MATLAB EXPO

电动汽车充电对电网影响的技术-经济分析

Emery Wang
MathWorks

MathWorks

电网基础设施需要应对电动汽车占有率的持续增加带来的诸多问题

电网能否支持电动汽车增加带来的额外负载？

新的充电站应该建在哪里？

核心点:
降低风险，建立投资者信心

如何匹配再生能源系统？

我们需要多大规模的储能以及太阳能设备？

需要借助技术-经济性分析以及优化来应对面临的诸多挑战

技术层面 + 经济层面

考虑因素比如：

- 储能规模
- 设备老化
- 应急计划
- 安全限值
- 系统效率

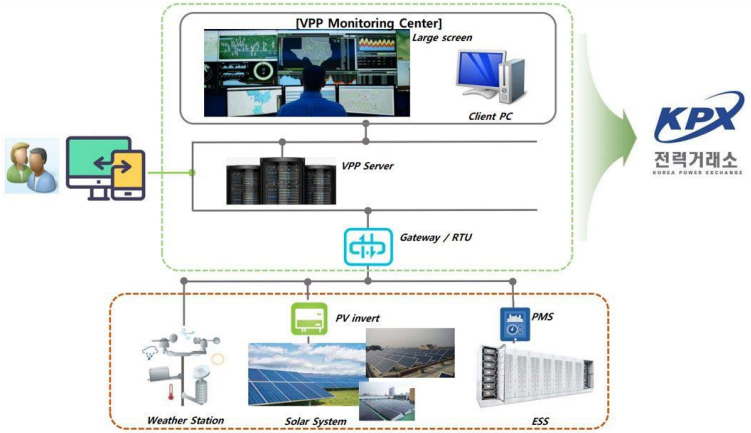
考虑因素比如：

- 能源加个
- 设备成本
- 维护成本
- 业务回报
- 能源交易

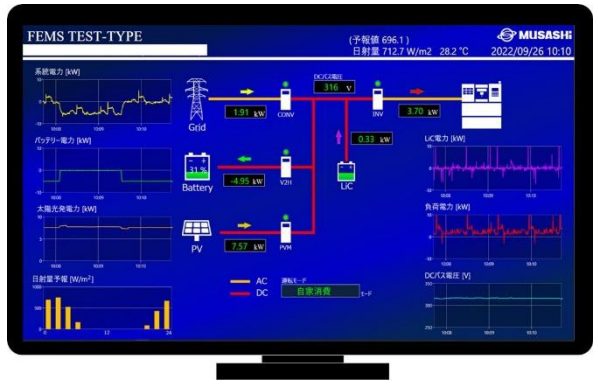
收益分析

- 降低风险，提高营收能力，建立投资者信心
- 了解系统长效表现
- 识别潜在问题并优化设计以及运营
- 针对复杂场景自动执行决策

MathWorks 助力客户实现技术-经济性分析以及优化



VGEN 开发了虚拟发电厂模型用于可再生能源预测和能源交易



Musashi Seimitsu Industry 开发 EMS 实现最大限度减少能耗以及电池退化

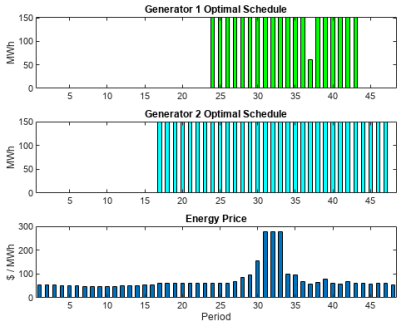
Otto von Guericke University Magdeburg 实现电网能量流以及能源生产优化

所用到的工具箱

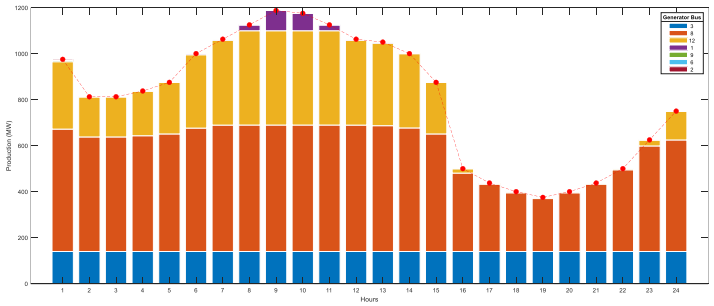
- Optimization Toolbox
- Statistics & Machine Learning Toolbox
- Simscape Electrical
- Simscape Battery
- Parallel Computing Toolbox

案例

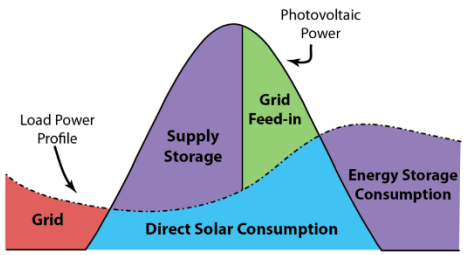
调度优化



Security-constrained unit commitment



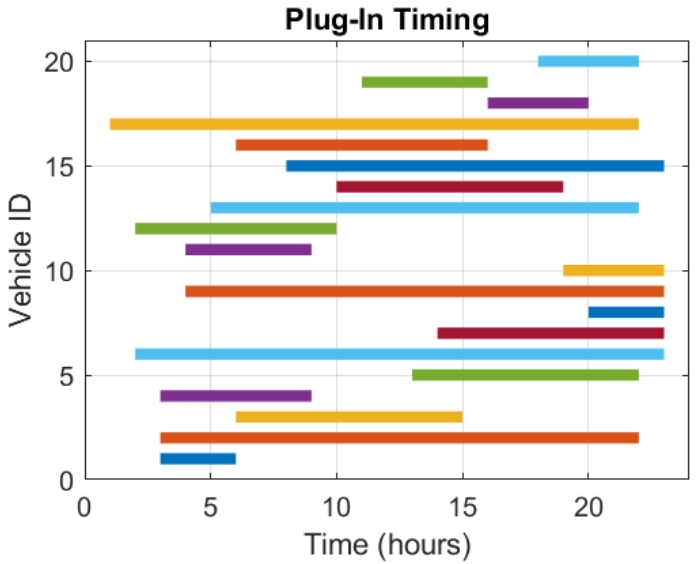
微网 EMS

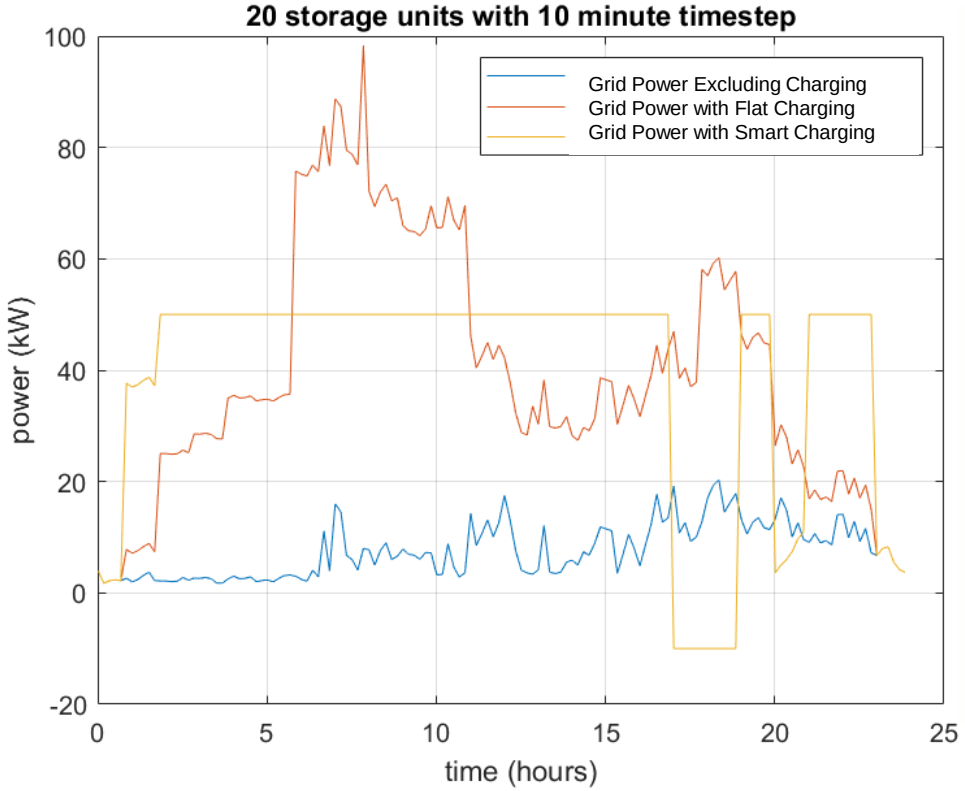


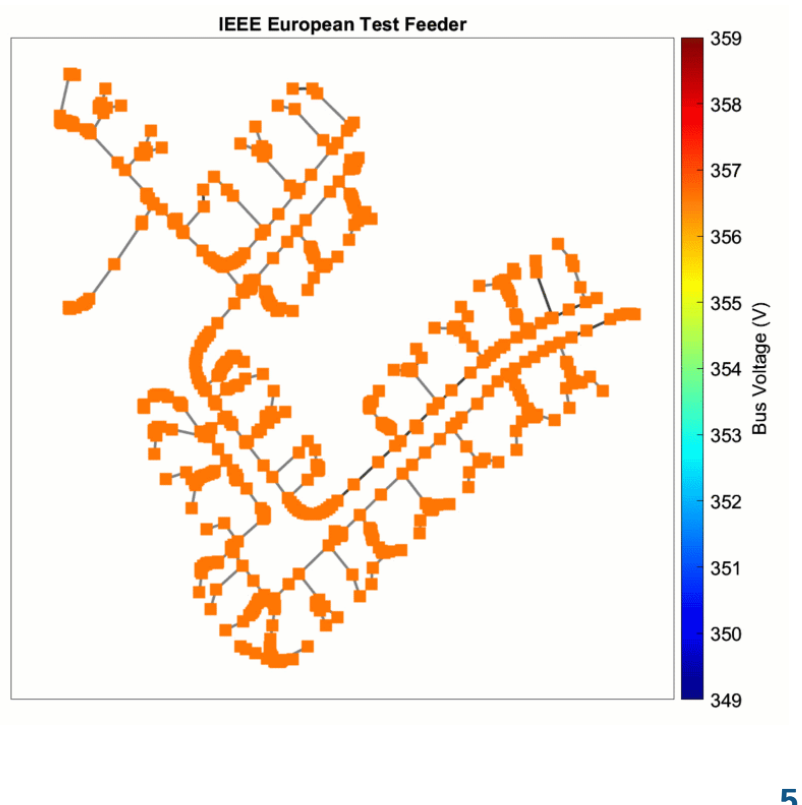
应用技术-经济优化方法来研究电动汽车充电对电网基础设施的影响

如果…

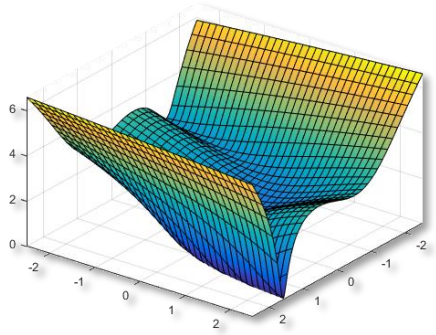
…基于电价来做充电调度规划?
…电动汽车可以相互供电?
…电力可以出售到电网?

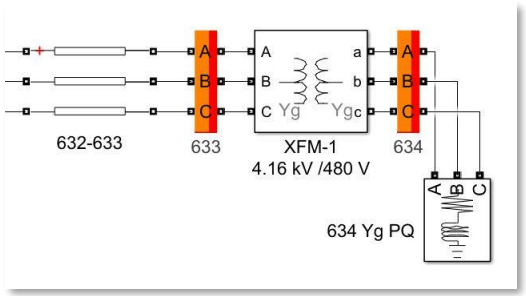


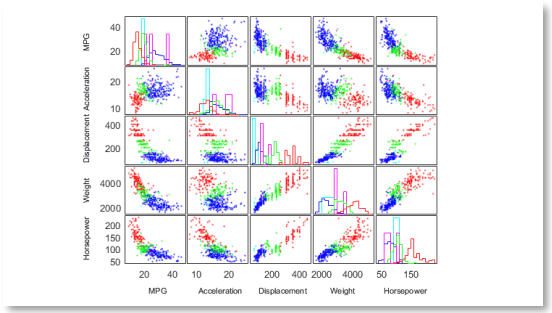


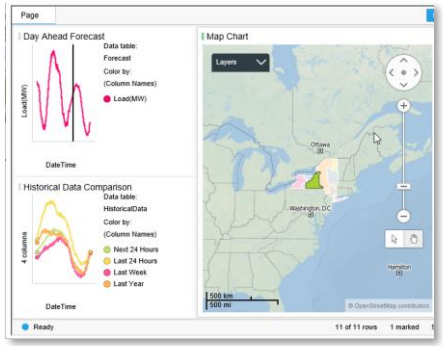


实施技术-经济性优化的工作流程









优化问题建模以及求解

电网仿真

电网分析以及图示

发布

Optimization Toolbox

Simscape Electrical

Parallel Computing Toolbox
Statistics & Machine Learning Toolbox

App Designer
MATLAB Web App Server
MATLAB Compiler

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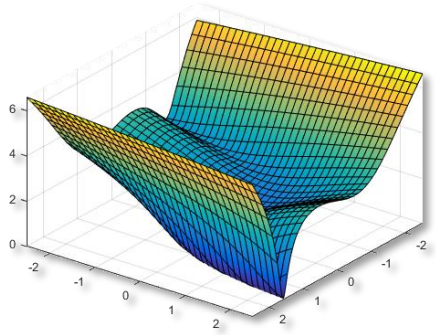

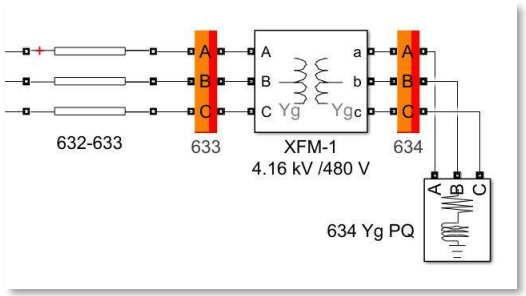

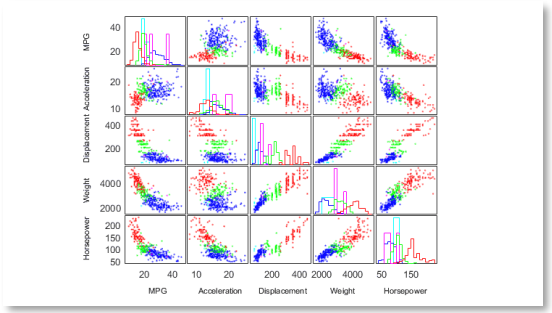

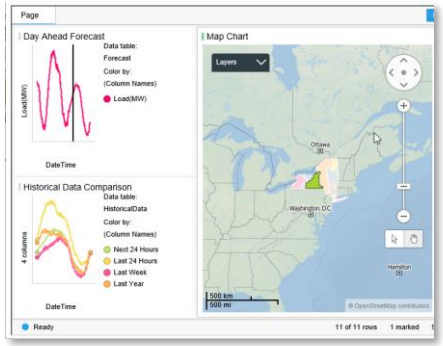

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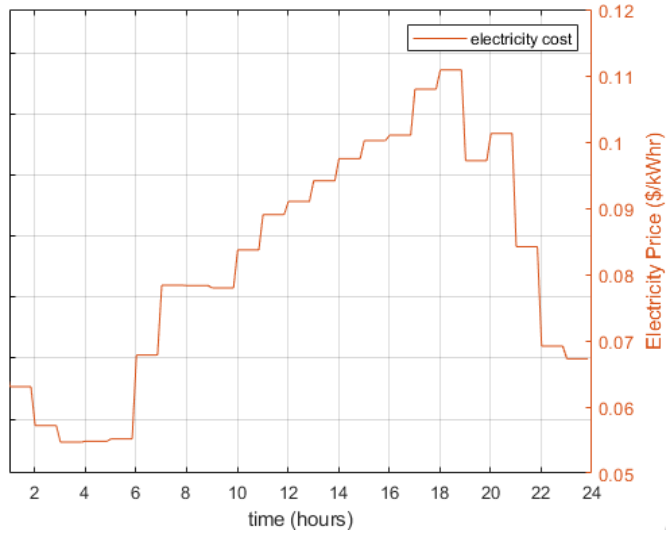
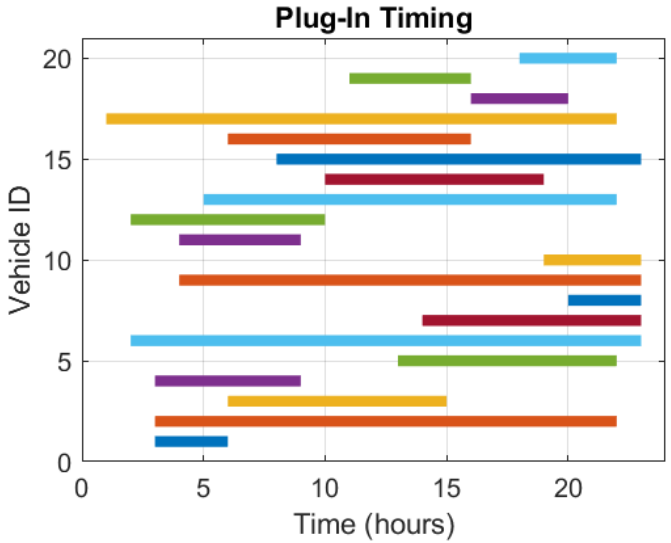
首先 描述我们这里的优化问题

- 输入数据:
  - 电网的能耗需求(随时间)
  - 各个 EV 储能单元的接入时间跨度
- 变量:
  - 各个储能单元的输入/输出功率
  - 从电网购买或向电网出售的功率
- 约束:
  - 对每个储能单元，SOC必须时刻维持在既定的上下限范围内
  - 对每个储能单元， 必须保证充满(最终SOC处于上限)
  - 电网功率必须维持储能单元功率和系统负载功率平衡
  - 电网功率必须在允许的上下限范围内
- 目标:
  - 最小化总的电力成本





基于问题的优化工作流
直观定义优化模型所涉及到的方程

- 变量定义举例: 从电网购买/出售的功率，限制在一定范围内

$$min \leq gridPower \leq max$$

```
gridPower = optimvar("gridPower",no_steps,1,"LowerBound",-0.2*no_units,"UpperBound",2*no_units);
```

- 约束举例: 电网功率必须和储能单元功率以及系统负载功率保持平衡

$$\sum storagePower + loadPower = gridPower$$

```
prob.Constraints.powerBalance = sum(storagePower,2) + loadPower' == gridPower;
```

基于问题的优化工作流
直观定义优化模型所涉及到的方程

- 优化目标: 最小化总电力成本

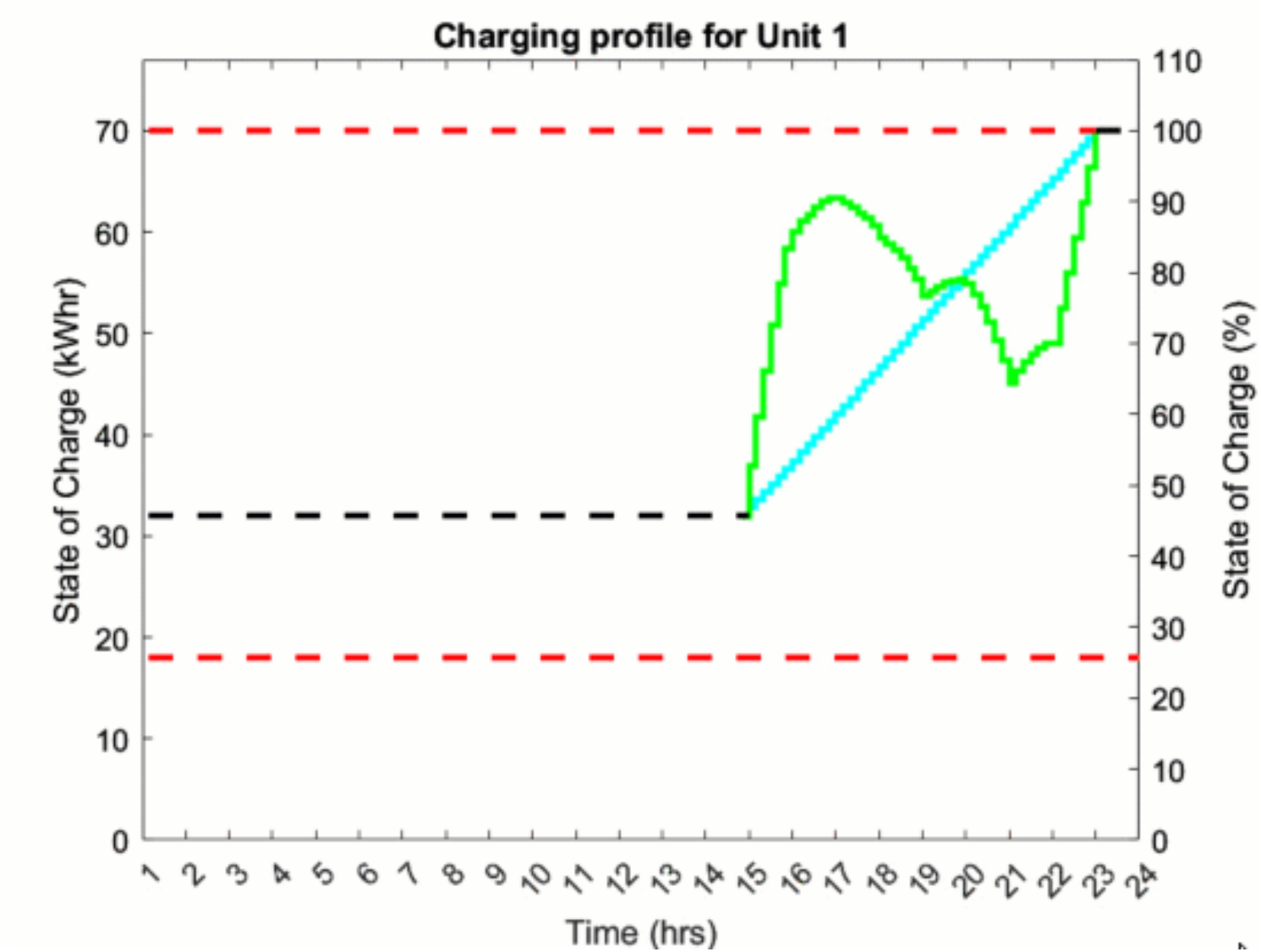
$$totalCost = gridPower \times price$$

```
prob.Objective = gridPower'*price;
```

- 问题求解

```
[sol,fval,exitflag,output] = solve(prob,"Options",optlin)
```

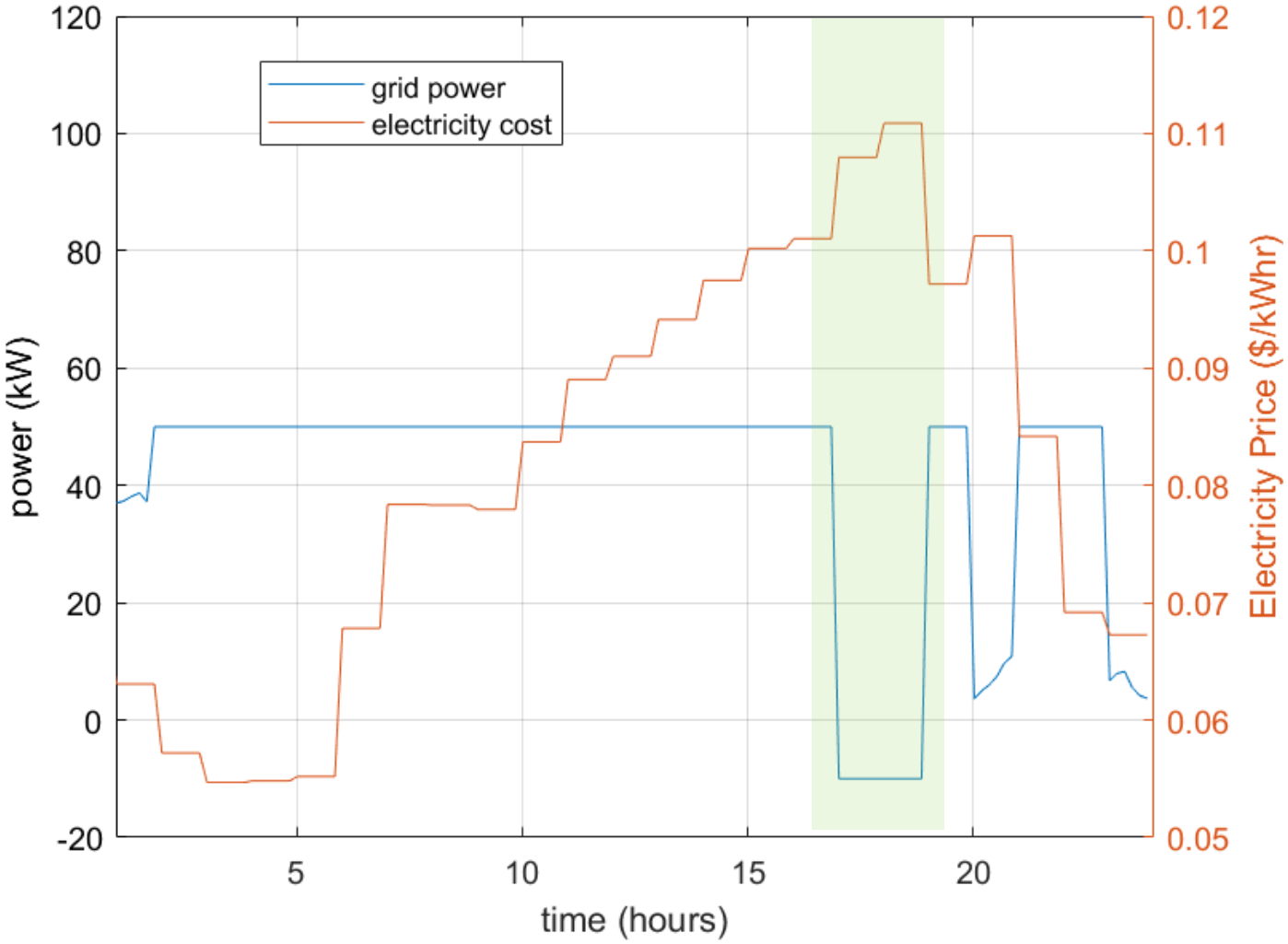
智能充电策略 – 基于系统收益的充电功率策略



Constant Charge

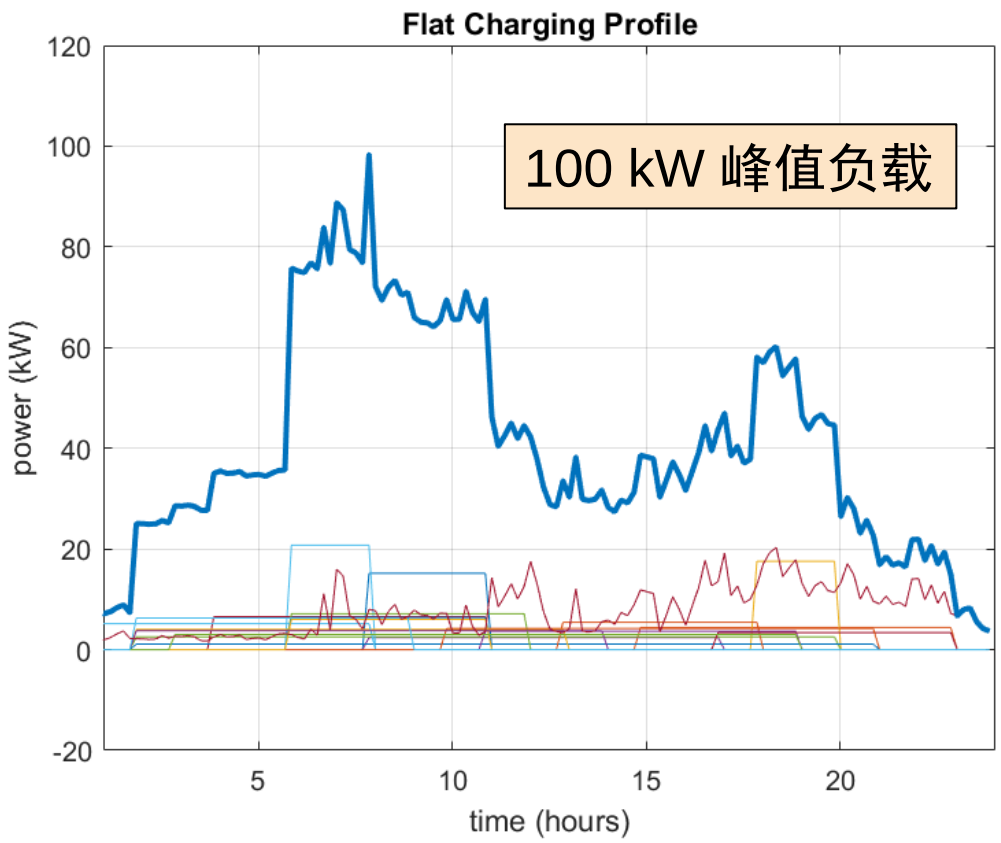
Smart Charge

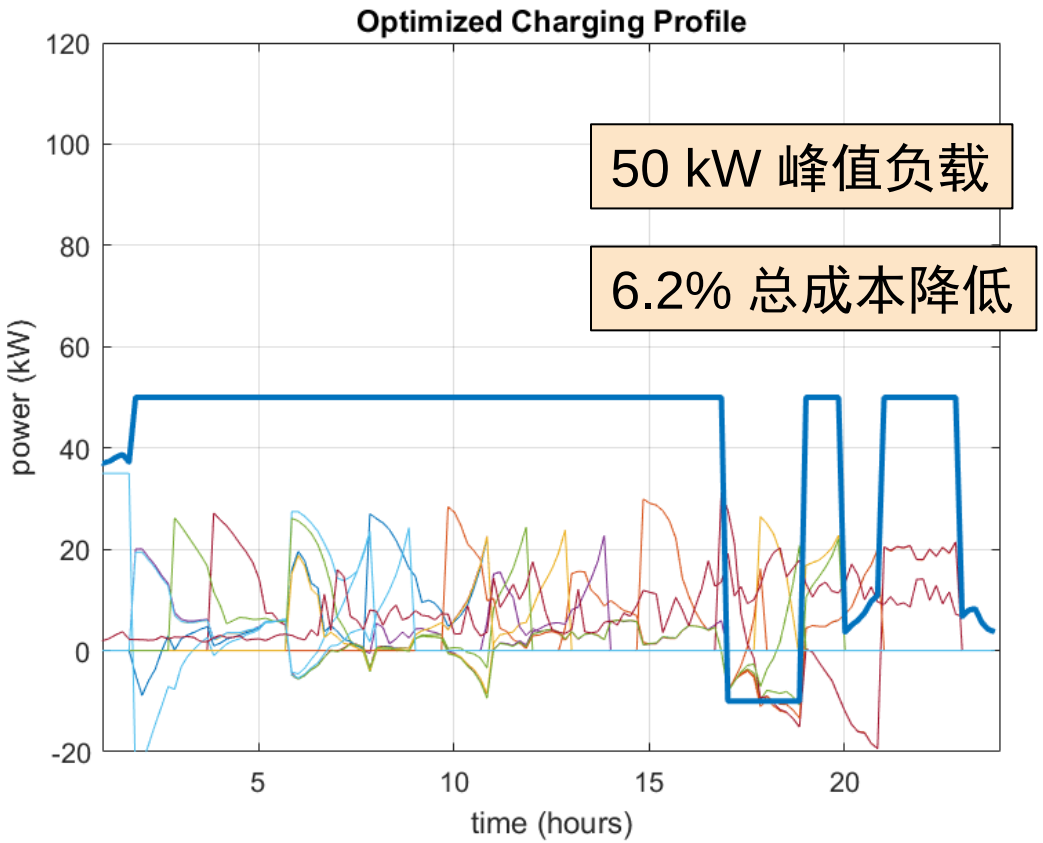
智能充电策略 – 高电价区段将电力回馈到电网



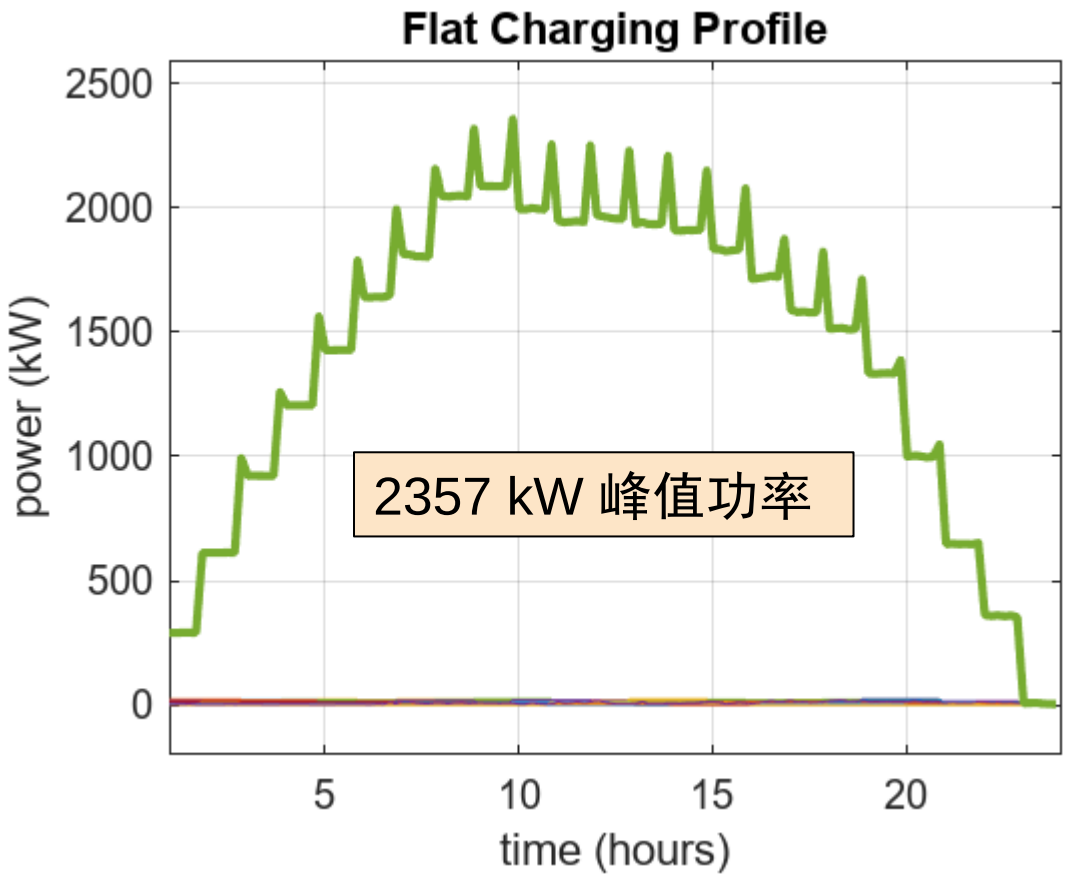
在这个场景下，智能充电策略比固化充电策略便宜 6.2%

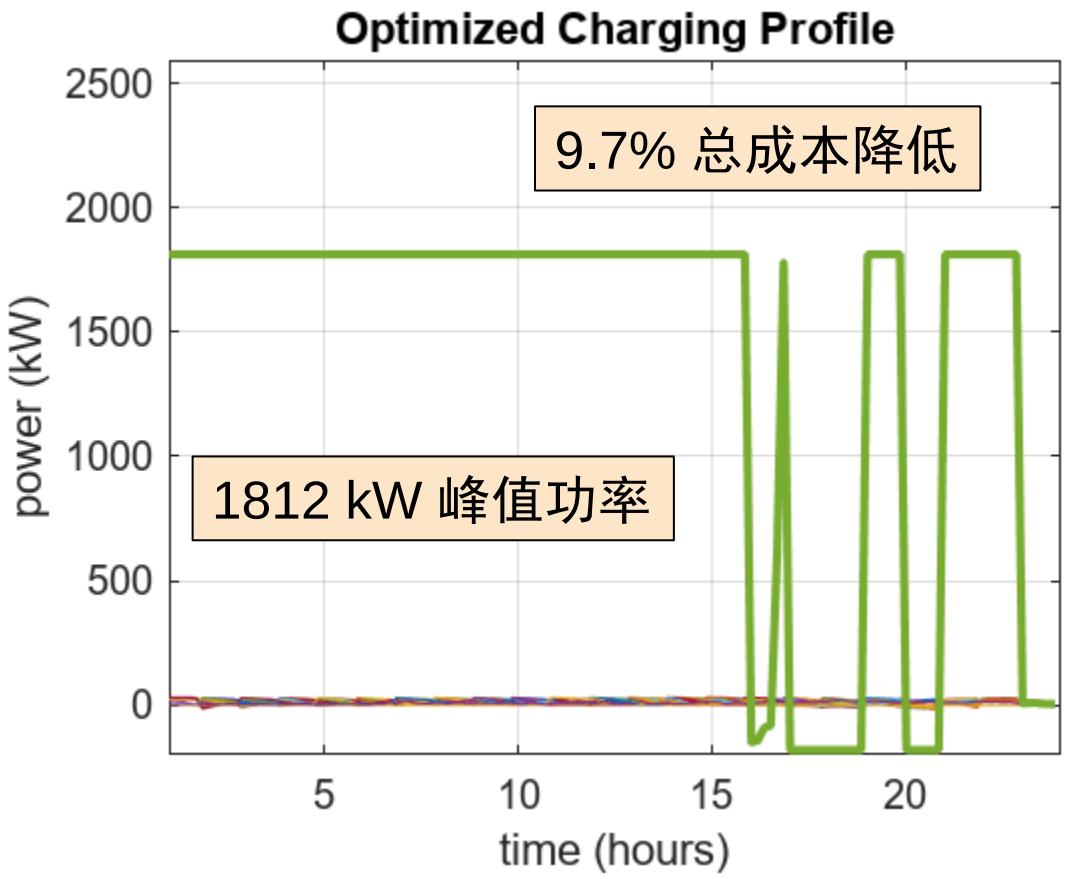
优化后的充电曲线最大限度的降低总成本并限制峰值负载



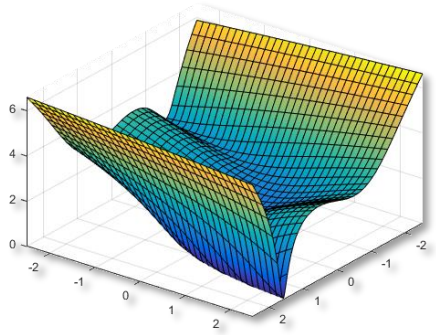


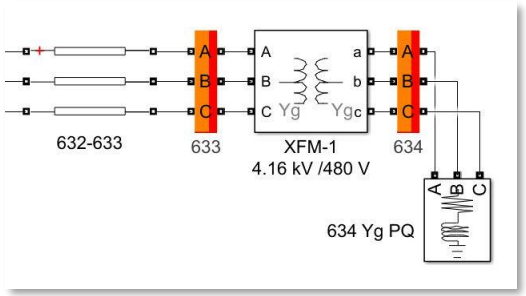
扩大分析规模 (906 单元) 显示的成本以及峰值功率收益

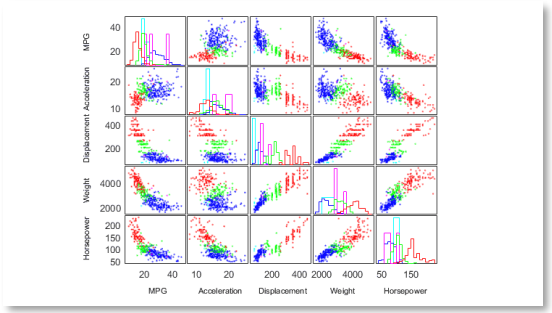


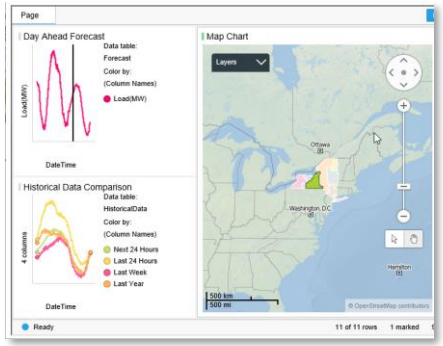


实施技术-经济性优化的工作流程









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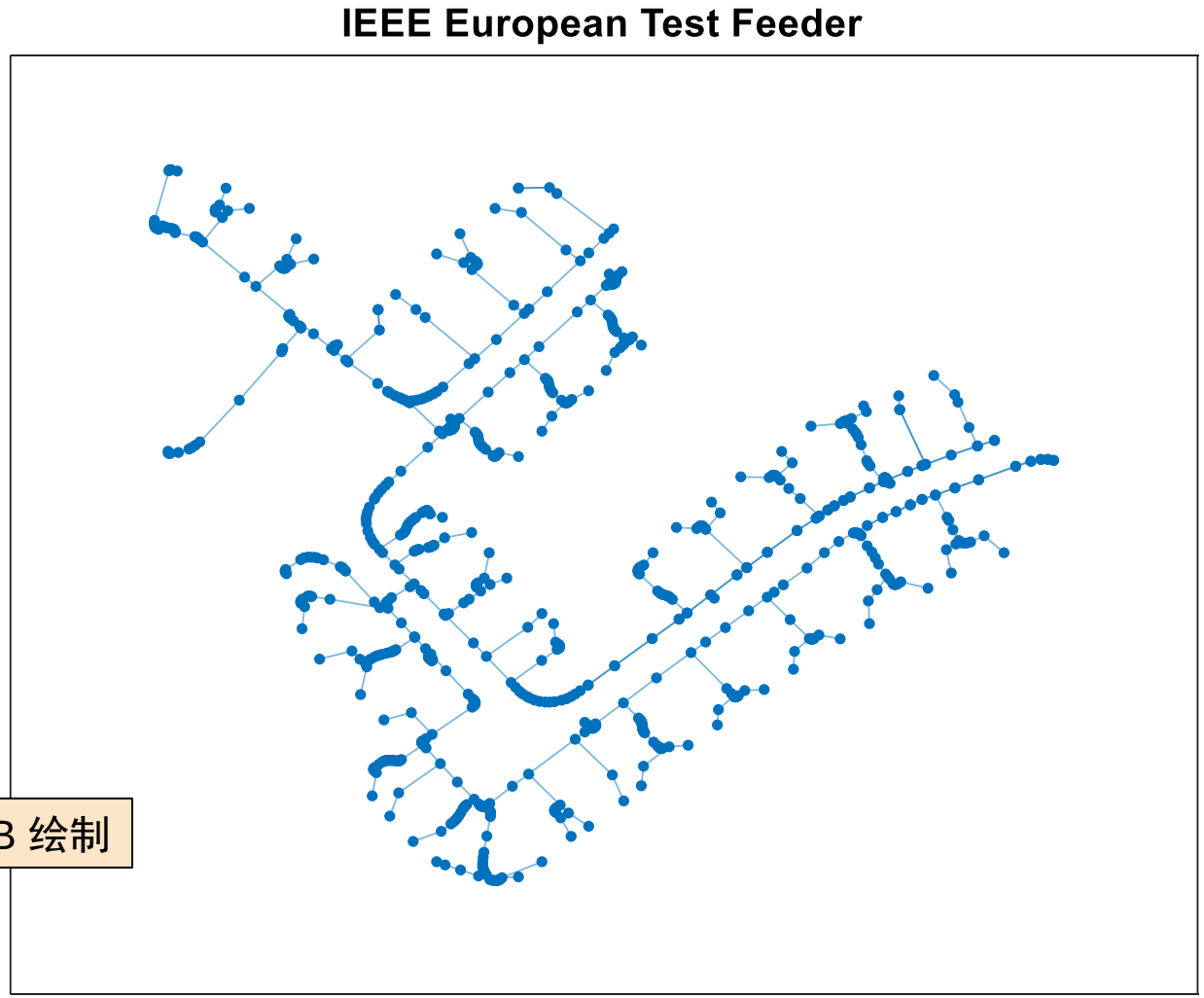
IEEE European Test Feeder

- 我们接着将基于这个 IEEE European Test Feeder 来评估充电策略；
- 这是个 906 节点的三相配电电网模型，由 IEEE AMPS Distribution System Analysis 委员会所发布；
- 网络数据可从下方链接获得；

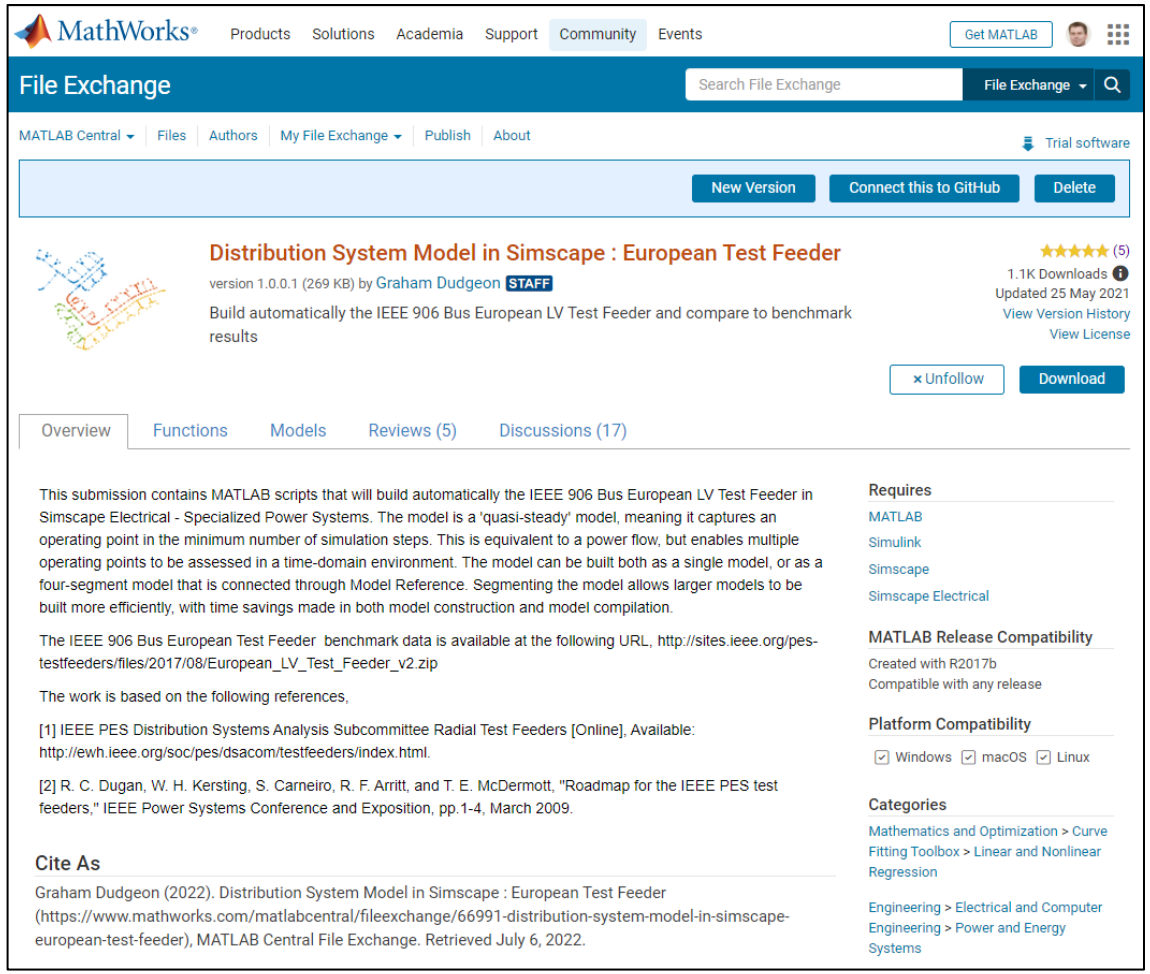


这个图片使用 MATLAB 绘制

https://cmte.ieee.org/pes-testfeeders/wp-content/uploads/sites/167/2017/08/European_LV_Test_Feeder_v2.zip

IEEE European Test Feeder

基于 Simscape Electrical 实现的 IEEE European Test Feeder 模型可从 MathWorks File Exchange 下载。

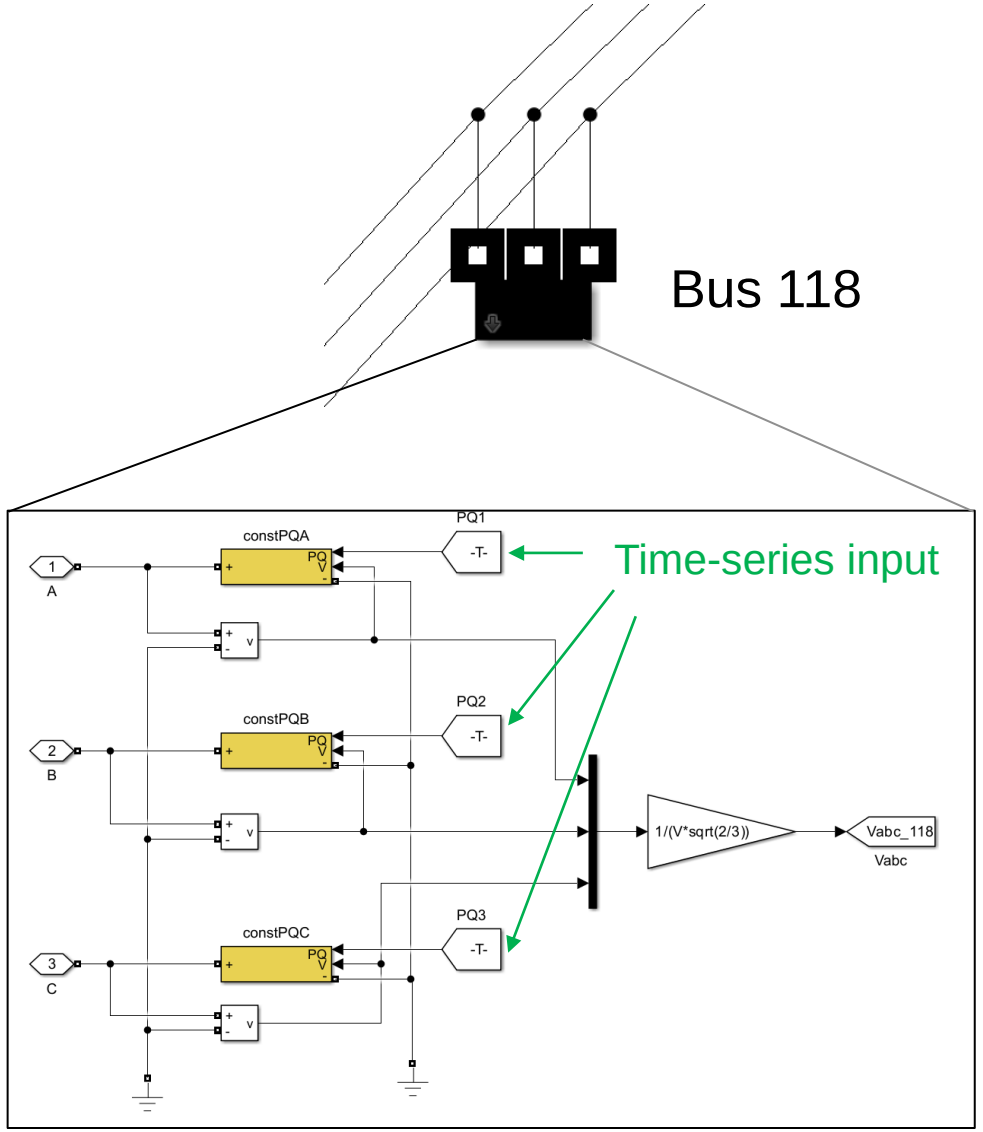


https://www.mathworks.com/matlabcentral/fileexchange/66991-distribution-system-model-in-simscape-european-test-feeder

根据待评估方案来进行电网仿真配置

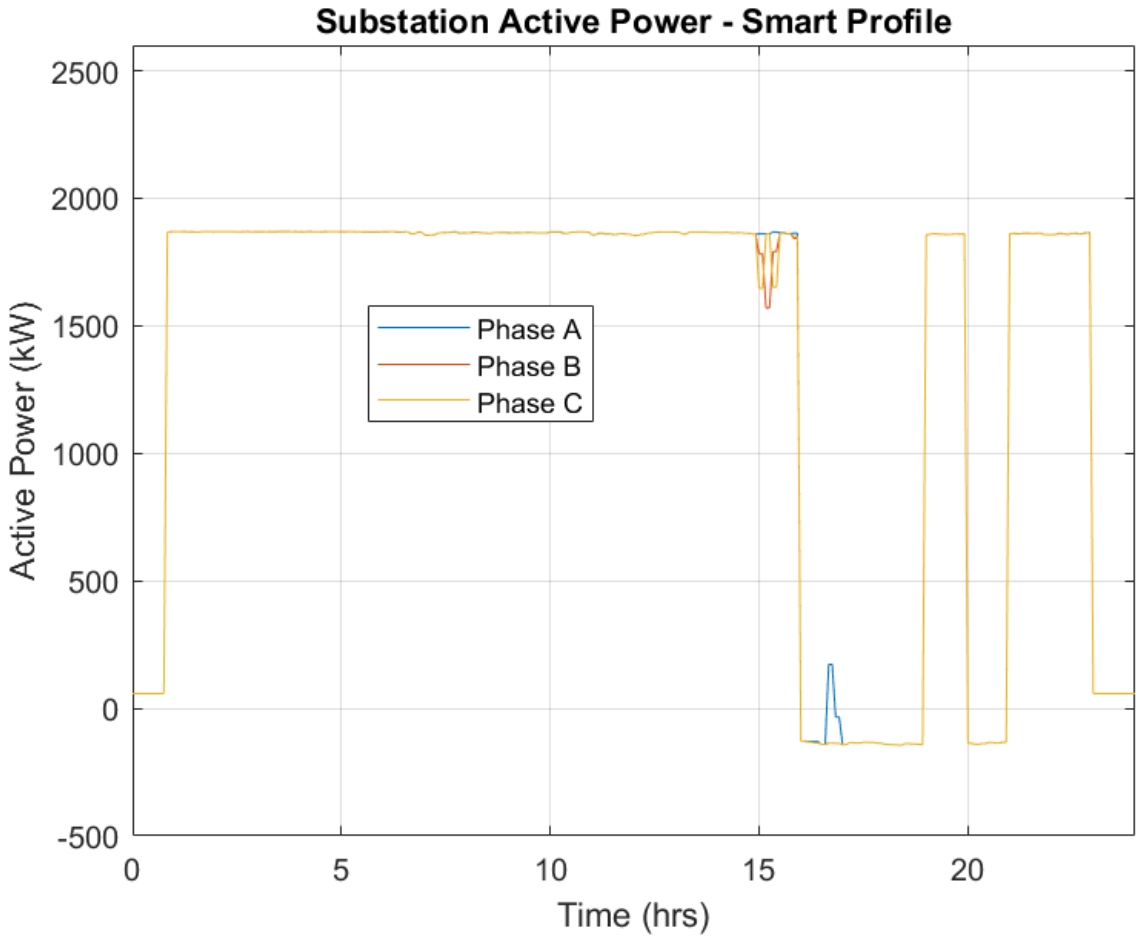
- 为了实现场景评估的灵活性，我们在每个节点接入一个双向功率输入模块，这样我们可以直接输入一个指定的时间-功率曲线。
  - 对于这个系统来说，我们有 2718个功率输入曲线

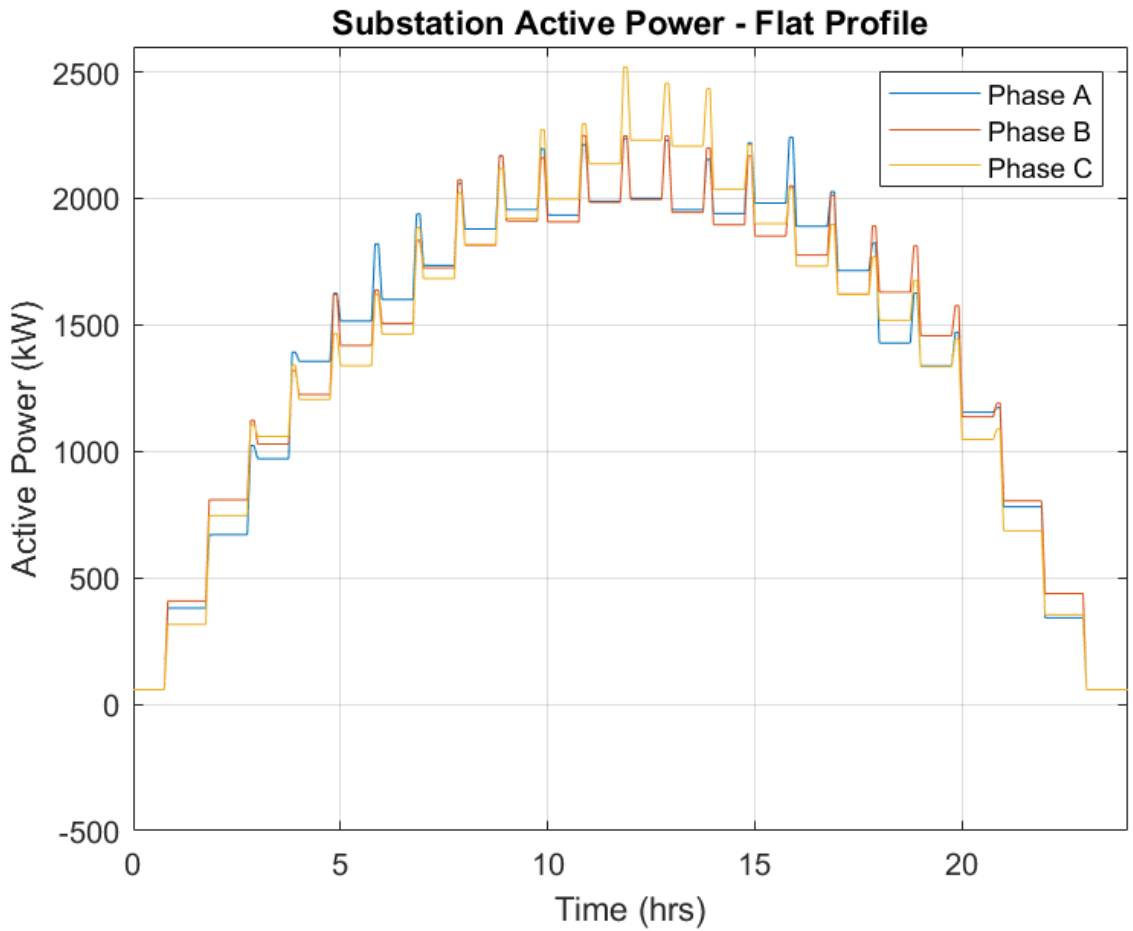
- 我们的一个场景有 2718个节点的储能单元，这里我们把每一相单独优化处理。每一相有 906 个储能节点…



根据待评估方案来进行电网仿真配置

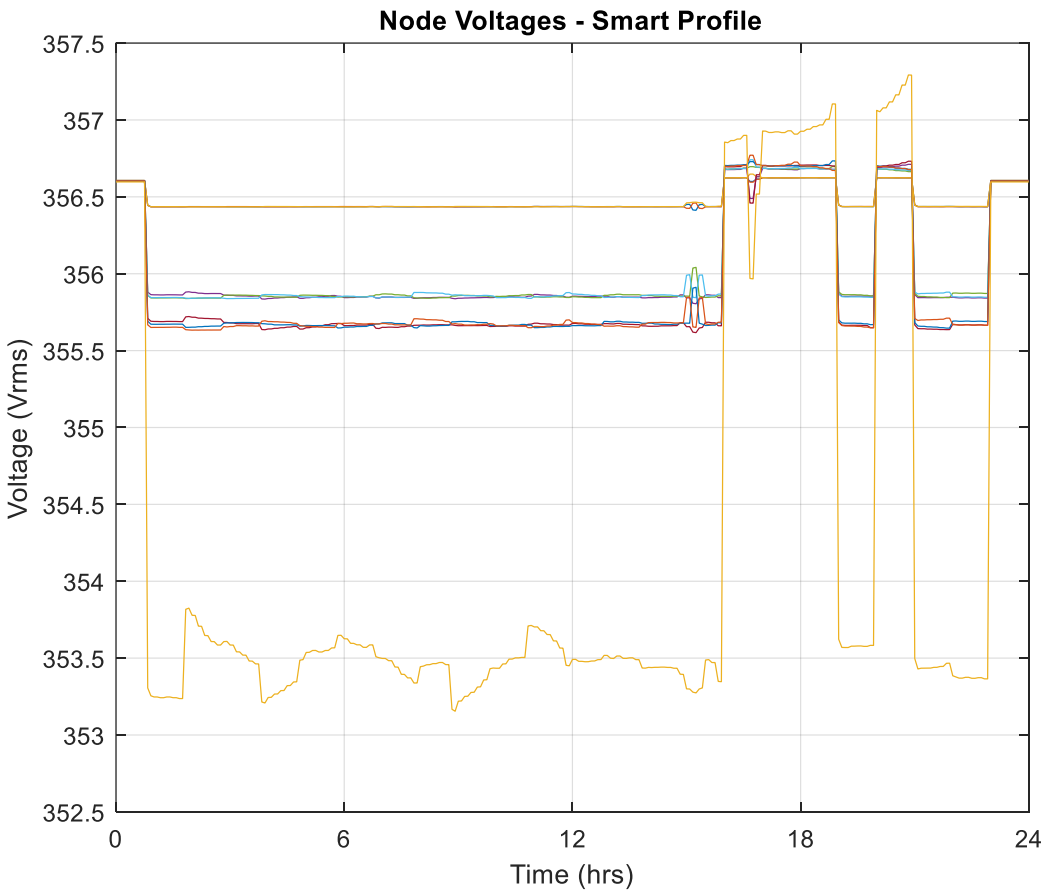
当采样时间 Ts = 300s, 24小时的场景仿真需要大约 6秒。下图中各相的差别主要来自于各个充电单元不同的接入/断开时间段。

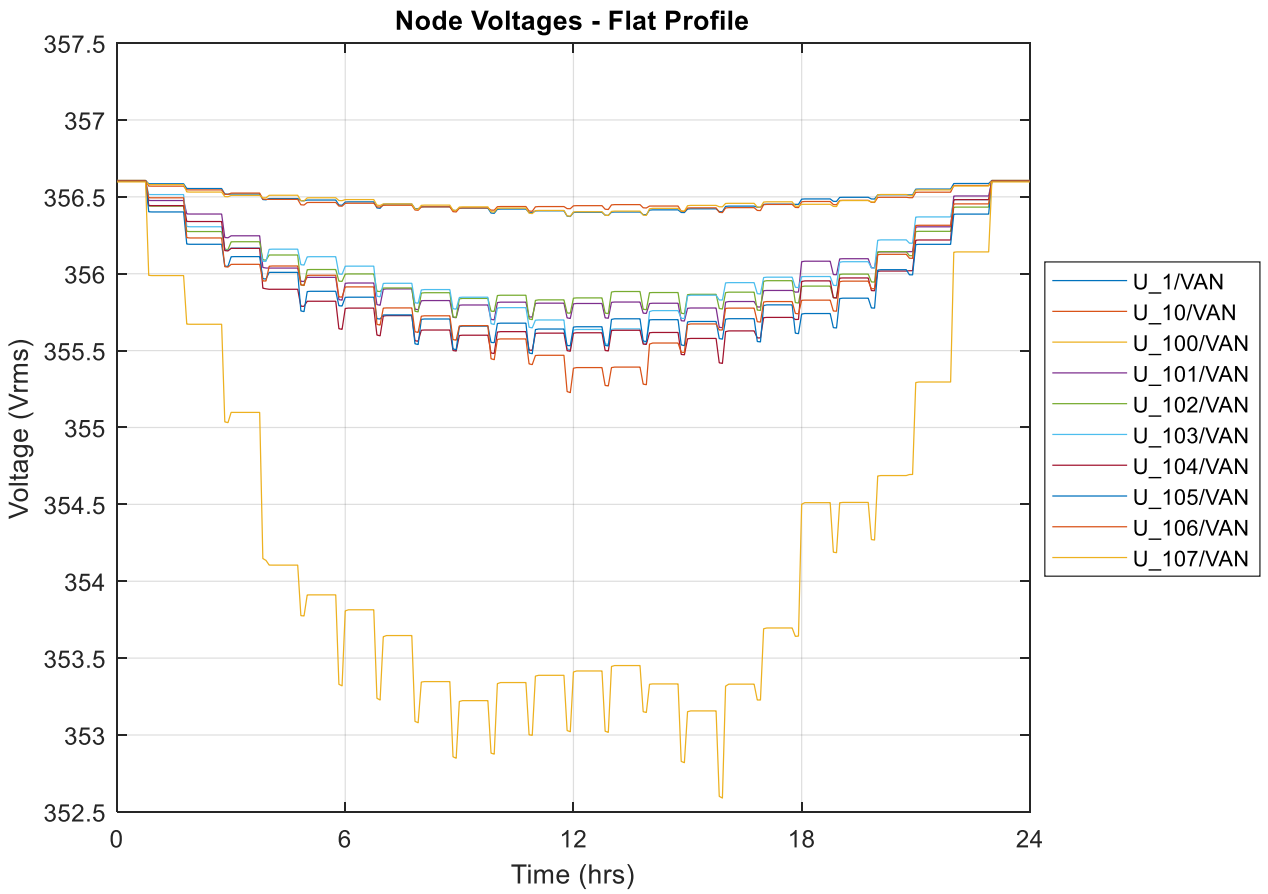




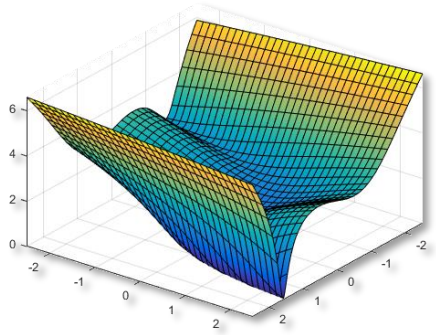
根据待评估方案来进行电网仿真配置

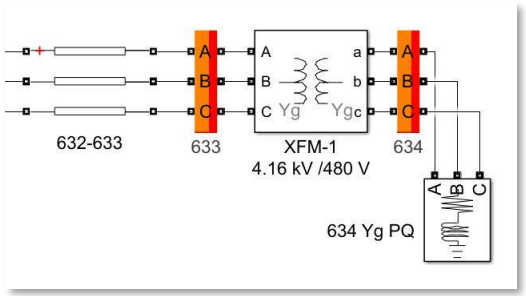
利用电网仿真，我们还可以得到电压和电流曲线.

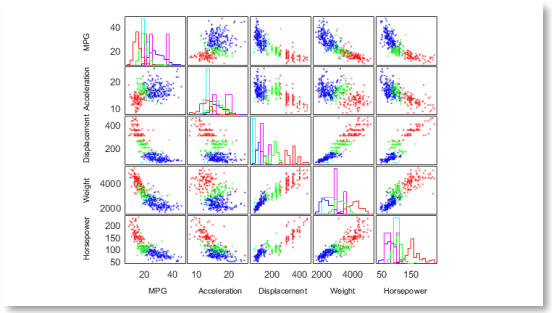


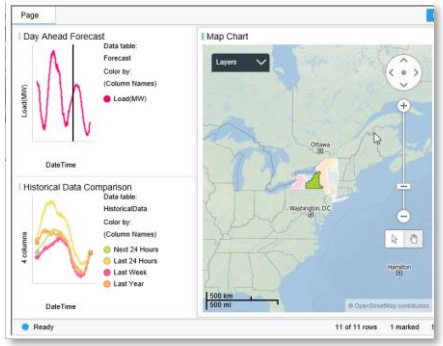


实施技术-经济性优化的工作流程









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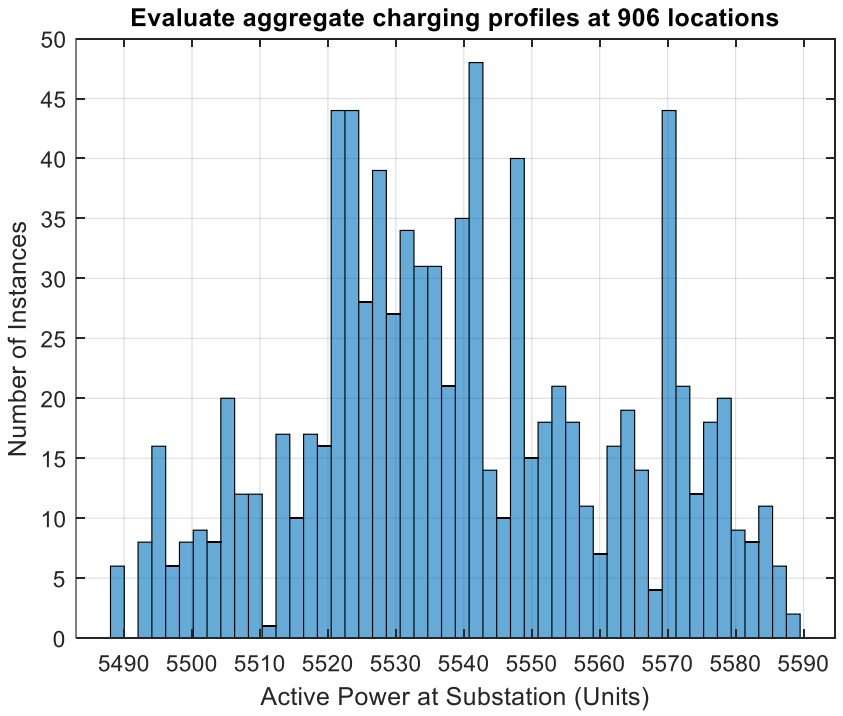
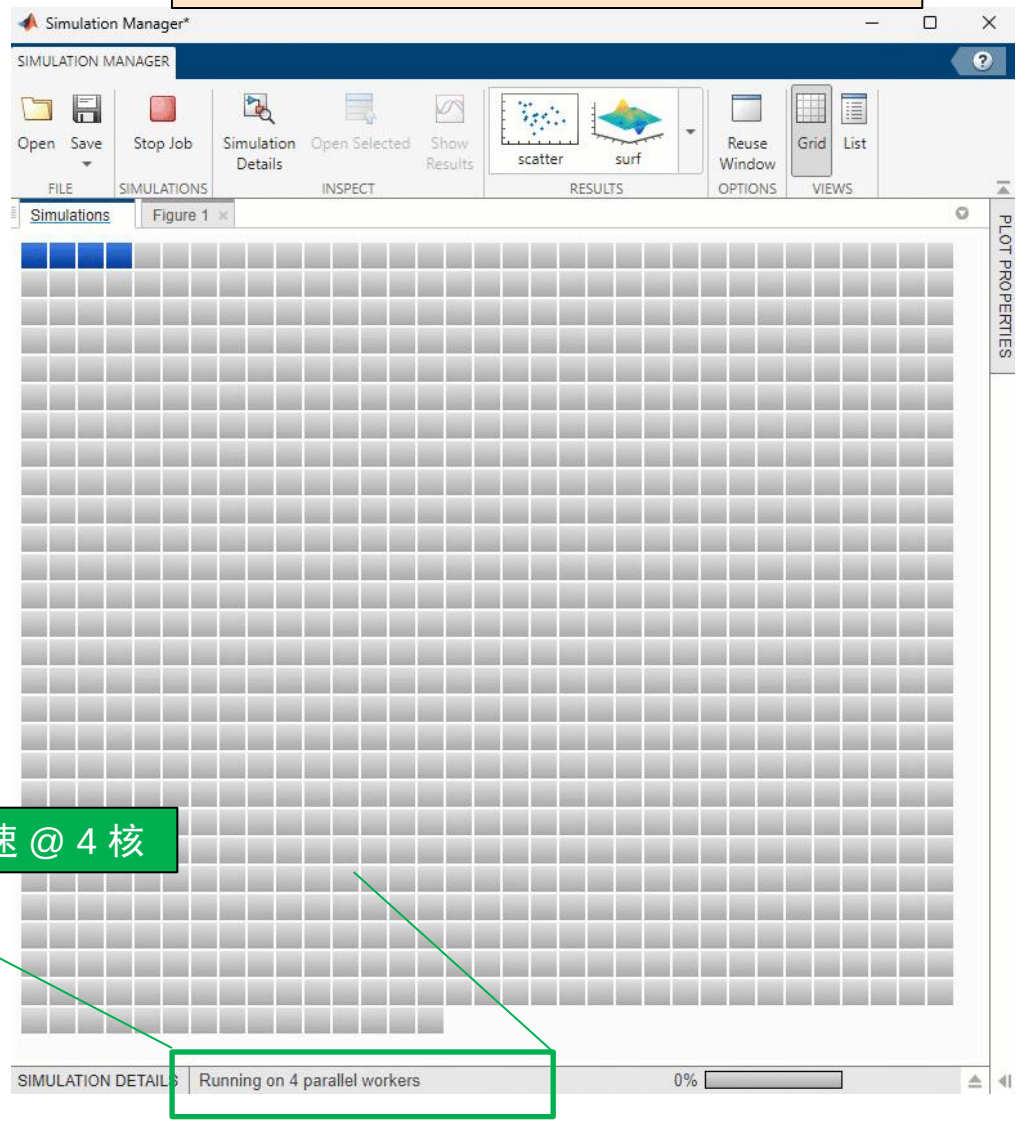
利用多核资源同步运行多个仿真场景

我们接下来将储能单元都连接到单个节点 – 我们有 906 个场景需要评估。
使用并行运算，我们可以同时评估多个场景，极大提高分析效率。



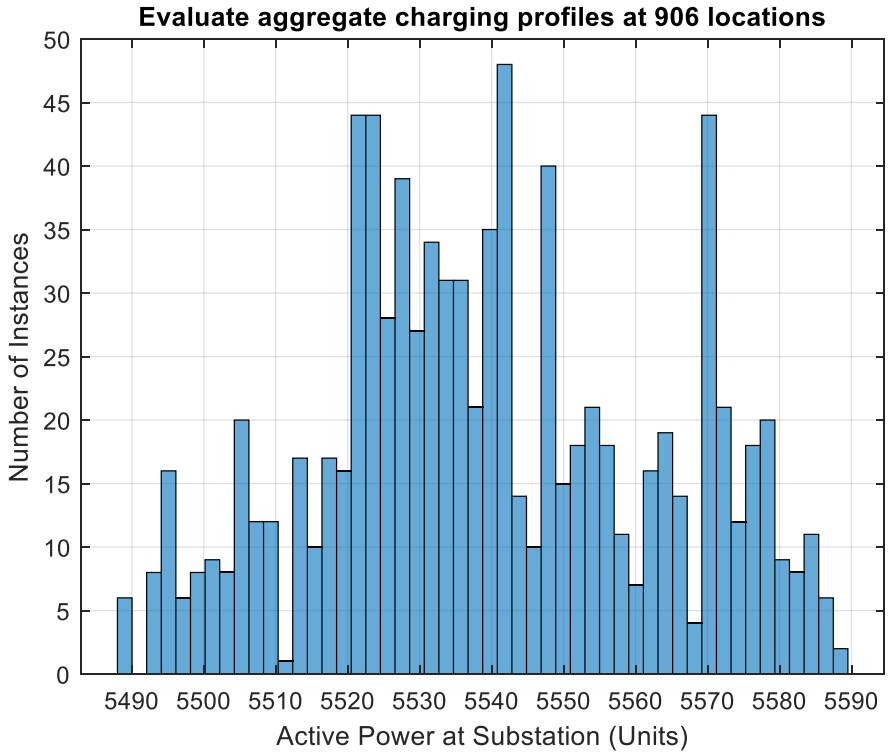
动画 60 倍加速显示显示了 906 个仿真场景

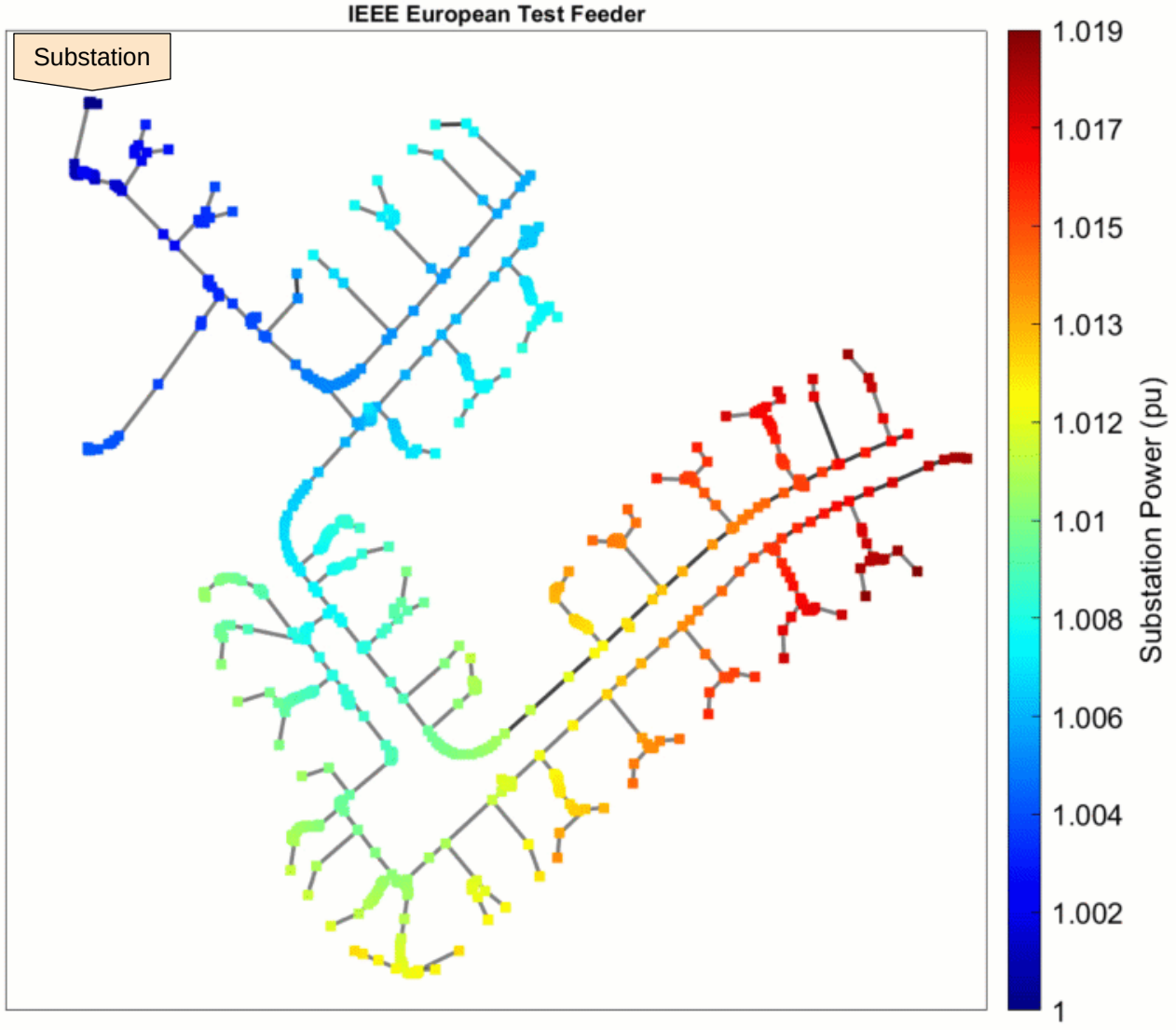


3.5倍加速 @ 4 核

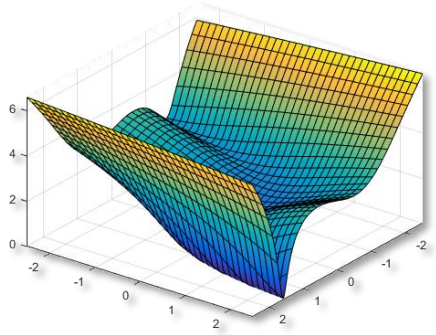
利用多核资源同步运行多个仿真场景

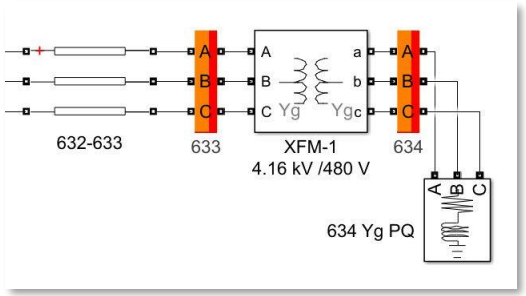
统计分析以及可视化手段让我们更方便理解系统

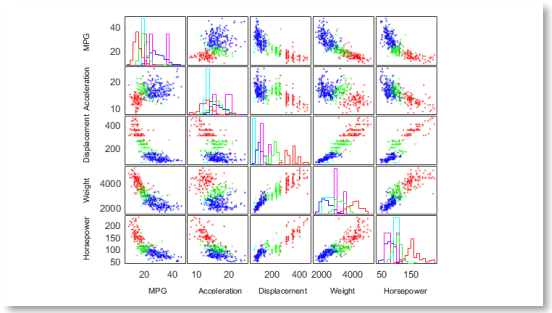


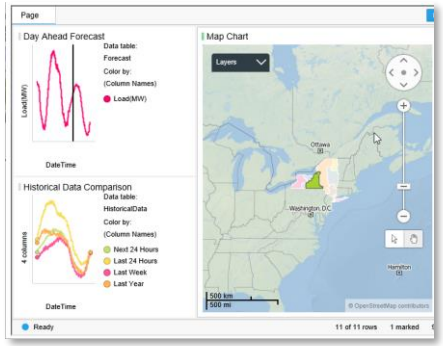


实施技术-经济性优化的工作流程









优化问题建模以及求解

电网仿真

电网分析以及图示

发布

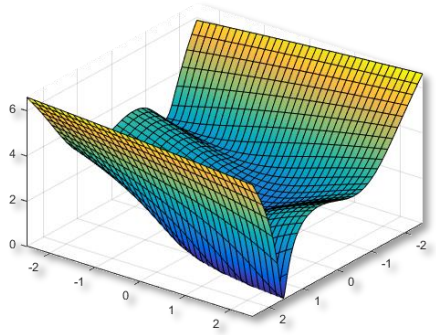
Optimization Toolbox

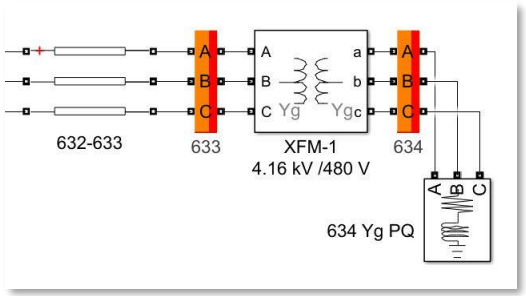
Simscape Electrical

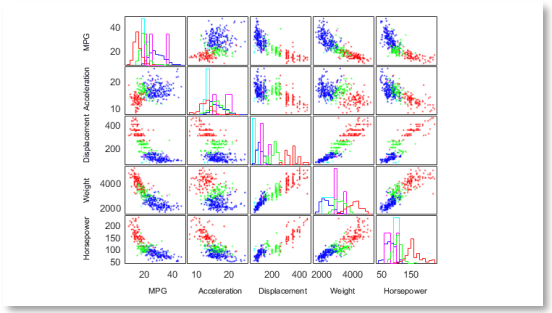
Parallel Computing Toolbox
Statistics & Machine Learning Toolbox

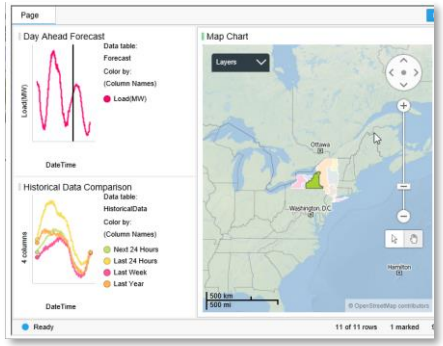
App Designer
MATLAB Web App Server
MATLAB Compiler

实施技术-经济性优化的工作流程









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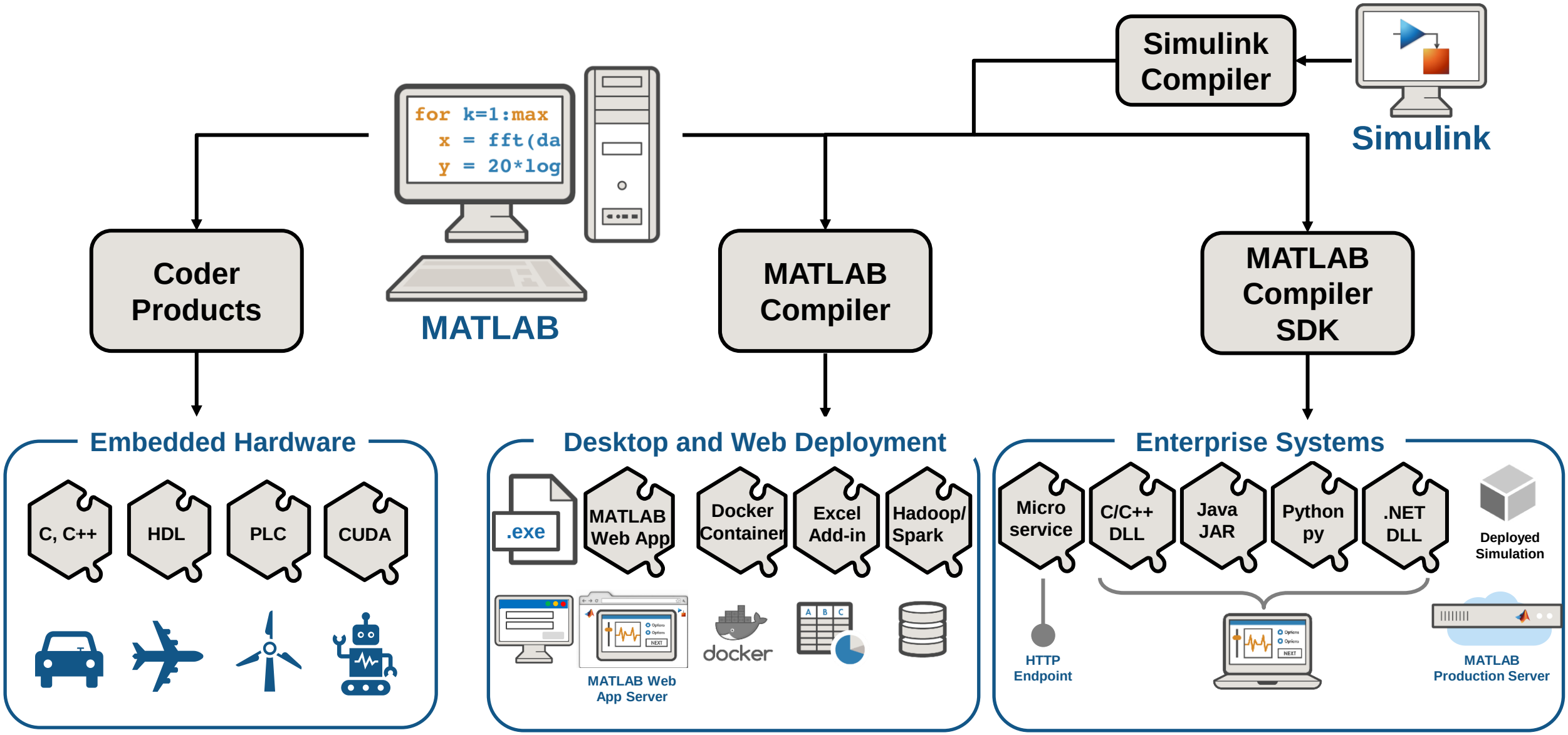
将技术-经济分析优化流程发布到生产环境以及嵌入式硬件



要点总结

通过技术-经济性分析降低风险并建立对电网能力的信心

使用 MATLAB 的高效率求解器并结合基于问题的建模手段来分析和解决这种大规模的优化问题

结合电网仿真并通过统计分析以及有效的可视化手段来加深对问题的理解

可通过多种途径来部署我们所开发的分析工作流

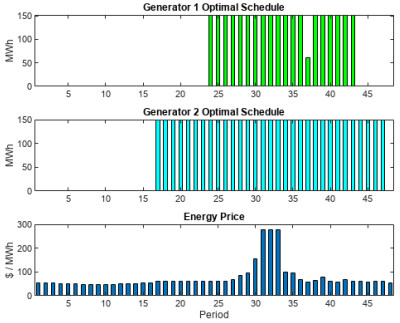
更多信息请参见

自学教程

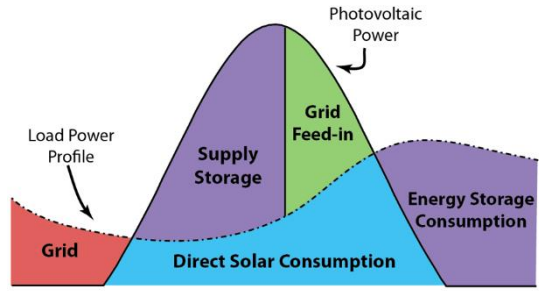
[Optimization Onramp]

[Simscape Onramp]

更多案例

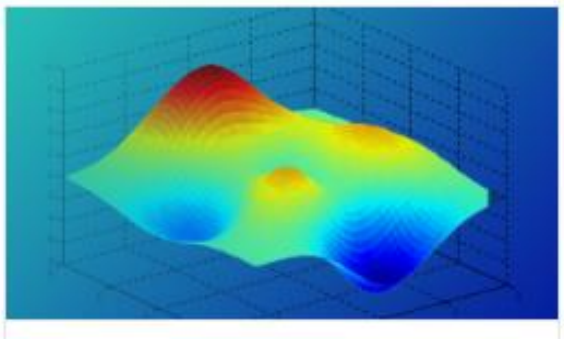


[Optimal Dispatch]



[Microgrid EMS]

培训课程

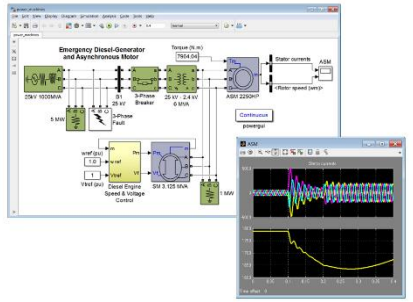


[Optimization Techniques in MATLAB]

[Modeling Electrical Power Systems with Simscape]

咨询方案

[Load Forecasting]



[Power Systems Simulation]

MATLAB EXPO

感谢！