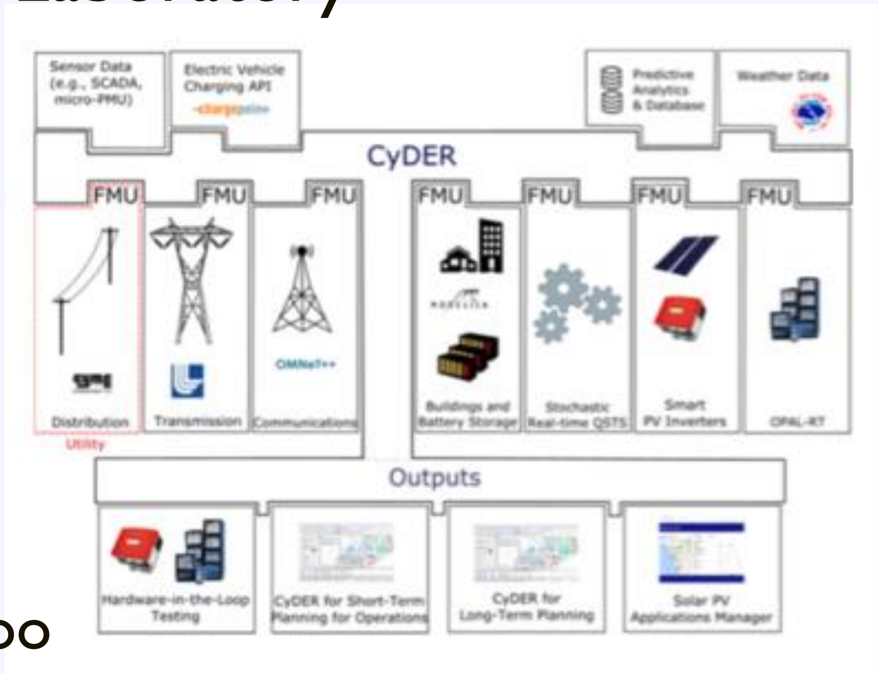
CyDER Overview

A Cyber Physical Co-simulation Platform for Distributed Energy Resources (CyDER) in Smart Grids

Lawrence Berkeley National Laboratory



July 21, 2017

SuNLaMP Workshop

Principal Investigator: Jhi-Young Joo

Team: LBNL, LLNL, PG&E, SolarCity, ChargePoint

Problem Statement and Targets

- **Problems**
  - Variability in penetration of PV and EVs at distribution, customers, and transmission levels
  - Limited accuracy, lack of measured data to calibrate and validate models
  - Lack of interconnection between transmission and distribution systems (T&D)

- **Targets**: to develop a planning tool that
  - are modular and scalable
  - enable the co-simulation of T&D systems
  - incorporate novel control strategies such as EV charging control and demand response
  - consider the stochastic nature of PV and DER
  - streamline and substantially decrease the interconnection PV approval time and costs for new PV installations

Project Objectives

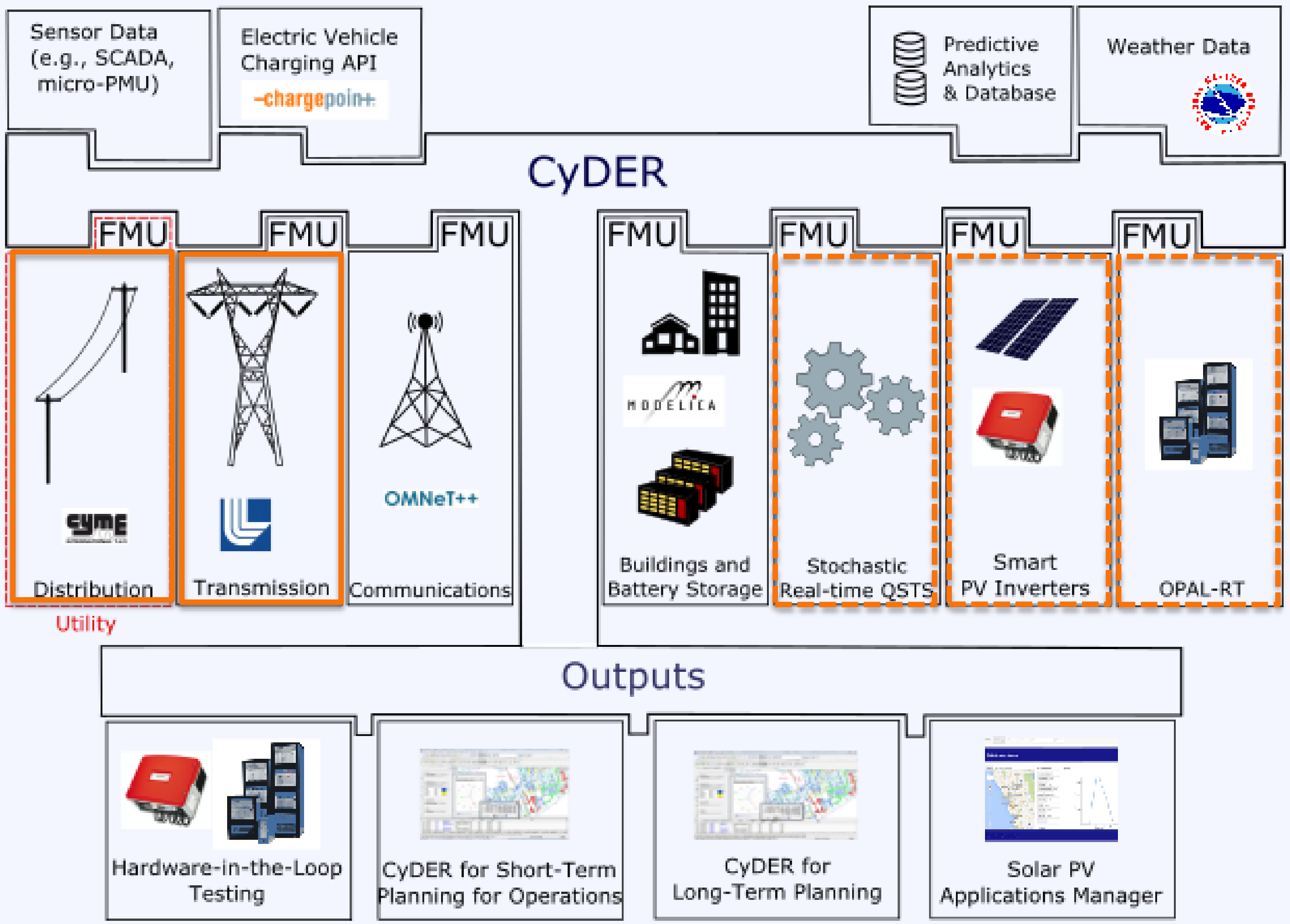
- Prototype a cyber-physical co-simulation platform for integration and analysis of high PV penetration that is
  - Highly modular
  - Scalable
  - Interoperable with commercial utility distribution planning tools
  - Integrates transmission and distribution (T&D) systems and their components

- Project will
  - Enable any level of high PV penetration
  - Handle large data sets
  - Decrease interconnection time and streamline processes

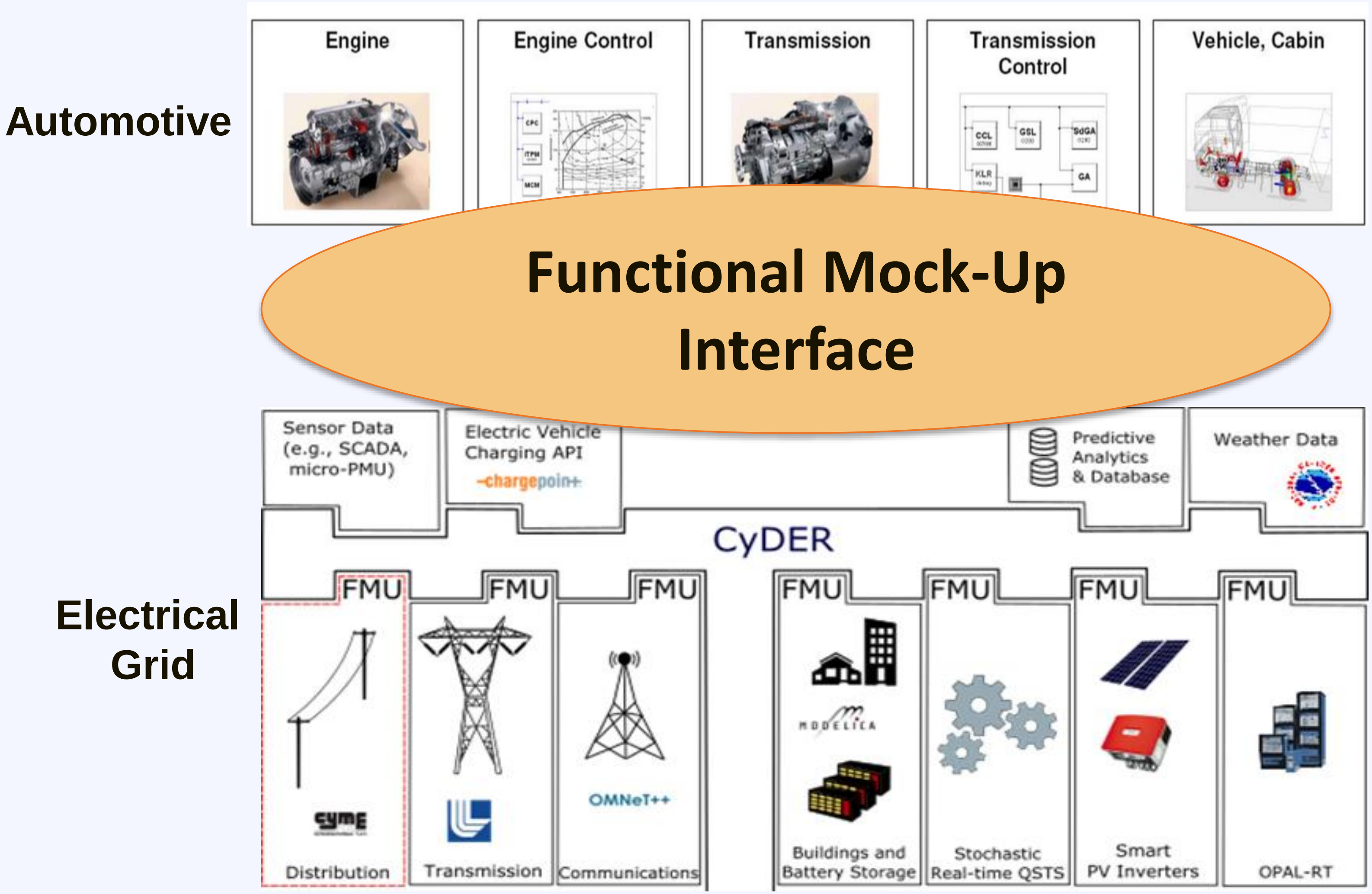
Innovation

- An advanced discrete-event co-simulation platform
  - Integrating the Functional Mock-up Interface (FMI) standard
  - For T&D co-simulation tool
- QSTS (Quasi-Static Time Series) Co-simulation
  - Enables system analysis over a time horizon rather than individual snapshots of time
    → especially useful for time-varying components such as EVs and PV
- Real-time Data Acquisition for Predictive Analytics
  - PV forecasts from weather and inverter data, EV charging forecasts from mobility data, feeder model validation with microPMU data
- PV applications manager
  - Expedite PV integration analysis and streamline utility/operator processes

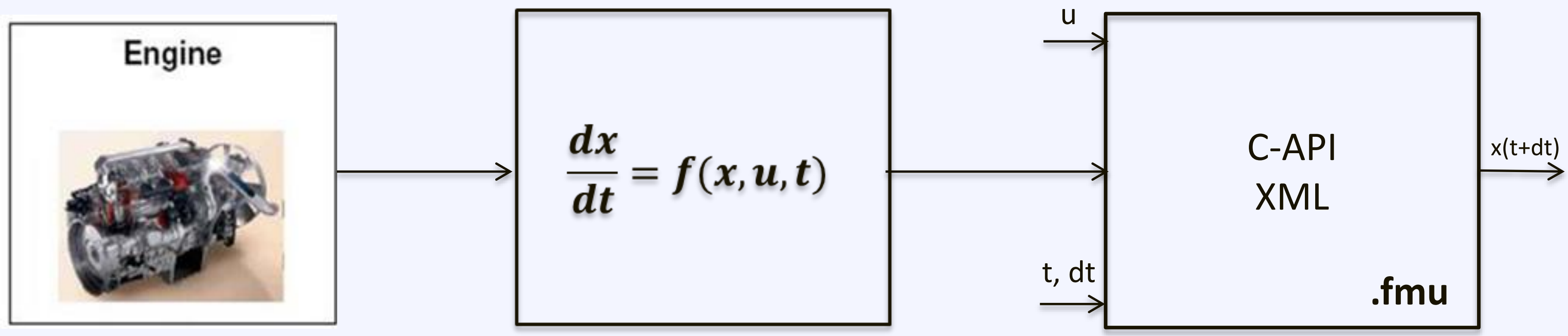
CyDER Concept

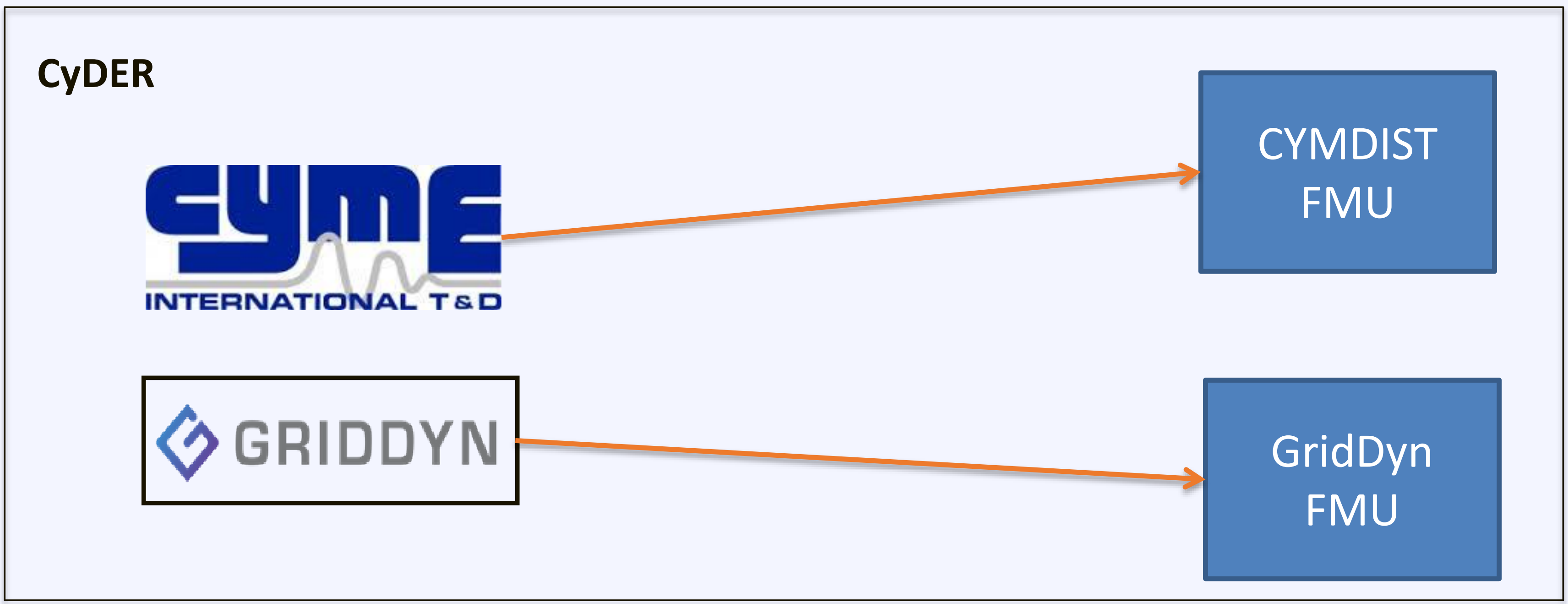


FMI Standard

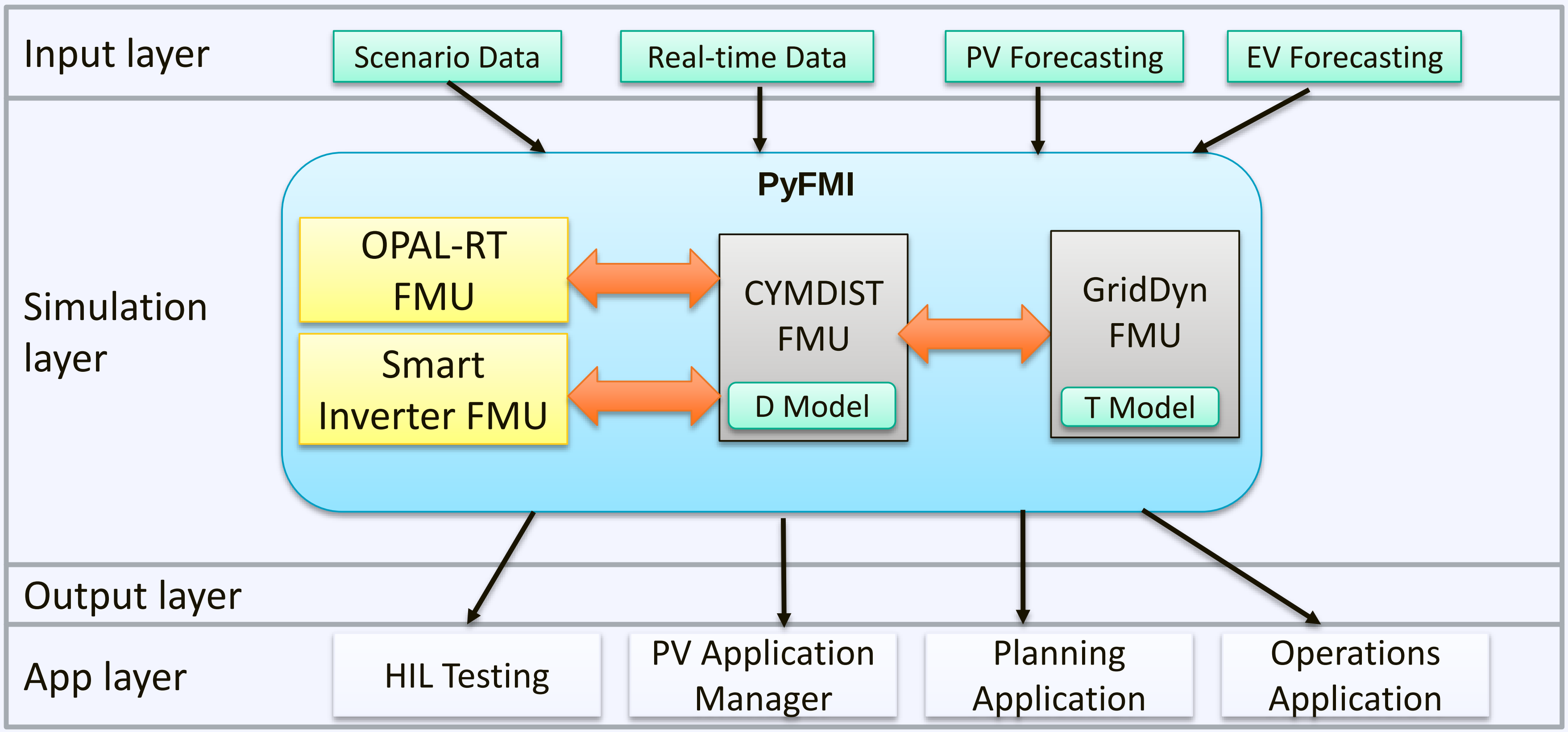


From Model to an FMU





CyDER System Architecture

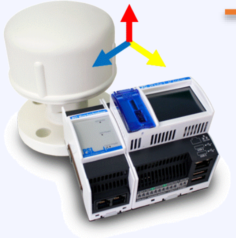


SunShot U.S. Department of Energy

CyDER for short-term planning for Operations

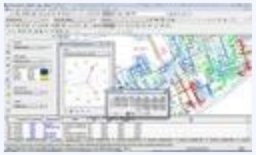
Data from EV Charging Stations

Real-time Data from SCADA and uPMU

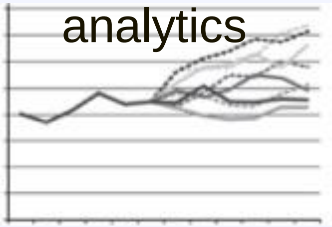


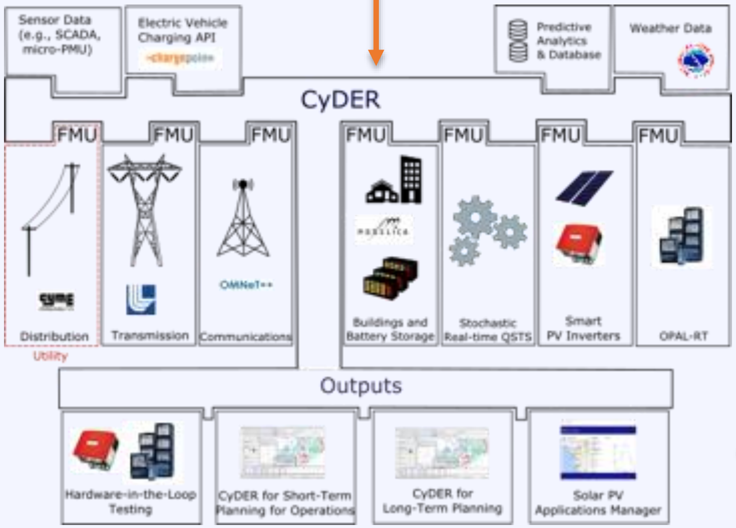
Real Network Data

QSTS and stochastic QSTS



Predictive analytics





<u>Outcome for Utilities</u>:
4-12 hours-ahead contingency analysis and appropriate planning of inverter setpoints and demand response

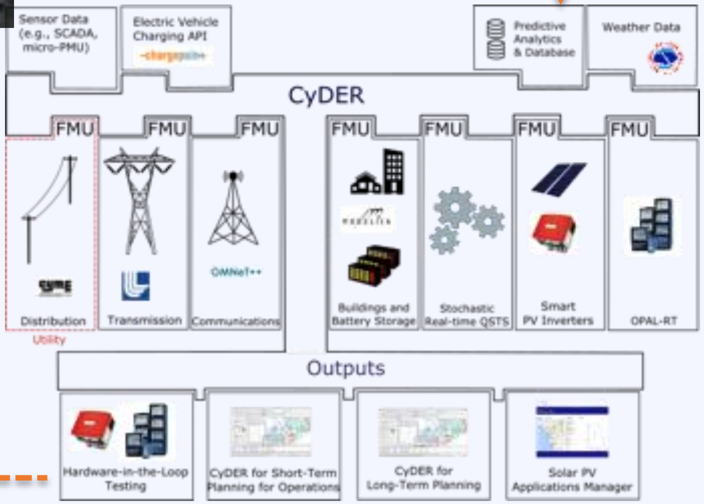
CyDER for Long-Term Planning

Forecasts of EV charging based on historic data

Multiple scenarios for load demand and PV Penetration

Real Network Data

LLNL's GridDyn for Transmission and CYMDIST for Distribution



Outcome for Utilities, Regulators, Consultants: Planning on Infrastructure Investments and novel DR control strategies to accommodate higher PV penetration

OPAL-RT Testing

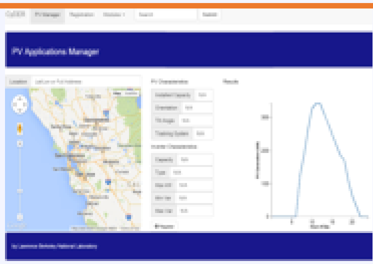
Smart Inverter Control Strategies

Hardware-in-the-Loop

CyDER PV Applications Manager

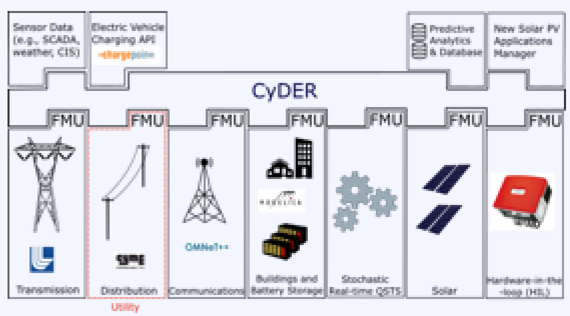
- Reduce PV interconnection approval time and cost:
  - <1 hour for residential, <5 days for commercial and utility
  - <$100 for residential, <$1,000 for commercial and utility

Applicant enters data for PV Interconnection



Location, PV Data

Automated Simulation Runs

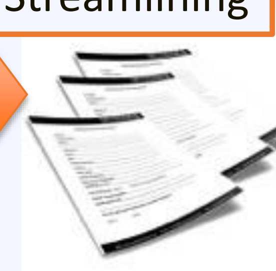


Distribution & transmission, DR, EV

Utility “single-click-accept/reject”

Checklist based on utility requirements

Streamlining



Automatic creation of all forms

Achievements & Challenges

- Achievements
  - Development and integration of individual modules for CyDER in FMI standard
  - Demonstration of use cases
  - Predictive analytics module for PV generation and EV charging

- Challenges (improvements to make)
  - Automated generation of FMUs

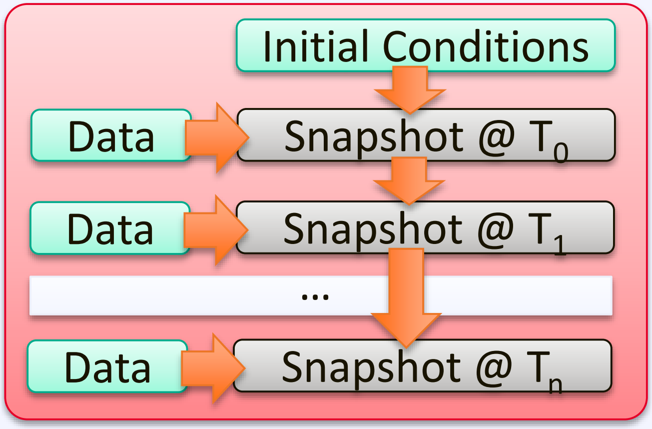
Demonstrations

Use cases of CyDER

- Use case 1: planning – housing development project with PV (> 500 kW) and EVs
  - Request by distributed PV aggregator
  - Location determined (not optional)
  - Possible market participation (CAISO) – for BP2
    - Can participate in both energy and ancillary markets as a DERP (DER Provider)
- Use case 2: operation – power quality issue with PV inverter
  - Frequent inverter connection issues with high voltage (>1.05)
  - Switched cap bank and LTC present
  - More PV installation anticipated (> 500 kW)
  - Diagnose high voltage issues, develop resolution plan with existing control and/or new mitigation strategies
  - Stochastic QSTS planned for BP2

Demonstrations

- Goal
  - To test successful interconnection of GridDyn and CYMDIST FMUs for QSTS simulations for multiple feeders and buses
- Distribution system input (load) drives the co-simulation at each time step
  - Load value changes by time step at the feeder
  - PV and EV scenarios create different load profiles

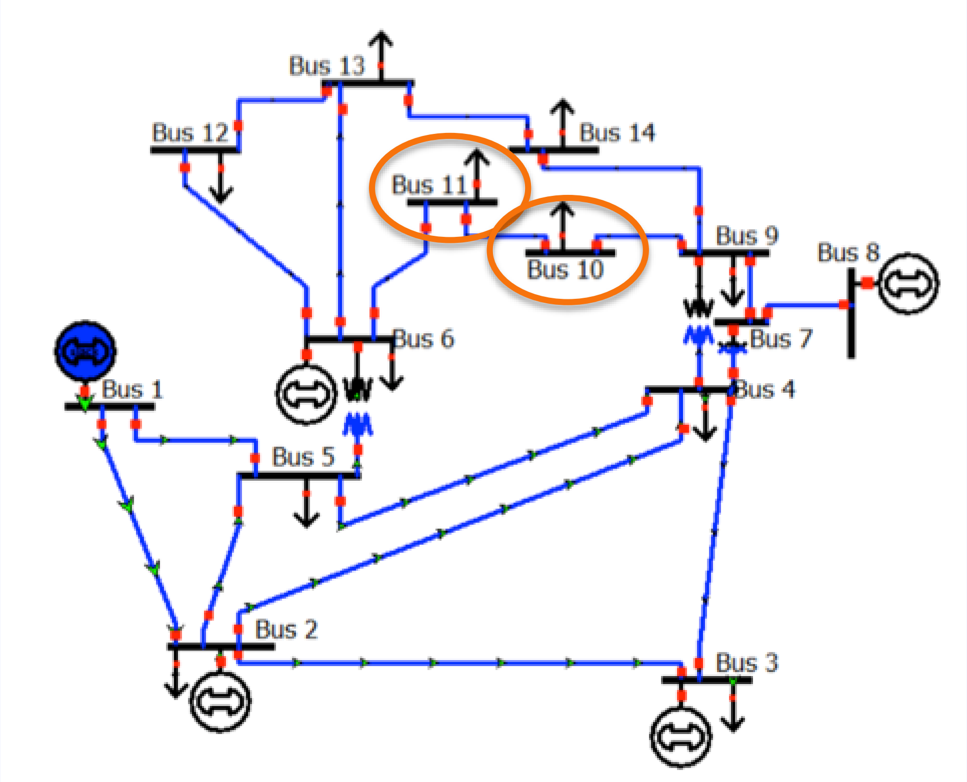


Demonstration: Grid Model

- Transmission (GridDyn): IEEE 14-bus test system
  - Feeders modeled at Bus 11 (3.5 MW, 1.8 Mvar load, 13.8 kV) and Bus 10
- Distribution (CYMDIST)
  - Feeder A at Bus 11
    - 4.2 kV, ~1.6 MW, 0.6 Mvar load
    - 161 nodes, ~2.2 miles, overhead+underground lines
    - 73 spot loads from which 40 are residential loads
    - 16 sections already installed with PV
    - 2 capacitor banks, one LTC for voltage regulation
  - Feeder B at Bus 10
    - 12.47 kV, ~3.2 MW, 1.8 Mvar load
    - 1097 nodes, 588 spot loads, ~10.7 miles, overhead+underground lines
    - 51 sections with PV installed
    - 5 capacitor banks, one voltage regulator

Demonstration: Grid Model

- Transmission system
  : IEEE 14-Bus Test System



http://icseg.iti.illinois.edu/ieee-14-bus-system/

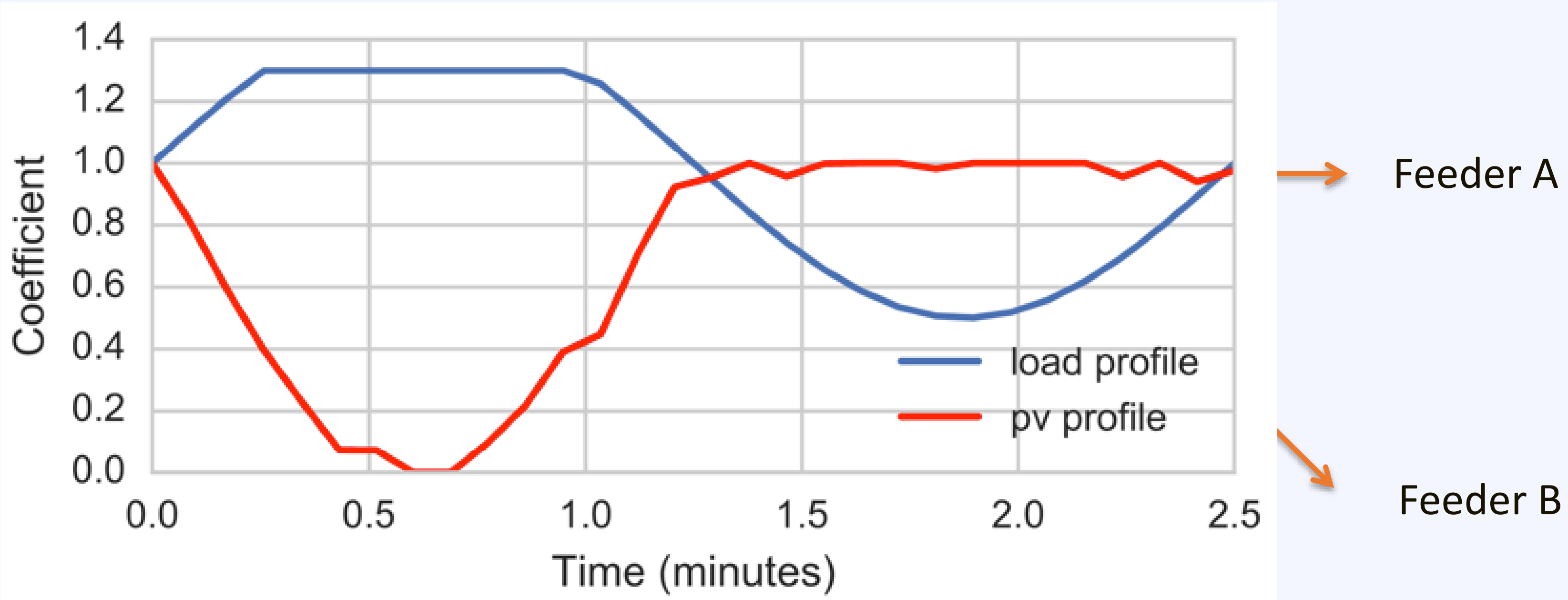
SunShot U.S. Department of Energy

Demonstration: Scenarios

- Scenarios
  1. Base case scenario
     : simple CYMDIST – GridDyn coupling over 2.5 minutes in 5-second interval
  2. Base case + 100 EVs on Feeder A, 200 EVs on Feeder B
     : over a day in 5-minute interval
  3. Base case + 100 houses on Feeder A,
     200 houses on Feeder B
     : each house with 3 kW load and 4 kW PV

Demonstration: Scenario I

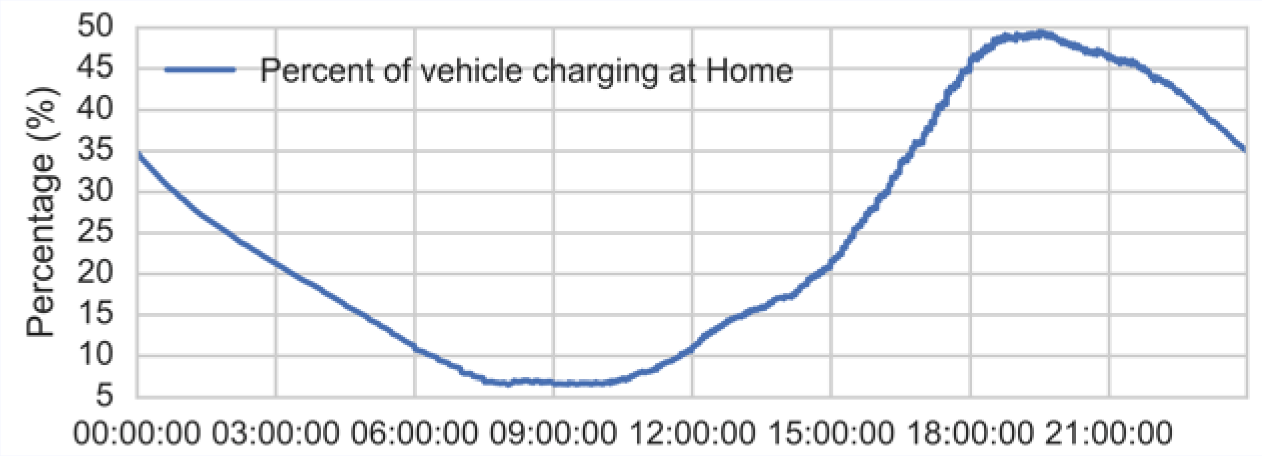
- Base case (2.5 minutes, 5 seconds interval)



Load and PV output change at every time step based on the profile

Demonstration: Scenario 2

- Electric vehicles penetration on the feeder



V2G-Sim simulation

× total EVs

= number of EV charging at *t*

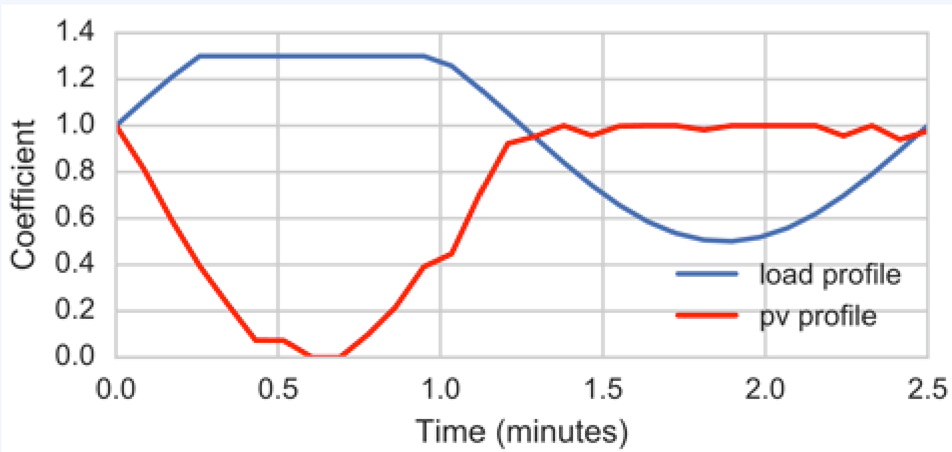
Feeder A

Feeder B

6.6kW power demand per vehicle

Demonstration: Scenario 3

- Base case + housing development scenario



Load and PV output changes at every time step based on the profile

+

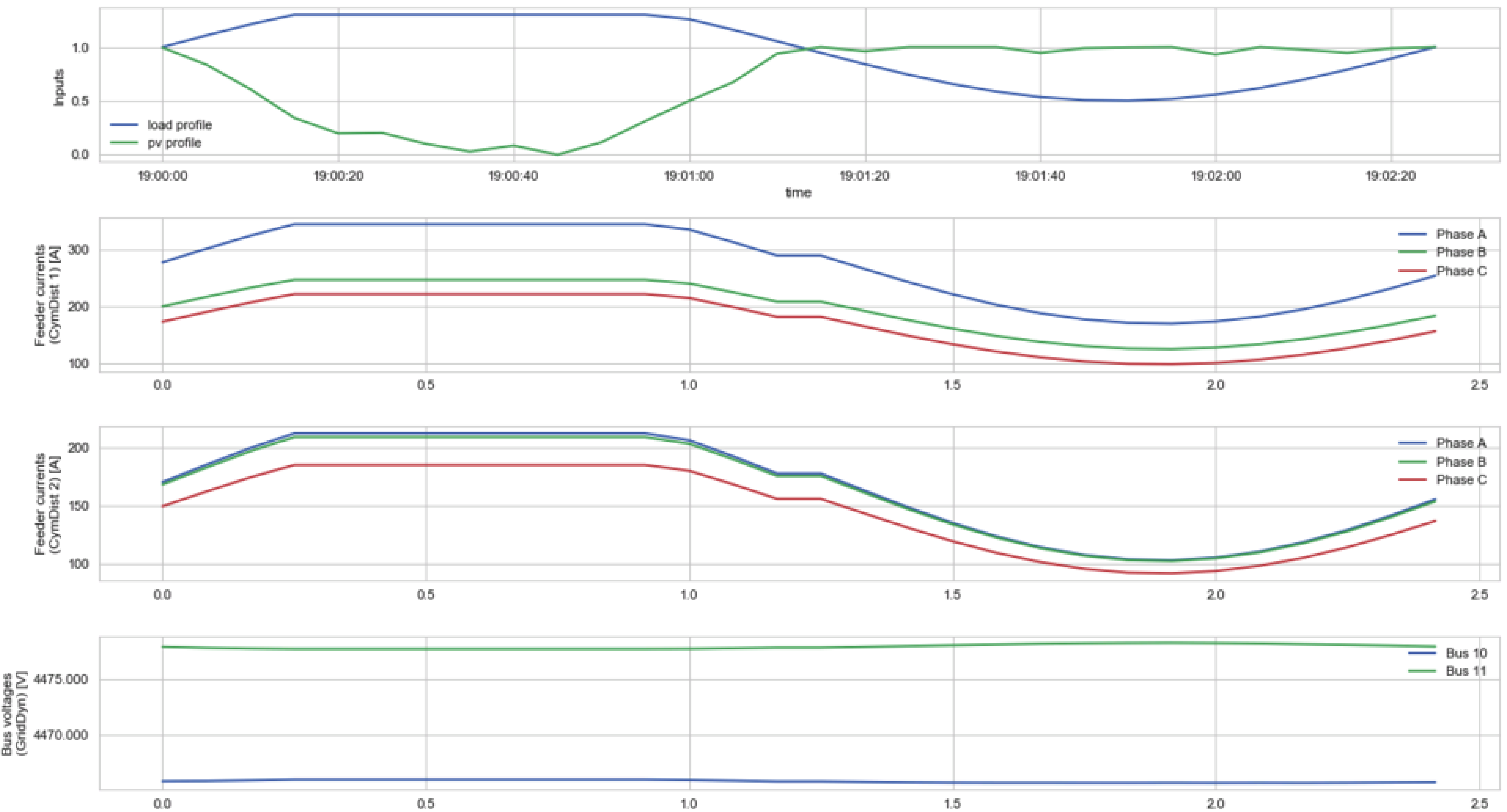
Housing development projects: 100 houses and 200 houses with each a 3kW power demand and a 4kW PV.

Feeder A

Feeder B

Demonstration: Case 1 Results

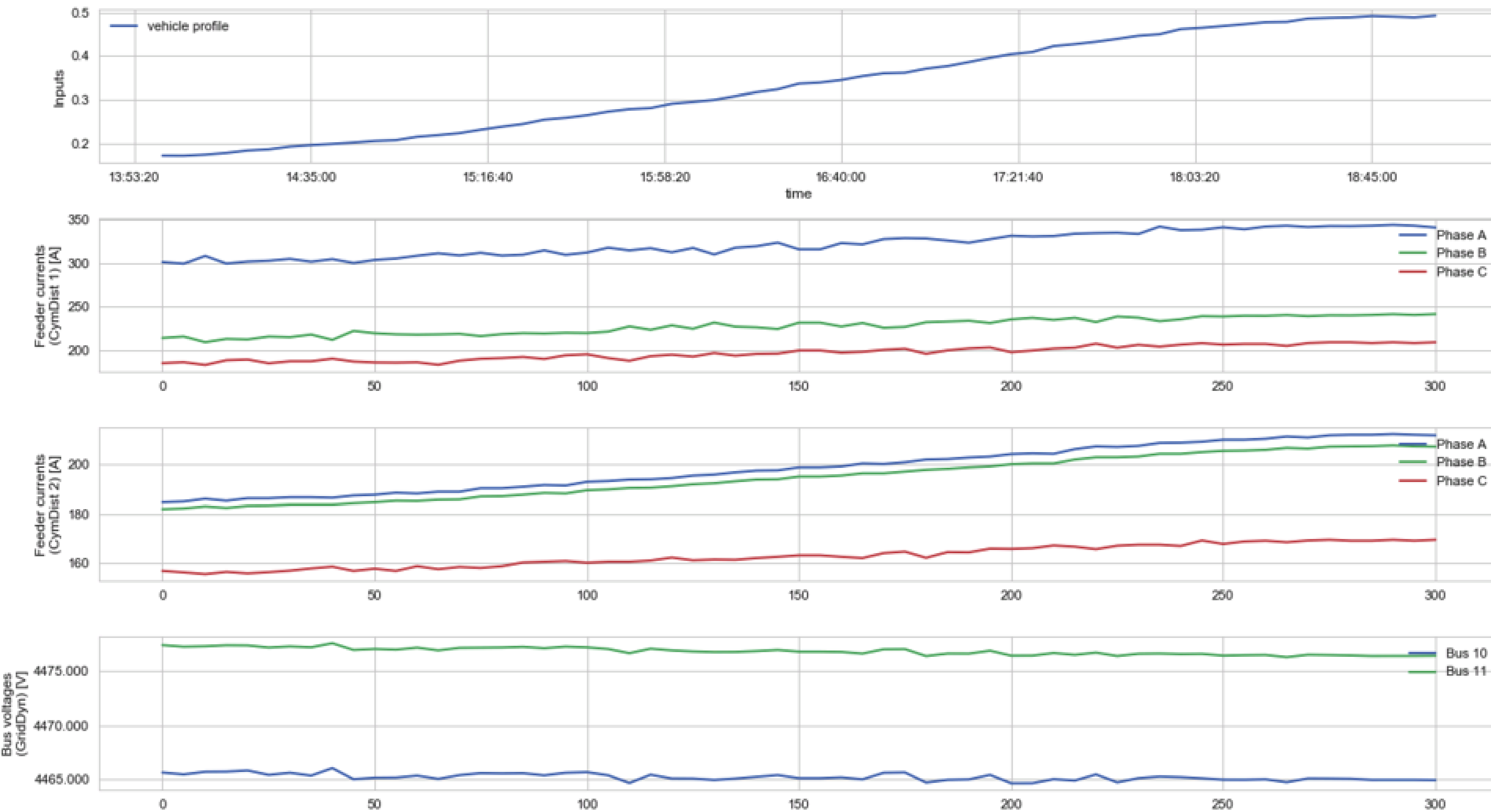
Base case (2.5 minutes, 5 seconds interval)



SunShot
U.S. Department of Energy

Demonstration: Case 2 Results

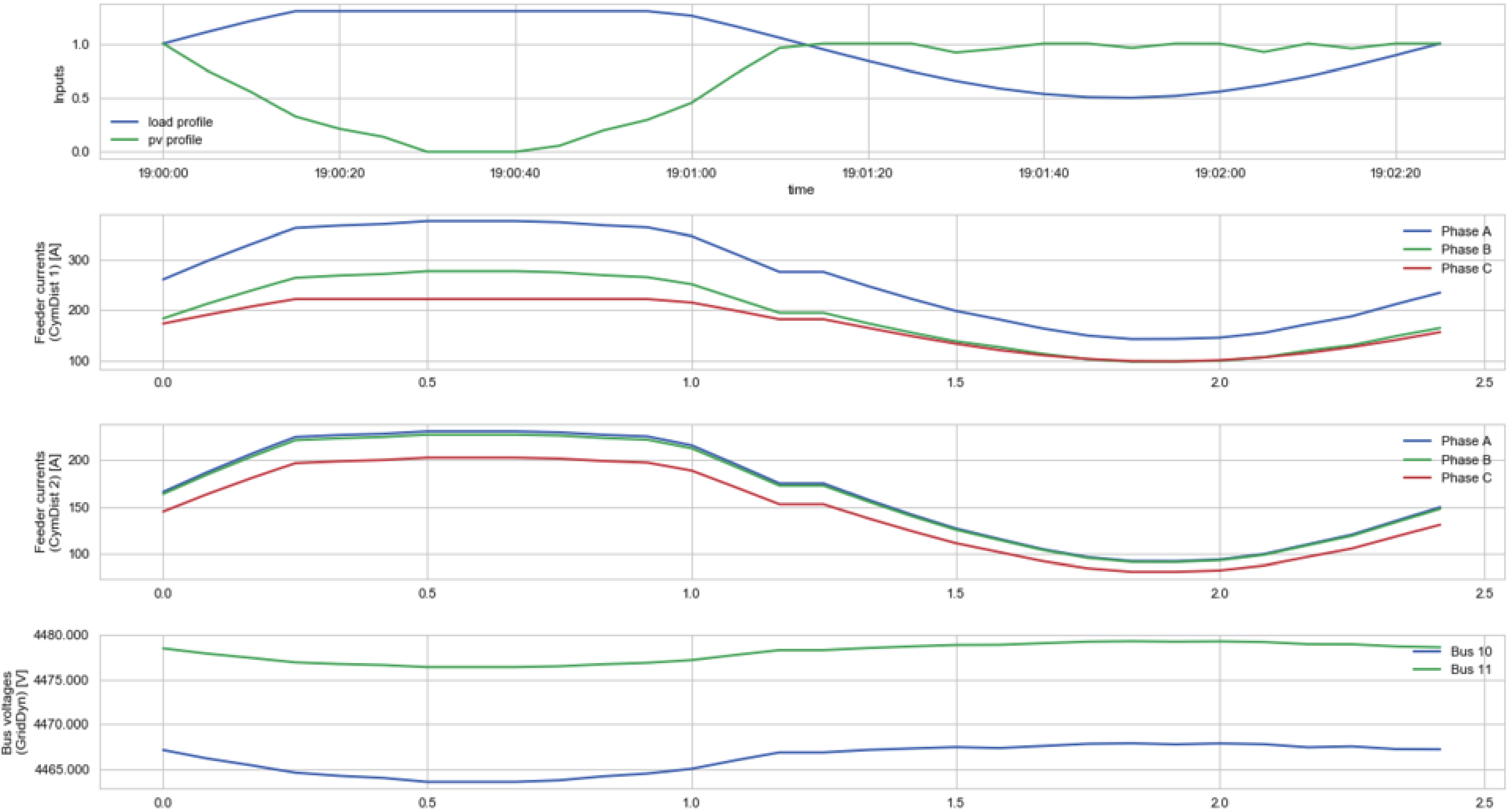
Electric vehicles



SunShot U.S. Department of Energy

Demonstration: Case 3 Results

Housing development

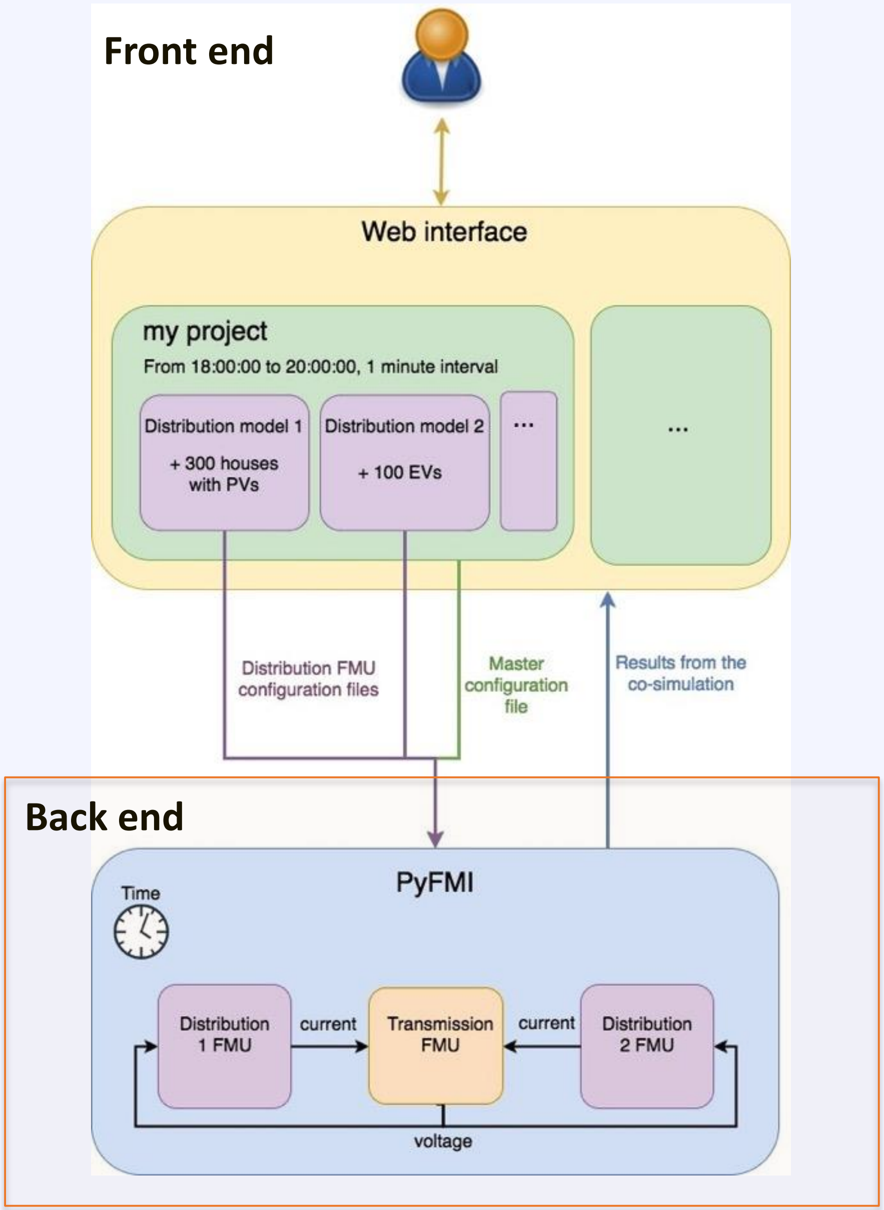


Thank you

CyDER system architecture

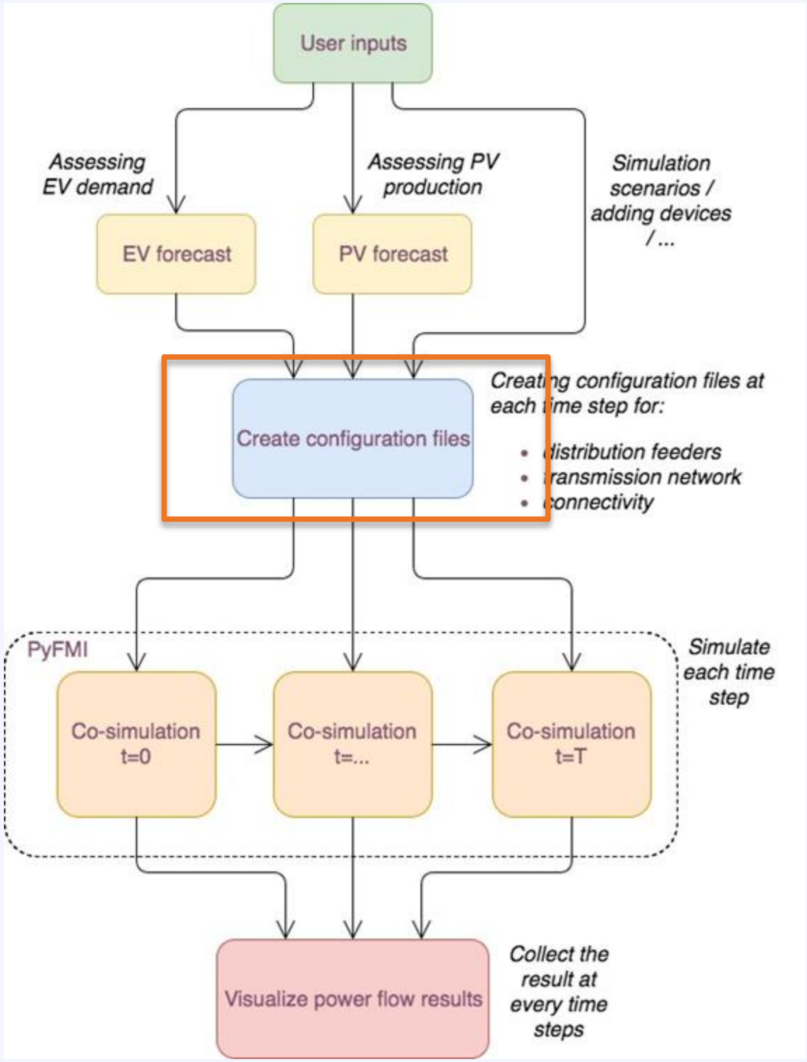
CyDER System Architecture

- Front end – Web interface
  - Enables users to create projects
  - A project contains a trans. grid + multiple dist. grids with individual scenarios (PV, EVs, …)
- Back end – Execution engine
  - Projects translated into configuration files for PyFMI
  - Results of simulation reported back to web interface

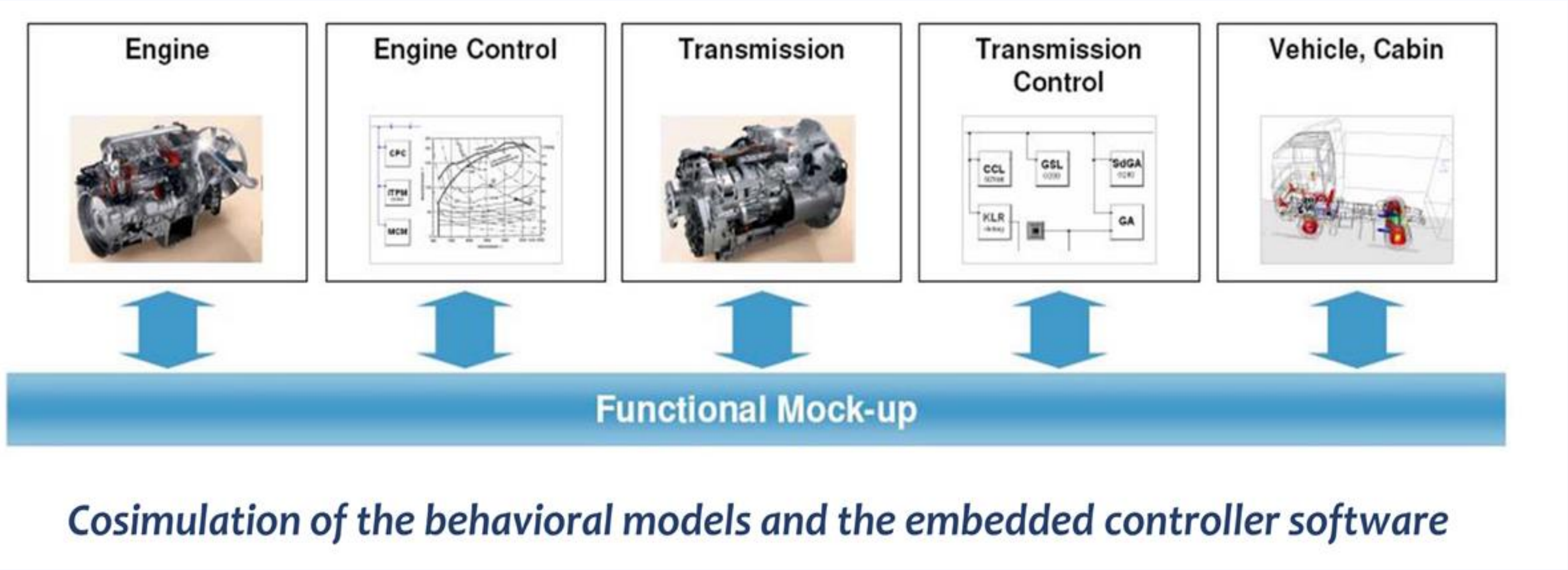


SunShot U.S. Department of Energy

CyDER System Architecture



FMI Standard



Developed to encapsulate and link models and simulators

Initially a 28 million € ITEA2 project with 29 partners.

Standardizes API and encapsulation of models and simulators.

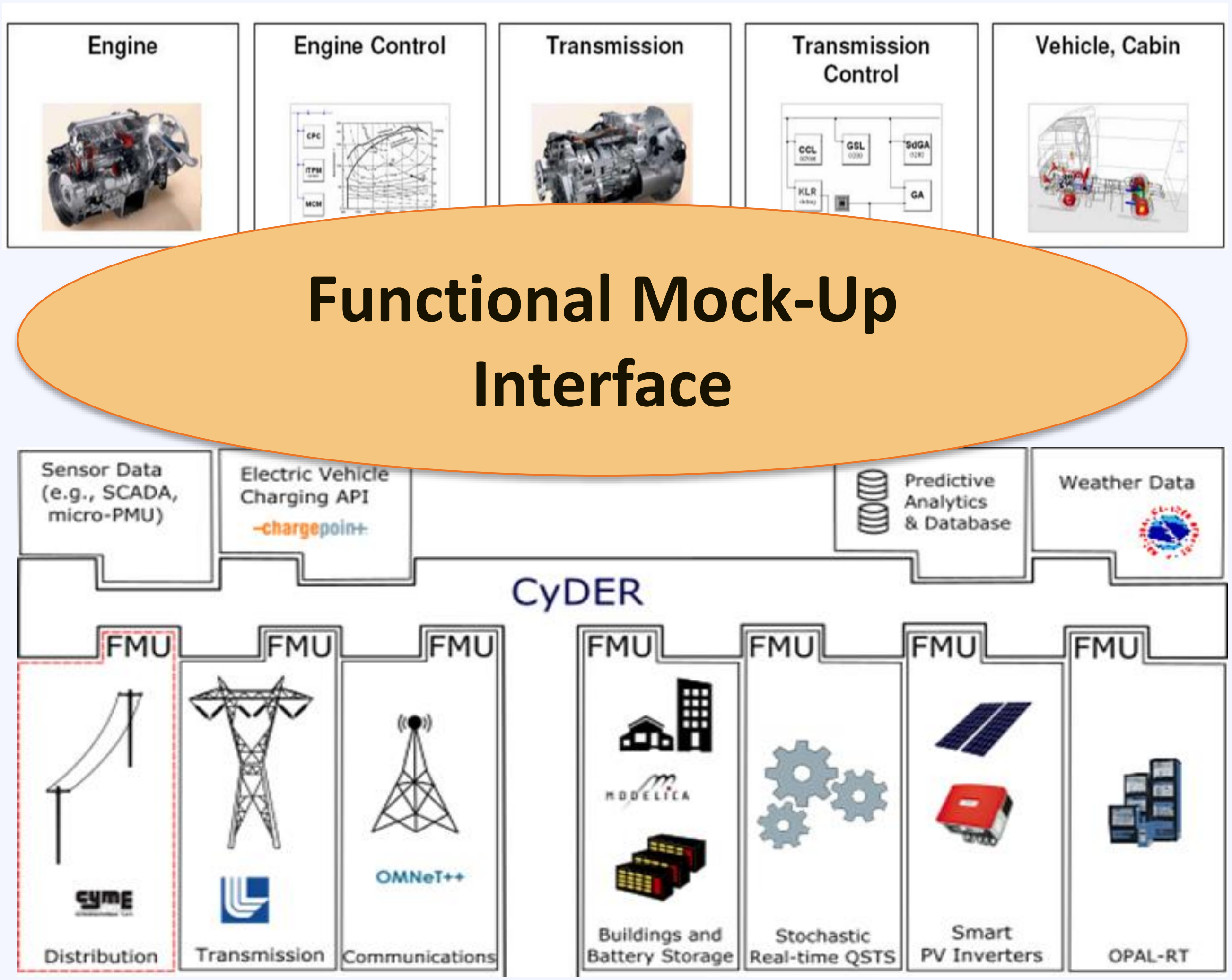
First version published in 2010. Second version published in 2014.

Initially supported by 35 tools, now supported by 90 tools.

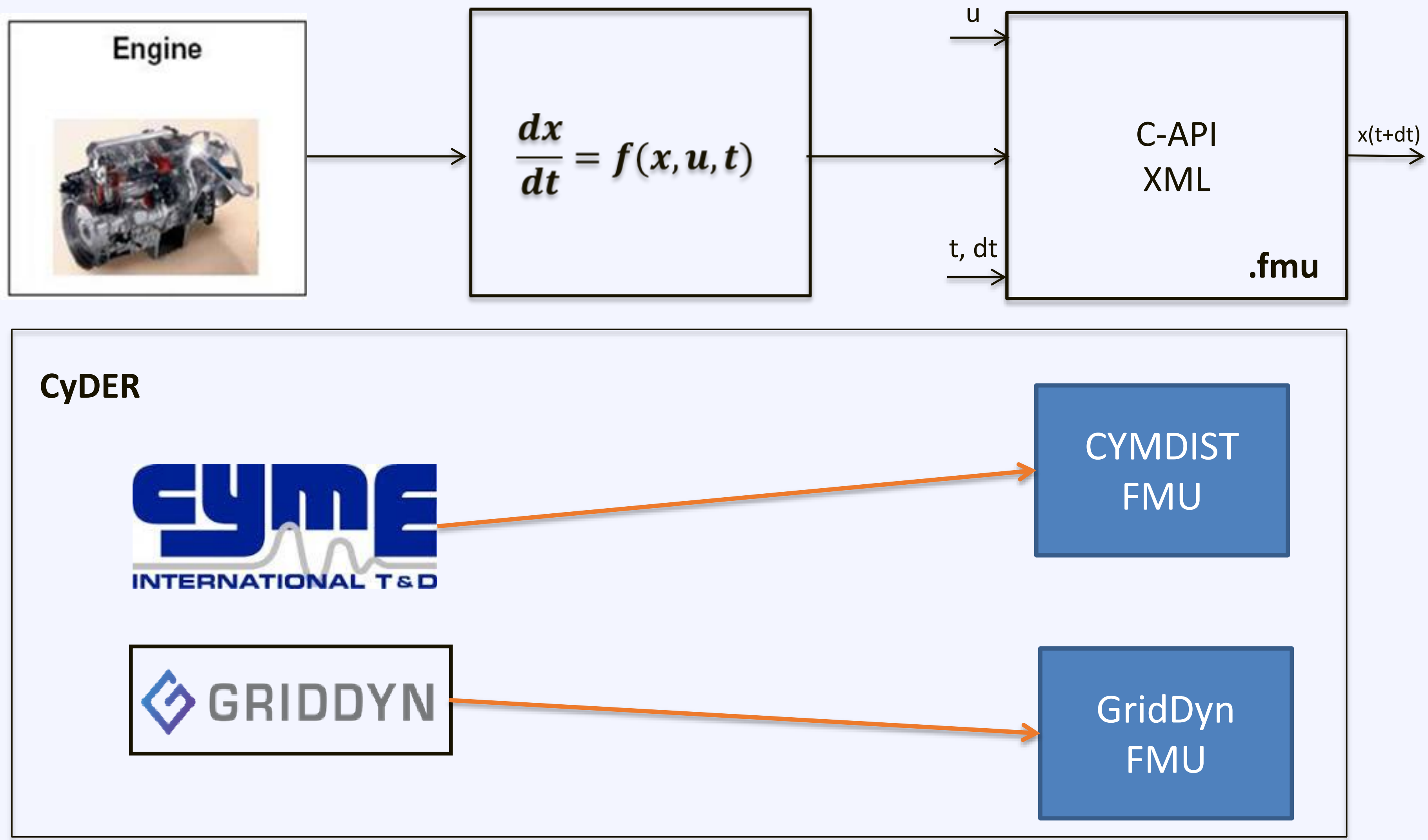
FMI Standard

Automotive

Electrical Grid

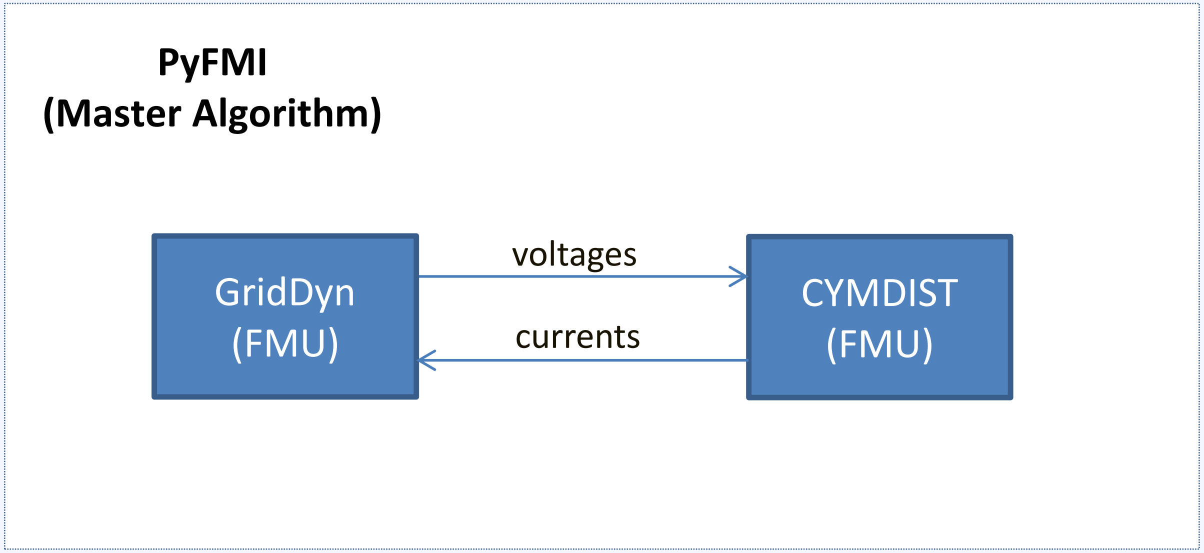


From Model to an FMU

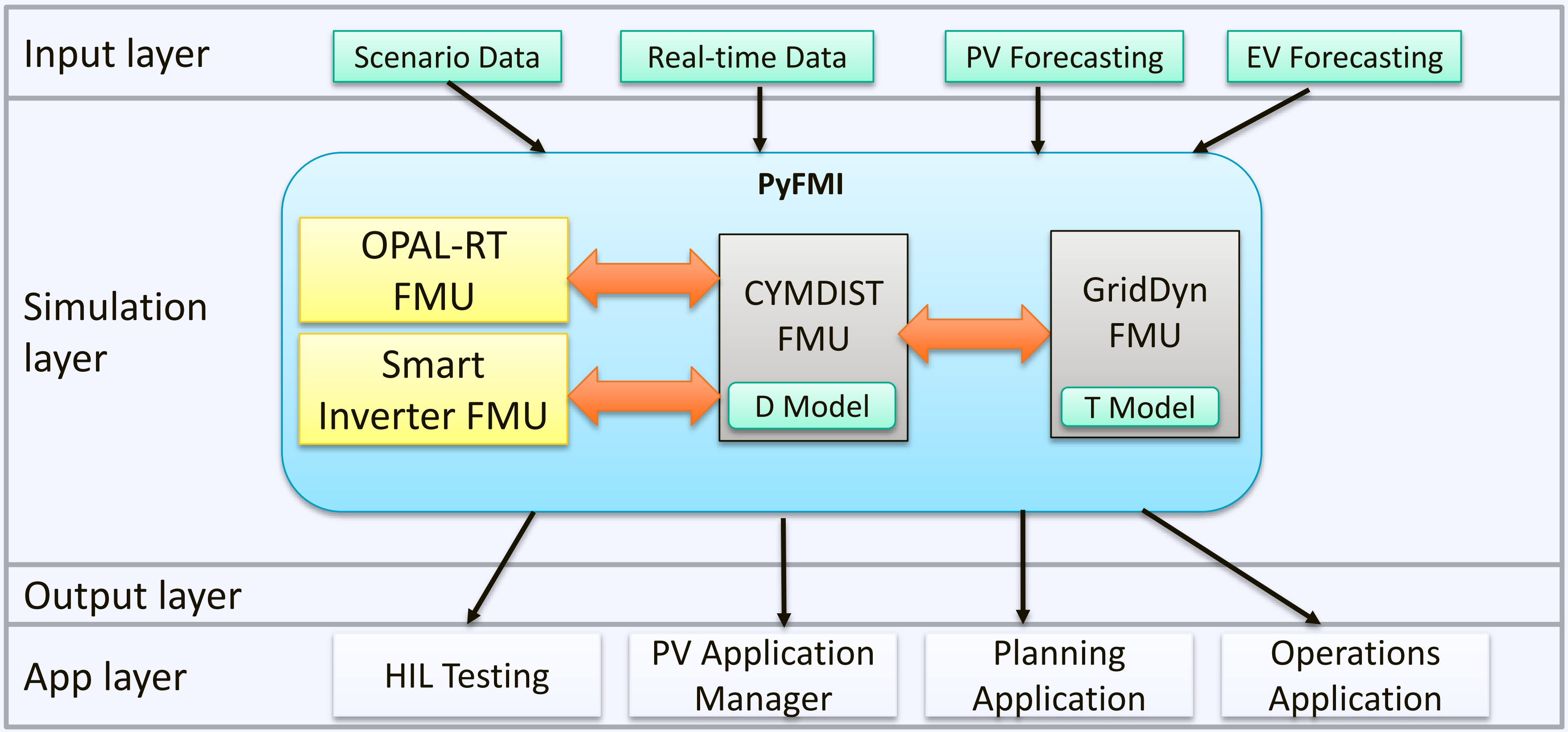


CYMDIST and GridDyn Coupling

- **PyFMI as Master Algorithm**
  - Python based and open source
  - All T & D models in same API
  - PyFMI can easily integrate new models



CyDER System Architecture



SunShot
U.S. Department of Energy

CyDER System Architecture

- Additional documentation (CYMDISTToFMU, Master Algorithm, Forecast module) are available at

  https://github.com/LBNL-ETA/CyDER