Synchrophasor-based Emergency Generation Dispatch

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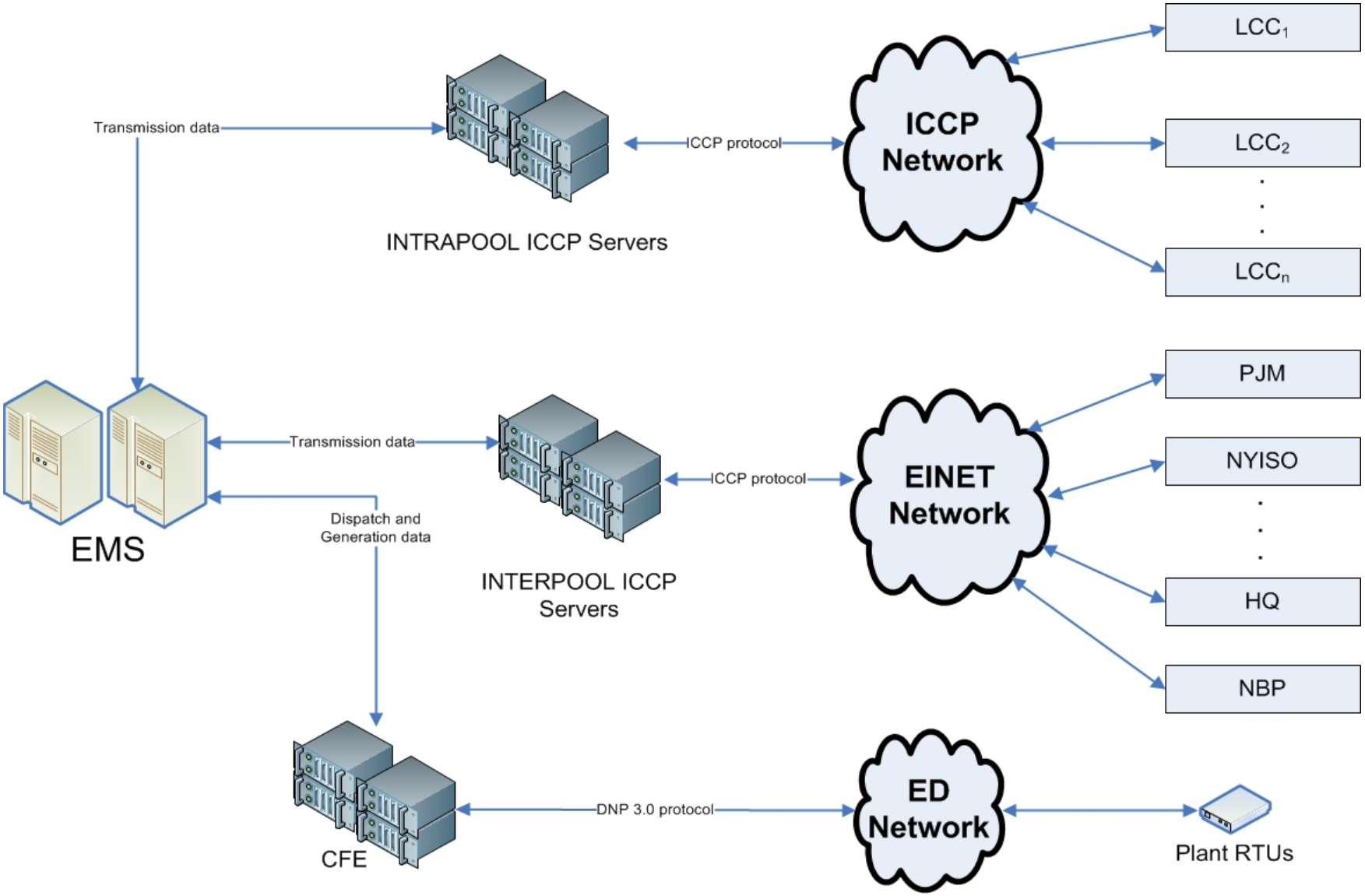
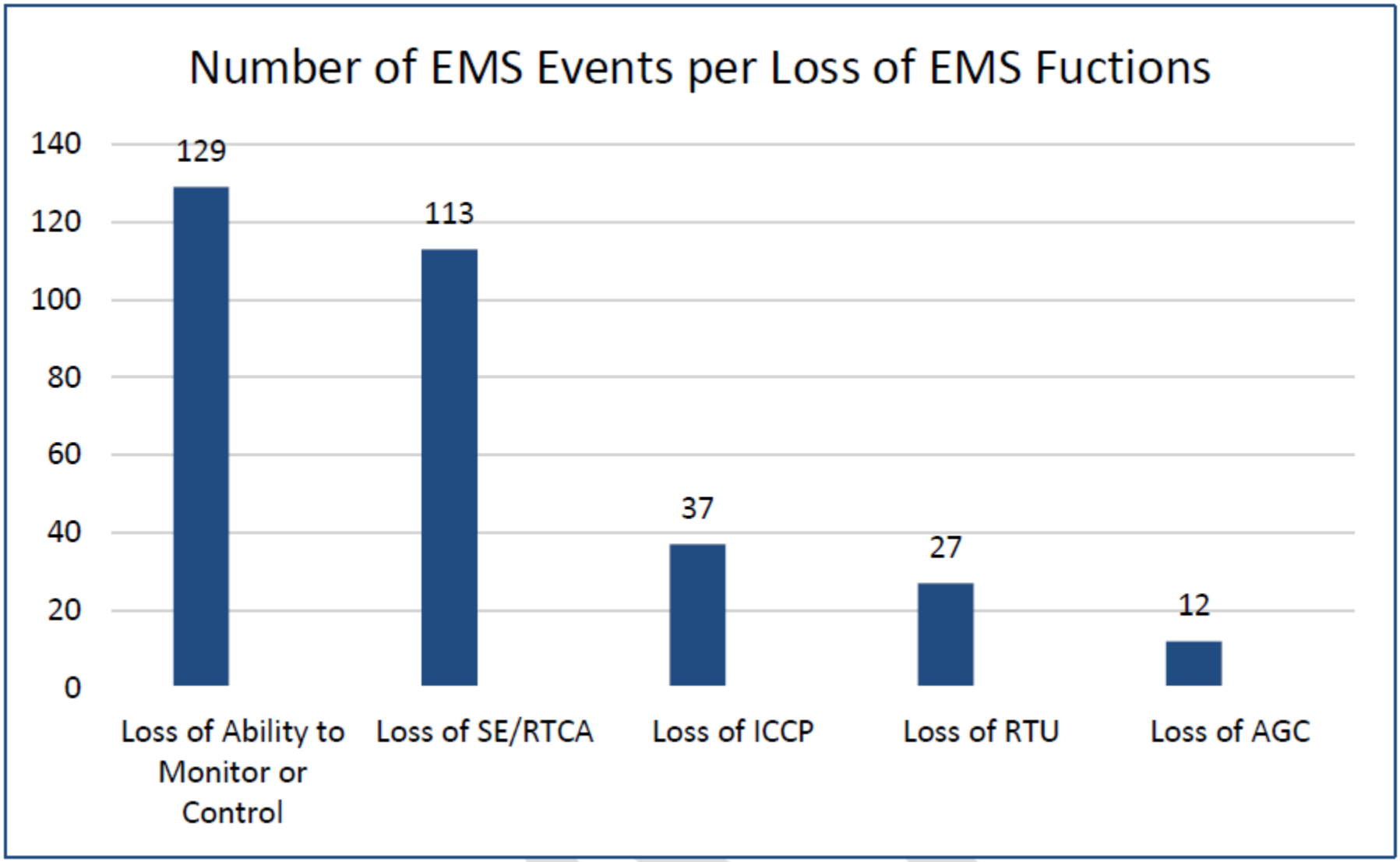
BUSINESS ARCHITECTURE AND TECHNOLOGY

Outline

- Motivation
  - Typical EMS communication network
  - Loss of SCADA/EMS
- Overview of ISO-NE's syncrhophasor infrastructure
- Synchrophasor-based emergency operation
  - Automatic Generation Control (AGC)
  - Emergency dispatch
- Prototype implementation
- Conclusions and future plans

Typical EMS Communication Network





318 EMS events (October 2013 – April 2017) from 130 NERC Compliance Registries

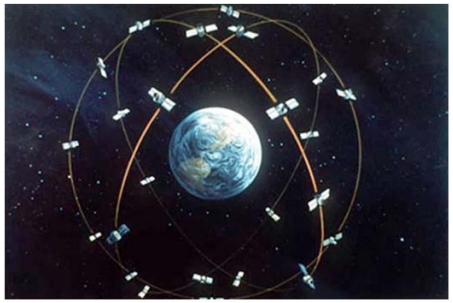
NERC report: Risks and Mitigations for Losing EMS Functions

Loss of SCADA/ICCP/EMS

- Low probability events, such as coordinated cyber or physical attack, EMP or natural hazards may cause complete failure of the SCADA/EMS system.
- Loss of monitoring and control capability
  - No SE, RTCA, SCED, AGC, etc.
- Staffing of key substations by LCCs, with a periodic update of meter reading and topology to the ISO
- ISO will determine the merit order dispatch manually for the expected change in load or tie schedule to maintain ACE
  - Manual DDP, if ED network is still available
  - Verbal manual dispatch by contacting the DE, if ED network is unavailable

Synchrophasor Technology

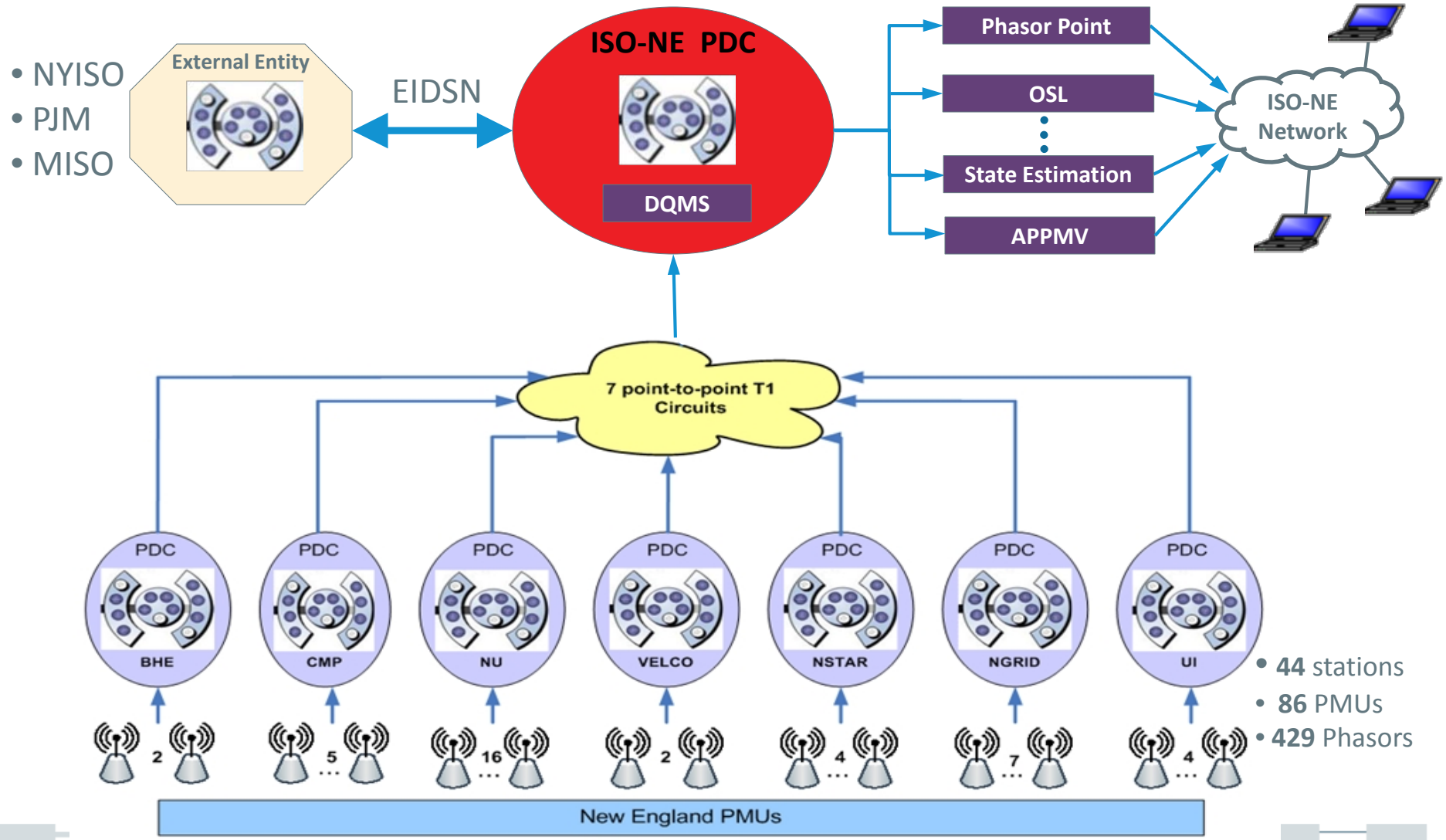
- Synchrophasor:
  - Phasor (magnitude and angle)
  - Precise GPS time stamp
  - High sampling rates
    - 30 to 120 samples per second



Synchrohasor = Phasor + GPS + high sampling rate

- PMU - Phasor Measurement Unit

New England Synchrophasor System



New England Synchrophasor System (Cont.)

- Approved Operating Procedure 22 changes, effective December 2017, requiring TOs to install new PMUs at:
  - All new 345 kV substations
  - Point of Interconnection (POI) for all new and existing power plants above 100 MVA
  - Other locations as designated by the ISO, mainly for IROL and SOL monitoring
- OP 22 changes will double the existing number of PMUs in the next five years.

Independent Synchrophasor Infrastructure

- The synchrophasor infrastructure is independent from the SCADA/EMS system
  - Separate communication infrastructure with its own circuits, routers, firewalls, encryption, etc.
  - Time aligned and synchronized with the GPS clock
  - MW flow and frequency of tie lines
  - MW and MVAr Outputs of large power plants at POI (100 MW and above)
  - All 345 kV and some 115 kV line flows
- Ideal as a backup for emergency monitoring and control when there is a complete loss of SCADA/EMS

Synchrophasor-based Automatic Generation Control (AGC)

- *Area Control Error (ACE)* is an indicator of a BA to meet its obligation to continuously balance its generation and interchange schedule with its load

$$ACE_p = \left(P_{tie}^{schedule} - P_{tie(p)}\right) + 10B\left(f_{area}^{schedule} - f_{area\,(p)}\right)$$

$P_{tie}^{schedule}$ - Scheduled net interchange

$P_{tie(p)}$ - PMU measured actual net interchange

$f_{area}^{schedule}$ - Scheduled system frequency (60 Hz)

$f_{area\,(p)}$ - PMU measured weight-averaged frequency

B - Frequency bias setting (MW/0.1 Hz)

- AGC: dead band, PI controller, low pass filter, AGC setpoints

Synchrophasor-based Emergency Generation Dispatch

$$\min \sum c_i \Delta P_i$$

$$s.t. \quad \sum \Delta P_i = \Delta L(T) - ACE_{control}$$

$$\left| \frac{\Delta P_i}{R_i} \right| \leq T$$

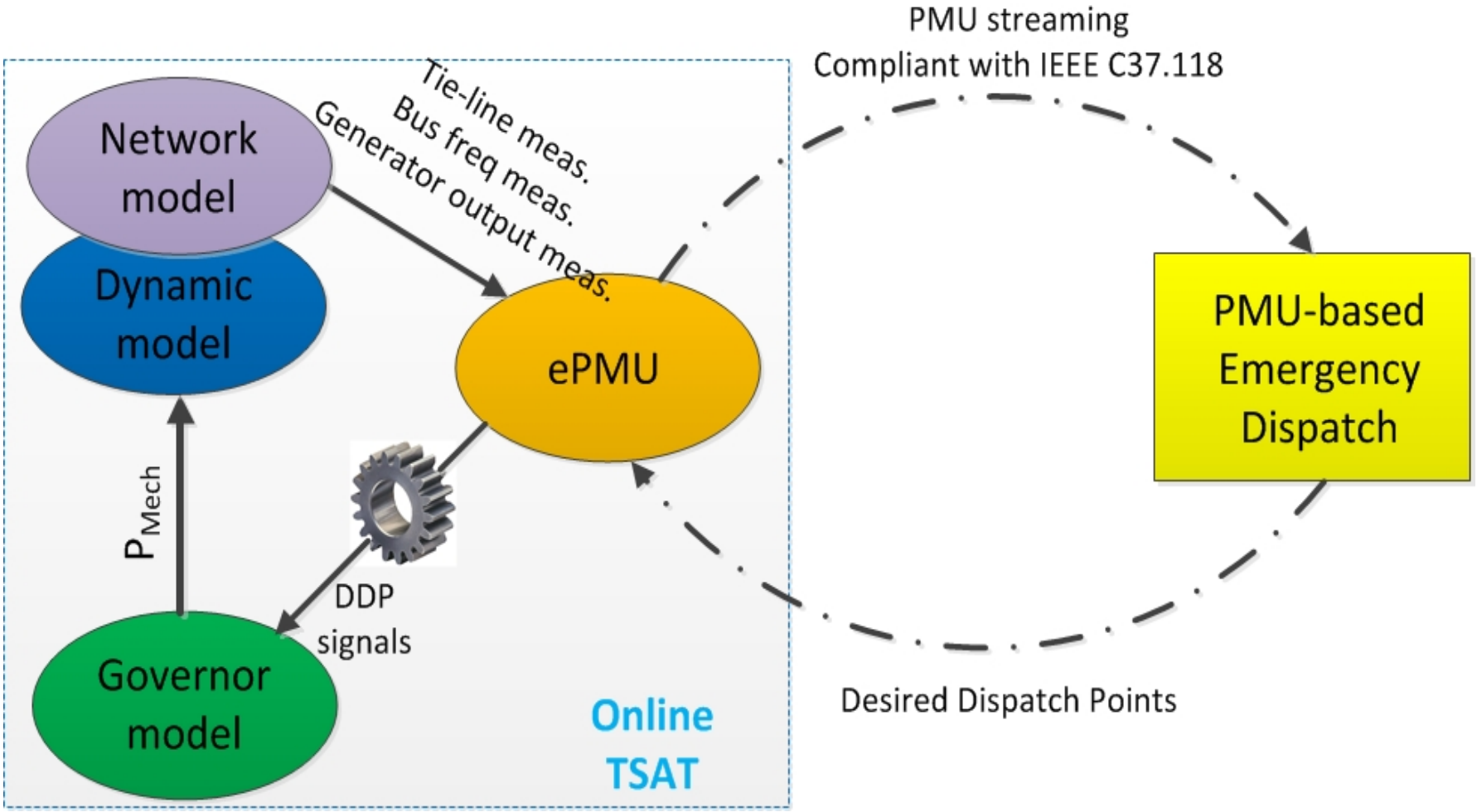
$$P_{min} \leq P_i^0 + \Delta P_i \leq P_{max}$$

i	--	PMU monitored generators
c_i	--	generator incremental cost
ΔP_i	--	generator delta dispatch amount
P_i^0	--	generator output
T	--	dispatch look ahead time (5 minutes)
R_i	--	generation ramp rate
ΔL	--	short term forecasted load change
$P_{min}\ P_{max}$	--	generator economic minimum and maximum operating limits

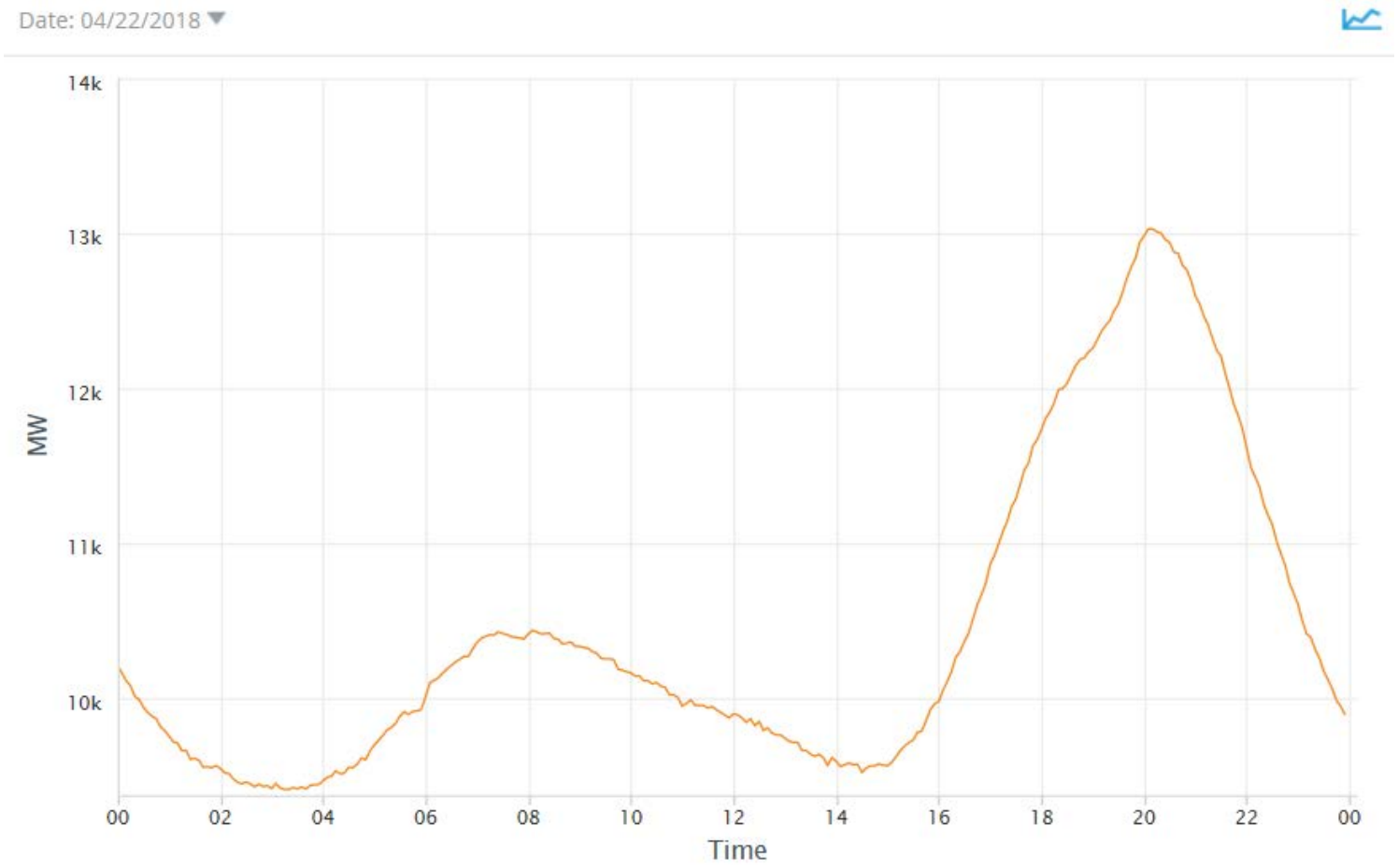
Synchrophasor-based Emergency Operation

	Loss of SCADA/EMS; ED network is available	Loss of SCADA/EMS; ED network is unavailable
Synchrophasor-based Automatic Generation Control (AGC)	Yes (every 4 seconds)	No
Synchrophasor-based Emergency Dispatch	Yes (every 5 or 10 minutes) ; only PMU monitored units	Yes (every 5 or 10 minutes) ; only PMU monitored units

Prototype - A Closed-Loop Simulation Platform

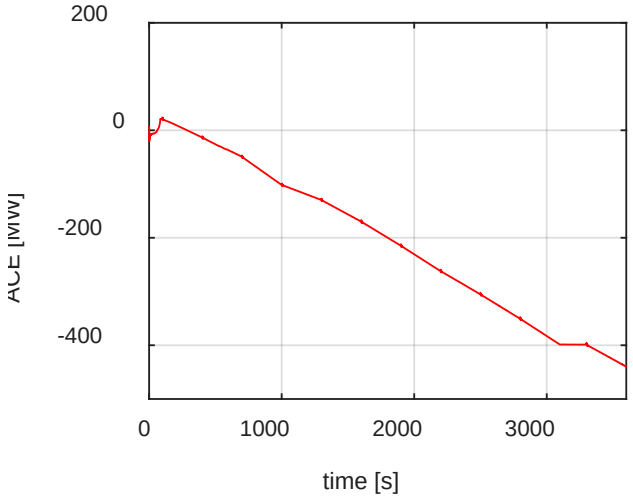


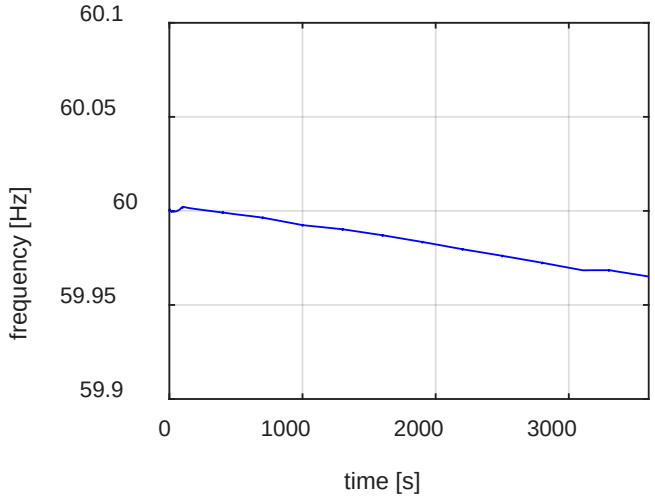
Test Case

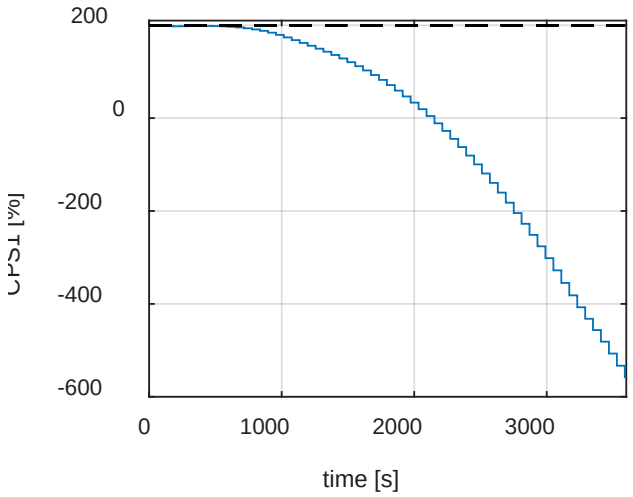


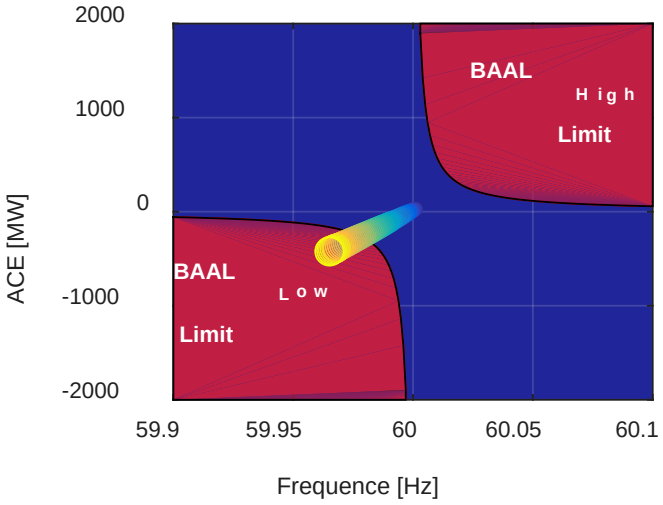
4/22/2018, 16:00 hr. – 17:00 hr., about 900 MW increase

Test Case – w/o Emergency Dispatch

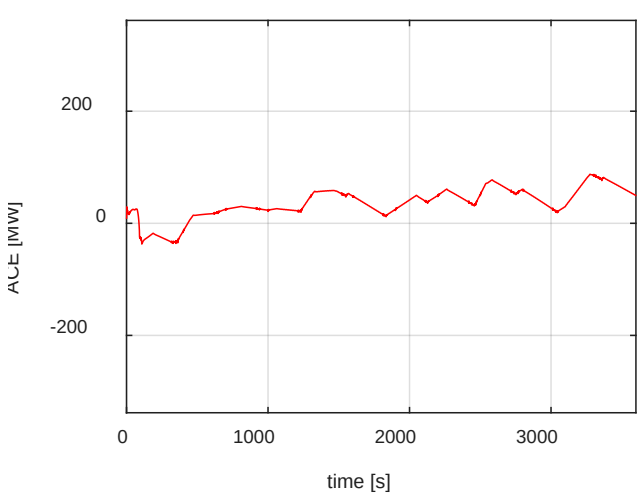


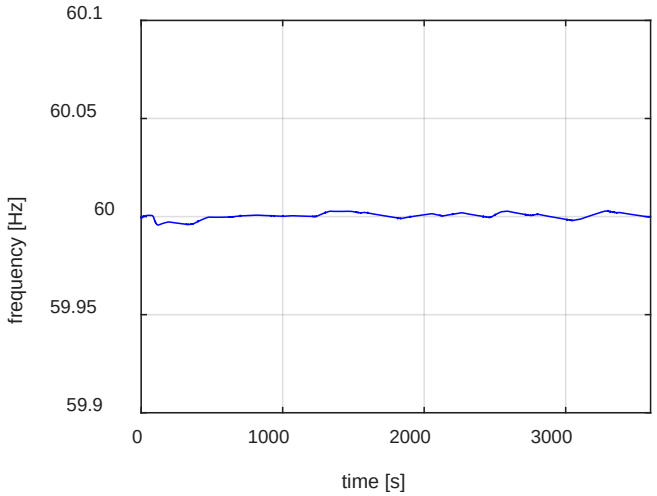


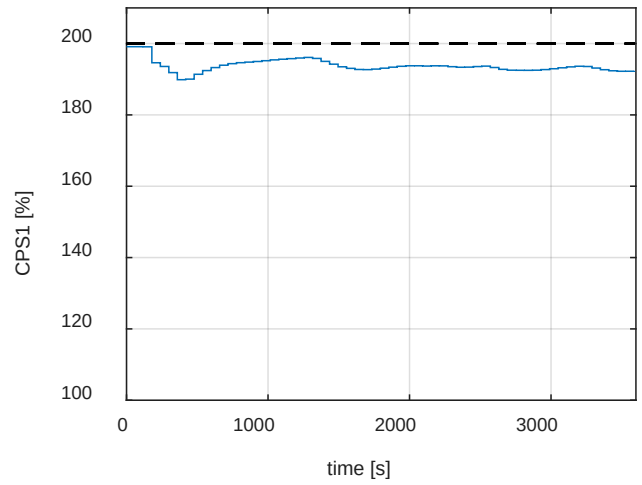


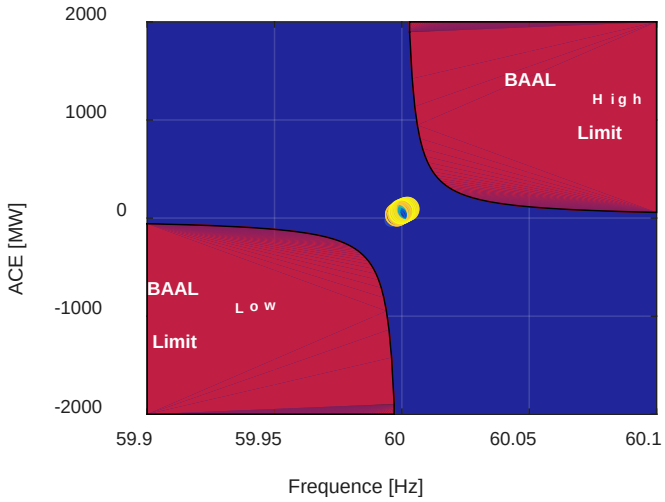


Test Case – with Emergency Dispatch

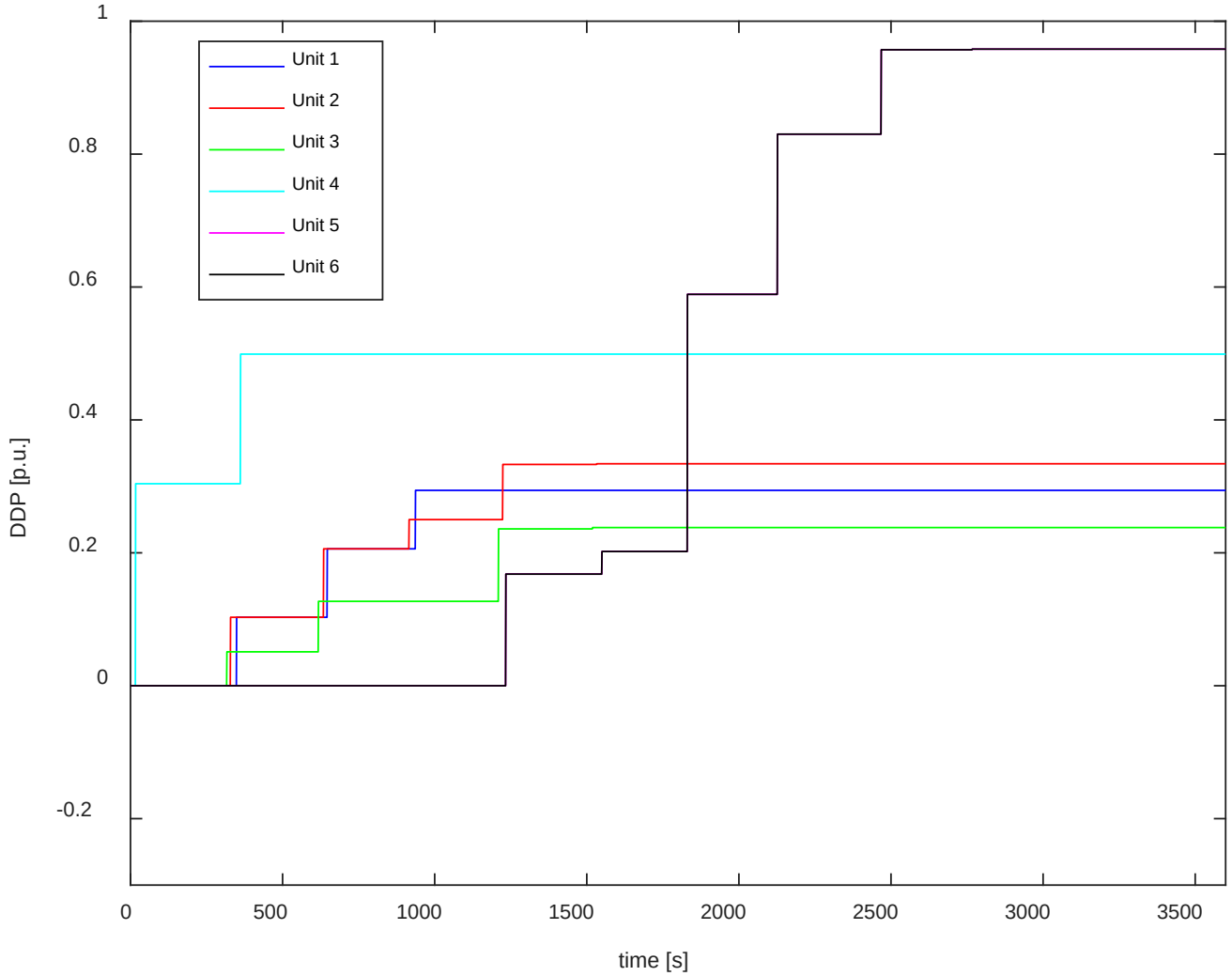




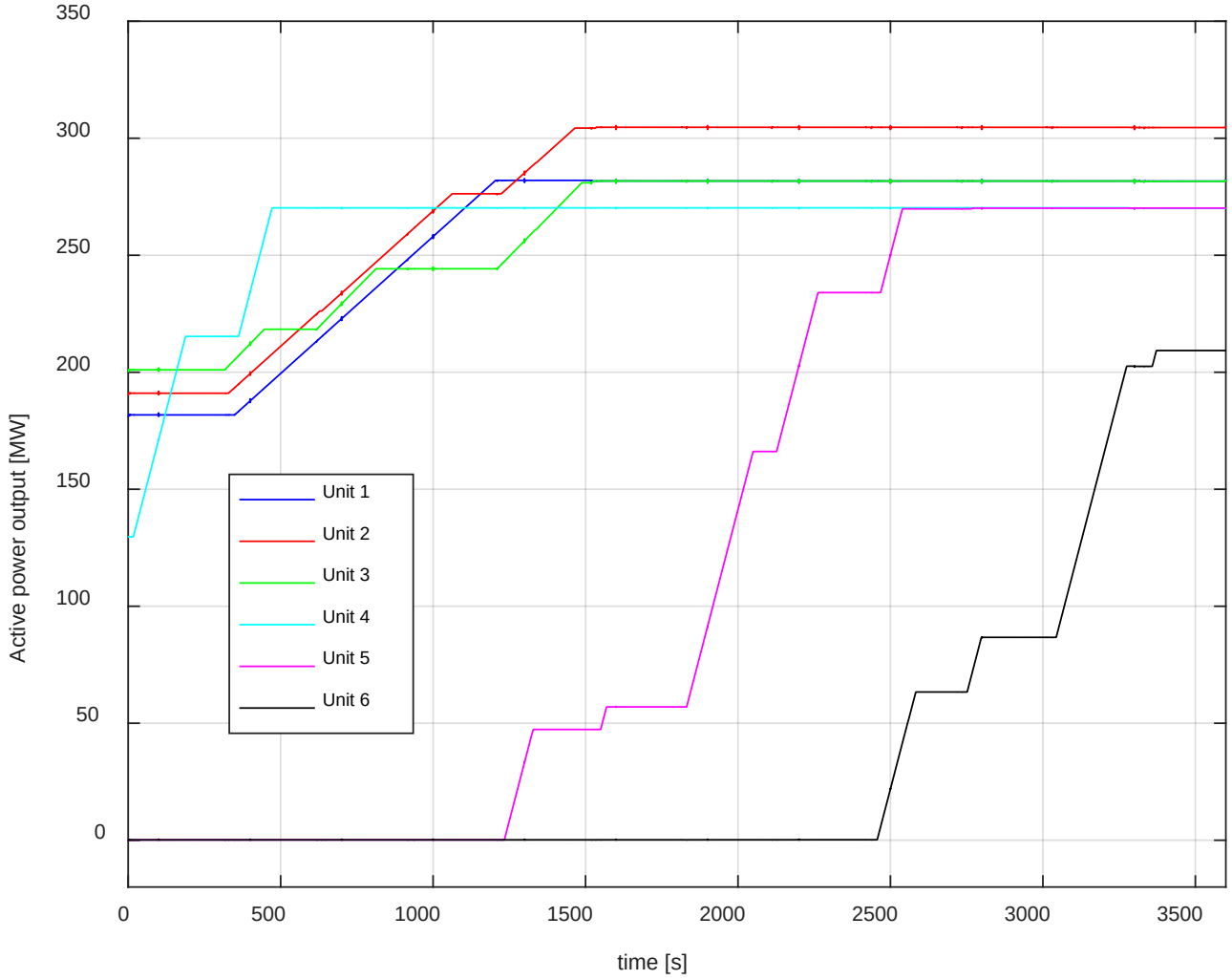




Test Case – Emergency Dispatch (DDP)



Test Case – Emergency Dispatch (MW outputs)



Conclusions and Future Plans

- Synchrophasor infrastructure is independent from the SCADA/EMS system
- Synchrophasor based AGC and emergency dispatch can be an ideal backup tool for monitoring and control when there is a complete loss of SCADA/EMS
- Once validated on the closed-loop simulation platform, the data source will be switched from simulation to real time PMU
- On-premises production implementation
- Future cloud hosted environment

Eugene Litvinov, Song Zhang, Xiaochuan Luo, "Synchrophasor-based generation dispatch for emergency area balancing", accepted for publication in 2018 IEEE PES General Meeting

Questions