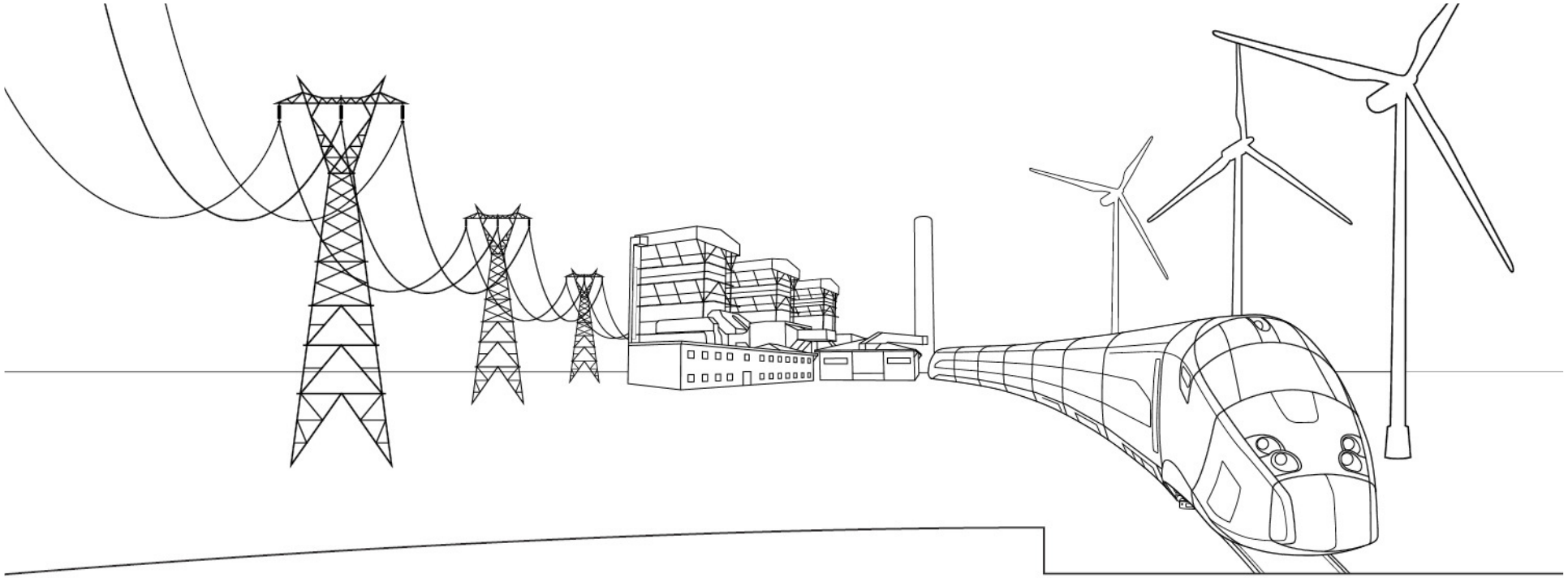

Smart Grid Applications for VRE Integration

Dr. Lawrence Jones
Vice President, Utility Innovations & Infrastructure Resilience
Alstom Grid Inc, North America

World Bank ESMAP Knowledge Exchange Forum
UN City / Copenhagen
October 21, 2014

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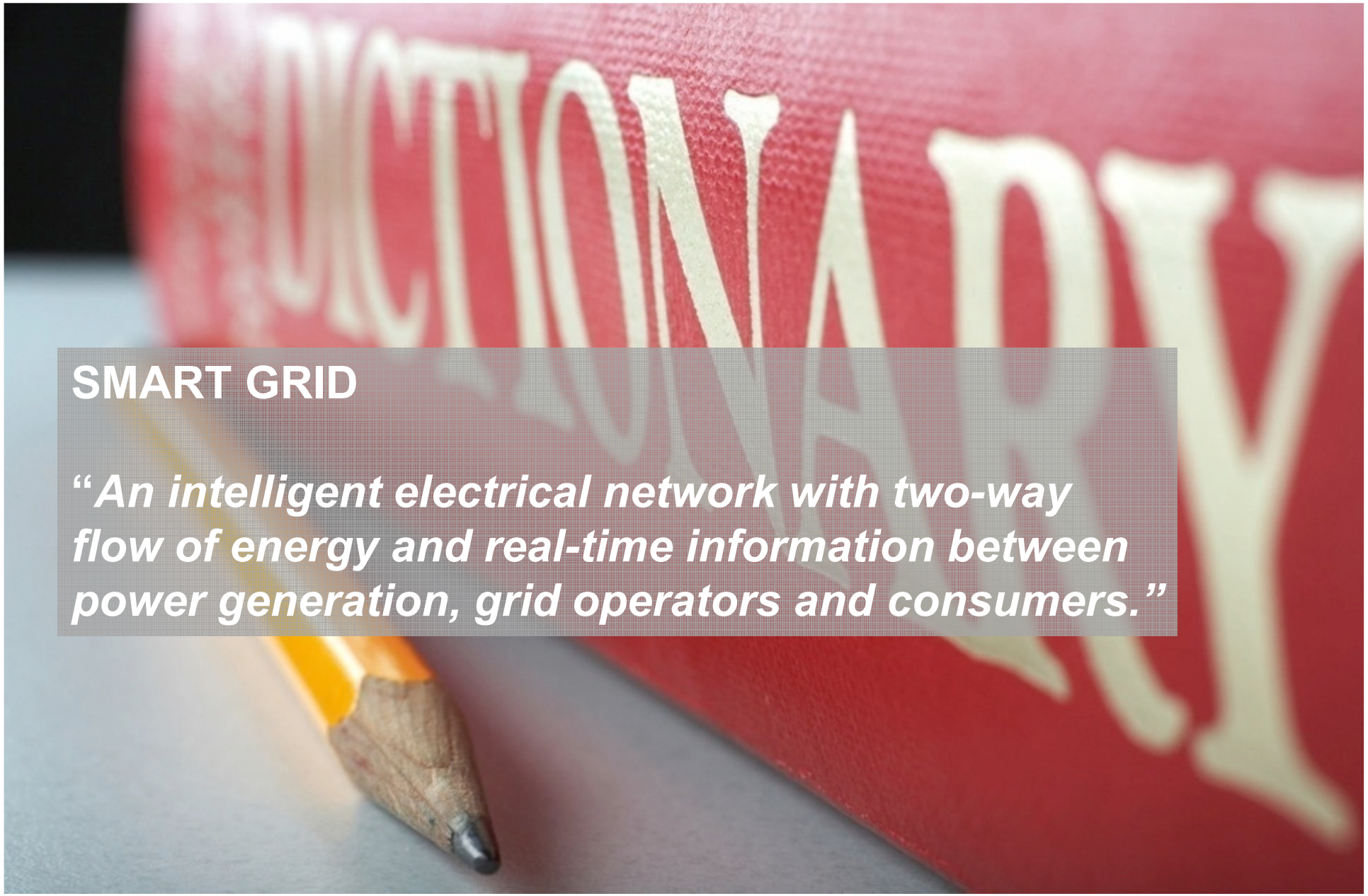
Shaping the future

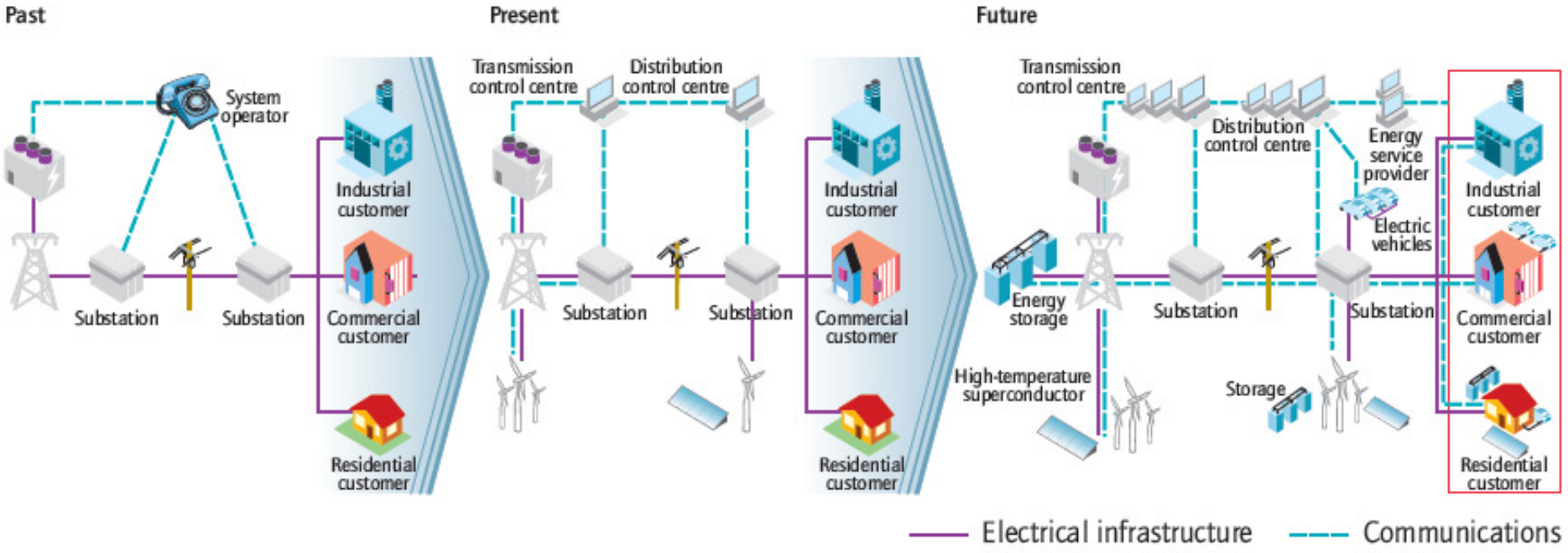


SMART GRID

"An intelligent electrical network with two-way flow of energy and real-time information between power generation, grid operators and consumers."

Smarter Grids: when energy meets information…

"A permanently evolving electrical network, with a real-time, two-way flow of energy and information, between power generation, grid operator, and end users. It is capable of ***integrating all traditional and new players: renewable generation units (wind, solar, etc.), electrical vehicles, electrical storage, or even entire smart cities***".



Source: IEA Smart Grid roadmap 2010

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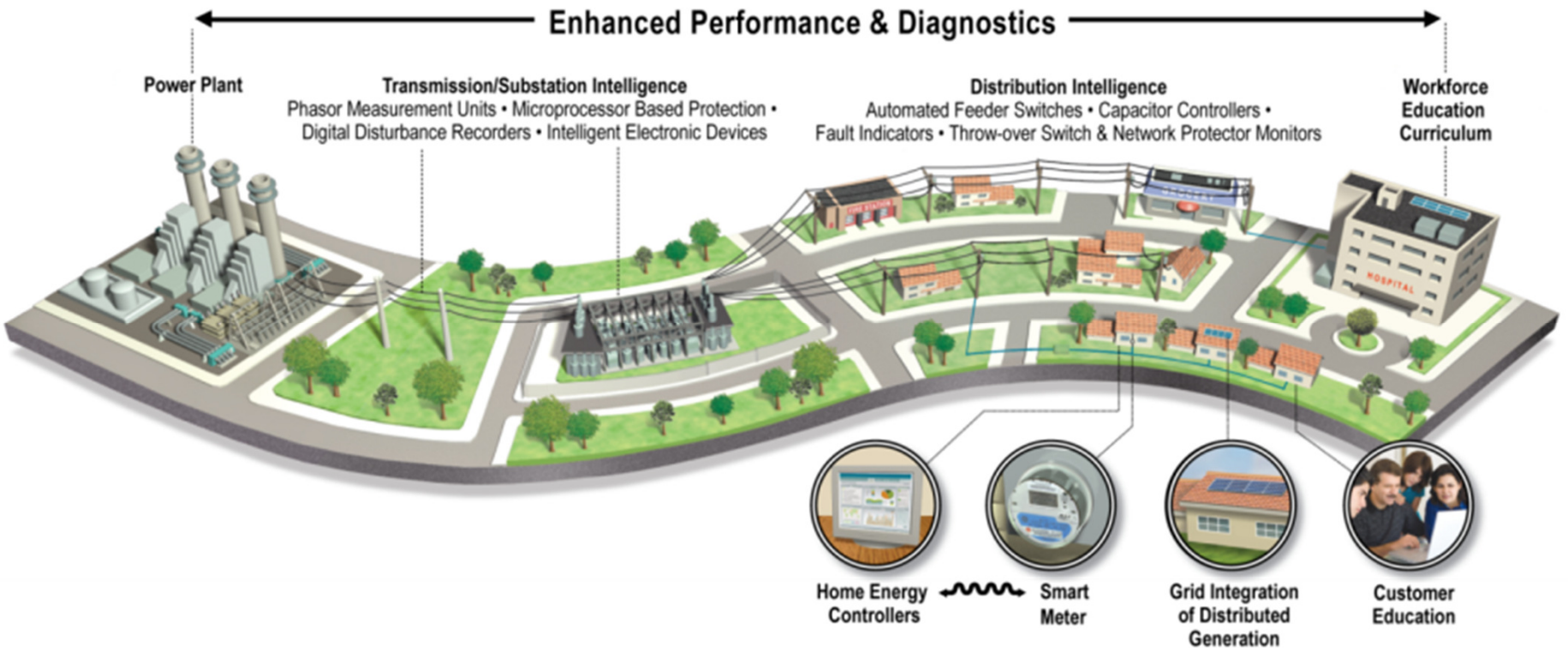
“Smart Grid” ➔ End-to-End Improvements Along the Electricity Value Chain



Graphic: Courtesy of LaMargo Sweezer-Fischer, FPL

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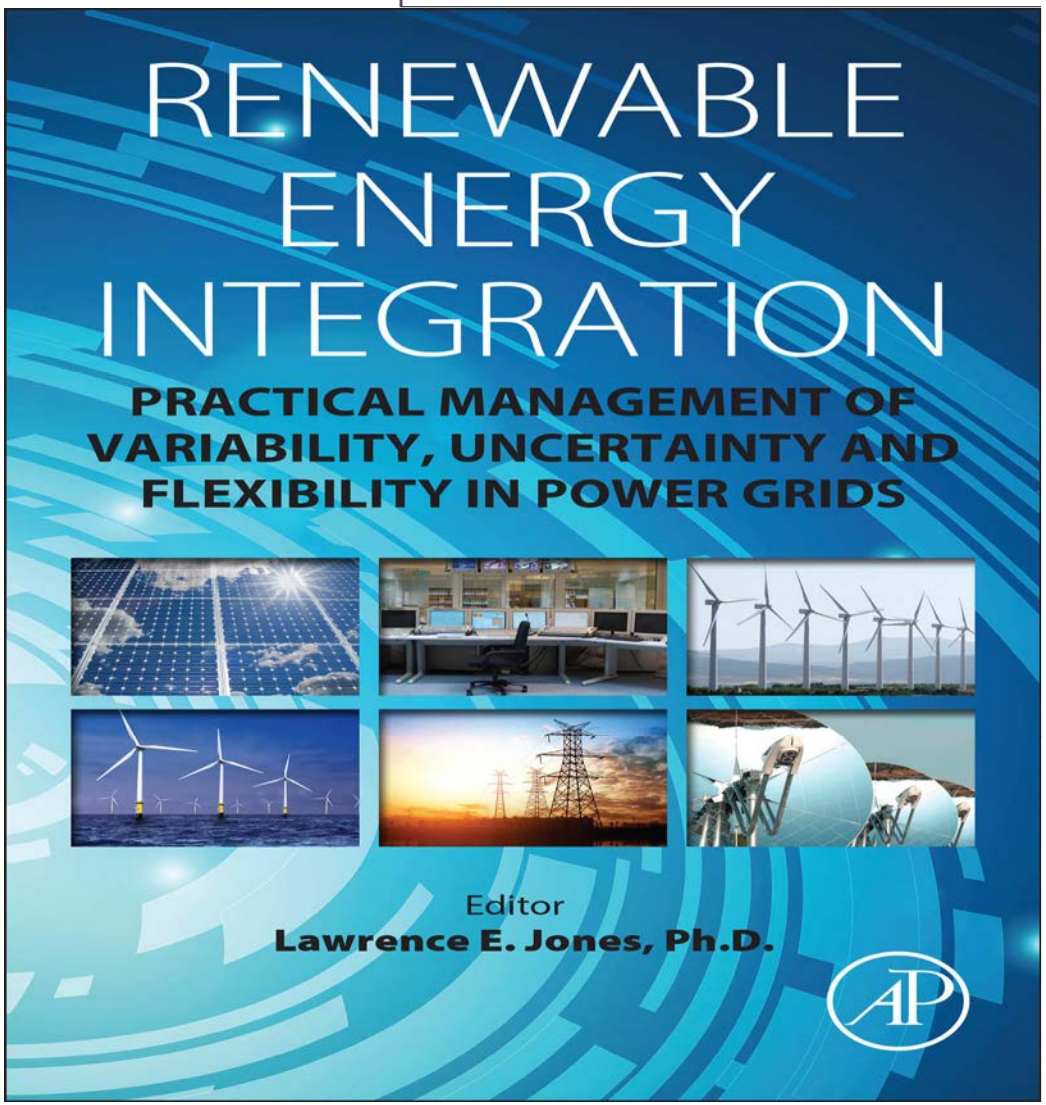
Enabling Technologies that Facilitate VRE Integration

- *Sensors*
- *Measurements*
- *Grid Analytics*
- *Advanced Controls*
- *Intelligent Devices*
- *Integrated Solutions*
- *Big Data Analytics*



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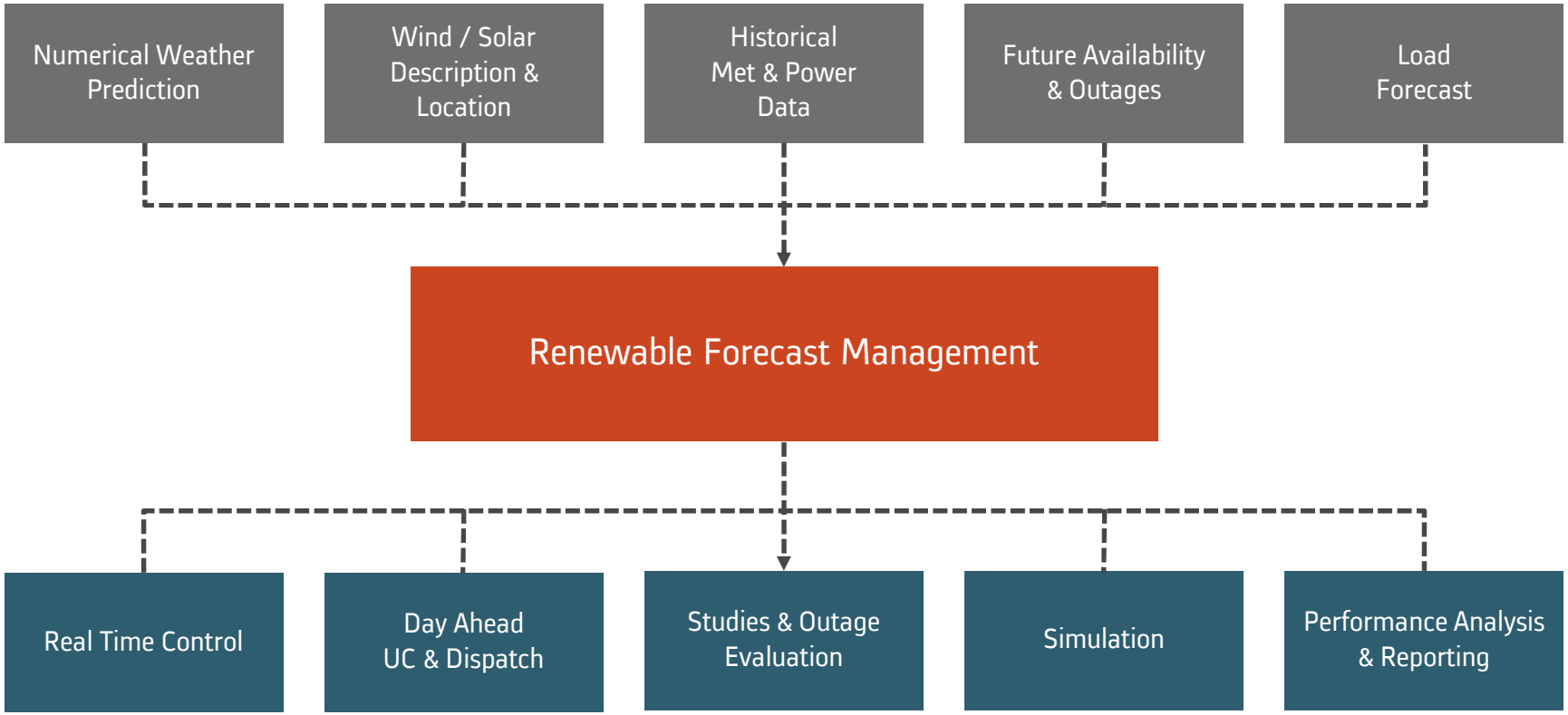
Managing Variability & Uncertainty ➔ Integrating Forecast Data in Planning and Operations



- Network security (current and look ahead)
- Load-following power balancing
- Wind/solar Generation Monitoring and control
- Reserve Monitoring
- Real time curtailment
- Archiving

- Market or Regulated env
- Wind Integration Policies
- Reserve Adequacy

- Steady State
- Dynamic Stability
- Look-ahead
- What-if scenarios
- Transmission Planning
- Generation Adequacy

- Operator Training
- Realistic wind simulation
- Scenario creation
- Event replay

- Centralized forecast
- Public publishing
- Market participants
- Wind plant operators
- Researchers

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Power System Flexibility

Flexibility expresses the extent to which a power system can increase/decrease electricity production or consumption in response to variability, expected or otherwise (i.e. under uncertainty).

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Demand Response

AUTOMATED DEMAND RESPONSE-ENABLED
SITES BY REGION, WORLD MARKETS 2012-2019

SOURCE: NAVIGANT RESEARCH

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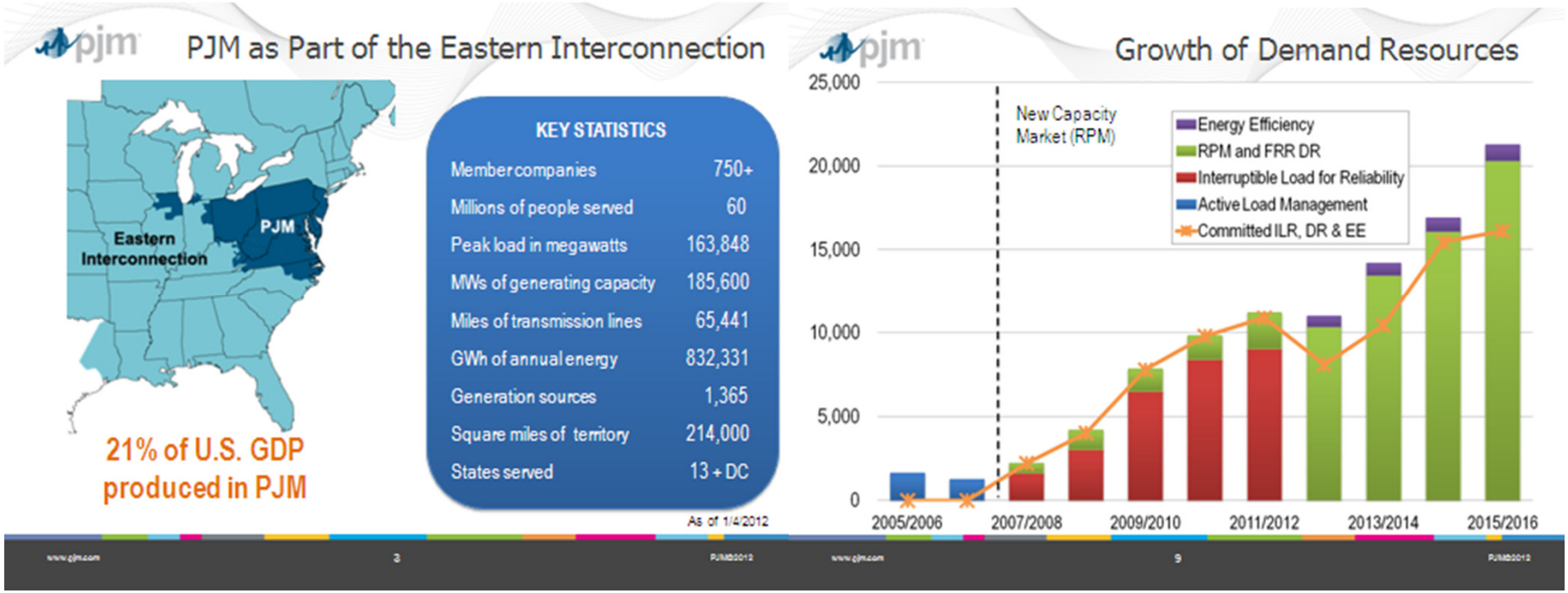
Demand Response is Becoming a Reality



From: "Demand Response and Alternative Technologies in Electricity Markets" by Andrew L. Ott, In *Renewable Energy Integration,* Elsevier 2014

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Distributed Energy Resources Can Provide Flexibility

From: "DR for Integrating Variable Renewable Energy: A Northwest Perspective" by Diane Broad and Ken Dragoon
In *Renewable Energy Integration.* Elsevier 2014

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Flexibility from Game Changers

New integration opportunities

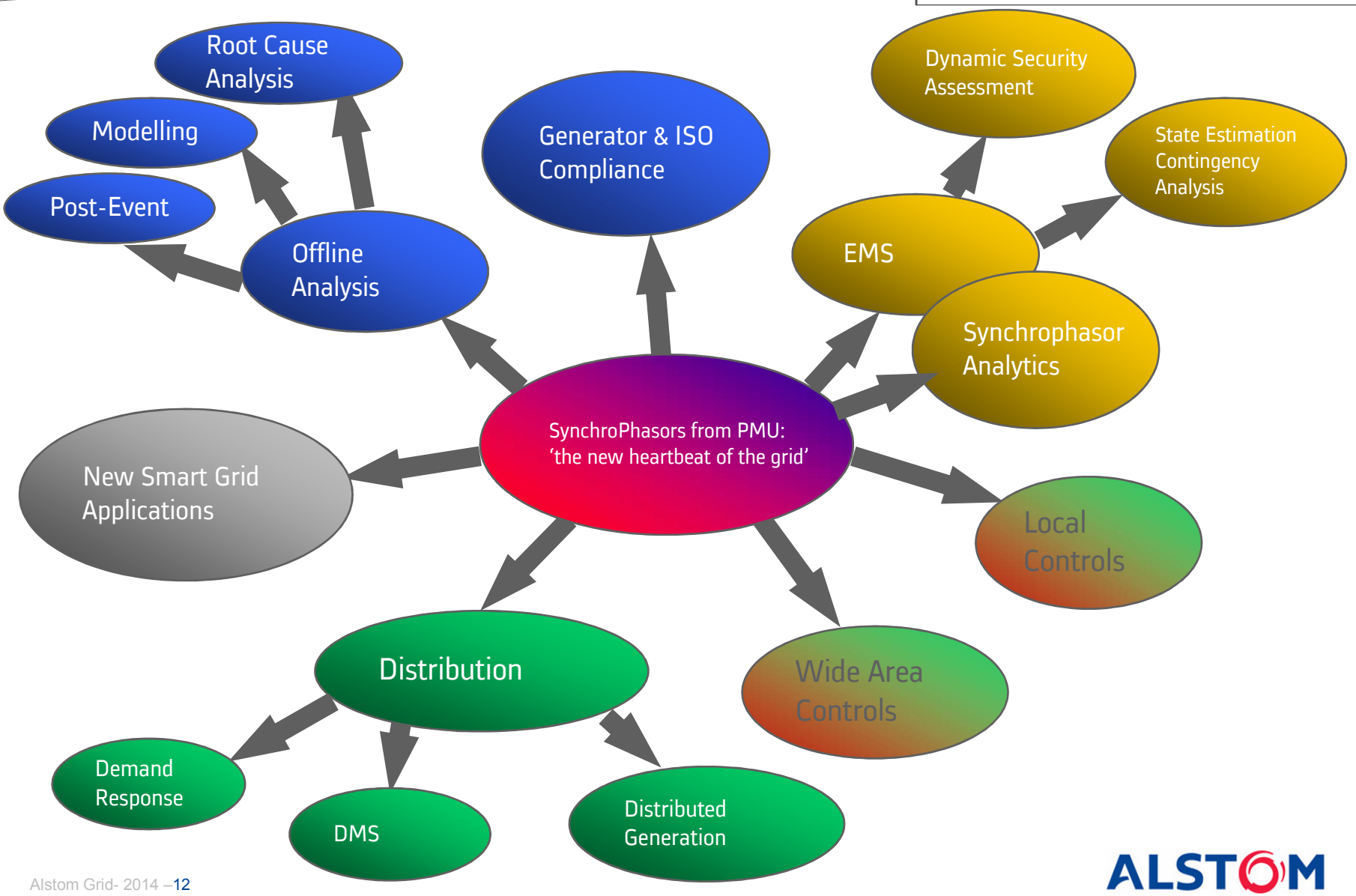
Transportation
EV/PHEV, Smart Appliances
- Can react to price fluctuation
- Can shave peak load
- Energy conservation

Energy Storage
Battery Storage,
Can react to price fluctuation
- Can shave peak load
- Augment renewables

New challenges

Synchrophasors: The New Heartbeat of the Grid!

Wide Area Situational Awareness Improves Renewable Energy Integration



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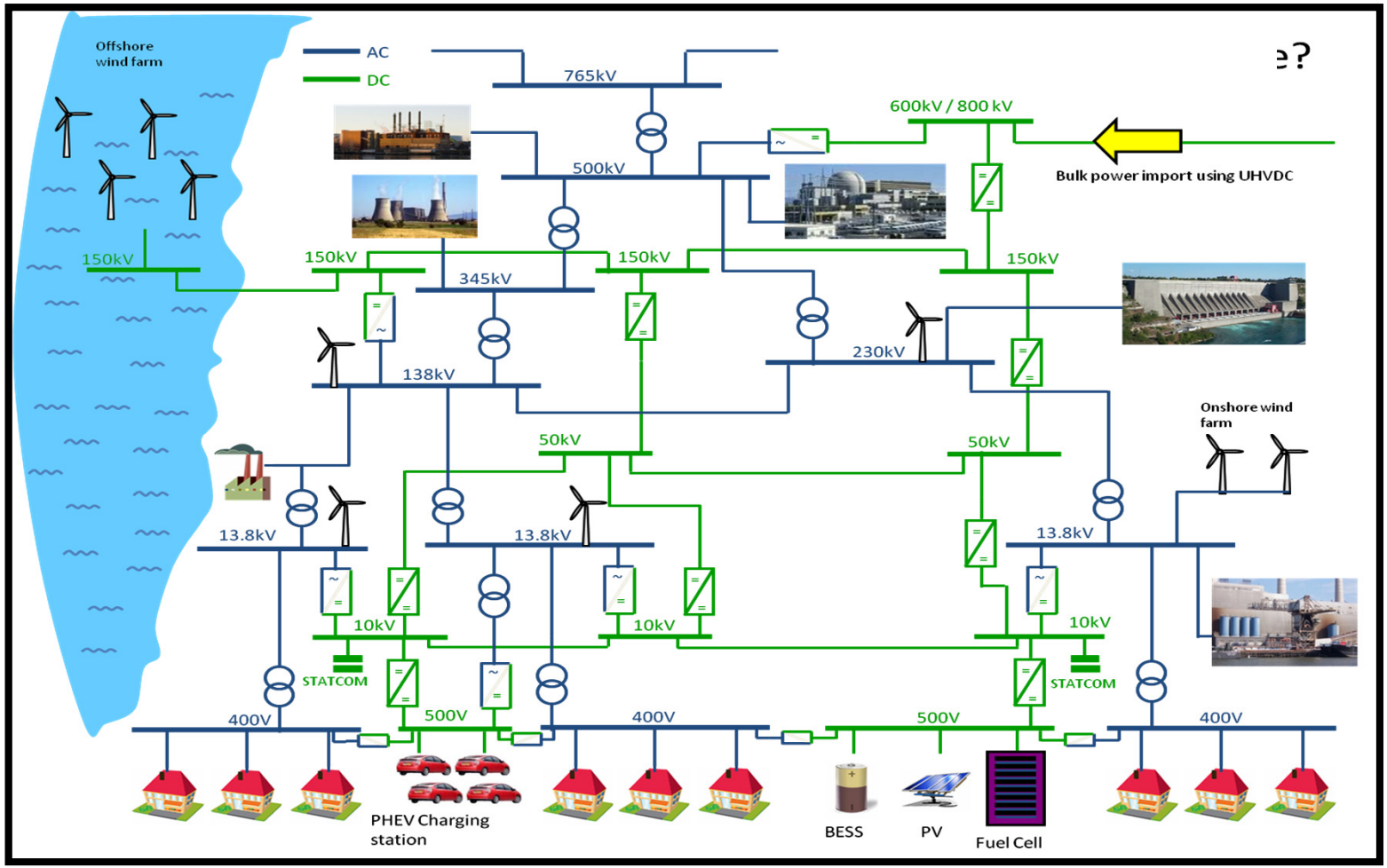
Smarter Transmission and Distribution Grids Enable Large-Scale Renewable Integration



Power Electronics and Controls (e.g. HVDC, FACTS, Smart Inverters) Improve Grid Flexibility

Courtesy of: Carl Barker, Author of "Practical Management of Variable and Distributed Resources in Power Grids." In *Renewable Energy Integration,* Elsevier 2014

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Thank You

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