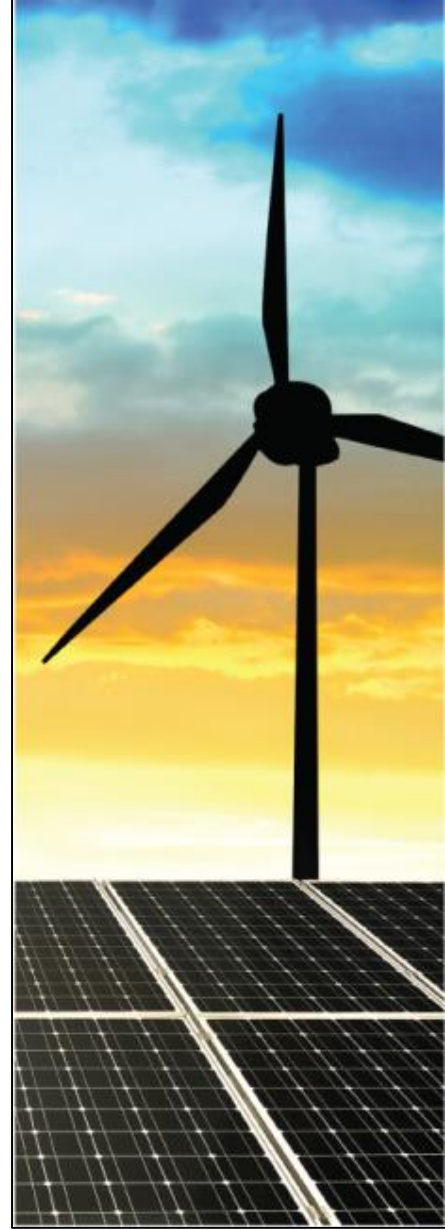


2018 Spring Technical Workshop and Annual Meeting

Tucson, Arizona
March 13-15, 2018



Utility Variable-Generation Integration Group

Charting the Future of Wind and Solar Power Integration and Operations



- **Pre-Workshop Tutorial on Tuesday Morning**
 - Energy Systems Integration – An Introduction
 - *Chair, Mark O'Malley, Chief Scientist, ESI, NREL*
- **Tuesday Afternoon – Working Group Meetings**
 - Research and Education WG – Chair, Mark O'Malley, NREL
 - *Definition and agreement on WG scope and activities*
 - Reliability WG – Chair, Nick Miller/Sebastian Achilles, GE
 - *Reliability challenges with high VG penetration*
 - System Planning WG – Chair, Aaron Bloom, NREL
 - *The Interconnection Seams Study*
 - Distributed Energy Resources (DER) WG – Chair, Debbie Lew, GE
 - *Pathways and case studies for high penetration DER*
 - System Operation and Market Design WG – Chair, Aidan Tuohy, EPRI
 - *Market design challenges for high penetration scenarios*

- **Wednesday Sessions**

- Welcome and Opening Remarks - Marie Jordan, Peak Reliability
- Plenary: System Markets for Very High Penetrations of Renewable Energy
Moderator: Bruce Rew, SPP
- Session A-2: Adequacy and Capacity Expansion with a Changing Mix
Moderator: John Simonelli, ISO-NE
- Session B-2: Integration of Transport into the Energy System
Moderator: Mark O'Malley, NREL
- Session A-3: Technology and Models for Very High Renewable Penetrations
Moderator: Bob Zavadil, Enernex
- Session B-3: Gas System Coordination
Moderator: Russ Philbrick, Polaris Systems Optimization
- Networking Reception

- **Thursday Morning Sessions**

- Session A-4: Power System Reliability with Increasing VG

Moderator: Charlton Clark, DOE

- Session B-4: DER Integration

Moderator: Debbie Lew, GE

- Closing Plenary: Future Developments and Int'l Collaboration

Moderator: Mark Ahlstrom, NextEra Energy Resources

- **Thursday Afternoon Schedule**

- Optional Tour: Avra Valley PV Plant and UA Tech Park Solar Zone

- DOE-GMLC Meeting

- Board of Directors Meeting

Recent Industry Developments

- EIM reports total benefits at end of Q4 2017 of \$288 million since its inception in November 2014. EIM includes CAISO, Pacificorp, NV Energy, APS, PSE and PGE, with Idaho Power and Powerex on track to join on April 1 , 2018. The Balancing Authority of Northern California/SMUD LADWP will begin participating in April 2019. Salt River Project and Seattle City Light are slated to enter the market in April 2020.
- FERC Order 841 issued in February 2018 requires ISOs to revise market rules to allow participation of energy storage devices >100 kw in the wholesale electricity markets
- FERC Order 842 issued in February 2018 requires all new generating facilities to install governor controls in support of PFC as a condition of interconnection.
- DOE NOPR on payments to coal and nuclear plants for providing reliability and resiliency services was rejected by a 5-0 vote at FERC
- *“Recent weeks have seen new block-chain based energy hopefuls cropping up like mushrooms after the rain.” Plus currencies like Bitcoin, SolarCoin, ...*
- IEEE 1547 is done!

Recent Industry Trends

- Wind and solar PV system prices continue to fall. In Jan '18, Xcel announces amazing results from solicitation, with median prices for 2023 delivery:
 - wind at \$18.10/MWh
 - wind plus battery at \$21/MWh
 - PV at \$29.50/MWh
 - PV plus battery at \$36/MWh
- Latest Mexican auction (Nov '17) average PPA PV price of \$19.70/MWh. Lowest wind price came in at \$17.70/MWh.
- Corporate demand for carbon-free energy is increasing. In 2017, Google, Apple, Facebook, GM, and others signed PPAs for 3100 MW of wind and solar
- Low energy market prices continue to drive market redesign efforts in US and Europe amid concerns over capacity adequacy, flexibility, and ERS
- Growing recognition globally of the need for greater system flexibility required to enable integration of high shares of renewable energy
- Increasing incidences of entities announcing 100% renewable goals

- Lazard reports on lowest unsubsidized energy costs at end of 2017 for:

Simple Cycle GT	\$156/MWh
Rooftop residential solar	\$187/MWh
Nuclear	\$112/MWh
Coal	\$60/MWh
Combined Cycle GT	\$42/MWh
Utility scale solar	\$43/MWh
Wind energy	\$30/MWh

- Other reports from industry pubs on recent PPA prices:

Utility scale solar	\$27-\$40/MWh
Wind energy	\$11-\$24/MWh

**Storage Systems are still struggling,
but starting to show promise...**

- Lazard reports at end of 2017 on estimated lowest unsubsidized energy costs for a range of storage systems (5 kw to 100 MW):

Peaker Replacement (4 hr @ 100 MW)

- Lithium Ion \$282/MWh

Distribution Substation (6 hr @ 10 MW)

- Lithium Ion \$272/MWh

Microgrid (4 hr @ 1 MW)

- Lithium Ion \$375/MWh

Commercial BTM (2 hr @ 125 kw)

- Lithium Ion \$891/MWh

Residential BTM (2 hr @ 5 kw)

- Lithium Ion \$1,028/MWh

- US wind capacity end of 2017 ~ 87 GW
- US solar PV capacity end of 2017 ~ 54 GW
- US VG installations in 2017
 - Wind 7 GW
 - PV 12 GW
- Ballpark estimates for 2018 US VG installations
 - Wind 8 GW
 - PV 10 GW

- China wind capacity end of 2017 - 188 GW
- China solar PV capacity end of 2017 - 130 GW
- China VG installations in 2017
 - Wind 20 GW
 - PV 53 GW
- Ballpark estimates for 2018 China VG installations
 - Wind 20 GW
 - PV 43 GW

- Global wind capacity end of 2017: 540 GW
- Global PV capacity end of 2017: 400 GW
- Global VG installations in 2017
 - Wind 53 GW
 - PV 92 GW
- Ballpark estimates for 2018 global VG installations
 - Wind 60 GW
 - PV 100 GW

From an article by David Roberts reporting on the NextEra Energy earnings release conference call of January 26, 2018 by CEO Jim Robo:

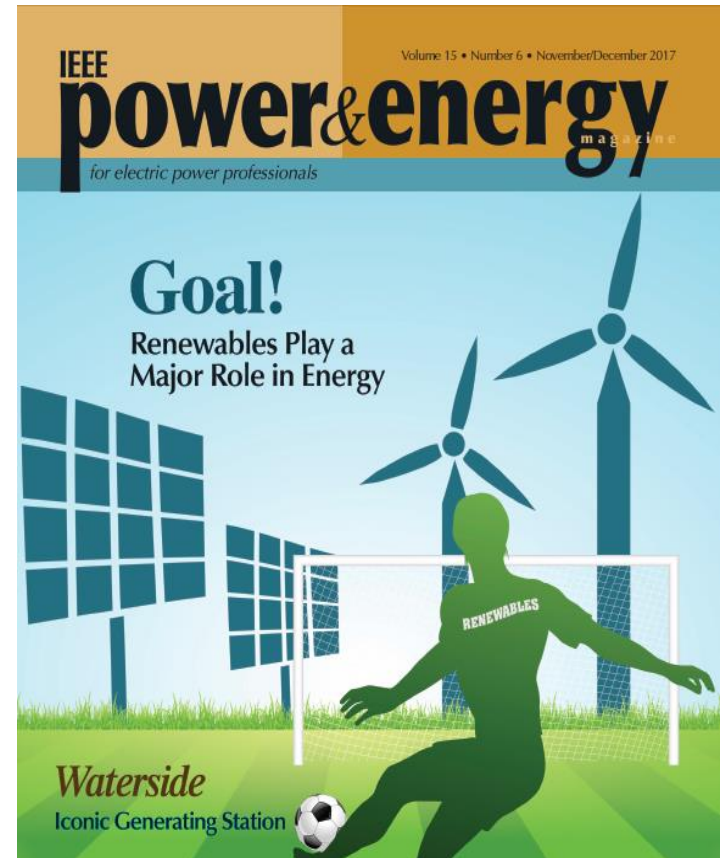
- Robo predicted that by the early 2020s, it will be cheaper to build new renewables than to continue running existing coal and nuclear plants.
- Here are the costs Robo anticipates 'early in the next decade':
 - Unsubsidized new wind: 2.0-2.5 cents per kilowatt-hour
 - Unsubsidized new solar: 3.0-4.0 cents per kilowatt-hour
 - Variable operating costs of existing coal or nuclear plants: 3.5-5.0 cents per kilowatt-hour
- If those predictions hold up, it is game over for coal (and nuclear, unless it gets support based on its low carbon emissions). No one will ever build another coal plant in America, and the ones still running would likely shut down sooner than scheduled.

David Roberts, Vox.com, Jan 29, 2018

As If That Wasn't Enough ...

- BP's latest Energy Outlook forecasts a peak in oil demand for the first time—while renewables will grow even faster than previously expected.
- Peak oil driven by the rise of shared and autonomous electric vehicles. Under the Evolving Transition (ET) scenario, which assumes that policies and technology continue to evolve at a speed similar to that in recent past, oil demand slows and then plateaus in the late 2030s.
- Several other energy research groups have upped their EV forecasts in recent years. However, BP's latest projection ranks among the most ambitious.
- Headline for GTM article on 2/20/18: “Coal plant closures accelerate under President Trump”. According to the Sierra Club in the same story, more coal capacity closed in the first 45 days of 2018 than in Obama's entire first term.
- BNEF says “nearly as much plant capacity set to shut down in 2018 as during the 2015 peak, when the coal industry dropped 15 gigawatts.”

- A warm welcome to visitors from afar:
 - China
 - Japan
 - Canada
 - Belgium
 - Ireland
 - Colombia
 - United Kingdom
 - Texas
- Take the time to make some new friends!
- Looking forward to another great meeting!



Upcoming 2018-2019 Meetings

2018 Forecasting Workshop

June 19-21, 2018

St Paul Hotel

Saint Paul, Minnesota

2019 Spring Technical Workshop

March 19-21, 2019

Hyatt Regency Tamaya Resort & Spa

Bernalillo, New Mexico

(near Albuquerque)

2018 Fall Technical Workshop

October 1 - 3, 2018

Embassy Suites

Denver, Colorado

2019 Forecasting Workshop

June 4-6, 2019

Embassy Suites

Denver, Colorado

THANK YOU

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