Phasor-based Power Control at the SyGMA lab, UCSD

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The SyGMA Lab at SDSC, UCSD

R&D in the emerging technology on electric grid instrumentation by development of new data processing, dynamic modeling and model validation tools for Synchrophasor Grid Monitoring and Automation of electric networks.

OSIsoft. Data storage and Processing

NATIONAL INSTRUMENTS — Hardware and Control Algorithms

SDGE — Applications/Control Algorithms on RTDS

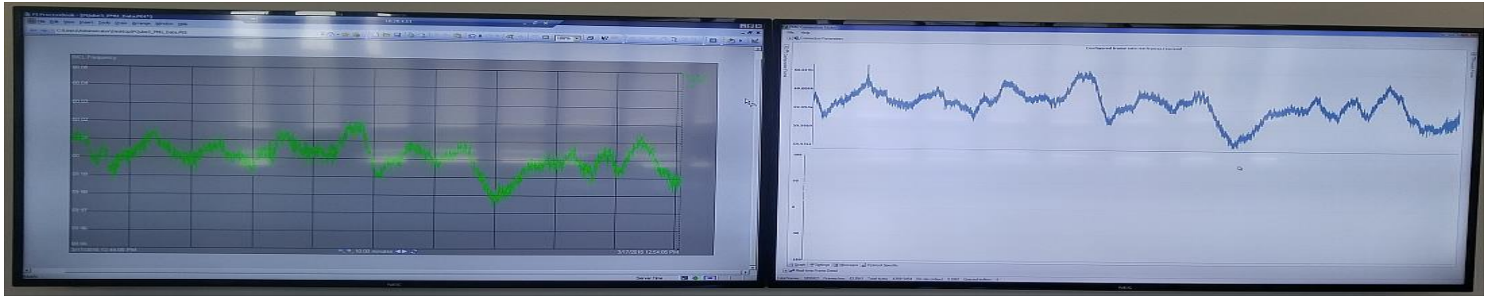
SDSC SAN DIEGO SUPERCOMPUTER CENTER — Facilities and Business Services

San Diego Supercomputer Center at UCSD

- Organized Research Unit & National Laboratory
- Considered a leader in
  - data-intensive computing
  - cyberinfrastructure
- Provides resources, services, and expertise to the national research community
- Co-located “green” data center

Use of OSIsoft products at the SyGMA lab

- PI Interface for C37 data stream from PMUs
- PI Data Archive & PI Asset Framework for PMU data
- PI Processbook for Display of Grid Disturbance Events



- PI Datalink for download of data (classes/courses)
- PI to PI interface (with SieGate)
- PI Advanced Computing Engine and Event frames

Expertise and Contributions SyGMA Lab

Unique to SDSC/UCSD/OSIsoft collaboration

- Training environment for partners and students
- Collaboration between researchers and industry partners

Current Contributions

- Event Detection driven by PMU data
- Dynamic modeling and validation of power flow

New Projects/Research

- Synchrophasor data quality validation
- Equipment monitoring using PMU data
- Monitor and control islanding conditions of μ-grids (CEC project)

Why Grid Monitoring and Automation?

- Phasor Measurement Unit (PMU) data:

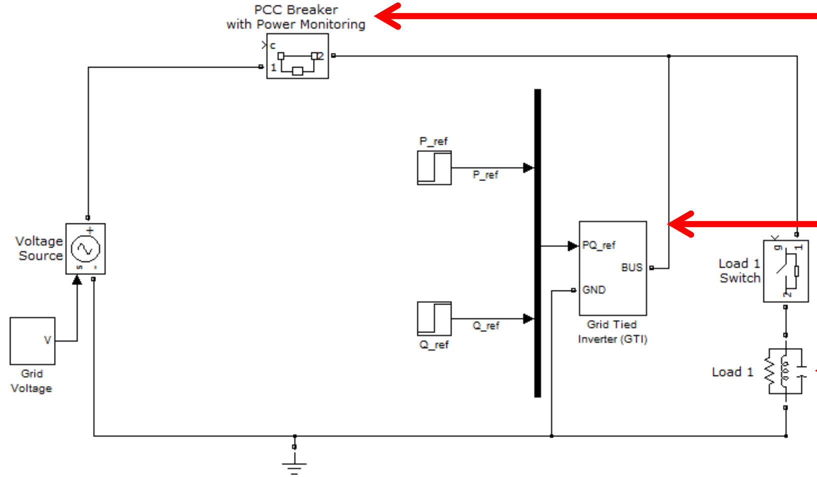
ATTRIBUTE	SCADA	PMU
Resolution	1 sample every 2-4 Seconds (steady State Observability)	10-60 samples per second (Dynamic Observability)
Measured Quantities	Magnitude only	Magnitude and phase angle
Time Synchronization	No	Yes
Total Input/output Channels	100+ Analog & Digital	~10 Phasors, 16+ digital, 16+ analog
Focus	Local monitoring and control	Wide area monitoring and control

- Vision: provide automated control solution to improve efficiency, reliability & security of a power grid based on real-time PMU data

Why Grid Monitoring and Automation?

- Conventional control of power systems:
  - Does not function well with distributed energy resources
  - Real power modulation using frequency control with operator
  - Coupling and slow controls: erratic frequency and voltage
- Advanced Control from Sempra/OSIsoft simulated & tested in the SyGMA Lab:
  - Real-time phasor feedback and dynamic model of grid
  - Fast and de-coupled control of real & reactive power
  - Frequency and voltage control in island mode

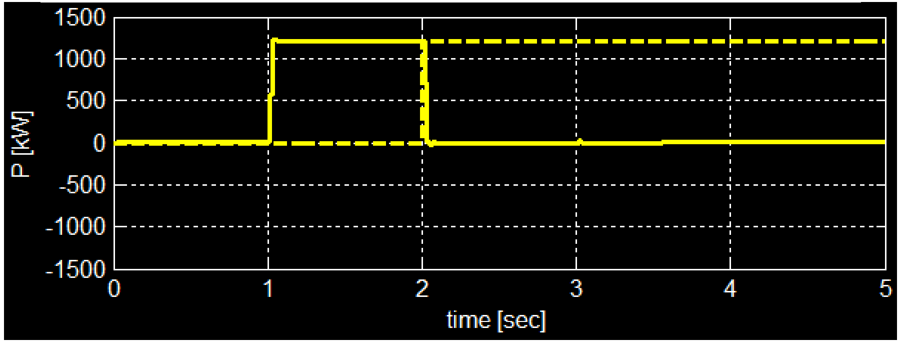
Motivating Example: “simple” decoupled power

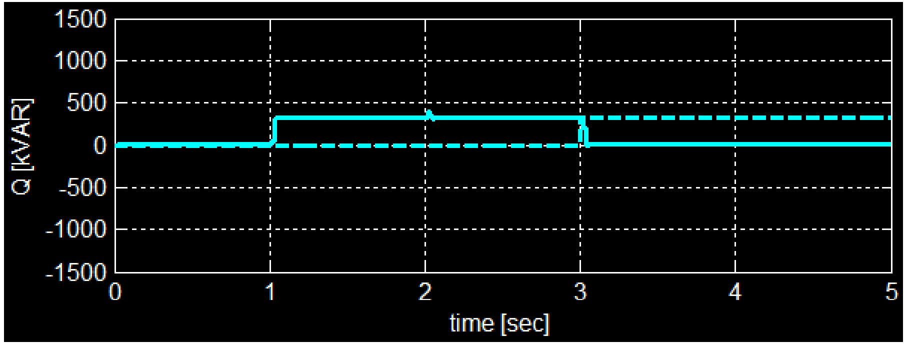


Power Flow at POI

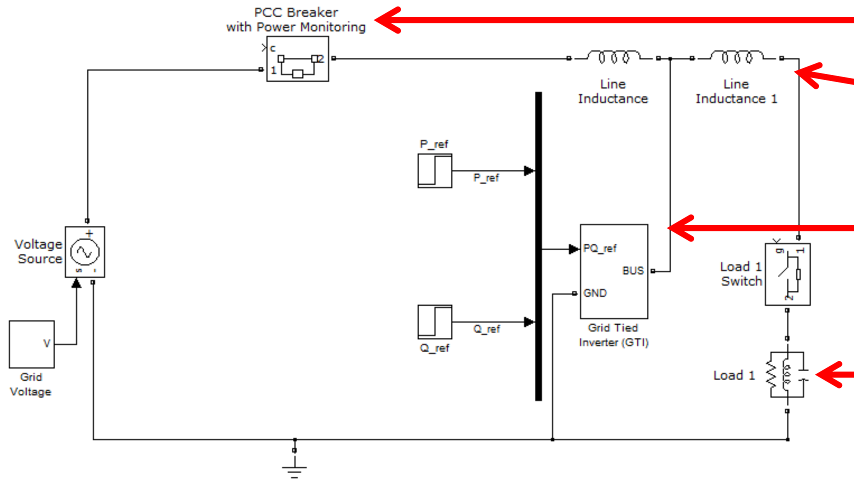
Grid Connected Inverter
(with P,Q references)

Single RLC load
(switched on at t=1sec)





Motivating Example: “difficult” coupled power

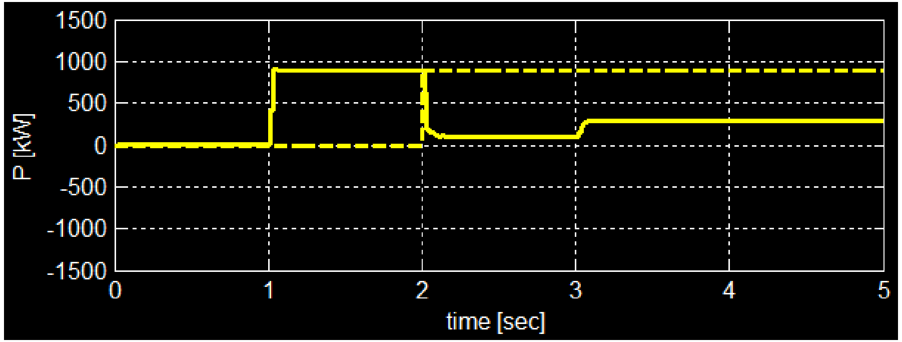


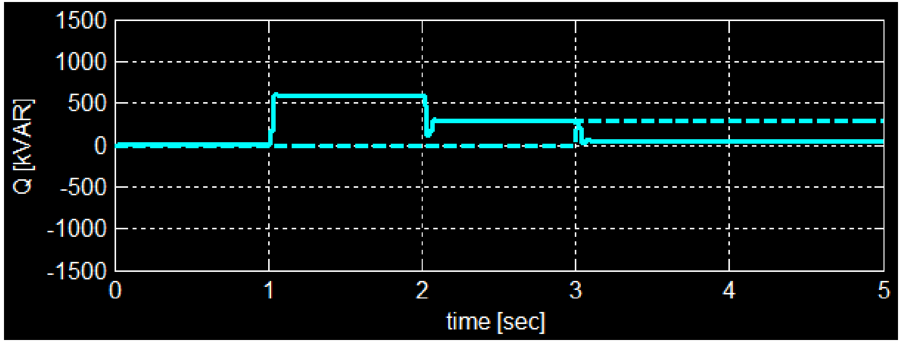
Power Flow at POI

Additional Line Impedance
(at grid and load buses)

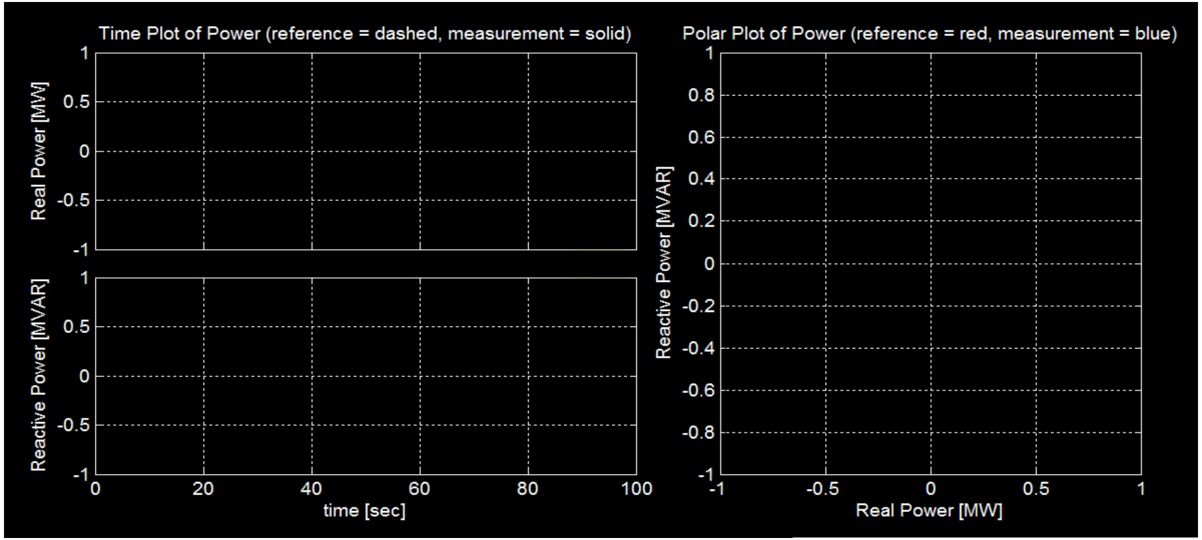
Grid Connected Inverter
(with P,Q references)

Single RLC load
(switched on at t=1sec)

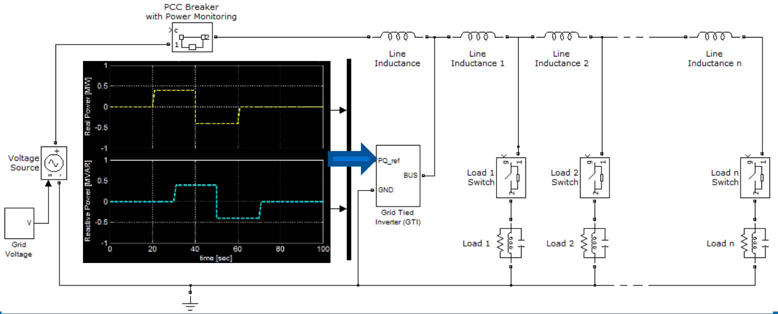




Motivating Example: dynamic coupled power

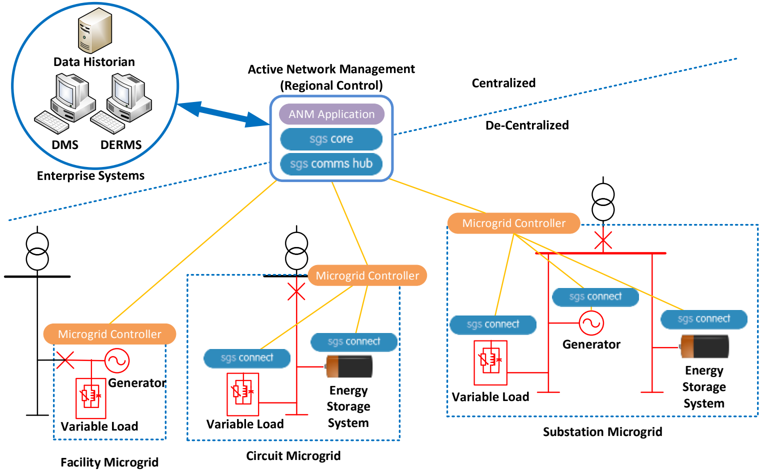


- Even harder to control
  in case of multiple loads!
- Need: decouple & track power



Solution: phasor based microgrid control

- Supported development/testing of Sempra/OSIsoft's advanced controller using hardware in the loop
  - Use of PMU data at POI/PCC to control P,Q at DER
  - Fast and de-coupled control real and reactive power

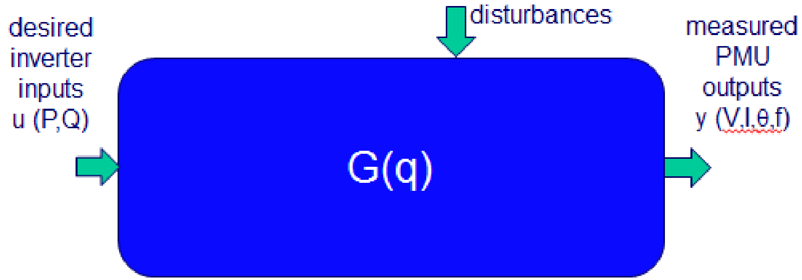


- Individual control of DERs
- Monitored by hierarchical control
- Closely integrated with OSIsoft software

Source: SmarterGridSolutions

High Level Concept: data driven modeling

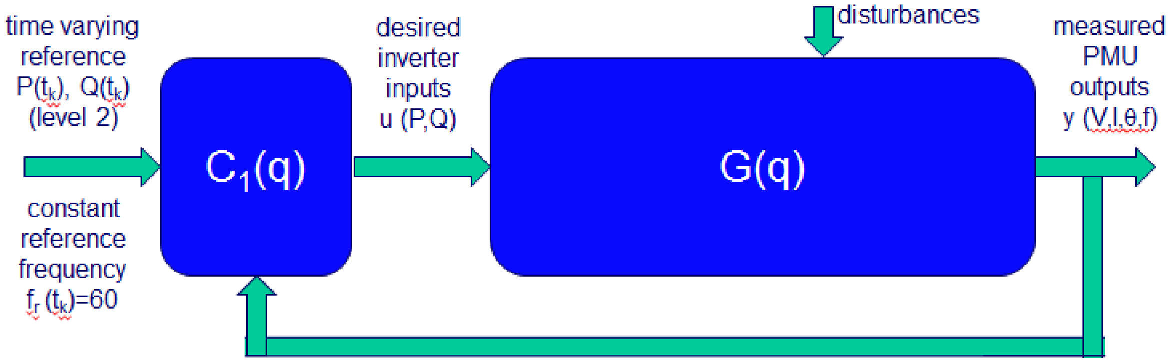
- Consider lumped dynamics from control through microgrid with comm/loads/disturbances to PMU output = “grid dynamics”



- Inverter input $u(t_k)$, Phasor data $y(t_k)$ are all sampled at regular time intervals.
- Grid dynamics G(q) desired (approximate) knowledge:
    - <u>Dynamics</u> (time delay & oscillation/settling time)
    - <u>Coupling</u> (dynamic and steady state)

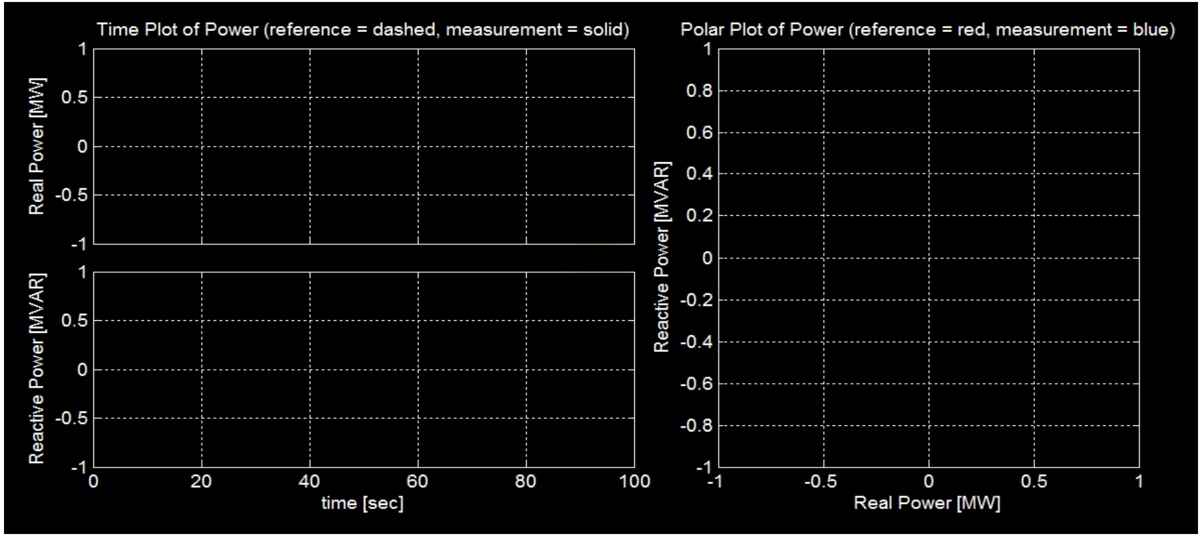
High Level Concept: data driven control

- Wrap around a Control Algorithm $C_1(q)$ so that:



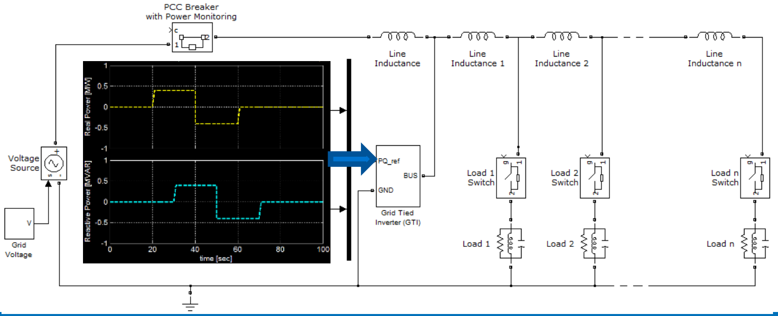
- Stabilization of feedback system (despite dynamics and delay)
- Track/Decouple power reference $P(t_k)$ and $Q(t_k)$
- Track/Decouple (voltage) angle reference $\theta(t_k)$ and $V(t_k)$

Motivating Example Revisited



Decoupled control of real/reactive power:

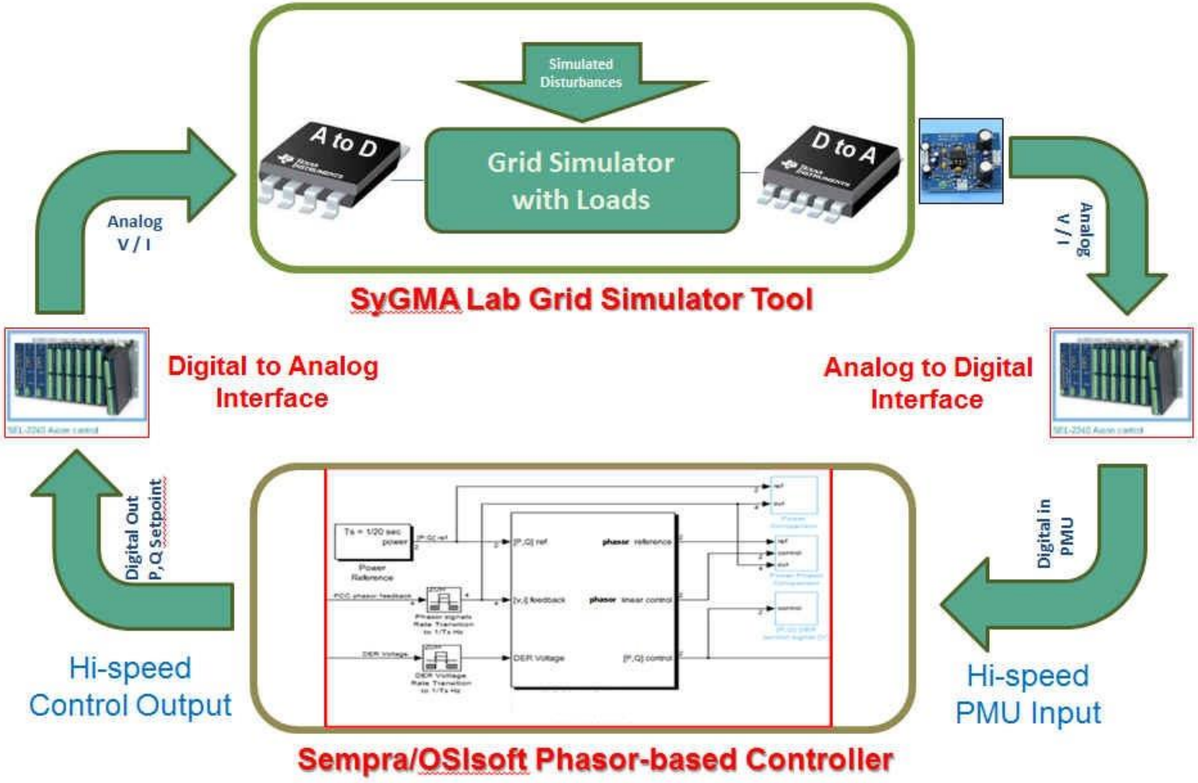
- Power tracking & peak shaving
- Load disturbances rejection



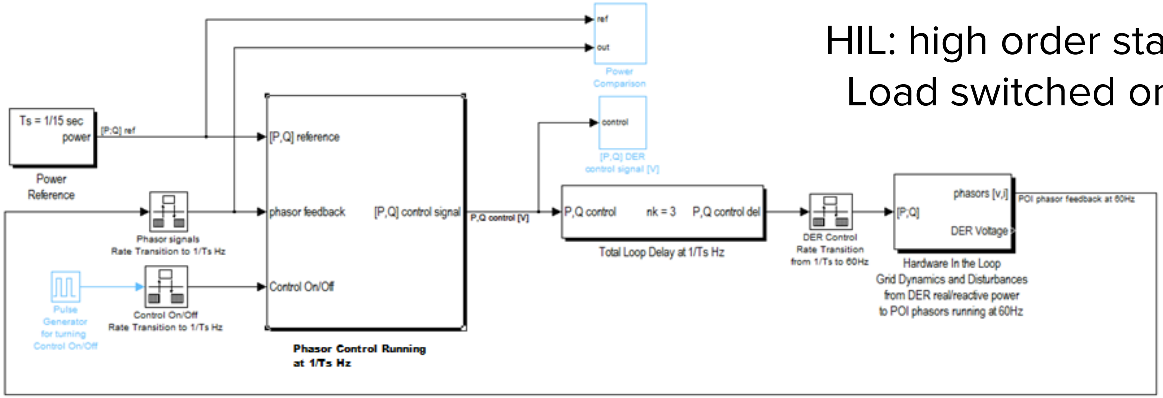
OSI Software: Usage & Development

- Software installed:
  - PI System, Coresight, ProcessBook,
  - SQL Server,
  - DataLink,
  - Asset Framework
- New software development with OSIsoft/Sempra:
  - C37.118 fast export
  - High speed data transfer to controller
  - High speed data transfer to AF and HMI
  - Modbus output
  - IEC Goose output

HIL tests at the SyGMA Lab

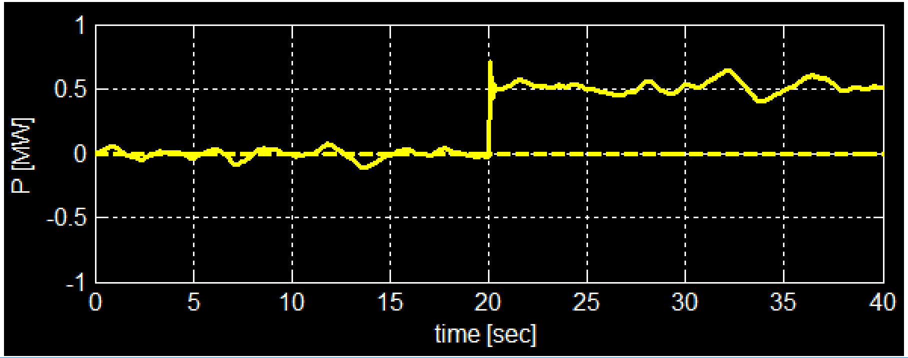


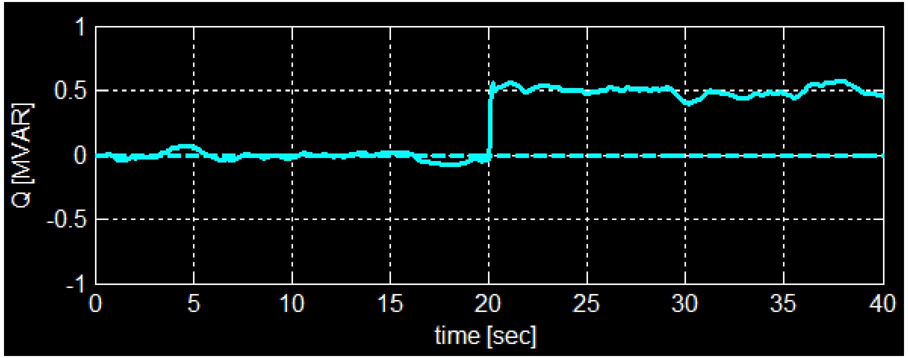
HIL control tests at the SyGMA Lab



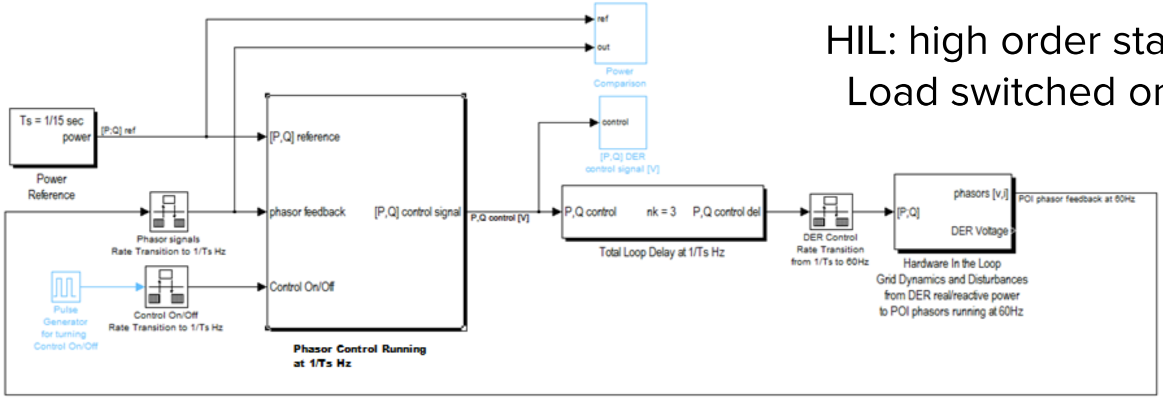
HIL: high order state space model
Load switched on in HIL t=20sec

No control (reference P=0, Q=0 at POI/PCC):



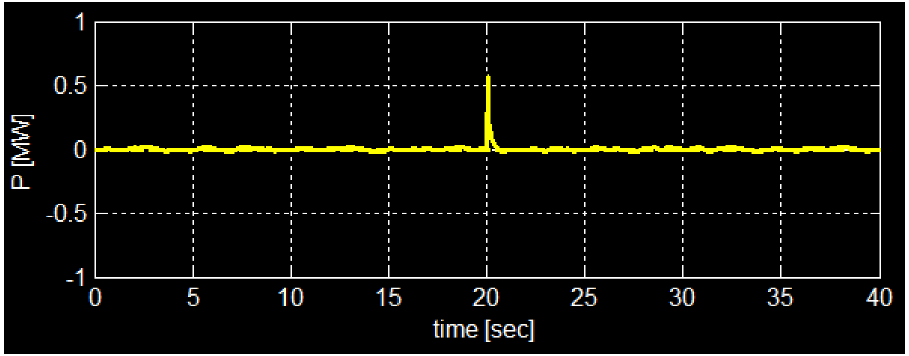


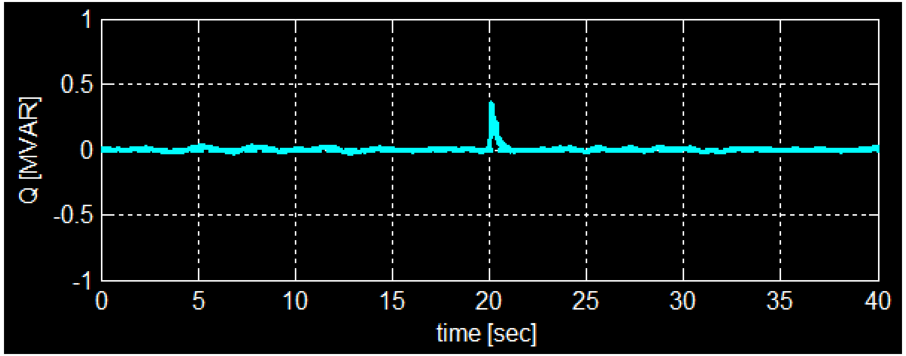
HIL control tests at the SyGMA Lab



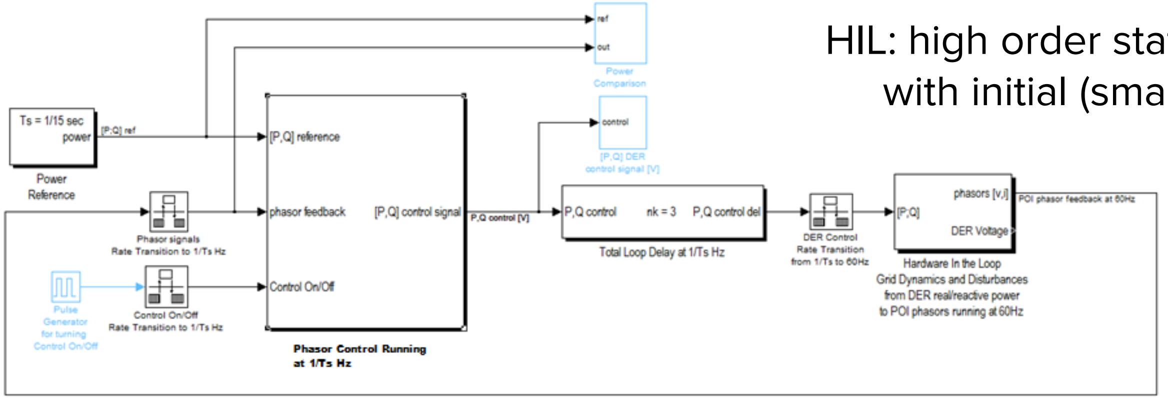
HIL: high order state space model
Load switched on in HIL t=20sec

With 15Hz control (reference P=0, Q=0 at POI/PCC):



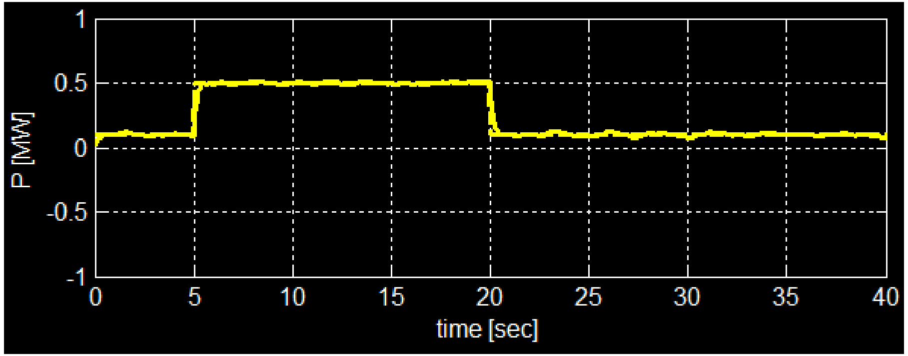


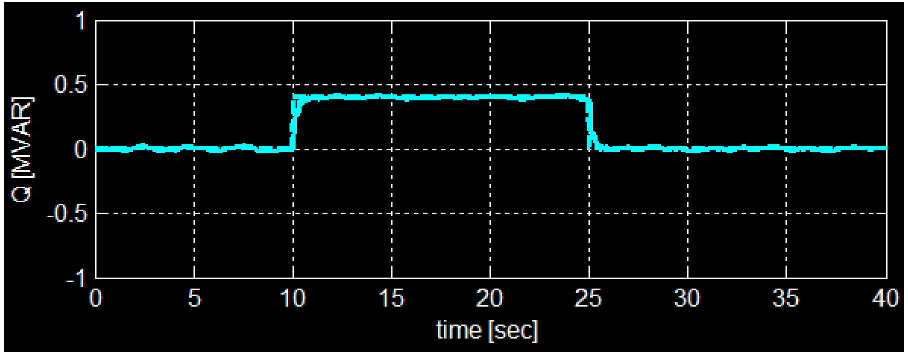
HIL control tests at the SyGMA Lab



HIL: high order state space model with initial (small) resistive load

With 15Hz control (reference P=0, Q=0 at POI/PCC):





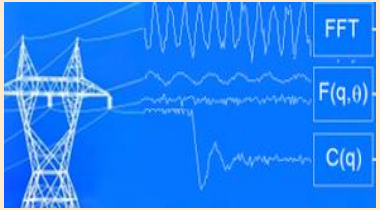
Summary of Challenges & Topics Addressed

SyGMA lab at SDSC

Focus on Grid Monitoring and Automation Technology

Full use of OSIsoft standard products

Simulation and testing of new signal processing algorithms that use synchrophasor data

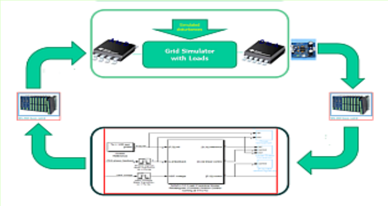


PMU data and storage

Event Detection driven by PMU data

Equipment monitoring using PMU data

Monitor and control islanding conditions of (micro) grids



Grid Automation

Automated control solution using real-time PMU data

Testing of fast and de-coupled control real and reactive power

Automatic power disturbance rejection and tracking

Integration with OSIsoft

Development of new grid monitoring and control application integrated with PI system

Vision: improve efficiency, reliability, and security of electric power grids

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Thank You

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감사합니다

谢谢

Danke

Merci

Gracias

Thank You

ありがとう

Спасибо

Obrigado