# Responses to questions asked during ESIG May Webinar: MISO's Renewable Integration Impact Assessment

1. **If every utility scale wind and solar plant had to add physical inertia (presumably using high inertia synchronous condensers) equivalent to what was displaced in the form of retired or curtailed conventional synchronous generation, how far do you think that would that go toward resolving the weak grid and dynamic stability problems? Do you see benefits (reactive power sources closer to the load, greater granularity of control, greater distribution of total system strength, etc.) to many smaller distributed high inertia synchronous condensers versus relatively few large ones connected to the transmission system?**

The study has identified (slide 27) that at very high penetration of renewables, synchronous condensers (SC) may be needed to resolve weak grid issues to operate system reliably. A detailed design SC can eliminate weak grid issues and help achieve the target renewable penetration.

Weak grid issues are identified as voltage stability issue at the Point of Interconnection (POI) of inverter-based resources. As can be seen in the slide 27, several distributed SCs were needed to be installed. The distribution of SCs will depend on location of inverters in the system and could be at transmission voltage level or distribution level. Another way weak grid issues could be resolved is through paradigm change in inverter control strategy (aka "grid forming").

2. **How many MWhours of battery storage would be need to avoid the inflection point?**

We have not explicitly studied this question. Battery storage can help with many of the areas raised in the presentation such as load/generation shifting to meet load needs, congestion relief, weak grid issues, and frequency response. In some cases the technology is proven, and in others cases it is not. In all cases though battery storage is part of the suite of solutions to help address specific challenges highlighted here. The only way to avoid the inflection point by use of batteries only is if battery storage can do a far superior job than other solutions in addressing the need. Another way to rephrase the question is "how many MWh of battery storage would be needed to replace the solutions used in the analysis to-date?".

3. **Do you see battery storage adding to the increase of renewable energy at the generation assets ?**

I don't know if I understand this question. Battery storage won't add to the amount of renewable energy available at a generation facility but can be used to boost the energy provided by a facility through overbuilding the energy producing portion of the plant and using storage to optimize output.

4. **What's the detail breakdown of the full system integration costs and why is it increasing sharply as the penetration level increases?**

The purpose of our work was not to provide a detailed cost estimate of integration costs; rather it was to provide insights into the areas of concern as we see more renewable energy on the system. The level increases non-linearly due to the cumulative nature of existing system needs and new ones as detailed in the presentation.

5. **Would the cost situation you describe be different if renewables were deployed as fully dispatchable units 24/7/365 (i.e., embedding storage and other technologies as part of their deployment) ?**

The purpose of RIIA is to understand the implications of adding more wind and solar to the system. The cost to make these facilities 24/7 would need to be set beside other solutions to fully understand if the cost picture would improve or degrade. I have heard the term fully dispatchable used in different ways and the answer to the question depends on definition. We have done analysis to achieve full 24/7/365 and the result looks significantly worse than what was presented. On the other hand, some define 24/7 "as needed". This looks only at the marginal need of the system and builds for that (i.e. only cover peak load). In this case the result would likely look more similar to the results presented, but as noted we haven't done detailed analysis.

6. **Thank you, Jordan, for the great presentation. Utilities are deploying advanced metering infrastructure. Was this part of what was considered as "current technology options" in terms of dealing with increasing complexity with variable generation? Slide 4**

This was not looked at. In regard to DER we modeled it as equivalent solar on the transmission side of the distribution interface which essentially assumes that all distribution issues are taken care of. Investigation on the impacts of distributed solar to the distribution system would be additive to our work.

7. **p. 6: What does "wind-heavy siting" mean? How does it affect the value of solar? Do the two lines on the solar graph represent location of the solar, rather than the amount of wind?**

Yes. When we project out a wind heavy scenario it shifts the location of solar resources to areas with lower wind potential.

**8. How do you interpret the firm solar/wind power generation results recently released in this USDOE/MISO report: http://mnsolarpathways.org/miso- ?spa/?**

We have not done a comprehensive comparative analysis of the two efforts.

A few things to note when comparing the two bodies of work.

1) RIIA is a more comprehensive technical assessment pulling in all major modeling domains into one coordinated project
    a. It does not seek to be a comprehensive economic assessment and thus will not state how much renewable energy should be built or what the end costs will be.
2) While RIIA focuses on MISO, detailed modeling of the Eastern Interconnection was conducted.
3) Many conclusions are consistent between the work products
    a. Benefits of larger balancing regions
    b. The non-linear relationship between the overlapping impacts of wind, solar and storage
    c. Benefits of blending wind and solar for resource availability and balancing
4) The main conclusion difference is in the "cost to achieve". RIIA concludes that the cost to achieve the benefits listed go up non-linearly as a function of renewable penetration level under current technology assumptions.

**9. Great presentation! Did you model a scenario where energy storage gets you to 100%?**

For the purpose of this work we only modeled through 50% annual energy except in Resource Adequacy section.

**10. How much load management/demand side flexibility has MISO modeled for each of these scenarios?**

We assumed the current level of load flexibility.

**11. Does Battery Storage add more value on MISO frr wind or solar generation assets?**

We haven't targeted this question as part of the analysis. Based on work to date it is a bit of both. Storage provides more value to solar to resource adequacy (shifting generation) and short-term volatility, while for wind it has the potential to provide more value for weak grid situations.

**12. Can you please explain a bit more by what you mean by 'complexity'**

Renewable complexity is measured as the incremental work needed to reach the next renewable milestone (i.e. penetration level). It is quantified by cost for the purposes of charting, but is in concept inclusive of risk and other supporting activities needed to achieve those renewable levels.

**13. Your slide on need for dynamic voltage support states that "Improvement of wind and solar technologies can bring down the cost of integration." The tech has been ready for a while. Isn't it trans operators that need to begin exploiting this capability?**

ESIG put out a nice one-pager on this topic.

https://www.esig.energy/download/10-things-you-should-know-about-grid-forming-inverters/

While grid-forming-inverters themselves are not new commercially available, utility-scale wind and PV today do not have GFM capability.

**14. Was the type of HVDC technology, LCC, VSC, MMC, a factor considered during this study of using HVDC for mitigating stability issues?**

In this work both LCC and VSC technologies were considered. In certain scenarios, upgrading the LCC rating was found be cost-effective, whereas in other scenarios (weak-grid), VSC was used, as VSC technology by design is better able to operate in weak-grids and bi-directionally to deal with variability and uncertainty posed by wind and solar generation.

**15. Can you clarify what the A and B notations on slide 17 mean?**

A and B refer to the picture on the right. A is the amount of synchronous generation providing frequency response, and B is inverter based generation providing frequency response.

**16. For the solutions, you mentioned for reactive power support on the system, is that considering that renewables can provide reactive power support as well, or is it without any reactive power support from renewables?**

Renewables were modelled considering reactive power limits per FERC directives (order 827). thus it can provide reactive support (steady-state and dynamic). . However, current technology used in renewables can provide limited reactive power support, and in general conventional units would be more effective in supplying necessary reactive power to maintain system voltage.

**17. To what level (if any) has storage technologies been analyzed in these studies?**

Please see responses to other questions.

**18. Can you discuss the bump in value of HVDC from 20% to 30% RE? Is there a written source of info documenting that?**

See slide 15. Essentially we did not 'observe any voltage stability issues until that milestone. When we started to see them, we first solved them through traditional means (Capacitor banks, STATCOMs synchronous condensers, etc.). As the issues intensified the traditional solutions no longer worked because other issues were introduced (oscillatory behavior between condensers). At this point we found HVDC to be the only practical solution for the given issues when looking through the lens of existing technology. Follow-up work has also shown value of limiting the amount of wind/solar generation in weaker areas on the system to be effective.

**19. If "innovation" is needed, what are the top 3 areas -- forecast, control, communication across distribution/transmission, others?**

The top 3 areas shown by our work to date are:

1) Resource Adequacy: Better aligning resource availability with load needs throughout the year
2) Energy Adequacy: Enabling solutions for balancing variability and energy transfer across a wider footprint
3) Voltage Stability: Developing solutions for "weak grid" problems caused by high inverter based resource penetrations

20. **Does the renewable integration cost include the new flexibility capacity investment? If yes, what technology types are the flexibility capacities**?

For simplicity we preserved and utilized existing resource flexibility as a proxy for new flexible capacity needs.

**21. Any sense of how much storage is needed to mitigate reliability risks?**

See question 2.

**22. Thank you for the presentation, it was very interesting. As you study penetration of renewables, did you take a look at the need to keep peakers available and how will they be compensated to stay available?**

RIIA is focused solely on the needs of the system and technical solutions to fill those needs. Results focus on the size of the need (e.g. MW of generation) rather than the exact type (peakers) or how to compensate them.

**23. Do you foresee a change in requirements for dynamic response? Voltage/frequency/generation dispatch?**

The analysis identifies different kind of dynamic issues and presents respective solutions. As the system gets closer to these issues presenting themselves in reality utilities will need to examine these situations more directly and determine how they should be addressed. For example:

1. Better dynamic response is needed to maintain reliability in weak-grids. Please see answers to question 1, 19, and 16.
2. While renewables can provide frequency response, they cannot support under-frequency events if they lack headroom. Certain hours of very high instantaneous penetrations need to ascertain that headroom is available on online resources to arrest frequency decline.
3. In the operational timeframe enhanced monitoring will be needed to "see" dynamic issues before they happen and craft efficient solutions to remain stable. Unless we can incorporate new technology to design the system to remain very stable as the penetration of inverters increases operations will need to be much better at navigating the edge cases.

**24. What combination of modeling tools was used to analyze the different aspects of complexity?**

Resource adequacy = Convolution, sequential Monte Carlo analysis = PLEXOS

Energy adequacy = Annual hourly SCED/SCUC for the Eastern Interconnection = PLEXOS

Operating reliability steady state = N-1, etc. contingency analysis = PSS/E

Operating reliability dynamic stability = voltage, small signal, frequency stability = DSA Tools (TSAT, VSAT, SSAT)

**25. At what point does it make sense to increase diversity by expanding planning beyond the MISO region?**

Our work shows a need to continuing improving planning and operational coordination across an area broader than MISO. It is hard to say at which point, rather it becomes continuously more important and renewable penetration increases.

**26. Can you elaborate on what reliability metrics specifically are being recommended? Voltage stability metrics or LOL-type metrics?**

Both. Transmission will play an increasingly important role in ensuring generation can supply load over broader temporal and spatial region to aid in times when renewable output is especially low or high in a geographic region for a particular time.

Also, transmission reliability metrics (i.e. voltage stability) that haven't seemed as important in the past for holistic grid planning will become more critical as the synchronous machine, inverter based machine ratio changes.

27. **What changes to support renewable integration do you think are not being pursued aggressively today, but are the cost-effective solutions for the future?**

See question 19.

**28. What are some of the innovations do you think are required to increase the penetration of renewables further in the MISO system?**

See question 19.

**29. How do you see thermal plants surviving in energy markets with high wind and solar penetration with low capacity factors aka low energy sales without dedicated reliability products such as capacity, ramping and inertia? as an alternative revenue streams**

Our work focused on the technical impacts/needs of the system rather than how to finance them.

**30. As Jordan mentioned, transmission infrastructure is needed to meet resource adequacy at high renewable generation. In MISO, how would new transmission lines be financed? By MISO, renewable generators/developers, or transmission investors? Thank you.**

MISO does not own nor finance any grid assets. New transmission is financed by both generation and transmission developers.

**31. Has the cost of integration of wind power and solar power, been compared to the operational cost savings, mostly from reduced fuel costs, of wind power and solar power? Production cost modelling can evaluate the operational savings. Thank you.**

Yes. While the exact results vary depending on future cost assumptions the general conclusion on slide 4 holds.