C2WT-TE: Command & Control Wind Tunnel for Transactive Energy

A Model-Based Co-Simulation Platform for Rapid Synthesis of Distributed Heterogeneous TE Simulations

HIMANSHU NEEMA
himanshu@isis.vanderbilt.edu

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Modeling and Simulation Challenges

- Transactive Energy presents a highly complex ***"Cyber-Physical-Human-Economical Problem"***:
  - multi-users,
  - multi-domain (e.g. analog transmissions & control, digital control, transients, thermal,…),
  - multi-time-resolution,
  - multi-time-scales of generators & consumers,
  - multi-tier grid control & synchronization,
  - multi-pricing-methods,…
- Huge challenges for correct modeling and simulation:
  - It is a multi-provider system with highly dynamic capacity – even consumers can be producers
  - Demand is highly dynamic, providers have diff. views – can lead to "instability or chaotic behavior"
  - Highly complex interdependent network – driven by highly unpredictable elements – weather, humans (users, policies, security, trust, irrationality, politics,..), malicious agents & cyber attacks, ..

Open Questions

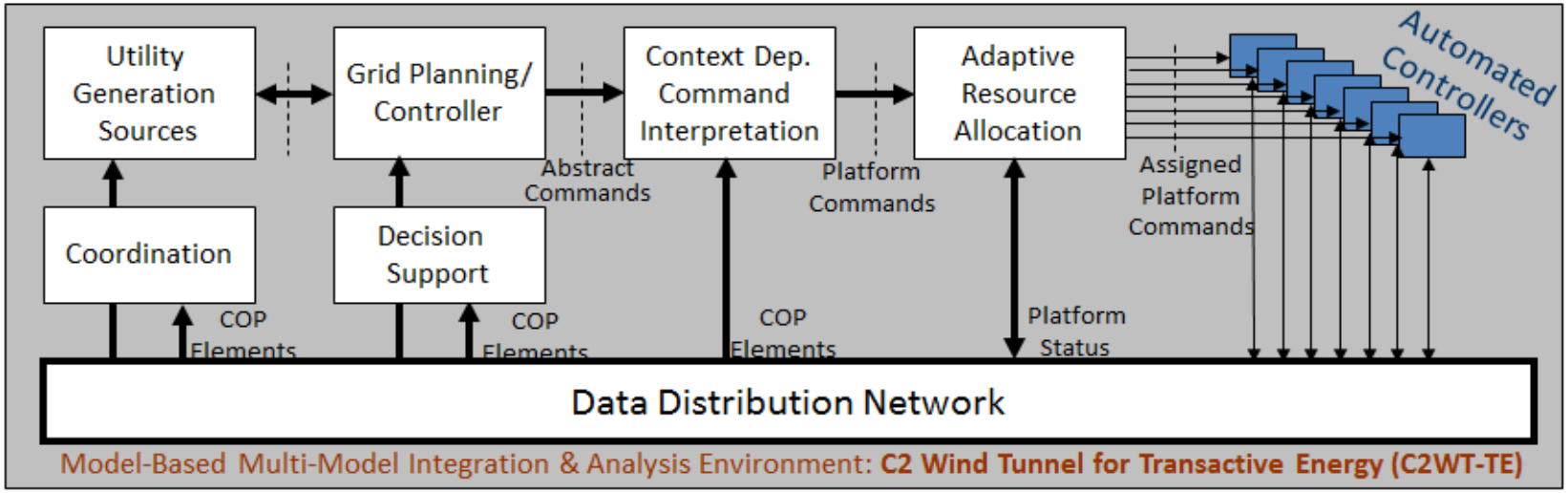
- How do we address the heterogeneity of TE issues and participating players (generators, distributers, power markets, controls, consumers,..)?
- How we address different operational policies and requirements?
- How do we ensure reliability and security of the grid?
- How do we generate insights into the behavior of TE approaches and gain confidence in control mechanisms for Smart-Grids?
- How to design policies, standards, & controls for max. resource utilization?
- How to provide resilience against cyber vulnerabilities?

- *As of this writing, there is no single tool*
  - *that can model power, communication, and control systems in a combined manner, or*
  - *that can model systems at transmission and distribution levels with fine-grained attention to details*

What is needed?

- An “Open Co-Simulation Platform” for:
  - Integrating and coordinating across a diverse suite of modeling and simulation tools, and conduct integrated experiments
  - Allowing multiple players to provide their solutions to parts of above problem relevant to them and use solutions provided by others to solve part of the problem someone else has already contributed
  - Supporting multi-rate execution, time synchronization, and communication among tools
  - Providing a publish/subscribe architecture that allows for fine-grained modeling of only relevant updates (e.g. within a given geographical area, around a certain location, between given time-period, etc.)
- The platform provides modeling, experimentation, and analysis facilities that will enable “weaving” of a customized TE simulation by selecting from the tools are already supported or were custom added by users.
- The platform also supports Model libraries, Simulation tool integrator libraries, Library of TE approaches, Library of cyber attack and defense models.

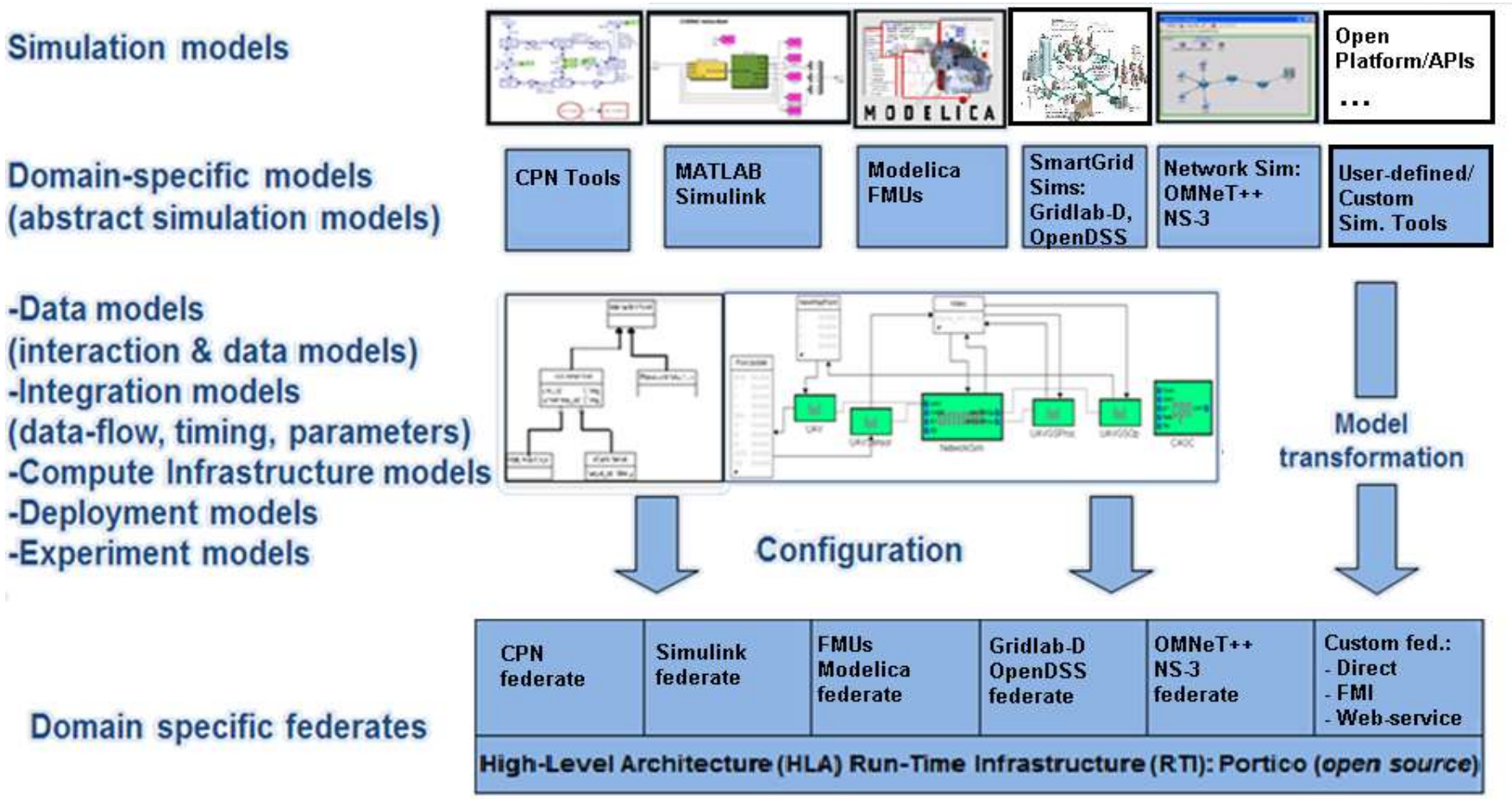
C2WT-TE: System-of-Systems (*notional*) Architecture



Transactive Energy issues to be studied experimentally:

- **Understand & Track Consumer behavior**
  - Individual Home Level
  - Aggregate substation Level
  - Incentives, Off-peak use, Real-time pricing
- **Seamless Integration of Automated controllers & Market factors**
  - Optimize utility services
  - Reliable and secure operations
- **Dynamic Utility Functions**
  - Demand-Response
  - Power network effects
- **System Level Impact Analysis**
  - Cyber attacks & resilient solutions
  - TE approaches

Model-Based Integration Approach in C2WT



Current Team and Project

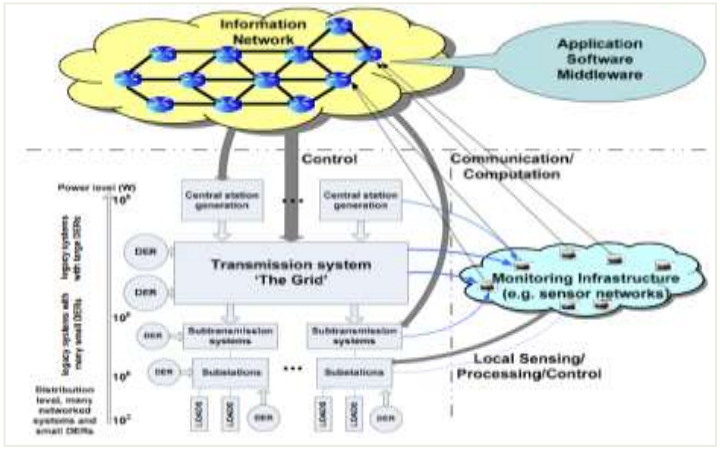
- Vanderbilt Univ. (led by **Dr. Janos Sztipanovits**) has formed a team with Univ. of Michigan (led by **Dr. Ian Hiskens**) and MIT (led by **Dr. Saurabh Amin**)
- C2 Wind Tunnel (C2WT[1]) is an existing generic co-simulation platform based on High-Level Architecture[2] standard. We are working on extending it to support tools for power flow dynamics, transmission & distribution, and market dynamics for evaluation of TE approaches.
- We plan to demonstrate modeling and analysis of grid stability in the presence of unpredictable network behavior (potentially cyber exploits) and market-based demand-response variations.
- We will welcome interested Transactive Energy tool vendors/users if they want to bring their tool/experience for improving the capability of the Open C2WT-TE Co-Simulation Platform.

1. *C2WT community wiki – https://wiki.isis.vanderbilt.edu/OpenC2WT*
2. *HLA standard – IEEE standard for modeling and simulation (M&S) high-level architecture (HLA) – framework and rules http://ieeexplore.ieee.org/servlet/opac?punumber=7179*

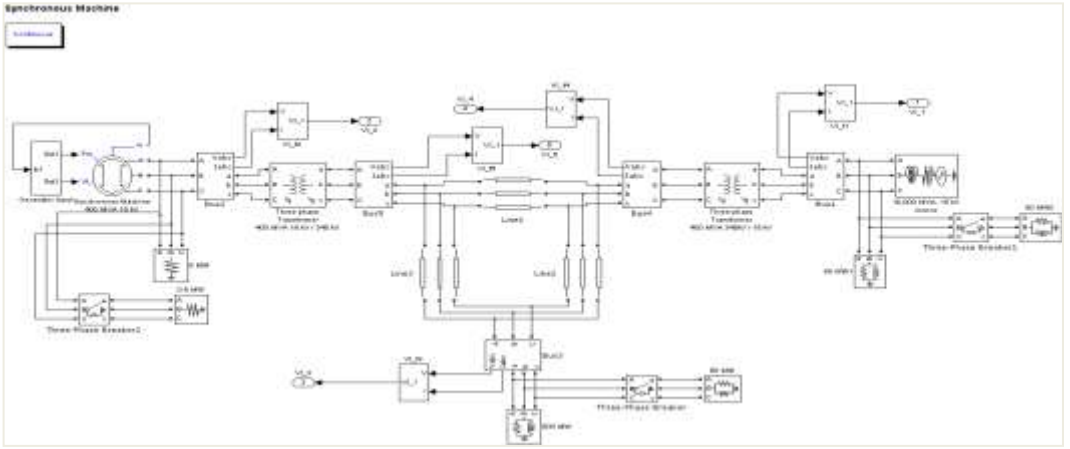
Backup slides

Basic Example[3] of Integrated Smart-Grid Simulation of Power, Communication, and Control Systems

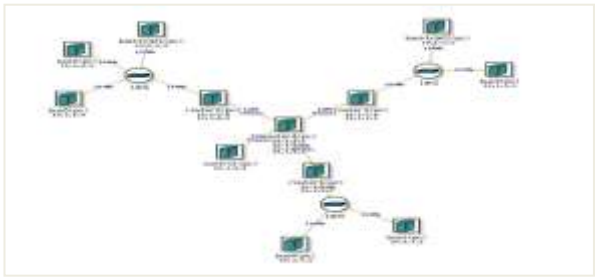
Integrated control, comm., and power system



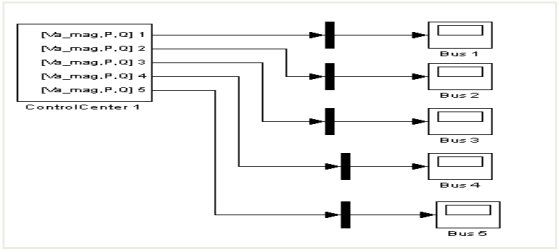
Power-Grid model (Simulink, SimPower)



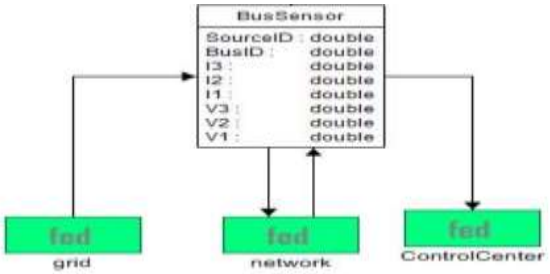
Communication model (NS-2)



Control Center model



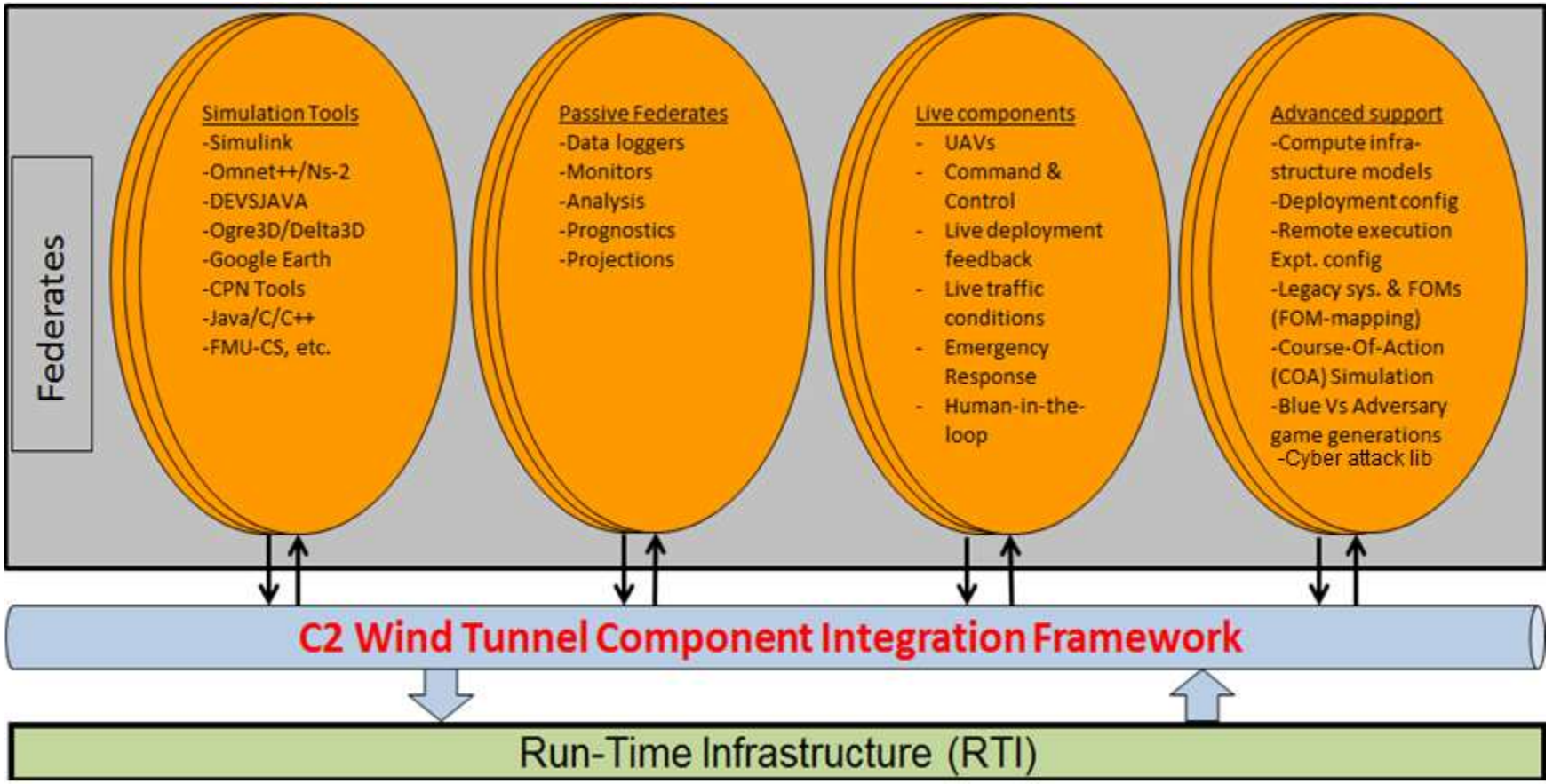
Integration model (simplified)



- Small 5-bus model including two generators, three transmission lines, two transformers and three loads
- Loads are modeled to be switched ON at given time during the runtime simulation as a step change

*3. Sztipanovits, J., Srivastava, A., Bose, A., Hemingway, G., "**Model-based integration technology for next generation electric grid simulations**", Power and Energy Society General Meeting, 2012 IEEE, pp. 1-8, 2012.*

C2 Wind Tunnel[4] Capabilities Summary



*4. Hemingway, G., H. Neema, H. Nine, J. Sztipanovits, and G. Karsai, "**Rapid Synthesis of High-Level Architecture-Based Heterogeneous Simulation: A Model-Based Integration Approach**", SIMULATION, vol. March 17, 2011 0037549711401950, no. March 17, 2011, Online, Simulation: Transactions of the Society for Modeling and Simulation International, pp. 16, 03/2011.*