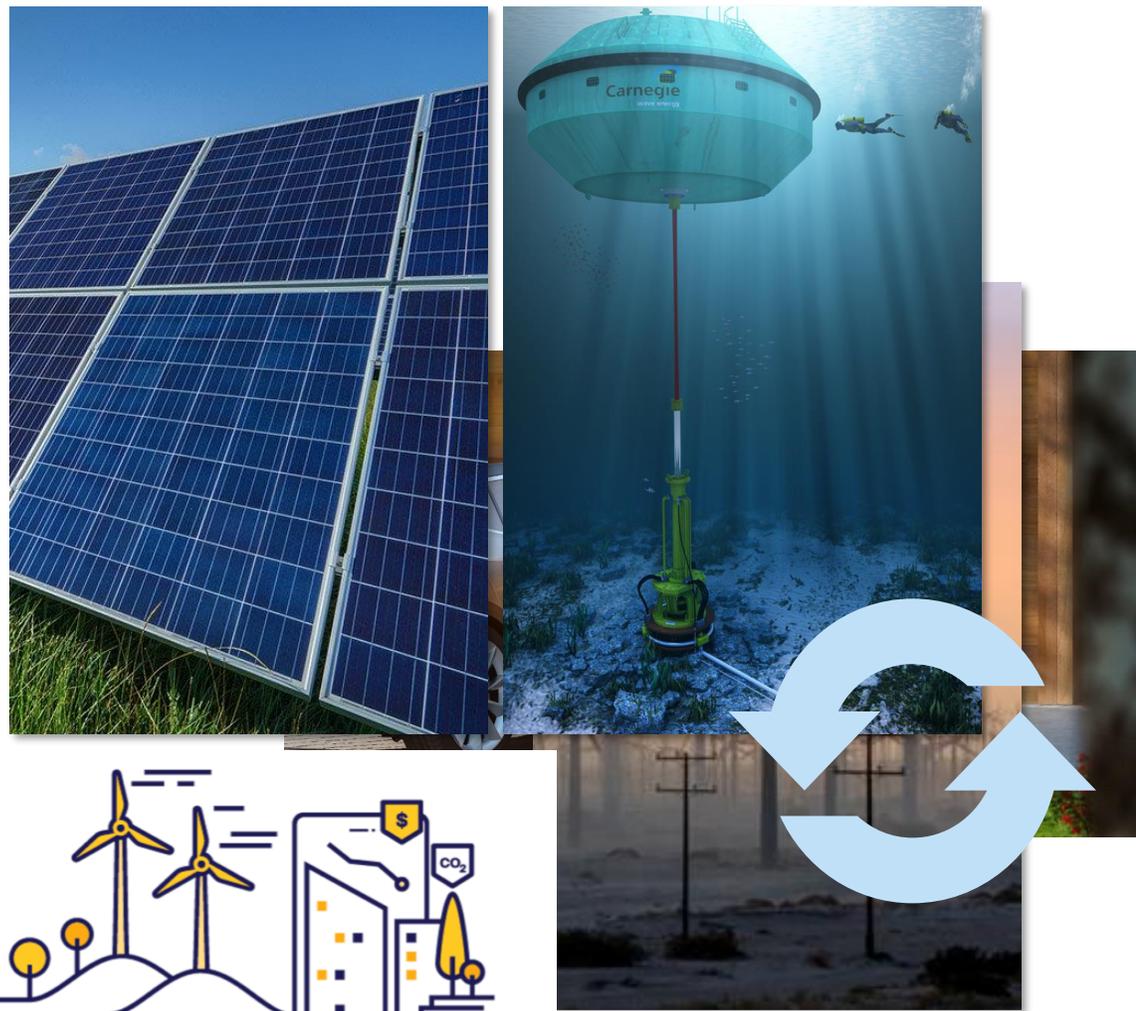


# MATLAB EXPO

## 微电网系统级设计及运行仿真

鲍经纬, MathWorks



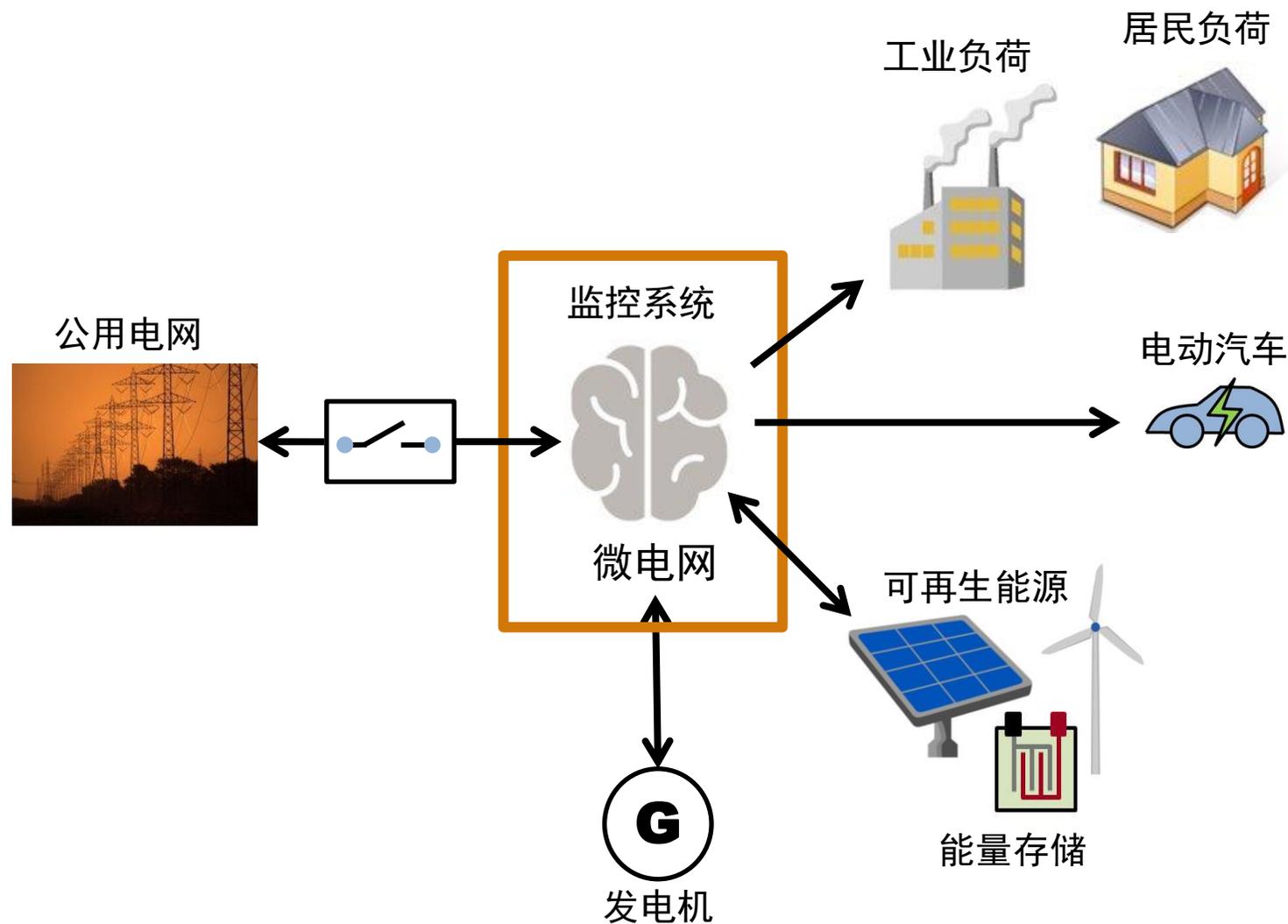


# 微电网



# 什么是微电网?

- 微电网是指由多种分布式电源、储能、负荷、能量转换设备及相关监控保护装置构成的能够实现自我控制和管理 的区域自治型电力系统。



# 微电网分类

## 是否与主电网相连



- 并网型
- 孤网型

## 电压母线类型



- 交流
- 直流
- 交直流混合

# 微电网需要应对诸多问题

如何确定电源规格及配比？



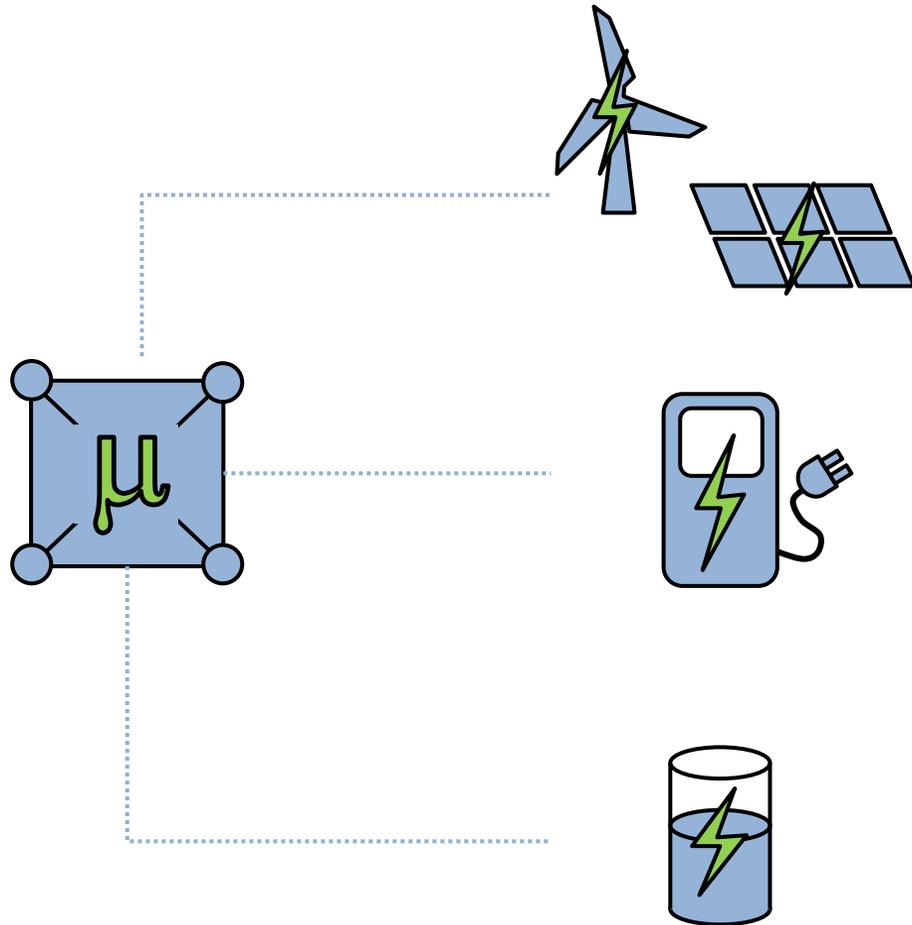
需要多大规模的储能设备？



是否可以进行电网连接？



# MathWorks 助力微电网系统开发



**Dev. Environment**  
**Component to System Design & Analysis**

High fidelity ← → Low fidelity

Component      Infrastructure      Electrical Grid

**Architecture Design**

**Operation (EMS, Trading)**

**Fault, Degradation, Stability**

**Component (sizing, integration, etc.)**

*Examples shown: HV Battery Charge/Discharge, 24-hour Simulation of a Vehicle-to-Grid (V2G) System*

**Eng. Resource**  
**Quick Ramp-Up**

Tool      Consulting      Training

**Simscape**

Electrical   Mechanical   Magnetic   Thermal   Custom equations  
 Hydraulic   Thermal Liquid   Two-Phase Fluid   Gas   Moist Air

**Modeling Electrical Power Systems with Simscape**

Learn to model three-phase systems, analyze and control electrical power systems, model power electronic systems, and speed up simulation of electrical models.

[Details and enroll](#)

## 用户案例



### 魁北克水电建立风电厂模型

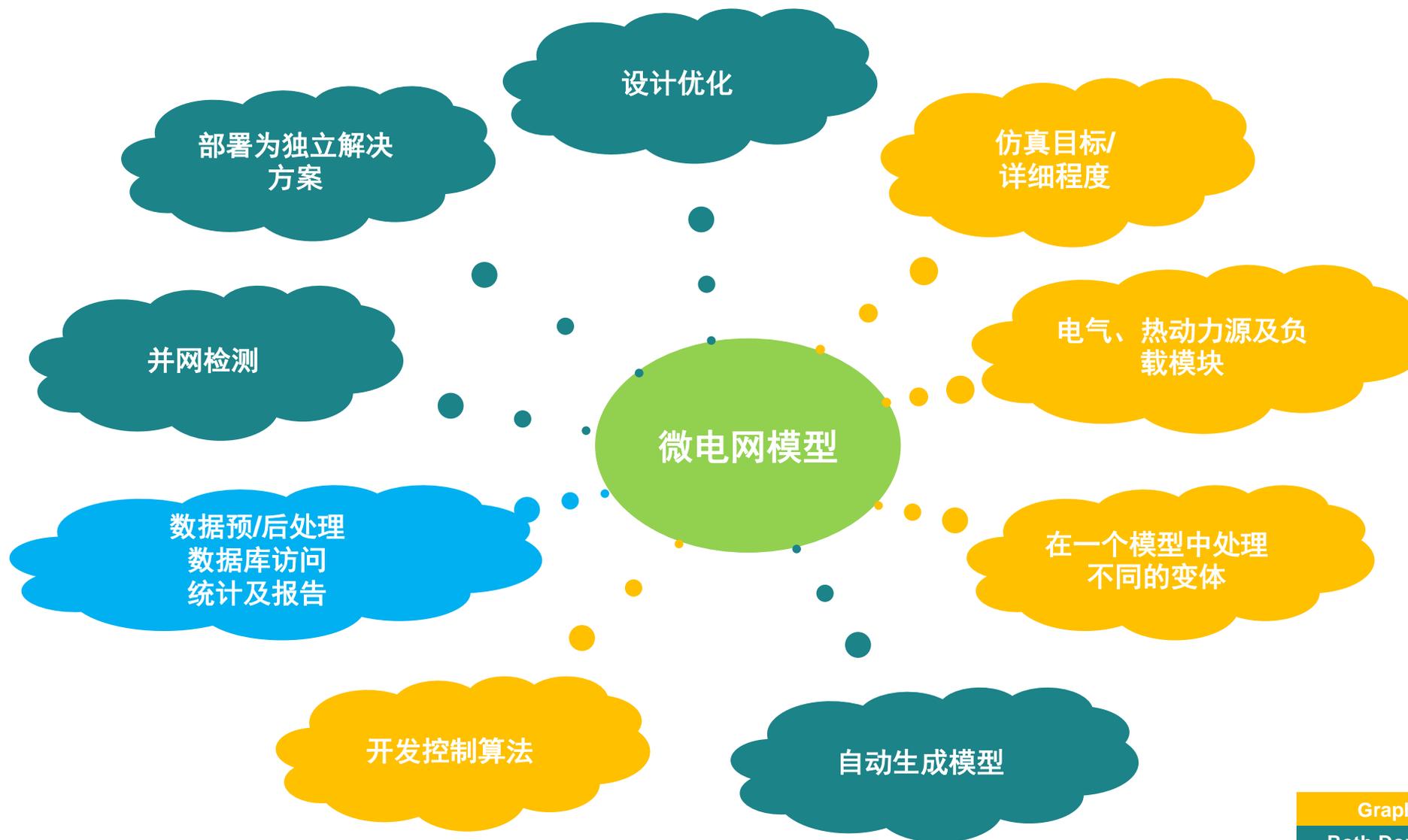
- 利用MATLAB和Simulink对电气、机械和控制系统进行设计和仿真
- 进行动态仿真和功率预测，以确保电网的可靠性
- **结果: 仿真速度提高到实时, 准确预测设备需求**

### 桑迪亚国家实验室模拟Hawaii的微电网

- 利用Simulink对光伏发电微电网配电系统进行建模和仿真
- 评估太阳能发电设施可靠运行所需的电池容量和控制系统
- **结果: 模型开发时间减少80%, 同时通过适合的电池容量设计极大地降低了系统成本**



# MATLAB & Simulink 为微电网系统设计提供的解决方案

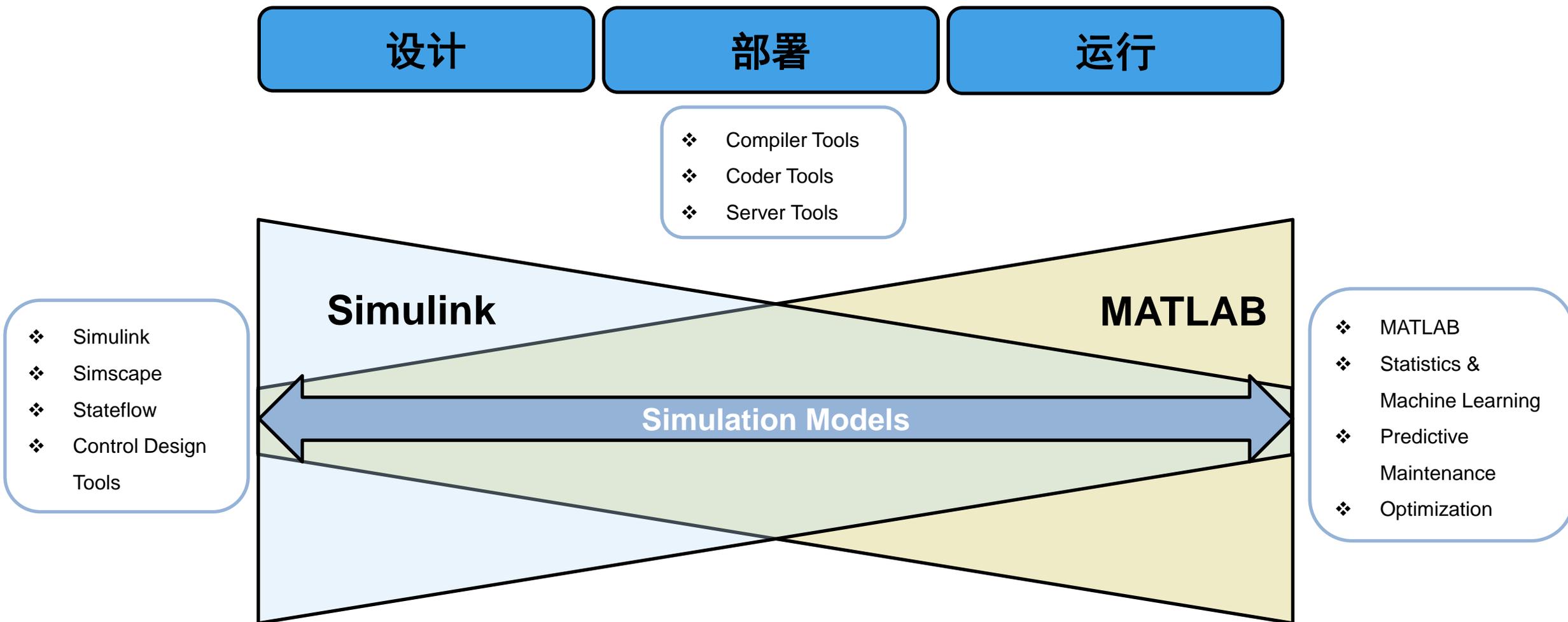


Graphical Modeling (Simulink)

Both Domains (MATLAB & Simulink)

Textual Programming (MATLAB)

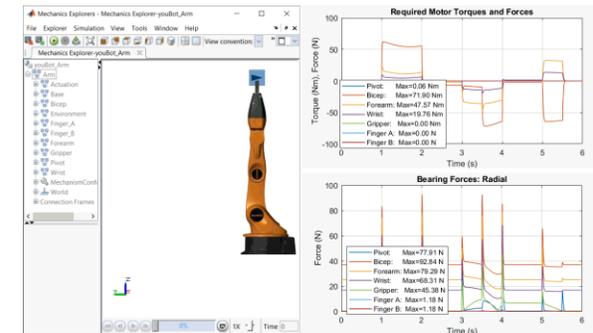
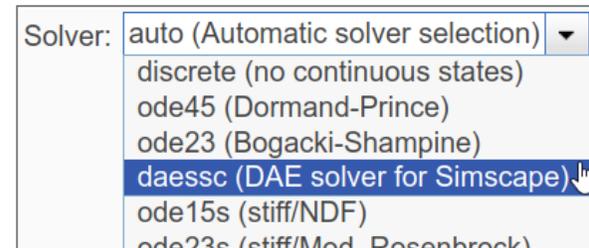
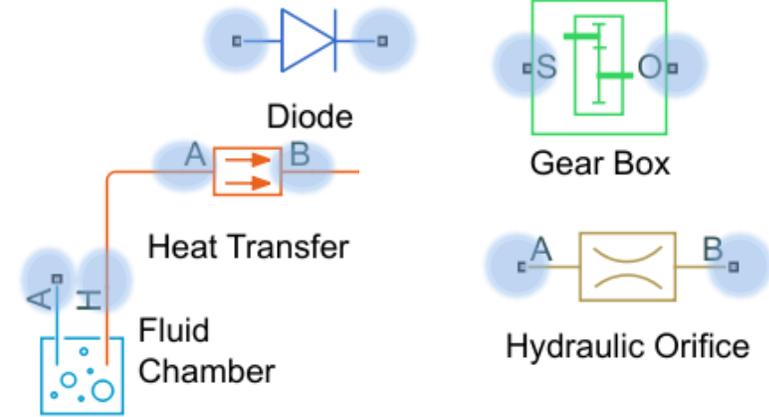
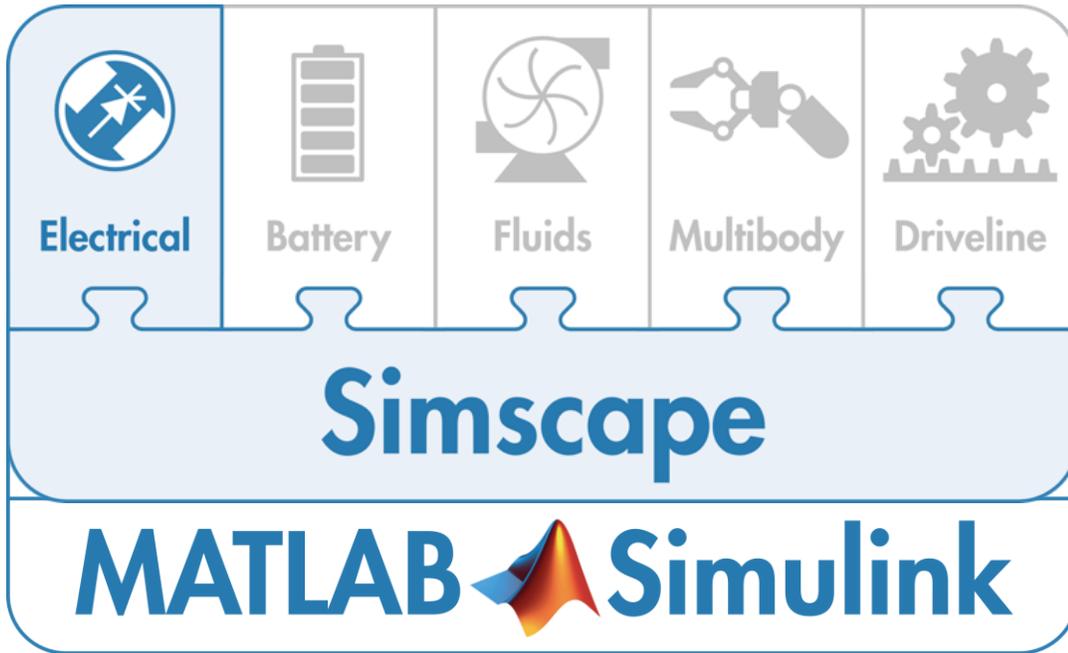
# MATLAB & Simulink 为微电网系统设计提供的解决方案



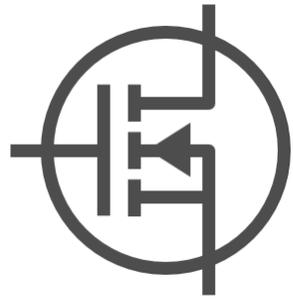
完整的系统模型支持项目全生命周期开发任务

# 微电网仿真与运行优化

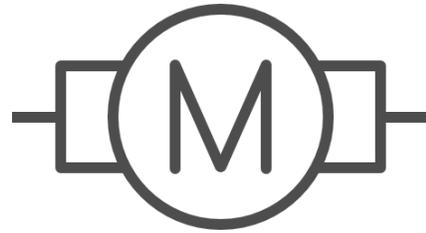
## - MathWorks 工具链



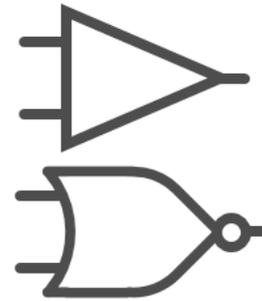
# 微电网仿真与运行优化 – Simscape Electrical 组件模型



**Semi-conductors**



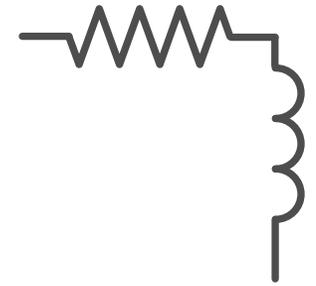
**Motors, Actuators**



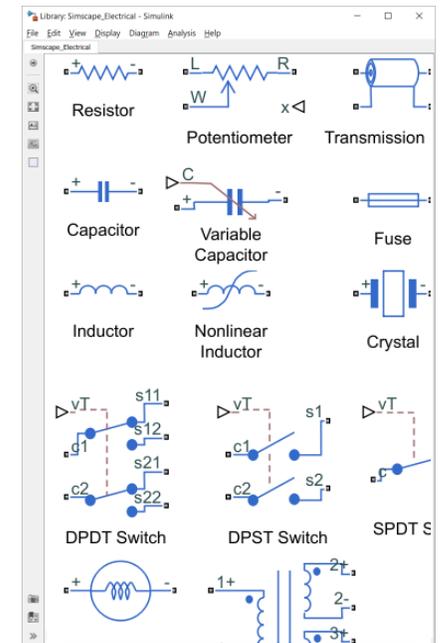
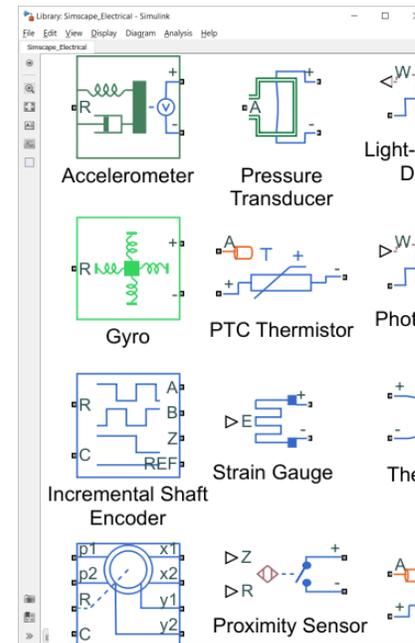
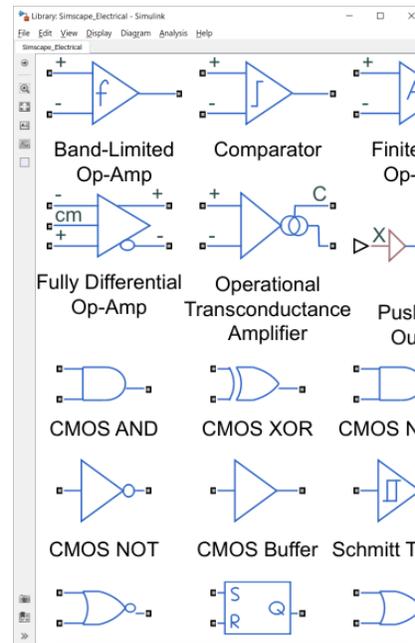
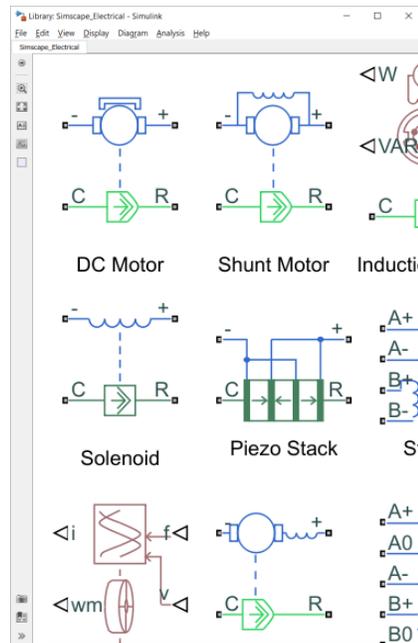
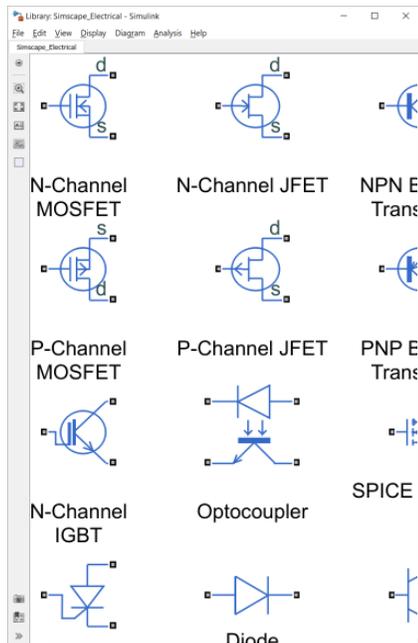
**Op-Amps, Logic Gates**



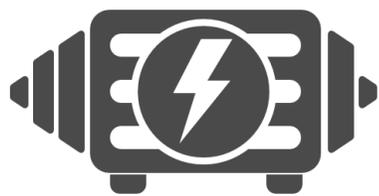
**Sensors**



**Passive Devices**



# 微电网仿真与运行优化 – Simscape Electrical 组件模型



Generators,  
Motors



Transformers



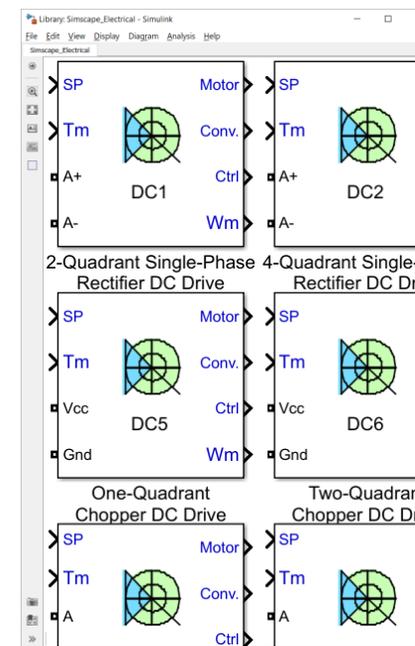
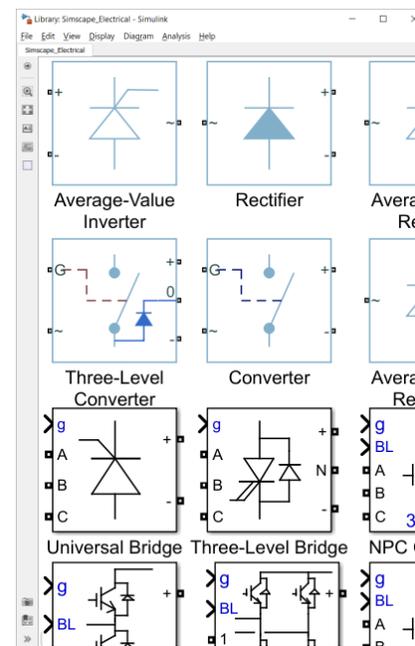
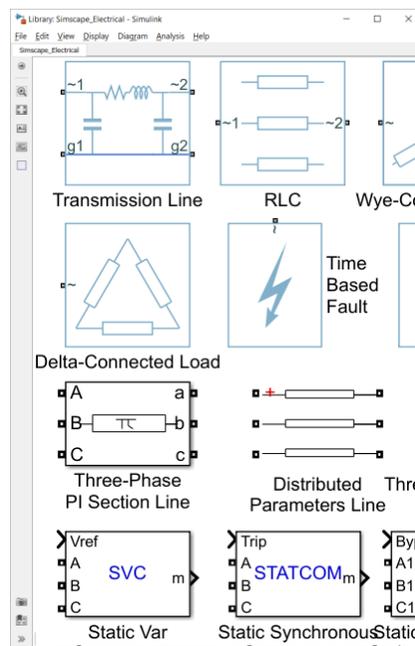
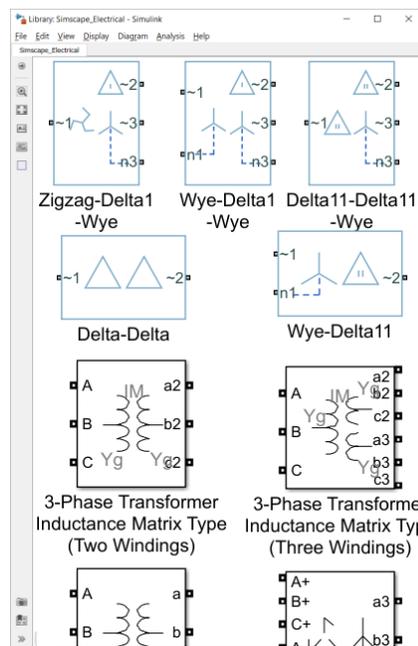
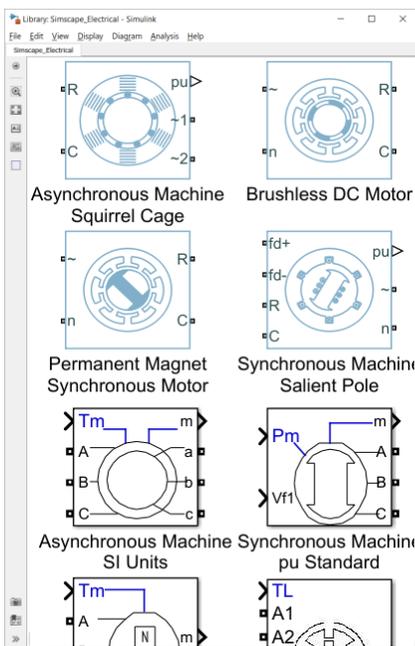
Lines,  
FACTS



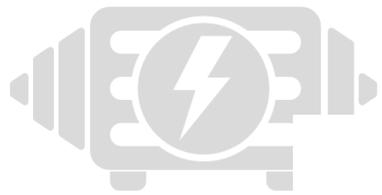
Converters



Electric  
Drives



# 微电网仿真与运行优化 – Simscape Electrical 组件模型



Generator  
Motors



Transformers



FACTS



Converters



Electric  
Drives

使用基于MATLAB的Simscape Language  
精确创建所需的内容

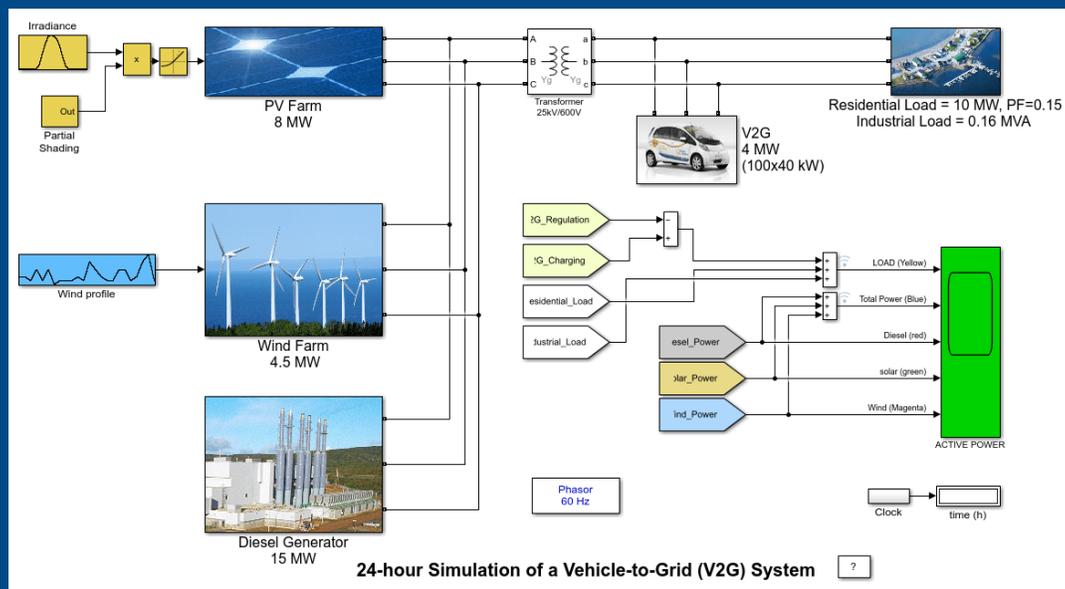
The screenshot displays the Simscape Electrical environment. On the left, a 'Custom Capacitor' component is shown with a circuit symbol consisting of two parallel vertical lines. Below the symbol, the text 'Custom Capacitor' is visible. On the right, the MATLAB editor window shows the following code:

```
equations
v == i*r + vc;
i == c*vc.der + g*vc;
end
```

The status bar at the bottom indicates 'Simscape model file' and 'Ln 16 Col 5'.

# 微电网系统设计及仿真运行 - 将模型保真度与工程任务匹配

## 低保真度



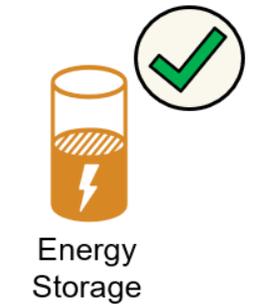
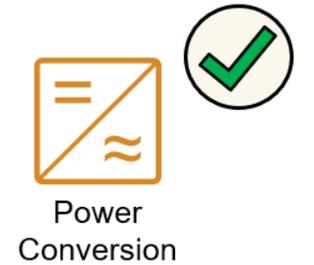
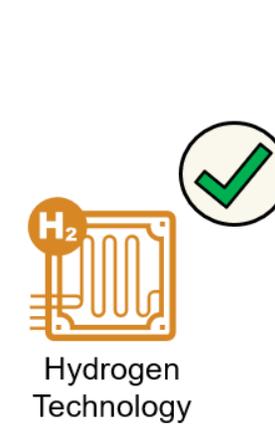
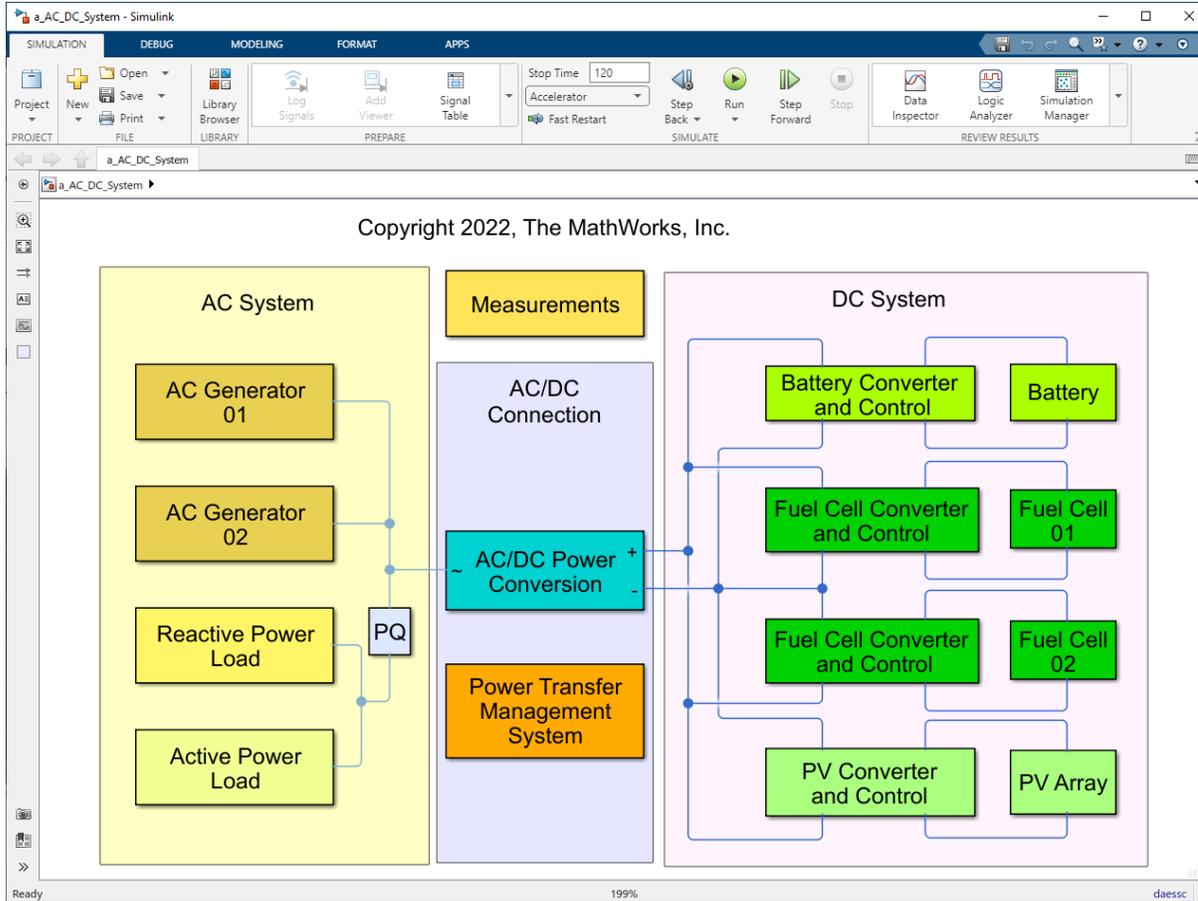
## 架构设计



故障、衰退和稳定性分析

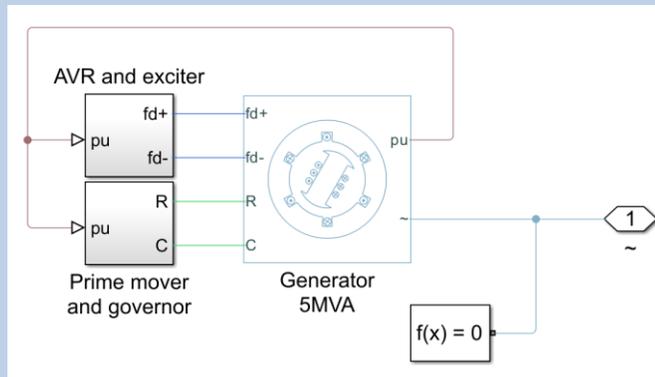
组件  
(规模, 集成, etc.,)

# 微电网系统设计及仿真运行 - 将模型保真度与工程任务匹配

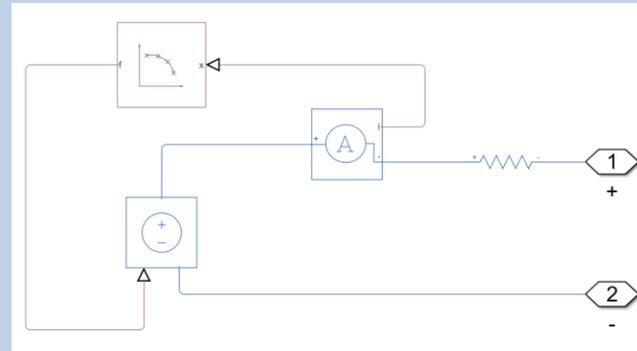


# 微电网系统设计及仿真运行 - 组件建模

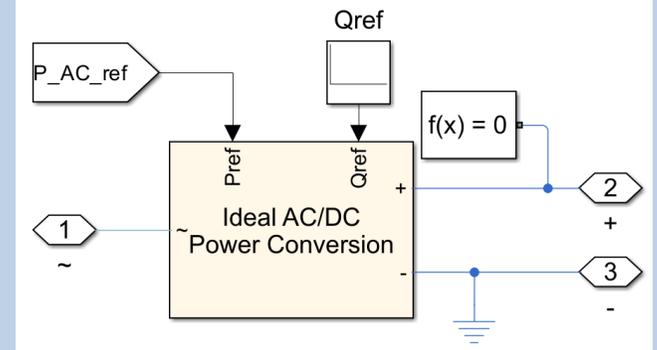
AC Generator  
01



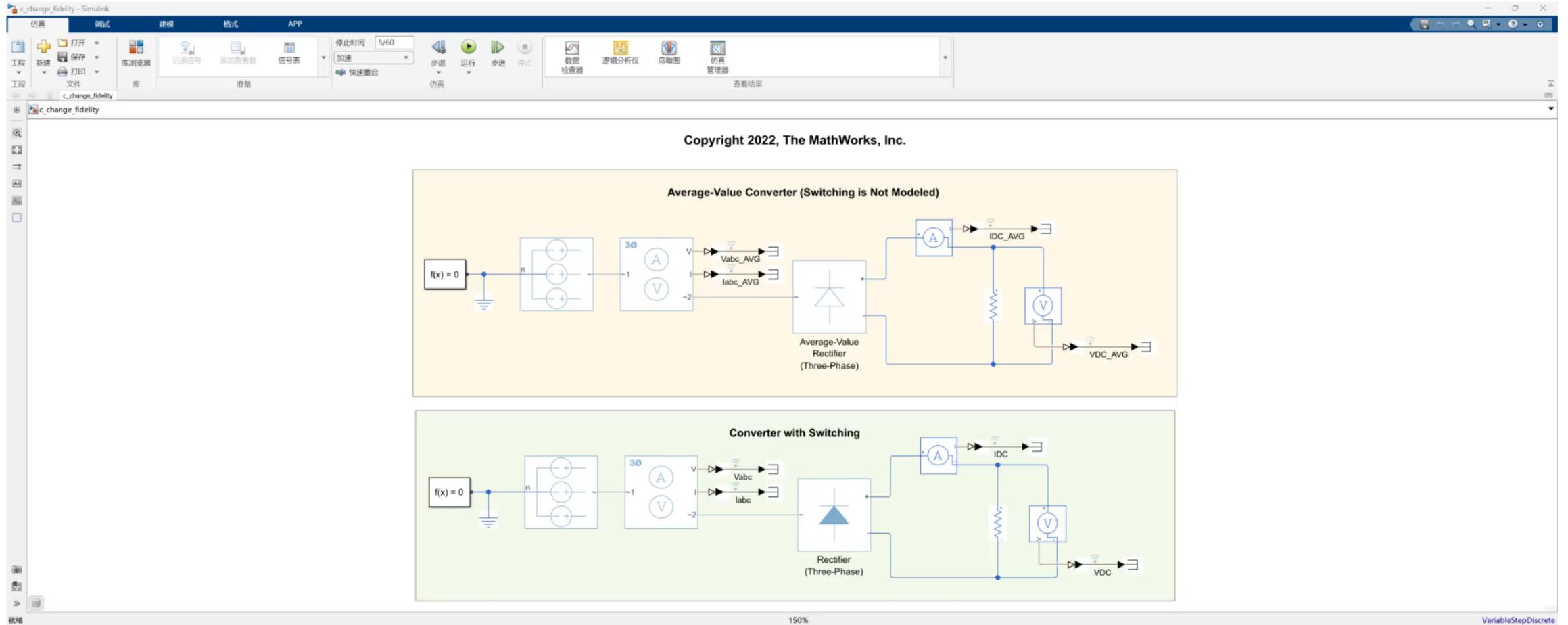
Fuel Cell  
01



AC/DC Power  
Conversion



# 微电网系统设计及仿真运行 - 将模型保真度与工程任务匹配





# 微电网系统设计及仿真运行 - 将模型保真度与设计任务匹配

Simscape Components

Specialized Power Systems

## 潮流计算(时间无关)

- Simulate voltages, currents, active / reactive power levels
- Can be used for initialization

## 高频电力电子开关特性(EMT)

- Detailed switching of semiconductor devices in converters

## 低频电力电子开关特性(EMT)

- Ideal switching of semiconductor devices in converters

## 电网故障模拟(EMT)

- e.g. Fault and Breaker

## 电磁暂态仿真(Phasor)

- Power system stability analysis
- Electrical machine models included
- Capture mechanical oscillations
- Analyze desynchronization

## 次同步谐振(EMT)

- Oscillations between torsion of shaft and capacity in grid
- Important for windfarms

## 电压电流波形(EMT)

- e.g. Fault and Breaker, Synchronization

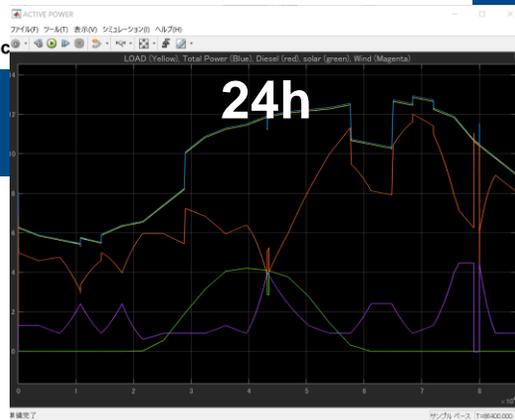
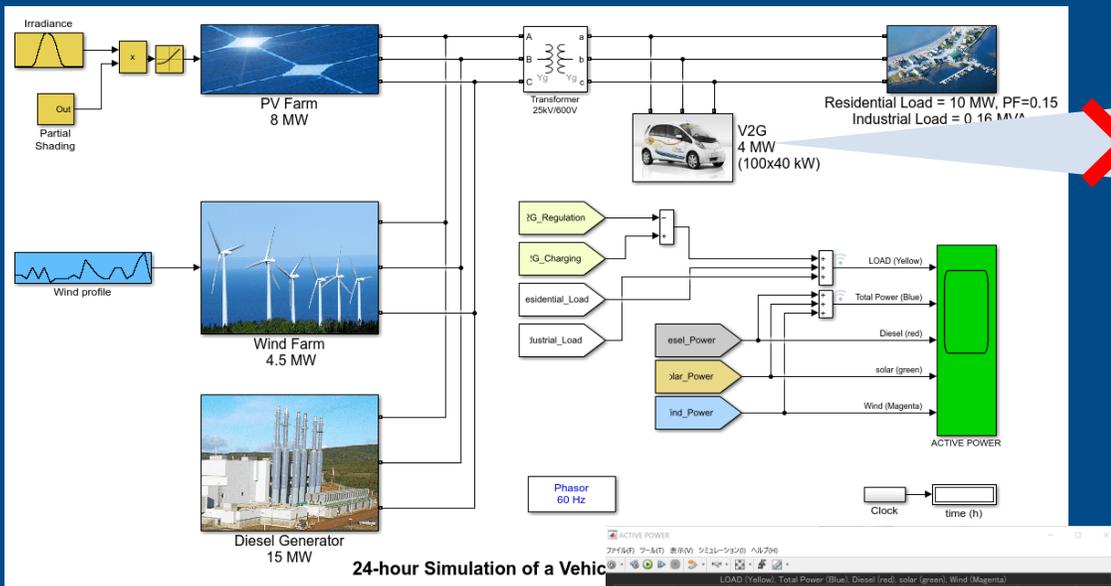
## 准稳态向量仿真(无动态)

- Energy flow simulation
- Idealized power sources and loads
- Used for sizing & planning purposes (e.g. energy storage)
- Simulate voltages, currents, active / reactive power levels
- Operational Changes are Defined by Time-Series Data
- Asymmetric loads
- Captures a new operating point in only a few time steps

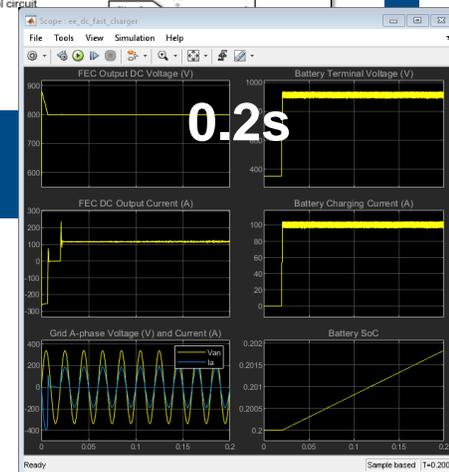
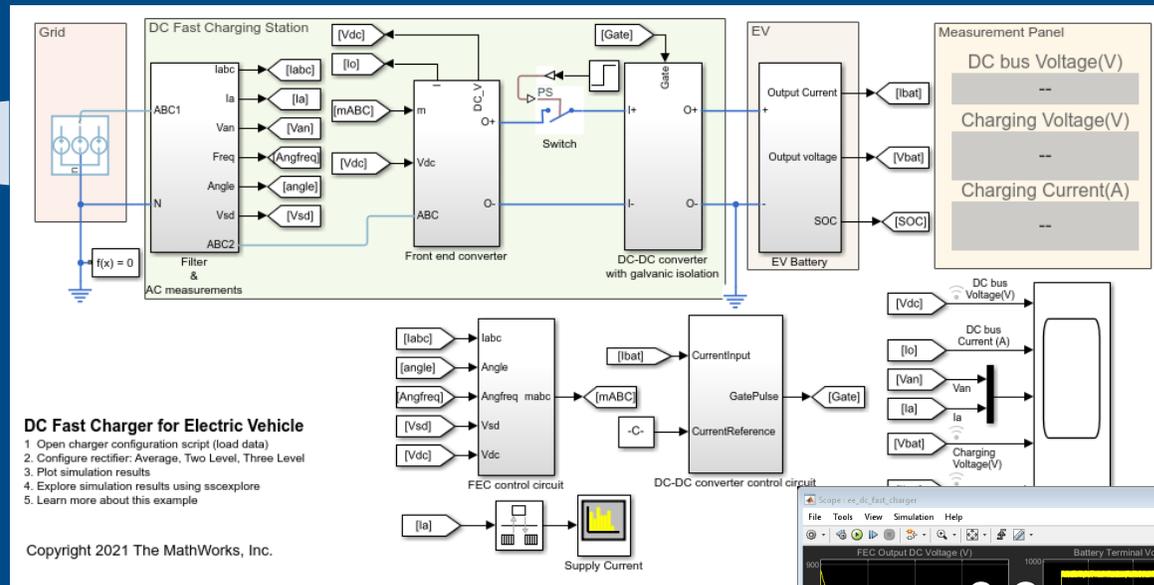


# 微电网系统设计及仿真运行 - 将模型保真度与设计任务匹配

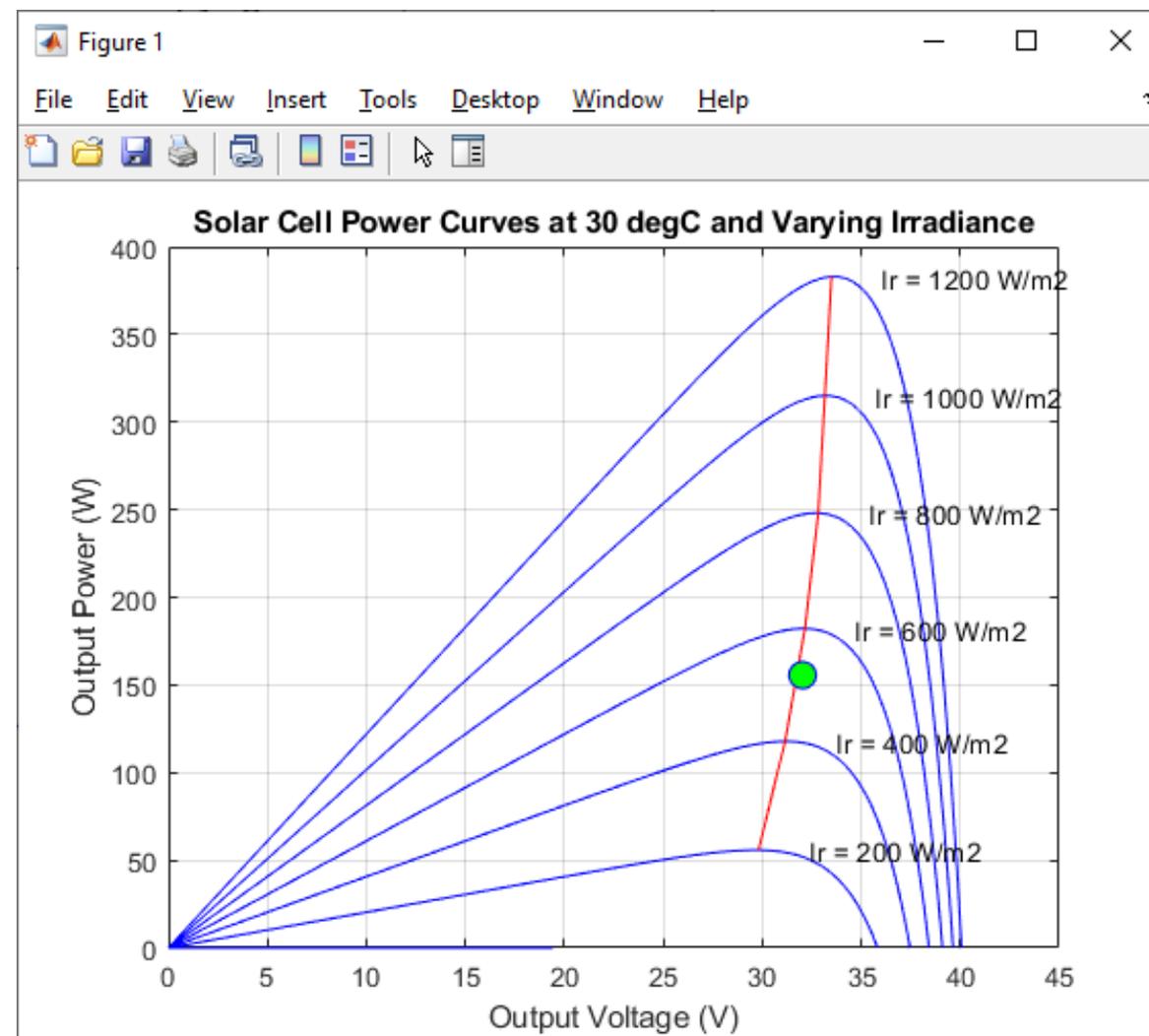
## 低保真度



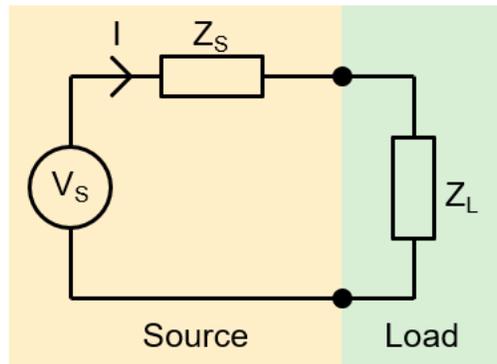
## 高保真度



# 微电网系统设计与仿真运行 – 逐步建立可信的系统模型



# 微电网系统设计及仿真运行 – 逐步建立可信的系统模型



If  $Z_L = Z_S$  then  $P_L = \max P$

If  $Z_L \neq Z_S$  then  $P_L < \max P$

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System 1 and System 2 Measurements

System 1

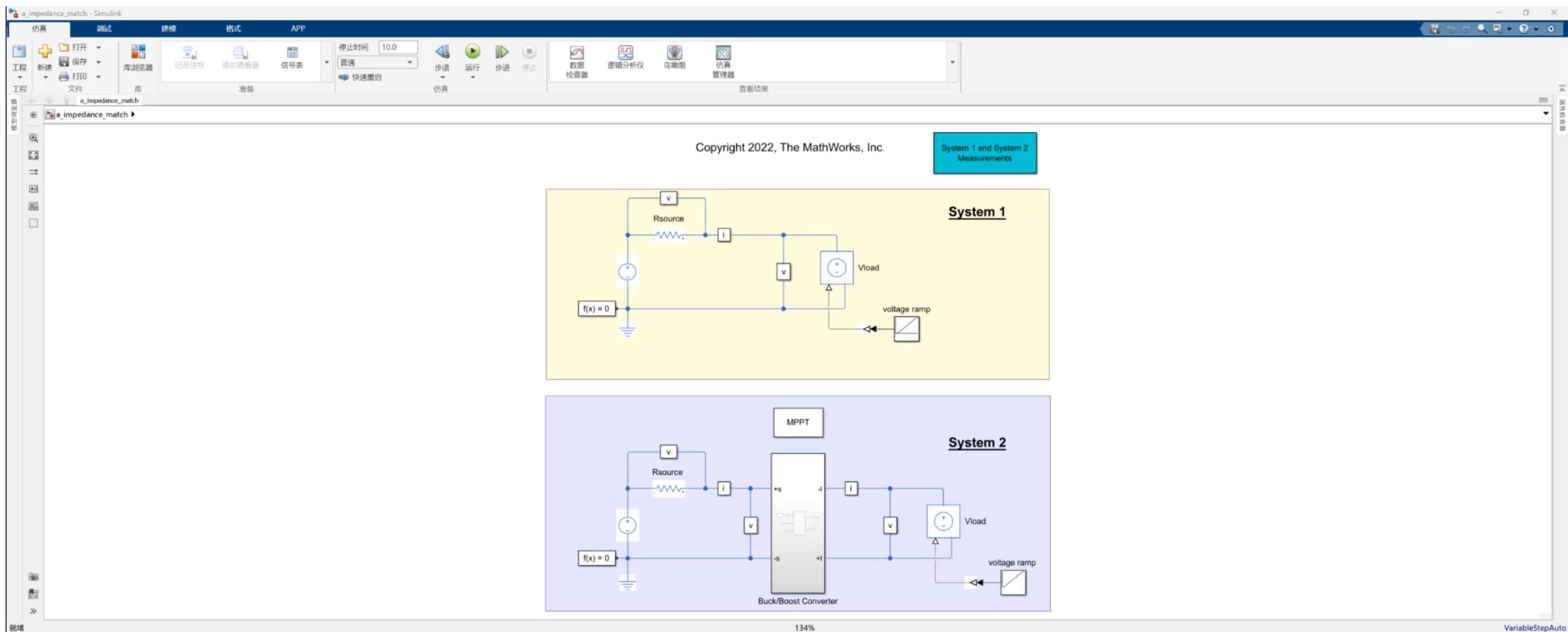
System 2

Buck/Boost Converter

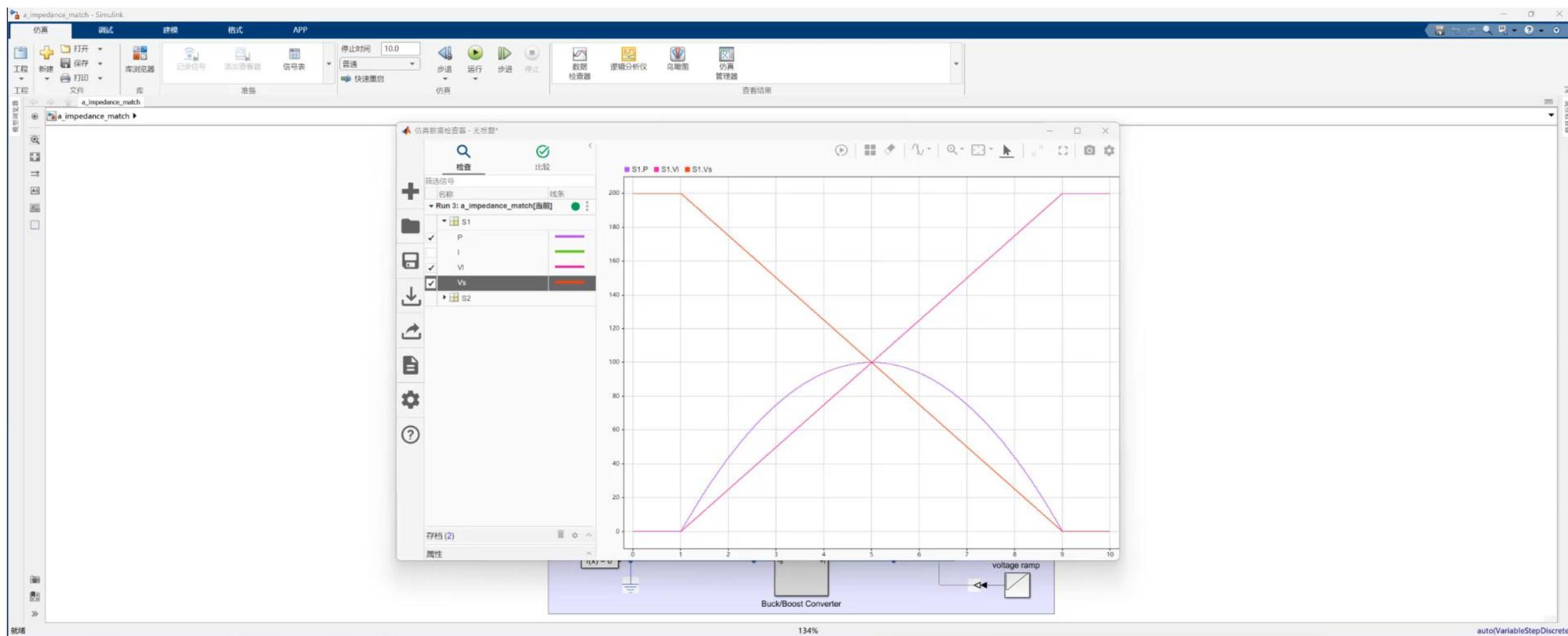
MPPT

Ready 118% VariableStepAuto

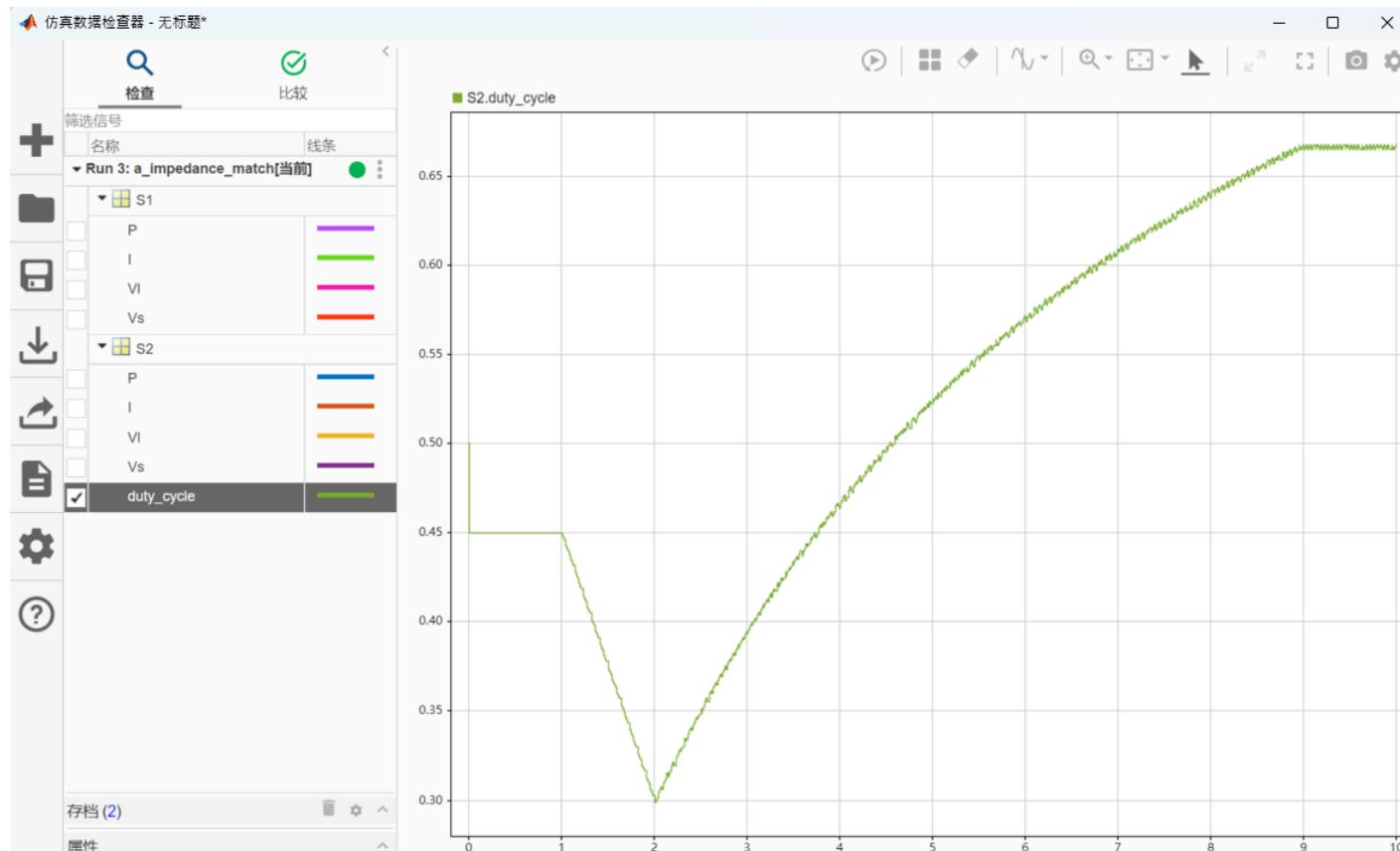
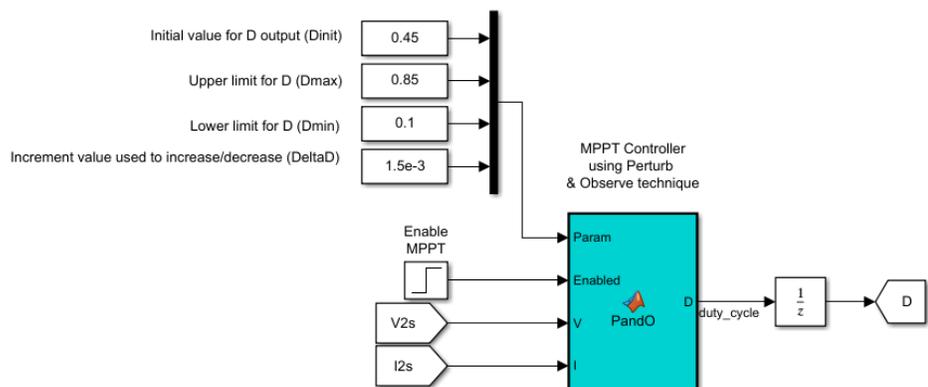
# 微电网系统设计及仿真运行 – 逐步建立可信的系统模型



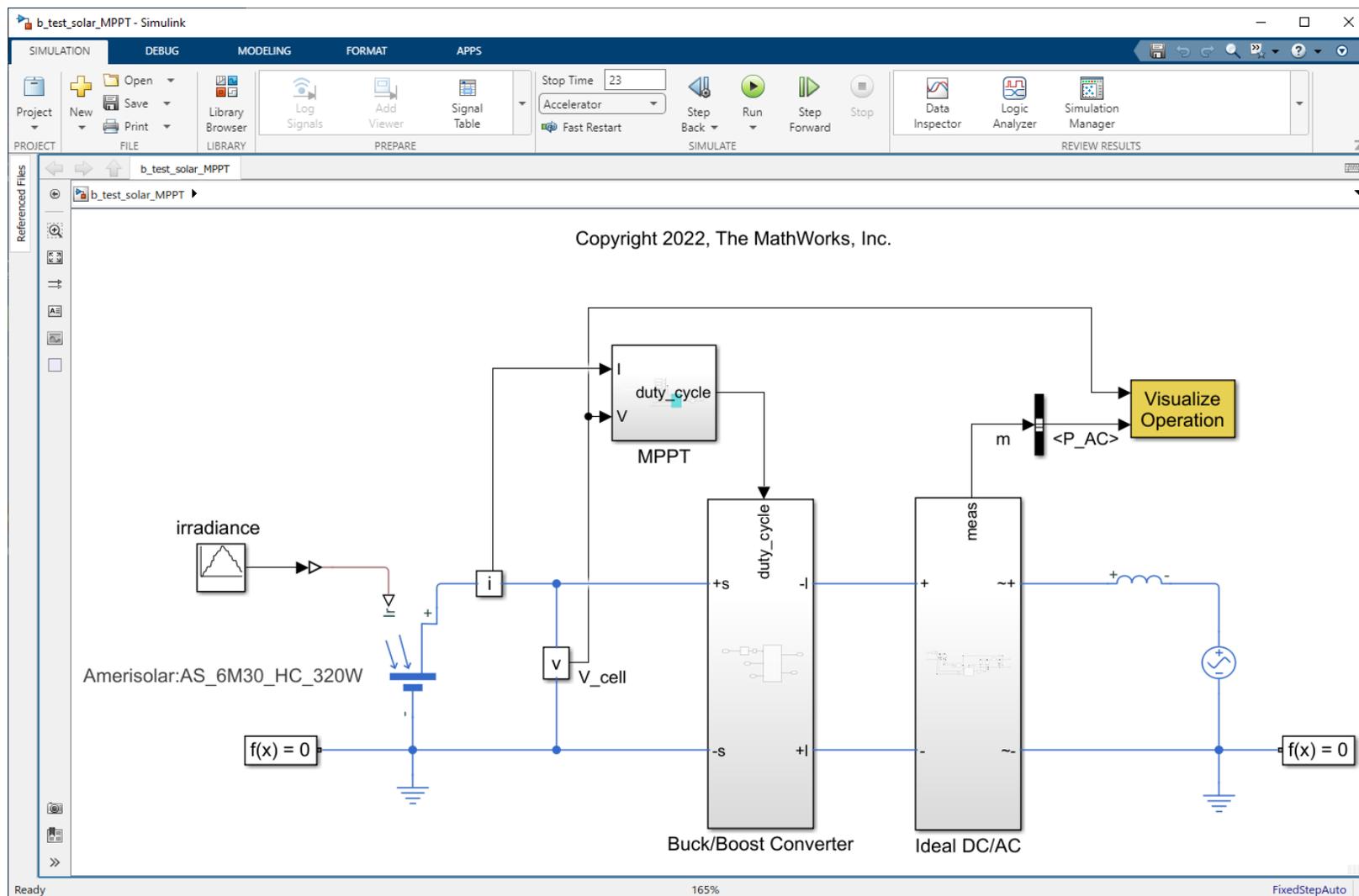
# 微电网系统设计与仿真运行 – 逐步建立可信的系统模型



# 微电网系统设计及仿真运行 – 逐步建立可信的系统模型



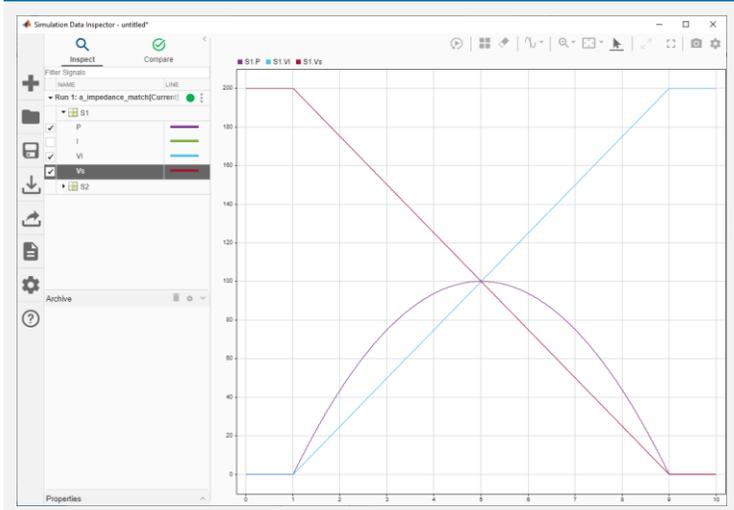
# 微电网系统设计与仿真运行 – 逐步建立可信的系统模型



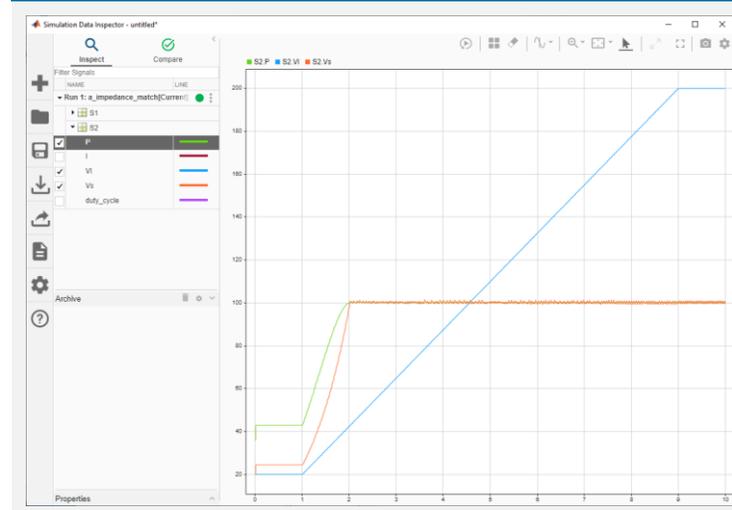


# 微电网系统设计及仿真运行 – 逐步建立可信的系统模型

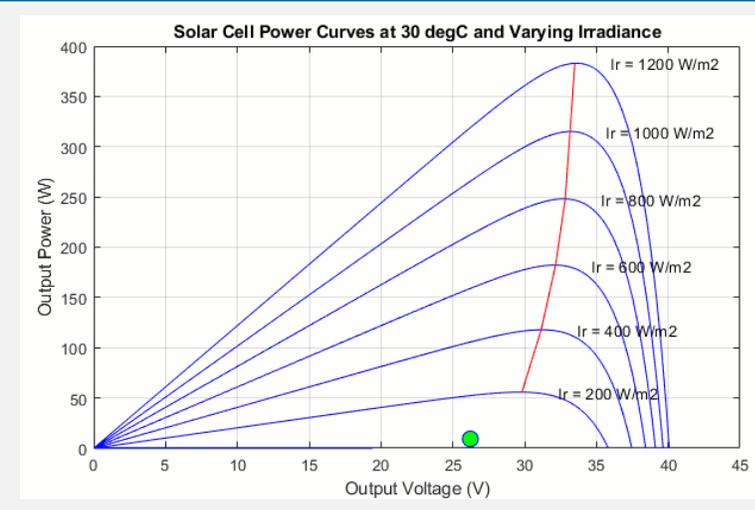
## 阻抗匹配



## MPPT测试



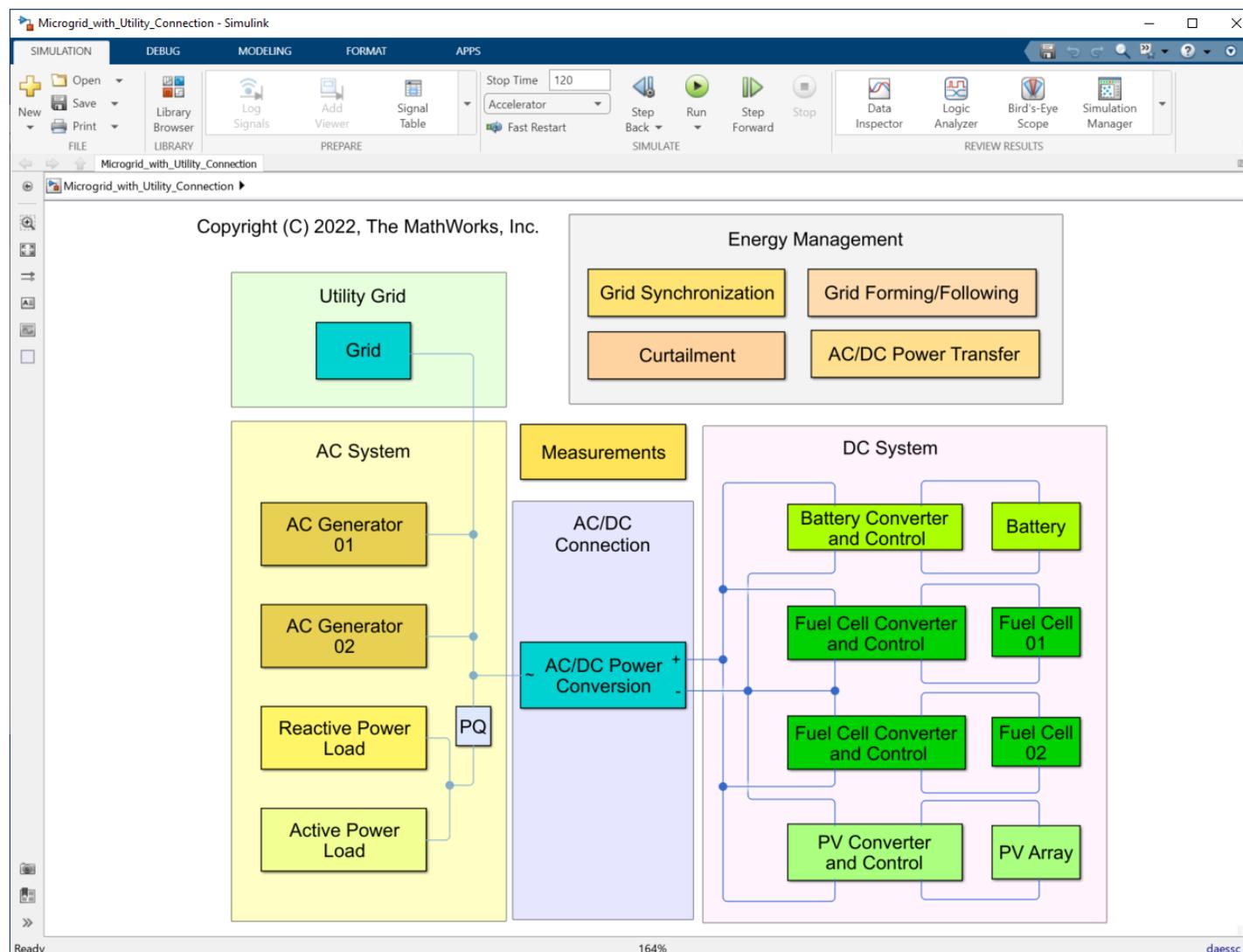
## 基于光伏发电系统的MPPT测试



## MathWorks助力微电网系统设计

- 集成多物理域仿真，如电力、热、机械和液压等
- 调节模型保真度
  - 扩展设计空间
  - 覆盖各种时间尺度
  - 支持从早期可行性分析到在役运行的技术研发
- 支持设计团队技能转型及优化

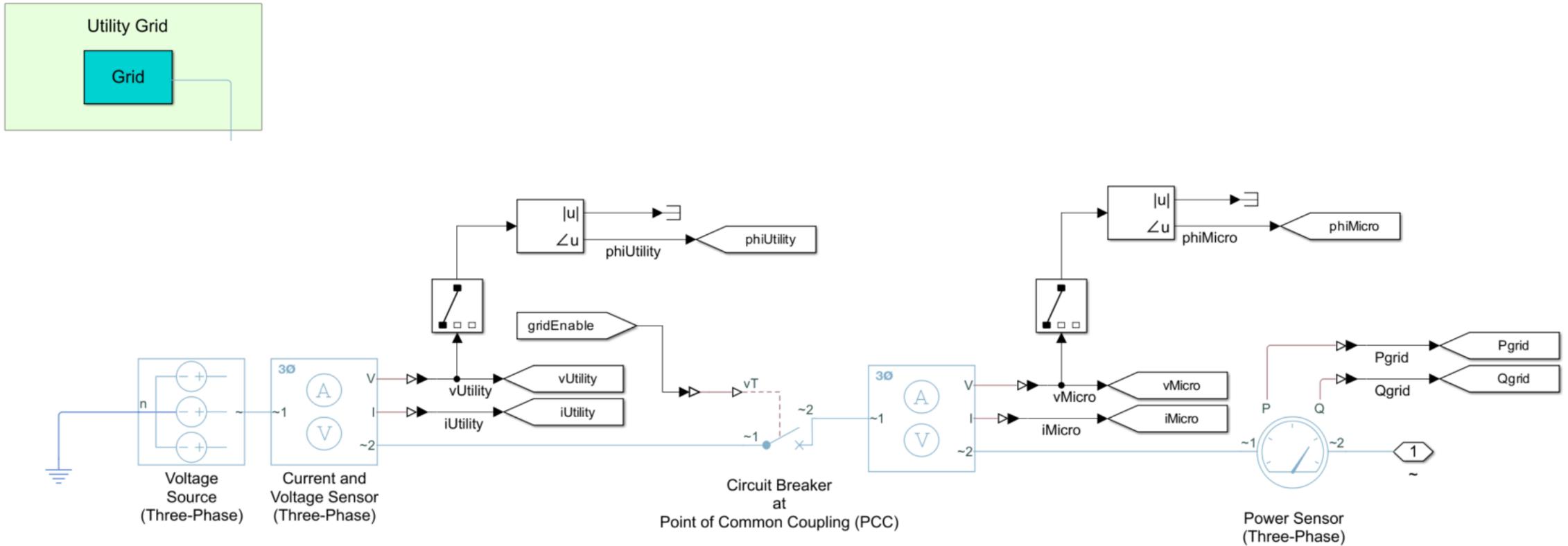
# 微电网能量管理系统设计



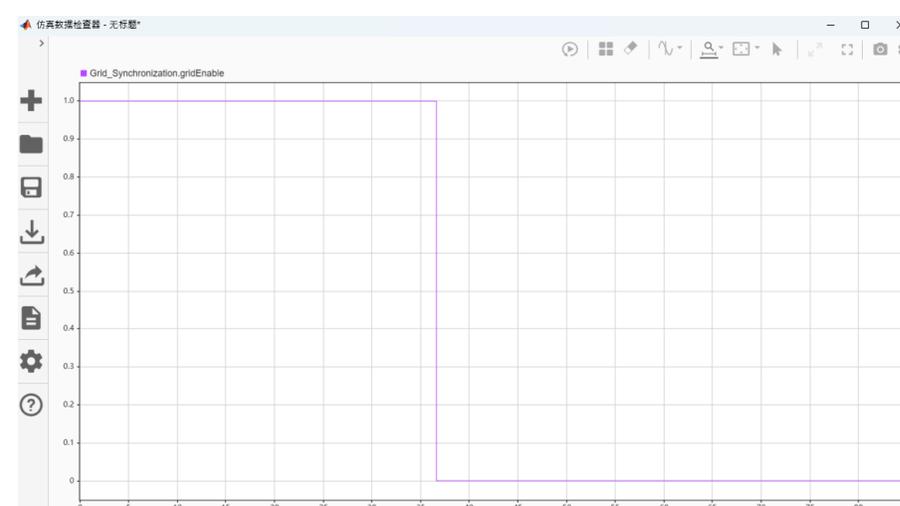
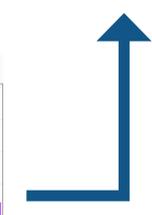
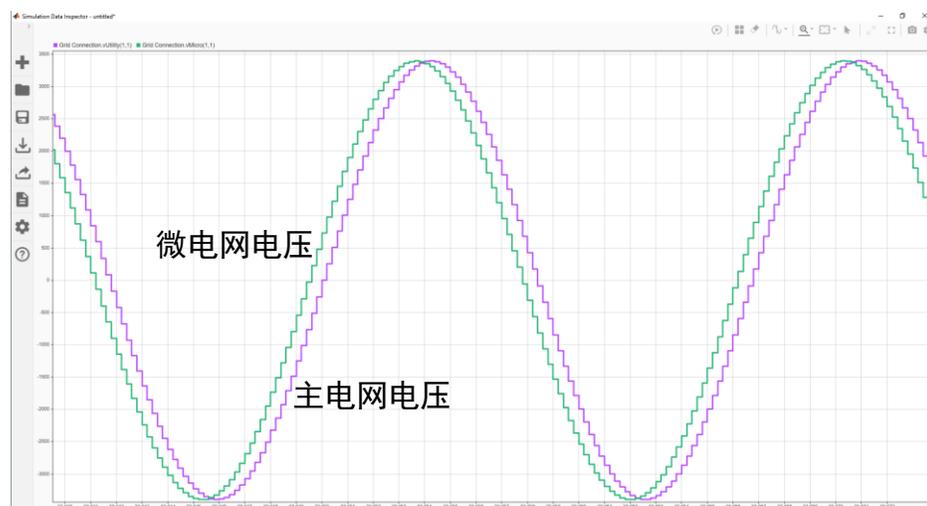
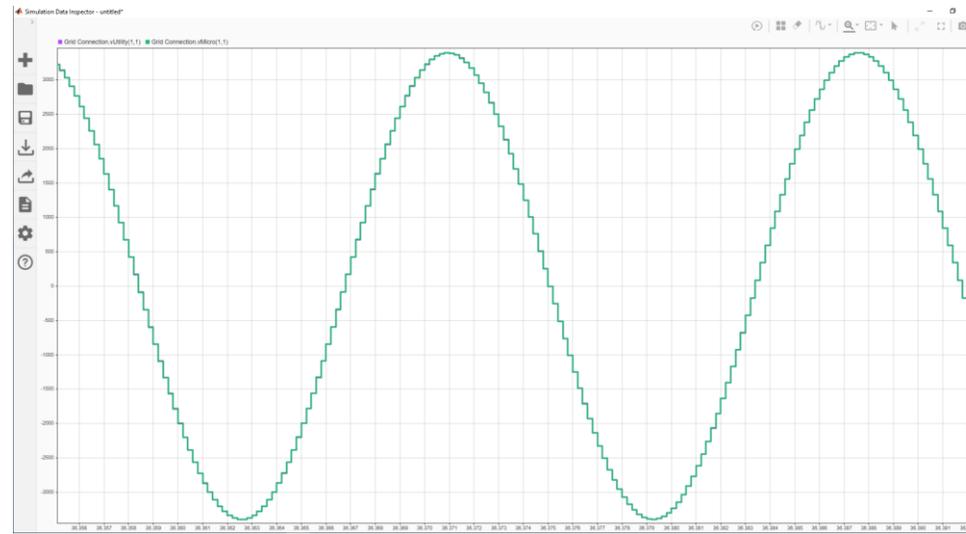
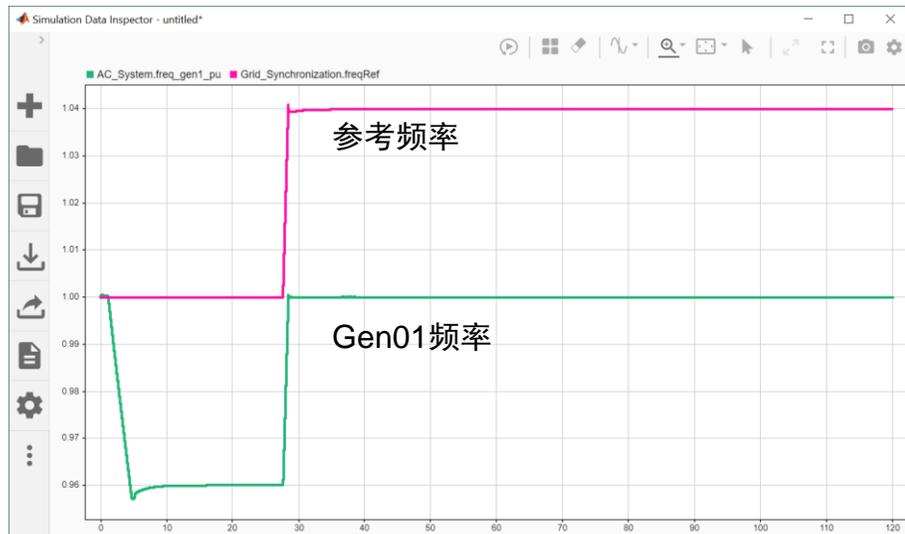
## 微电网能量管理系统设计

- 能量管理系统用于监控、调度电力系统，在技术和经济方面优化系统性能
- 能量管理系统设计以电力系统模型为基础，低保真度模型能够帮助能量管理系统设计快速迭代

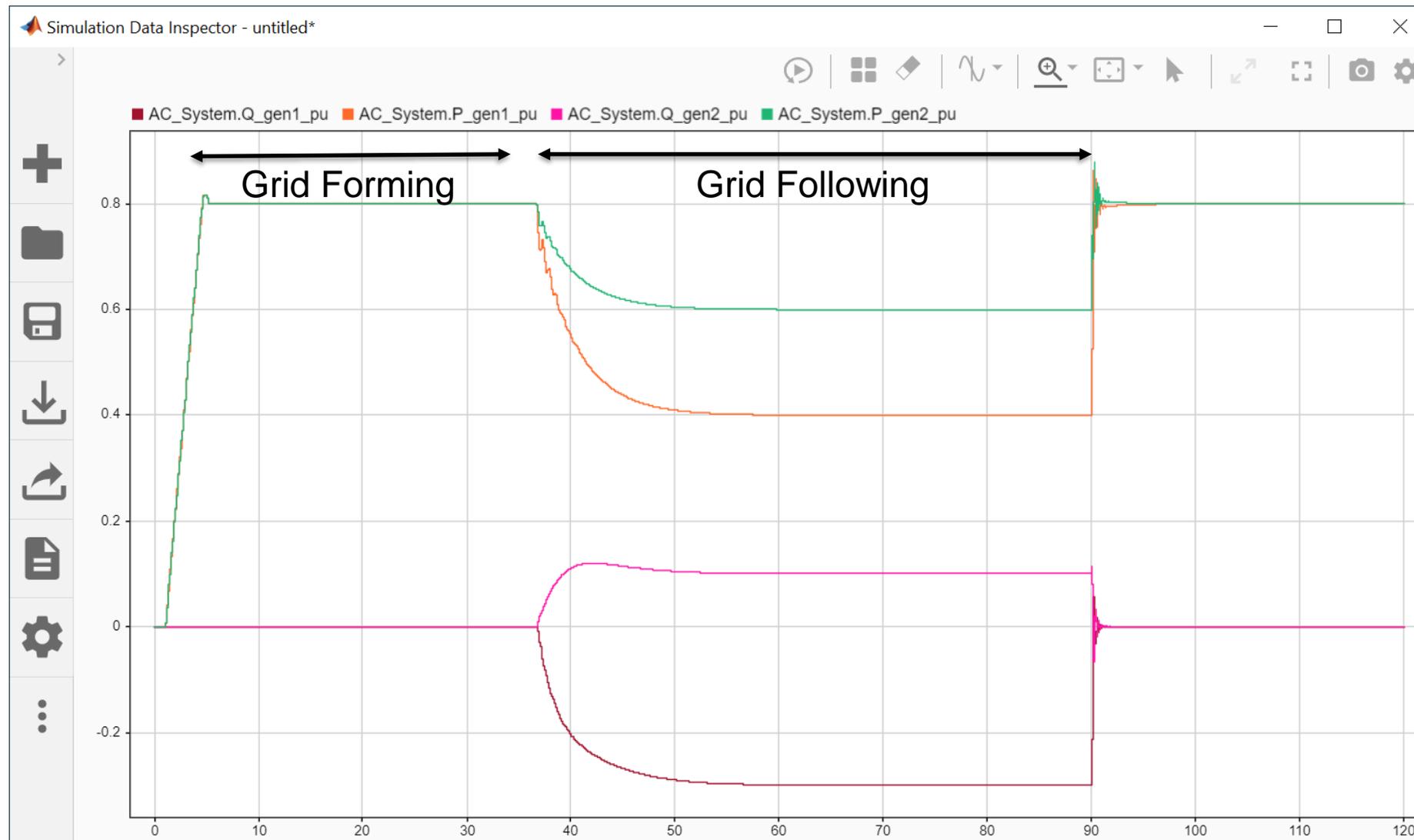
# 微电网能量管理系统设计



# 微电网能量管理系统设计



# 微电网能量管理系统设计 – 构网跟网控制



# 结论

## 技术要点

- 使用 MATLAB/Simulink 进行微电网仿真与运行优化，您可以
  - 匹配不同保真度的模型以适应工程化任务
  - 支持项目全生命周期设计任务，在统一的框架下建立完整可信的微电网系统
  - 基于系统级模型优化能量管理控制功能，保证系统运行正常高效

## 更多信息...

- 获取演示案例:

<https://ww2.mathworks.cn/matlabcentral/fileexchange/114945-hybrid-ac-dc-microgrid-with-pv-battery-and-fuel-cells>

- 获取 Simscape Electrical 产品信息

<https://ww2.mathworks.cn/products/simscape-electrical.html>

- 获取更多微电网相关资料

<https://ww2.mathworks.cn/solutions/electrification/microgrid-smart-grid-charging-infrastructure.html>

# MATLAB EXPO

Thank you



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