Electric Power HIL Controls Collaborative

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Microgrid and DER Controller Symposium

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U.S. DEPARTMENT OF ENERGY
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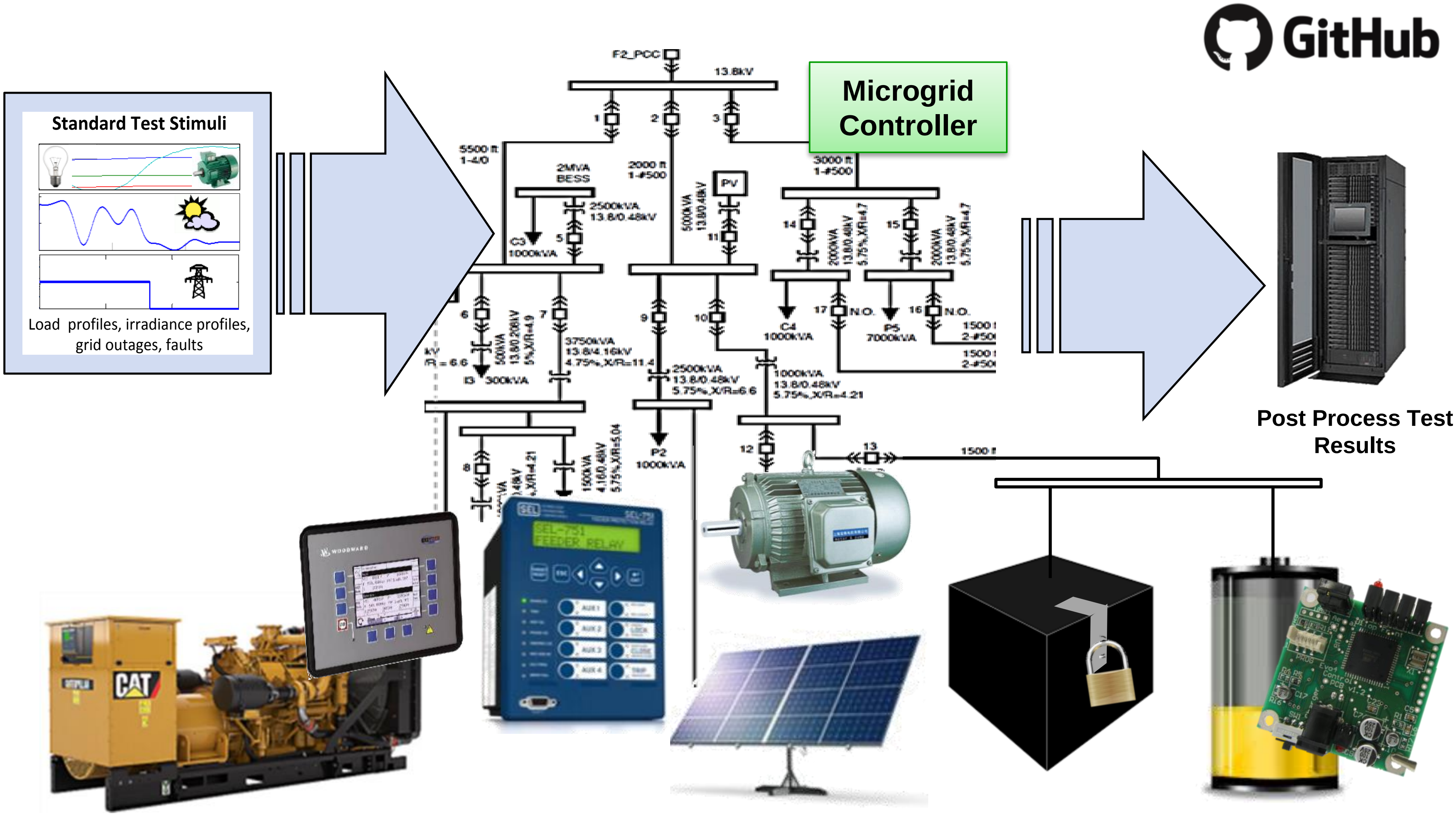
Overview

- EPHCC Overview
- Simulation Platforms
- Organization of Repository
- Component Details
- Typical Usage

Electric Power HIL Controls Collaborative (EPHCC)



HILLTOP Simulation Platforms

Typhoon HIL

From SEL

RTDS Technologies

From Eaton

PSCAD

MATLAB SIMULINK

speedgoat real-time simulation and testing

OPAL-RT TECHNOLOGIES

Carnegie Mellon University

MIT

CAMPS /
Smart Grid in a Room Simulator

Organized for Collaborative Design

- CaseStudies
- Components
  - CAMPS
  - RTDS
  - SimulinkOpal
  - SimulinkSpeedgoat
  - Typhoon
- DataProcessing
- DistributionSystems
  - SimulinkOpal
    - Banshee
    - Canary
    - Siren
- HighLevelDocs
- SimulationTools
- Templates

Contents of SimulinkOpal:

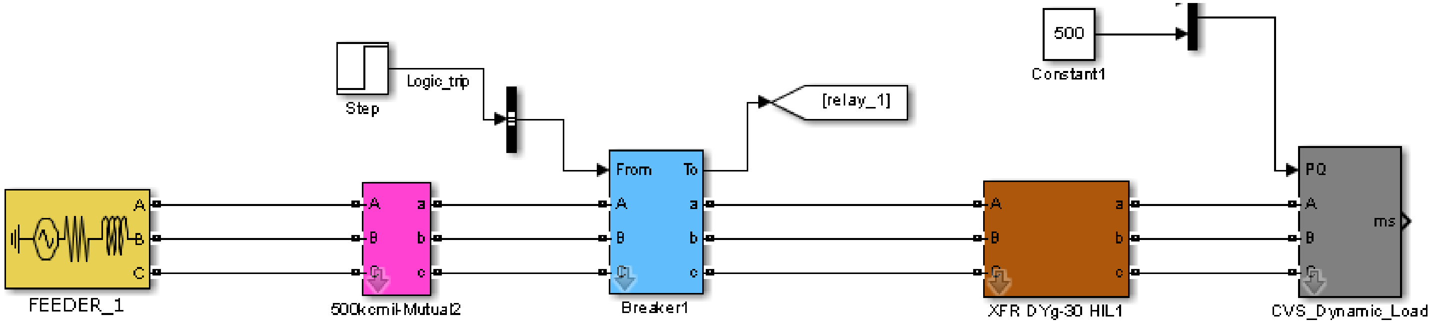
- SimulinkOpal
  - ActiveLoad
  - Cable
  - CHPandThermal
  - CircuitBreaker
  - DMSandTestSeq
  - EPC_BESS_PV
  - ESS
  - Fault
  - Genset
  - HWController_Diesel_Genset_4MVA
  - HWController_NGCHP_Genset_3p5MVA
  - HWCtrl_IO_InterfaceBlocks
  - MeasurementBlocks
  - Motor
  - PassiveLoad
  - PV
  - Relay
  - SEL751_InterfaceBlocks
  - Transformer
  - UDP
  - WoodwardEasyGen3500_InterfaceBlocks

Contents of Relay:

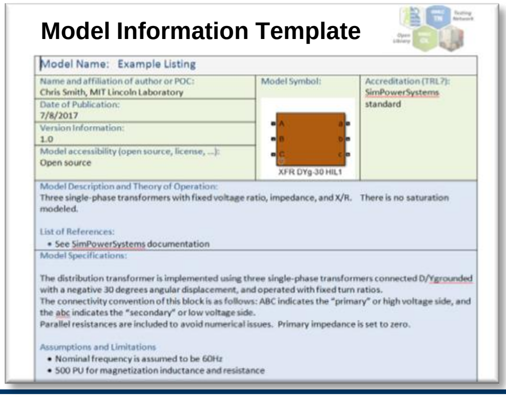
- relay_settings
- relays_configuration_files
- relay box wiring schematic20161104
- relay_ANSI_50P_script
- relay_ANSI_51P_script
- relay_ANSI_59P_script
- relay_ANSI_F25_lib
- relay_ANSI_functions_li
- relay_mgc_cmd_lib
- relay_modbus_lib
- relay_PLL_lib
- relay_PQSPF_lib
- RelayLogicDiagram
- SEL751_Test_F1
- SEL751_Test_F2
- SEL751_Test_F3
- SEL751Settings.rdb
- SEL751Settings
- SWRelay_CommTest
- UnitTest_relay_tripOutMng
- VC707_2-EX-0001-2_2_6_61-32AIO16DIO16DIOSel-01-01.bin
- VC707_2-EX-0001-2_2_6_61-32AIO16DIO16DIOSel-01-01.conf

Portable Components

- **Unit test model**
  - **Shows how component would typically be used**
  - **Which function a component does and does not meet**
  - **Allows for checking compatibility across simulation tools**



- **Documentation sheet**
  - **High level overview**
  - **References, theory, assumptions, parameters, etc.**



Model Information Template

Model Name: Example Listing

Name and affiliation of author or POC: Chris Smith, MIT Lincoln Laboratory	Model Symbol: XFR DYg-30 HIL1	Accreditation (TRL?): SimPowerSystems standard
Date of Publication: 7/8/2017		
Version Information: 1.0		
Model accessibility (open source, license, ...): Open source		

Model Description and Theory of Operation:
Three single-phase transformers with fixed voltage ratio, impedance, and X/R. There is no saturation modeled.

List of References:
- See SimPowerSystems documentation

Model Specifications:

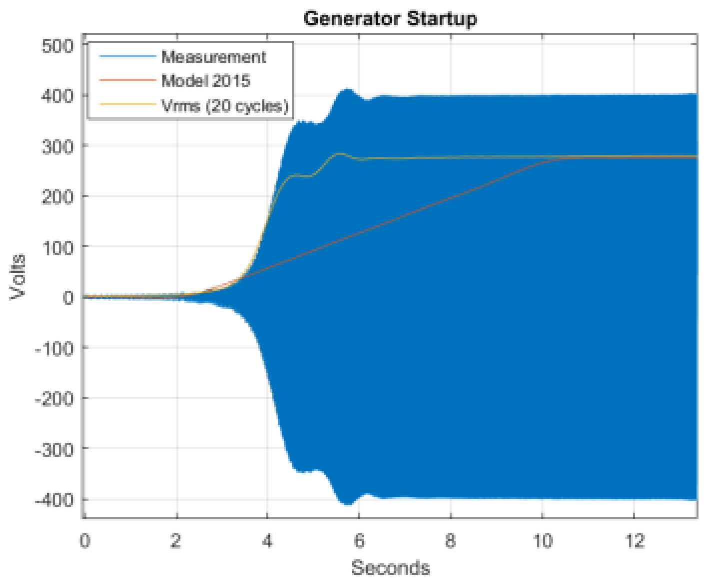
The distribution transformer is implemented using three single-phase transformers connected D/Ygrounded with a negative 30 degrees angular displacement, and operated with fixed turn ratios.
The connectivity convention of this block is as follows: ABC indicates the "primary" or high voltage side, and the abc indicates the "secondary" or low voltage side.
Parallel resistances are included to avoid numerical issues. Primary impedance is set to zero.

Assumptions and Limitations
- Nominal frequency is assumed to be 60Hz
- 500 PU for magnetization inductance and resistance

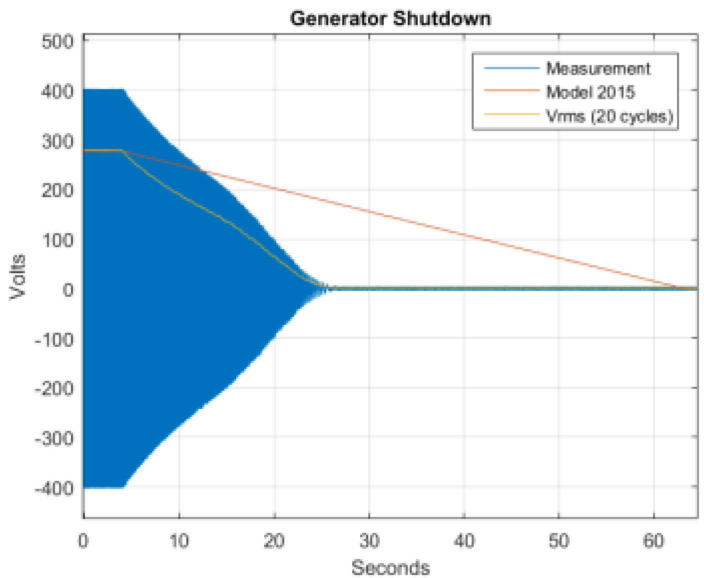
Diesel Powered Synchronous Machine

- 1 MVA
- 480Vac
- 3 phase

- **Field verified model elements**
  - Governor
  - Field Regulator
  - Prime mover
  - Electric machine

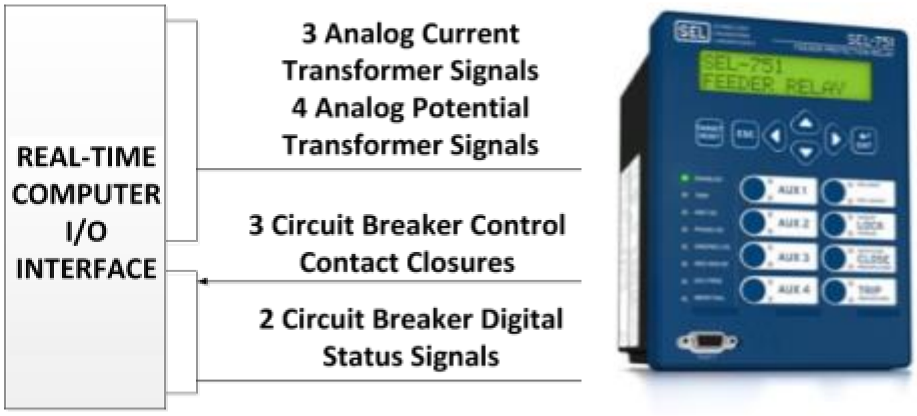


Start-up of Generator and Model

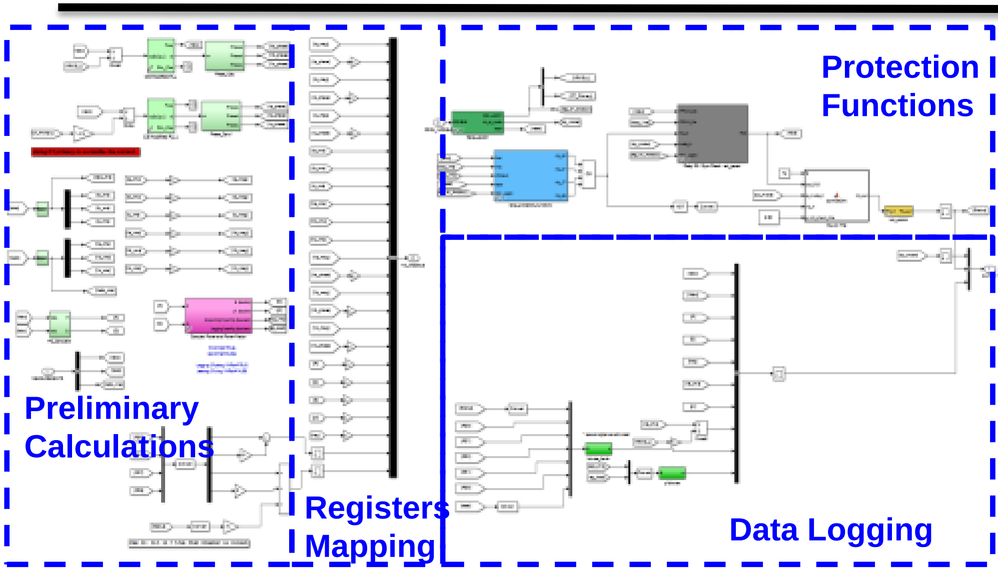


Shutdown of Generator and Model

CHIL Integration – SEL 751 Relay



OPAL-RT INTERFACE WIRING DIAGRAM



- SEL Collaboration
- Three feeder protection relays implemented in hardware
- Hardware I/O interface to PTs, CT's, breakers
- Protection features:
  - Overcurrent (50, 51)
  - Over/under voltage (27, 59)
  - Synchronism check (25)
  - Grid-tied protection
  - Islanded protection
- Modbus TCP interface

Component Inventory for Model Curation

Component Type	Repo. Category	Description	IP Owner	Dev. Environment	Real-time Platform	Verification	Fidelity
Breaker	SW device model	Ideal switch w/ time delay	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Breaker	SW device model	*Oil*					
Breaker	SW device model	*Gas-insulated*	*SEL*				
Breaker	SW device model	*Molded case*					
Cable	SW device model	Cable, RL, not coupled	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Cable	SW device model	Cable, RL, coupled	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Cable	SW device model	Cable, Pi section	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Transformer - 3ph	SW device model	D-Yg, linear magnetizing branch	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT		
Transformer - 3ph	SW device model	*D-Yg, non-linear magnetizing branch*					
Transformer - 3ph	SW device model	*Yg-Yg*					
Transformer - 3ph	SW device model	*D-D*					
Transformer < 3ph							
DG - Machines	SW device model	Diesel genset	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	3 - agrees with literature	
DG - Machines	SW device model	Diesel genset	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	4 - unit tested	
DG - Machines	SW device model	Governor	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
DG - Machines	SW device model	AVR	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
DG - Machines	SW controller	Diesel genset controller	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT		
DG - Power Electronics	SW device model	Generic power converter, 3ph, bidirectional, average model	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT		
DG - Power Electronics	SW device model	Generic power converter, 3ph, bidirectional, switching model	MIT-LL		OPAL-RT		
DG - Power Electronics	SW controller	Battery: grid-tied power converter controller	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
DG - Power Electronics	SW controller	PV: Grid-tied inverter controller	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Load	SW device model	Static PQ					
Load	SW device model	Static RL	MIT-LL	Matlab 2011b, SimPwrSys	OPAL-RT	2 - textbook implementation	
Load	SW device model	Static ZIP					

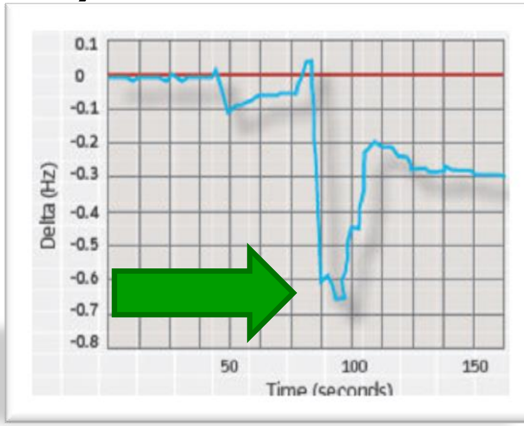
- **Work continues to identify additional key components and additional industry partners**

Typical User Story

- **A new microgrid has a “special” critical load**
- **Customers want to be ensured that it can always be supported**
- **Everyone thinks it should be fine except:**
  - **During worse case conditions (hard to run on the real system)**
  - **Unsure if all the relay protections will allow**
  - **Too costly to run through all the scenarios on site**

Typical User Story (con't)

- An engineer quickly assembles a model that uses
  - Existing components
  - Existing test feeder
  - New site specific load stimuli
- Simulations are run and things look good but
  - one relay function isn't available (under frequency - 81)
- The relay component is modified to include new feature
- Simulations are re-run and an under frequency trip is found
- Settings are tweaked and now things look good
- New component is uploaded to EPHCC repository



Use Case: Evaluate new technology ability to provide grid services

Use Case: Evaluate novel energy storage technology

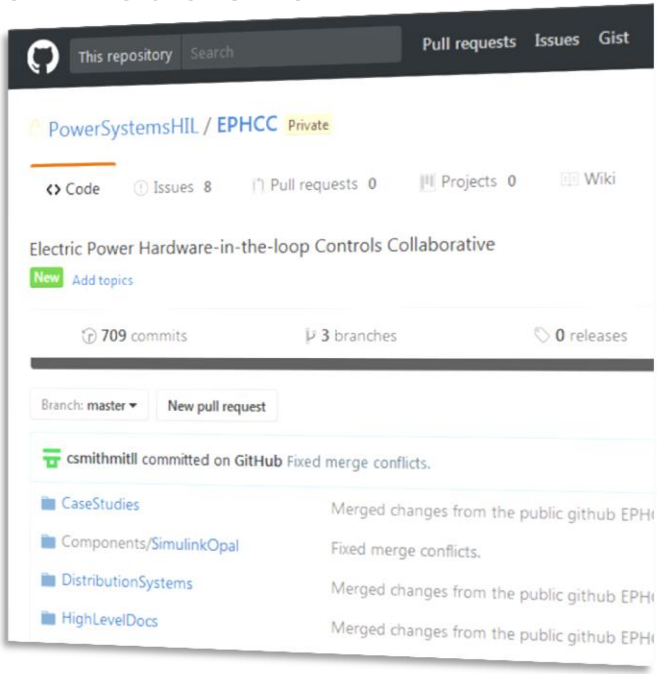
LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Use Case: Evaluate effect of high PV penetration on feeder

Use Case: System integrator evaluates applicability of novel solution

Conclusion

- **EPHCC Repository is an excellent source of models for microgrid simulation**
- **FY15 repository is public**
- **FY17 will be made public on GitHub in coming weeks**
- **Interest in working with users to improve**
  - **Breadth of components**
  - **Validation**
  - **Test cases**
  - **Simulation platforms**



https://github.com/powersystemshil

- **Collaboration will reduce cost to simulate microgrids . . .**

…and accelerate deployment!