• The National Association of Regulatory Utility Commissioners (NARUC) is a non-profit organization founded in 1889.

• Our Members are the state utility regulatory Commissioners in all 50 states & the territories. FERC & FCC Commissioners are also members. NARUC has Associate Members in over 20 other countries.

• NARUC member agencies regulate electricity, natural gas, telecommunications, and water utilities.
ABOUT NARUC’S CENTER FOR PARTNERSHIPS & INNOVATION

- Grant-funded team dedicated to providing technical assistance to members.

- CPI identifies emerging challenges and connects state commissions with expertise and strategies to inform their decision making.

- CPI builds relationships, develops resources, and delivers trainings.

Regularly updated CPI fact sheet with recent publications & upcoming events under Quick Links at:

https://www.naruc.org/cpi
NARUC Innovation Webinar Series

One Thursday most months
All NARUC members and stakeholders are invited

Advances in Resource Adequacy
March 16, 2023 | 3:00 – 4:00 PM EST

More webinar information will be added soon!
https://www.naruc.org/cpi-1/innovation-webinars/

NARUC Winter Policy Summit
February 12 – 15, 2023
In-person | Washington, DC
Grid Architecture

Why it Matters

A panel discussion on the fundamental transformation of the electric grid and how we can effectively plan for it

Moderated by Hon. Katherine Peretick
Commissioner, Michigan Public Service Commission
The Panel

Taming runaway complexity, cost and unintended consequences

Mark Paterson, Strategen Lead Systems Architect
A globally-connected energy system transformation leader with 25-years of experience in technology strategy, power systems architecture and thermal and fluid systems. He is known for his expertise in leading the navigation of complex issues, systems thinking and co-design of transformation pathways.

Kay Aikin, Chief Product Officer of Dynamic Grid
A utility software company based in Portland Maine. She is a graduate of Pennsylvania State University, holding a degree in energy/sustainability engineering. Kay is a recognized Transactive Energy expert as well as distributed intelligence in the electrical grid. She is on the Board of the Grid Wise Architecture Council (GWAC), working on architecture and interoperability in grid modernization and smart grid.

Lorenzo Kristov, Principal Market Architect
Independent consultant focusing on power system transition to integrate high levels of distributed energy resources (DER). His expertise includes wholesale power market design; DER participation in wholesale markets; distribution system operator (DSO) models; whole-system grid architecture. Lorenzo worked at California ISO as a principal in market design and infrastructure policy.

Applying grid architecture in the regulatory process
Mark Paterson

Taming runaway complexity, cost and unintended consequences
The Grid is in the Middle of Fundamental Transformation

*Driven by Decarbonization, Decentralization, Digitization, and Democratization – 4 D’s*

- Transition **from hundreds** to **tens of millions** of participating energy resources (generation and loads)
- **Affordability and equity** requirements are growing
- Prosumers are increasingly looking to participate and **beneficially interact** with the grid to access additional savings
- Mass electrification risks **burdening the grid** at some times while **minimum demand** occurs at other times
- The historically dominant ‘Supply-side / Demand-side’ bifurcation is **eroding with profound implications**
- **System load nearly 2X** and **peak demand 2 – 3X**

New system capabilities will be need to be layered over the legacy system while still operating efficiently and reliably
The Grid Transition

**FROM** centralized generation and passive loads...

**TO** both centralized and distributed generation and vastly more active participatory loads / flexibility

![Diagram of grid architecture](Image: IRENA System Operation Collection (2020))
Grid Architecture
Why it Matters

"Any intelligent fool can make things bigger and more complex – it takes a touch of genius – and a lot of courage to move in the opposite direction."

Albert Einstein

The Grid is becoming **vastly more dynamic** and **systemically complex**.

Customer demand and variable generation must still be kept ‘in balance’ every microsecond of the year as proportion of dispatchable generation declines.

Similar to the modernizing aerospace sector before it, additional tools are required to ‘tame’ runaway complexity, cost and unintended consequences.
So what? Why are ‘Systems Architecture’-based methodologies so critical?

**Every complex system** ever created by humans has an underpinning structure or **architecture** that is essential to its operation.

Although less visible than the system’s components, its underpinning architecture has a **disproportionate** and **irreducible influence** on what the system as a whole can cost-efficiently and reliably perform.

The established Systems Architecture discipline provides formal tools for examining the **elements and actors** of a complex system, the critical **linkages and relationships** between them, and the ‘emergent’ **behaviours of the system** that arise as system changes over time.
Applies to every decarbonizing grid requiring more flexibility

21st century grids require bulk energy, transmission and distribution systems – and deep demand-side flexibility – to **function holistically** to avoid over-build, duplication and/or stranded investments.
Grid Architecture tools empower stakeholders to better evaluate grid expansion proposals by applying both ‘present forward’ + ‘future-back’ thinking and analysis.

For example: “How might our portfolio of $-billion projects be moderated for a future where whole-system-coordination can significantly enhance operational efficiencies?”
Kay Aikin

Transitions, networks, operational coordination and future requirements
Parallel Paths

This transition requires parallel implementation paths and whole system approaches like Grid Architecture.
The Grid is a ‘Network of Structures’

Systems Architecture tools are critical for ‘taming grid complexity’ and navigating this network of structures and provide Operational Coordination.
Operational Coordination

‘Operational Coordination requires interaction between both Markets and Control structures

Solution:
An ensemble of both market and control features is required

Marks
- Long-term Planning & Investment
- Residual & Real-time System Optimization

Controls
- System Operations

Image / Concept: Newport Consulting and Pacific Northwest National Laboratory (Adapted)
Grid Architecture is critical for making key structural choices to enable a more intelligent, self-optimising power system for the 21st century.

**Customer Benefits**
- VRE & DER energy and systems services rewarded
- Coordination of desirable system behaviors
- OPEX and CAPEX efficiencies

**System Benefits**
- Affordability, quality and resilience outcomes for all
- Enhanced equity

**Societal / Environmental Benefits**
- New offerings for customers
- Enhanced decarbonization

**GOOD FOR ALL**
- Coordination of desirable system behaviors
- VRE & DER energy and systems services rewarded
- OPEX and CAPEX efficiencies

Image: Strategen Consulting
Future Requirements

New emerging requirements that Grid Architecture can help regulators to understand, adapt and evolve the grid.

- Affordability
- Equity
- Variable generation
- Dynamic load balancing
- Load Shaping
- Load following generation
- System constraints (load and DER)
- Infrastructure upgrades
Future Questions for Regulators

There are estimates that distribution grid upgrades to manage this transition is from $2 to $10 Trillion

- Distributed solar adoption rate?
- Where solar happen first?
- Impact of federal incentives?
- Impact of FERC 2222 on distribution?
- What kind of tariffs?
- What kind of future planning?
- Power quality impacts?
- Investments in grid modernization who pays and how much?
Lorenzo Kristov

Applying grid architecture in the regulatory process
Two uses of the word ‘architecture’

1. The “architecture” of a complex system is the arrangement of actors who comprise the system, along with their responsibilities, functions, roles & interactions with one another.

2. ‘Grid Architecture’ (aka ‘Power Systems Architecture’) is a discipline & set of methods for representing, analyzing & understanding the electricity system as a whole system, & tracing the impacts of changes to the system.

In the regulatory process, the discipline & methods of Grid Architecture assist regulators to better align the performance of regulated entities with the public interest.
The Grid Architecture Discipline — cloud level

(A) Structure Phase — Making decisions about the system & market structure

(B) Design & Implementation Phase — Policy & technical details to implement the adopted system & market structure

(C) Monitoring & Feedback Phase — Evaluate system & market performance, & guide adjustments as needed

1. Design & implementation follow structure
2. Monitoring is ongoing:
   • The electricity system is a complex adaptive living system
3. Most adjustments are within the existing structure, design & implementation
4. Major changes in conditions warrant revisiting the structure
Grid Architecture — The Structure Phase (A)

**Step 1**
Define the public interest: Specify the societal goals the electricity system must support

**Step 2**
Specify electricity system performance & outcomes required to support the goals

**Step 3**
Identify major Functions, Roles & Responsibilities required to achieve desired performance

**Step 4**
Construct system structure models & compare them based on criteria from Steps 1-2

Policy decisions that shape system & market structures

The policies, mandates & societal interests the system must support

Performance & external impacts of the system — the “outside-the-system” perspective

Before deciding which Actors do what, specify all required functions — the “inside-the-system” perspective

A “structure model” is an assignment of Functions, Roles & Responsibilities to Actors; + market structure (competition vs monopoly) & unbundling of functions
Takeaways

- The structure phase (A) is where system & market structure policy decisions are made, to best align system performance with the public interest.

- The electricity system has existing operating & market structures today (the status quo structure).

- The Grid Architecture discipline starts by mapping & understanding the existing structures.

- Major changes in conditions warrant revisiting the structure.

- A decision not to revisit structure, to skip phase (A) & make major changes in design & implementation (B), is an implicit decision to retain the status quo structure.
Thank you

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Distribution system operations

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