Cyber-Physical Systems as a Power System Development Tool

By
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Hyper Gang

Combining Hardware and Software for Accelerated Technology Development
From EO 14008, Sec 205: "The plan shall aim to use, as appropriate and consistent with applicable law, all available procurement authorities to achieve or facilitate: (i) a carbon pollution-free electricity sector no later than 2035"
Power Technology Development Today

- The current technology paradigm requires two decades
- The highest risk is always associated with pilot development
- Critical Go-No Go relies on a pilot scale technical assessment

Critical Go-No Go

1. Conduct Initial Assessments
   a. Engineering
   b. Environmental
   c. Economic
   d. Legal
2. Technical Assessment
3. Conceptual Costs and Schedule
4. Summarize Results
5. Management Direction

U.S. DEPARTMENT OF ENERGY
Power Technology Development Today
Hardware Simulations

Changing the Paradigm
HILS vs CPS
Cyber Physical Systems are used to replace physical systems that:

1. are irreplaceable,
2. are expensive,
3. can't meet performance targets.
4. don't exist... yet
Technology Development Opportunities

Concept & Lab Testing → Numeric Models → Pilot Plant → Power Plant

Material and Geometry → Cyber-Physical System → Iteration

More Cyber → Real-Time Model Development

More Physical → CPS Component Development

Conceptual Design

Connection Design

Component Testing Cycle Design
Technology Development Tools

Net-Zero Power Generation Realized

Pilot Plants (Physical Models)

Concept

Cyber-Physical Models

Numeric Models

Hyper
The Hybrid Performance Project Facility
Replacing Components that Don’t Exist...Yet
The Hybrid Performance Project Facility

Hyper Facility

Source

Sink

TES

SOEC

CSP

Wind

Solar

Nuclear

SOFC

Chemical Storage

Electric Storage

SDFC

Puran

Planar

ICE

HX

ETA

Hyper

???

Innovation

Storage
Technology Development Flexibility

CSP/Fossil Hybrid

SOFC/GT Hybrid

Hyper Facility

Geothermal & CHP

TES/Fossil Hybrid

Reconfigurability

Nuclear/Fossil Hybrid
Technology Development Capital Costs

Siemens Westinghouse pilot demonstration
220kW SOFC/GT Hybrid

Cost: ~$10 M

NETL cyber-physical system
400kW SOFC/GT Hybrid

Cost: ~$1 M
Low Emission Advanced Power (LEAP)

Over 140 leading researchers from 13 countries, 9 national labs, 33 industrial organizations, and 30 universities participated in the event.
Session 1
Bryan Morreale (NETL), Bhima Sastri (FECM), Sam Thomas (FECM), Aristide Massardo (UNESCO)
Transitioning to net-zero, EO-14008, and social justice
“Getting There” from the U.S. and European perspectives

Session 2
Jen Kurtz (ARIES), Rob Hovsapian (NREL)
Renewables, hydrogen, and electric integration with storage
Intermittency, use of electrolysis and electric storage
Need for integration with dispatchable power

Session 3
EPRI, Southern Co., Exelon
Impact and potential costs
Need for FECM and EERE new technologies in generation and distribution
Session 4
Steven Saffel (Pepco), Byron Washom (UCSD), Scott Samuelson (UCI), Stone Edge Farm
**Microgrids**
Coupling non-dispatchable with dispatchable generation

Session 5
Alberto Traverso (TPG), NETL, NREL, INL, Sandia
**Thermally/chemically integrated systems**
SOFC/SOEC/GT/ICE/TES/CCS/CSP/NE/etc. and other crazy ideas

Session 6
Jack Brouwer (UCI NFCRC), NETL, UNIGE, WVU
**Part load and dynamics for hybrid power systems**
Challenges for highly coupled systems, non-linear interactions, control issues
Advanced Systems Integration (Wednesday)

Session 7
David Tew (ARPA-E)
**ARPA-E paths to commercialization**
Commercialization of integrated energy systems for hybrid electric power in INTEGRATE and REEACH

Session 8
Paolo Pezzini (Ames), Emerson, ABB, NETL, NREL, INL
**Controls for integrated energy systems and novel concepts**
Need for high-speed coordination of dynamic control with supervisory control, agents, MIMO, MOOD

Session 9
All Speakers,
**Conclusion and summary of results**
Need for a new paradigm in technology development, simultaneous co-design of components, systems, and control
Session 10
Mark Bryden (Ames), Nathan Johnson (ASU), Sydni Credle (NETL), Mario Ferrari (TPG), Melanie Herbst (DLR)
Introduction to Cyber-Physical Modeling
The energy sector and net-zero carbon generation
Energy: A quickly changing landscape
The need and challenge of reaching a net zero carbon energy system
Breakout Sessions for discussion

Session 11
Scott Ferguson (NCSU)
Cyber-physical modeling and energy system design
Rethinking traditional design strategies for energy systems
Building a CPM community for energy systems development
From cyber-physical modeling to intelligent systems
Breakout Sessions for discussion

Session 12
Michael Shelton (ACTS), Comas Haynes (GTRI), Paolo Pezzini (Ames)
Building cyber-physical energy system models
Hardware and software needs to support CPM in the future
Developing continually adaptive cyber-physical systems
Breakout Sessions for discussion
Cyber-Physical Modeling (Friday)

Session 13
Scott Ferguson (NCSU)
Intelligent, reconfigurable, adaptive energy systems
Adaptive design for a changing world
A cyber-physical modeling energy system development process: creating intelligent, reconfigurable, adaptive energy systems
Breakout Sessions for discussion

Session 14
All Speakers led by Ames and NETL
Next steps in cyber-physical modeling of energy systems
Open invitation to participate in developing a CPM community
Summary

➢ New technologies will be required for transition to economically viable renewable generation assets
➢ Key dynamic interactions need to be characterized/quantified
➢ Cyber-physical systems can enable exploration of highly integrated systems at lower cost
➢ World leaders participated in the virtual LEAP workshop focused on integration issues and Cyber-Physical Modeling
➢ A systematic approach to CPS is essential
Acknowledgements and Disclaimer

➢ This material is based upon work supported by the Department of Energy Advanced Sensors and Controls, FWP-1022427

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Cyber-Physical Systems are Awesome!!!