FREEDM Industry Advisory Board Minutes
September 7, 2017
10:00 am – 11:30 am US eastern

Attendees

Company	Name	Membership Level
Pos-En	Paul Gregory	Associate
SAS	Arnie de Castro	Associate
Schneider Electric	John Shea	Associate
Total	Wente Zeng	Full
Weidmann	Giuseppe Gatti	Associate
FREEDM	Ken Dulaney Thomas Dotson Rishabh Jain Ewan Pritchard	

The meeting began with attendance and reading the antitrust statement. Minutes from August were approved. Since the last meeting, the IAB approved funding for two Industry Innovation Grant proposals. Dr. Bhattacharya and Dr. Helen Li will lead those projects. Ken followed up on the budget discussion from August with a narrated powerpoint that seemed to work well for everyone. (Arnie noted later that budget approval requests need to include the actual amounts requested in the email.) The IAB also approved funding for the Total Fellowship since last meeting. Shea motioned for minutes approval, de Castro seconded. Approved via voice vote.

Ken noted the new video on the website and mentioned several upcoming conferences. He also described recent recruiting efforts and member engagement activities. Mercedes, Fuji and Danfoss are planning lab tours at NC State. Ken also met several Duke Energy attendees at a meeting in DC regarding IEEE 1547. FREEDM is also sending a delegation to Universidad del Norte in October to foster university relations.

Ken also stated that North Carolina is funding a state-wide evaluation of energy storage technologies and FREEDM is proposing on this project. But there is a cost share requirement from non-state funds and he may be calling for donations. Ken later sent a separate email regarding this opportunity.

We then heard from two students who discussed their summer internships. Both presentations are in Appendix A.

Rishabh Jain worked at the National Renewable Energy Lab. He conducted a meta-study of reserve estimation in domestic and international renewable integration studies. His work will be included in a forthcoming book titled Integration of Large-Scale Renewable Energy into Bulk Power Systems. Rishabh also worked on two other projects: the impact of location of DERs on voltage and frequency stability during faults, and improving the characterization of wind turbine output using machine learning. During his presentation, we briefly discussed the recent US DOE study regarding baseload plant retirements and the impact on reliability. This summary article from Utility Dive includes a link to the full study.

The next presentation was from Thomas Dotson who worked for the Market Services division at the Midcontinental Independent System Operator. MISO extends from Manitoba, Canada to Louisiana. He worked with IEC communication standards and then focused on DER impacts to MISO load profile. Thomas estimated the market potential of residential PV at various future dates using the free System Advisor Model from NREL. He also estimated $/kwh values for PV to achieve certain penetration levels on MISO's system.

The annual conference needs a planning committee of both faculty, staff, and industry members. Ken asked for volunteers to serve and will also reach out to some individuals directly. Committee members will have much more influence over the agenda and keynote speaker selection.

Ewan led a brief discussion on best practices for partnering with industry members on proposals. He discussed a specific example with EV battery management at higher charging power levels. Proposal teams usually develop over a few weeks so it's important to have partnerships developed prior to the release of RFPs or FOAs. Members mentioned that it may be difficult to form the business case for getting involved in federal proposals since the university would often be looking for cost share from the industry member.

The meeting adjourned at 11:30 am. Our next meeting will be October 5, 2017 at 10 am US eastern time.

Action Items

1. Ken and Iqbal: Prepare Center budget summary to share with IAB.
2. Ken: Survey IAB for December meeting dates and proposed location.

Appendix A
Student Presentations

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Reserve Estimation in Renewable Integration Studies

Rishabh Jain

About Me

Graduate Student in ECE

Advisors: Dr. Srdjan Lukic, and Dr. David Lubkeman

Research Interests: Power System Protection, Grid Integration of Renewable Resources, Stable formation and operation of microgrids, Automated Service Restoration and Fast Transition between MG and Grid modes.

Past: National Renewable Energy Lab, Schweitzer Engineering Labs

Internship @ NREL

Supervisor: Dr. Bri-Mathias Hodge
Transmission and Grid Integration Group

Getting the Internship:

1) Application via LinkedIn
2) NREL had an upcoming project : Needed skillset:

- OpenDSS
- Real time HIL testbeds
- Experience with Power System Operations
- Transient analysis.

During the Internship

1) The project never got started – So, they wanted me to work on the Renewable Integration Studies Review (Unlikely to have happened otherwise)

2) With a bit more convincing, I got two more projects:
    a. Impact of location of DERs on Voltage and Frequency Stability of the Grid during faults (Previous experience with Fault response, and Transient Analysis)
    b. Improving the characterization of Wind Turbine Output by considering Wind turbulence using Machine Learning

Reserve Estimation in Renewable Integration Studies

Need:

- Understanding if and how the reserve requirements need to change to account for the increasing renewable generation share in the system
- Overestimation = Higher Cost, Underestimation = Possible System Outages

Challenges:

- Modeling Complications of studying large and integrated systems with multiple constraints.
- Addressing the variability and uncertainty introduced due to renewable generation
- Correctly modeling Ancillary Services to understand the impact of Renewable generation
- Modeling the Production Cost Model of the System correctly

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Differences in Reserve Requirements

Same Terms,. Different Contexts

<table>
<tr><td rowspan="2"></td><th colspan="7">Frequency Regulation</th></tr>
<tr><th>Primary</th><th colspan="2">Secondary</th><th colspan="4">Tertiary</th></tr>
<tr><td rowspan="2">PJM</td><td rowspan="2">Frequency Response</td><td colspan="5">Operating Reserves</td><td rowspan="2">30-min Reserves</td></tr>
<tr><td colspan="2">Regulation</td><td>Spinning</td><td colspan="2">Quick-start</td></tr>
<tr><td rowspan="3">CAISO</td><td rowspan="3">Spinning Reserve</td><td colspan="4">Operating Reserves</td><td colspan="2" rowspan="3">Replacement + Supplements</td></tr>
<tr><td colspan="2">Regulation</td><td colspan="2">Contingency</td></tr>
<tr><td colspan="2">Spinning</td><td colspan="2">Non-Spinning</td></tr>
<tr><td>VDN, Germany</td><td>Primary</td><td colspan="2">Secondary</td><td colspan="2">Minutes</td><td colspan="2">Hours + Emergency</td></tr>
<tr><td rowspan="2">RTE, France; Belgium</td><td rowspan="2">Frequency Containment Reserve</td><td colspan="2" rowspan="2">Automatic Frequency Restoration Reserve</td><td colspan="4">Tertiary</td></tr>
<tr><td colspan="2">Manual Frequency Restoration Reserve</td><td colspan="2">Replacement Reserve</td></tr>
<tr><td>Spain, Netherlands,</td><td>Primary</td><td colspan="2">Secondary</td><td colspan="4">Tertiary</td></tr>
<tr><td rowspan="2">Great Britain</td><td rowspan="2">Frequency Reserve, Disturbance Reserve</td><td colspan="2" rowspan="2">Does not Exist</td><td colspan="2">Operating</td><td colspan="2">Contingency</td></tr>
<tr><td>Regulating</td><td>Standing</td><td>Fast-start</td><td>Warming; Hot standby</td></tr>
<tr><td>Australia</td><td>Contingency Reserve (fast/slow/delayed)</td><td colspan="2">Regulating Service, and Network Loading Control</td><td colspan="4">Short Term Capacity Reserve</td></tr>
<tr><td>New Zealand</td><td>Instantaneous Reserve Fast/Sustained Over-frequency</td><td colspan="2">Frequency Regulating Reserve</td><td colspan="4">Not named separately</td></tr>
<tr><td rowspan="2">Canada (NPCC)</td><td colspan="3">10-minute Reserves</td><td colspan="3" rowspan="2">30-minute Reserve</td><td rowspan="2">Inter-BA Reserve</td></tr>
<tr><td>Synchronized</td><td colspan="2">Non-synchronized</td></tr>
<tr><td rowspan="2">ERCOT, NYISO</td><td rowspan="2">Regulation Reserve</td><td colspan="2">10-min Reserve</td><td colspan="4">30-minute Reserve</td></tr>
<tr><td>Spinning</td><td>DSR</td><td>Non Spinning</td><td colspan="2">Spinning</td><td>DSR</td></tr>
<tr><td rowspan="2">CAISO</td><td rowspan="2">Frequency Response</td><td colspan="2">Regulating Reserve</td><td colspan="4">Tertiary</td></tr>
<tr><td>Reg Up</td><td>Reg Down</td><td colspan="2">Spinning</td><td colspan="2">Non-Spinning</td></tr>
<tr><td rowspan="2">ENTSO-E</td><td colspan="7">Operational Reserves</td></tr>
<tr><td colspan="2">Frequency Containment Reserve</td><td colspan="2">Frequency Restoration Reserve</td><td colspan="3">Replacement Reserve</td></tr>
</table>

Comparison of different Reserve Requirements around the World [Table 5.1,[2]]

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Conclusions

- Contingency Reserve Requirements (long term, and usually based on the Single-Largest Contingency [SLC])
  - Should remain largely unaffected by the increased renewable penetration, because SLC doesn't change

- Regulation and other operating reserve (short term, and based on ramp rates of loads and generation)
  - Should increase because of the increasing variability and uncertainty in the system generation
  - Using Hourly dispatch schedule for reserves may not reflect the variability and reserve needs of the system (time scale of minutes). Sub0hourly schedules may need to be considered.
  - System variability was actually found to decrease when both PV and Wind generation increase in the system, because they tend to offset each other
  - Islanded (or systems with smaller footprint) will need to have more aggressive regulation reserve requirements.

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Work + Play = A Great Internship

BONUS!

- Golden, CO – Beautiful place with hiking grounds in the backyard

- Chance to observe how open-source communities are flourishing at National Labs and how they improve the impact – And how we can help

  (Python, OpenDSS, GridLab-D, OpenModelica, and so on)

- Was able to collaborate with Kandler Smith from NREL to acquire degradation models for Li-FePO4 batteries which has been improved by Yuhua, Me to be used in our DESD subthrust.
  (2 Papers : ECCE’16 and PESGM’16)

Publications for Work during Internship

[1] R. Jain, Yingchen Zhang and B. M. Hodge, "Investigating the impact of wind turbines on distribution system stability," *2016 IEEE Power & Energy Society Innovative Smart Grid Technologies Conference (ISGT)*, Minneapolis, MN, 2016, pp. 1-5. doi: 10.1109/ISGT.2016.7781210

[2] Stoll B., Jain R., Brancucci Martinez-Anido C., Ibanez E., Florita A., Hodge BM. "Reserve Estimation in Renewable Integration Studies". In: Du P., Baldick R., Tuohy A. (eds) Integration of Large-Scale Renewable Energy into Bulk Power Systems. Power Electronics and Power Systems. Springer, Cham (2017) Available: https://doi.org/10.1007/978-3-319-55581-2

[3] Jie Zhang, Rishabh Jain, Bri-Mathias Hodge, "A data-driven method to characterize turbulence-caused uncertainty in wind power generation," Energy, Volume 112, 1 October 2016, Pages 1139-1152, ISSN 0360-5442, https://doi.org/10.1016/j.energy.2016.06.144

Contact Information

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Midcontinental Independent System Operator Intern

Thomas Dotson

2017

Who are MISO?

- MISO is an independent system operator(ISO) based out of Carmel Indiana

- Serve as a Regional Transmission Organization for 15 states and Manitoba, Canada

- Manage an energy market that brings together buyers and sellers of electricity

- Keep the lights on for about 42 million electricity users

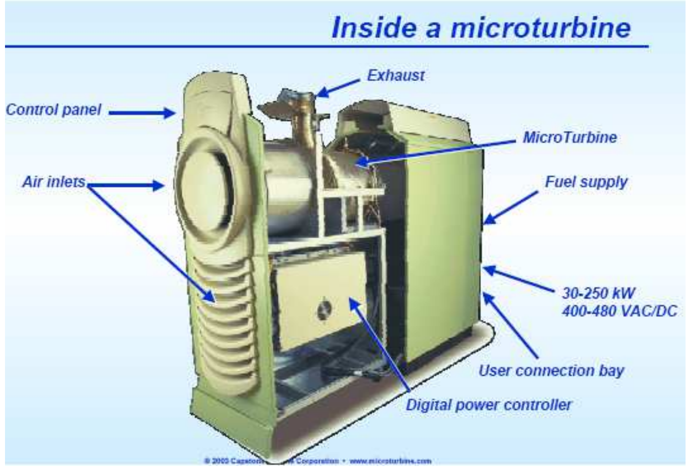
https://www.misoenergy.org/Pages/Home.aspx

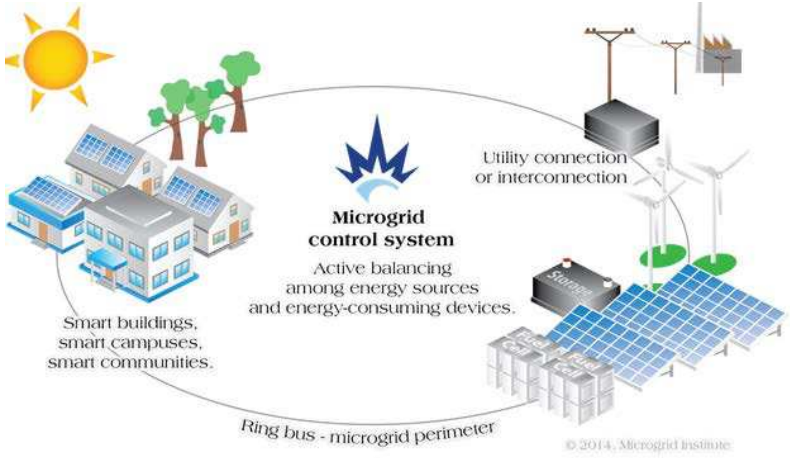
What I did

- I worked in the Market Services division of MISO
- My main responsibility was Research and Development (R&D)
- My efforts were scattered around different projects for the month of June
  - Mostly reading and reporting
- For July, I was given a project related to distributed energy resource (DER) presence in MISO's footprint
  - Lots of reading, coding and using solvers

Distributed Energy Resources(DER)

- A source or sink of power that is located on the distribution system, any subsystem thereof, or behind a customer meter
- Examples:
  - Microgrids
  - Energy Storage
  - Rooftop solar
  - CHP
  - Demand response

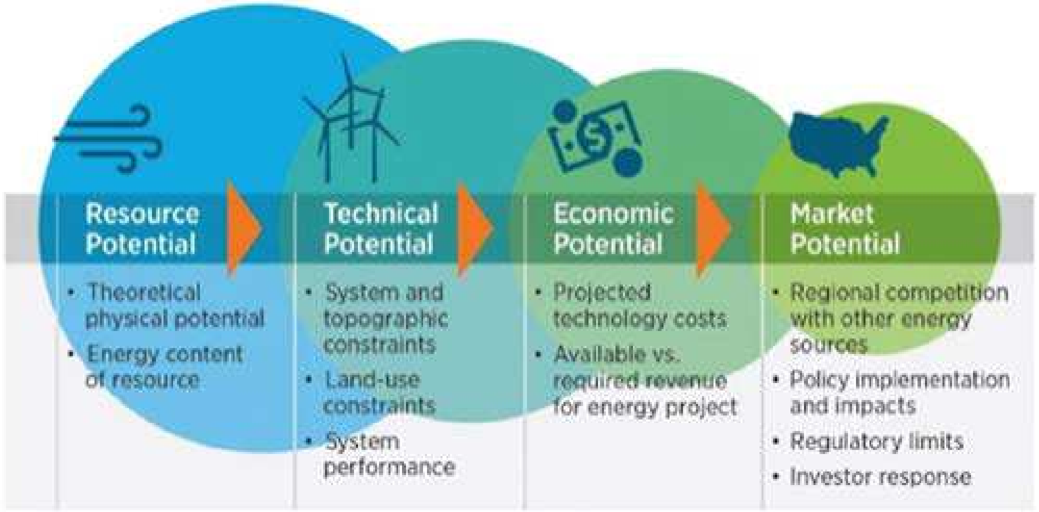




https://www.ferc.gov/whats-new/comm-meet/2016/111716/E-1.pdf

Economic Potential

- The goal of my main project was to study economic potential of rooftop solar PV within MISO footprint
- I used an algorithm developed by NREL
    - Defines economic potential by subtracting levelized cost of energy from levelized avoided costs to find net present value (NPV)
    - All of the areas with a positive NPV is the economic potential for the resource



https://www.nrel.gov/docs/fy15osti/64503.pdf

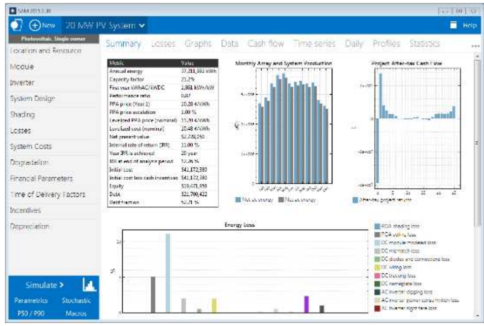
Megawatts to Megawatt-hours

- Another goal of my project was to determine an algorithm that could convert a PV MW rating into a MWh generation profile.
- The algorithm had to use local weather data and PV characteristics to determine hourly generation profiles.
- Previous studies had used the PVWatts online calculator to generate profiles for locations throughout the MISO footprint.
- I was tasked with evaluating that method, and given 2 options:
  - Update it with new numbers
  - Update the method, and validate by using PV Watts

http://pvwatts.nrel.gov/

SAM

- I found a tool by NREL that I could use to do my simulation. This tool is the System Advisor Model (SAM)
- SAM is a very powerful model for both performance and economics.
- A software development kit (SDK) could be used to interact with the underlying engine dynamically, rather than use SAM's GUI to manually input parameters for every iteration

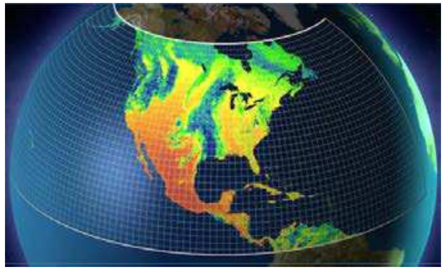


https://sam.nrel.gov/

Economic Study Methodology

- For my study, I chose 37 locations within MISO's footprint
  - Locations were chosen based on population density within MISO's 10 load resource zones(LRZ)

- I downloaded local weather data from the NREL solar resource database(NSRDB)
  - All weather data was from the year 2014



- I also downloaded data from the Open EI utility rate database
  - Residential time-of-use (TOU) rates

https://nsrdb.nrel.gov/

https://openei.org/wiki/Utility_Rate_Database

Economic study assumptions

- Only the federal tax credit of 30% is used
    - Some states have as many as 50 direct cash incentives and tax credits that apply to residential solar energy
    - This would require coding a representational state transfer (REST) application programming interface (API), or manually entering incentive data from the DSIRE database for each location
- All solar arrays are paid for with 25 year mortgages with 5% interest
- A single annual load profile is used for the entire PV lifetime
    - Peak power = 4.16 kW
    - Annual energy = 12,000 kWh
- No net metering is used
    - Excess PV generation was rolled over to the next month's bill in kWh

Economic Study Conclusions

- At the price point of $2.92/W, the economic potential of the simulated locations is about 29%.
  - 29% of the locations have a positive net present value
- The biggest driver for value of solar energy is the avoided cost of utility energy.
  - Areas with less generation, but higher utility rates, can receive higher value for their energy
- A price of $2.42/W yields an increase in economic potential of 50%
- A price of $1.10/W would increase the economic potential to 100%