



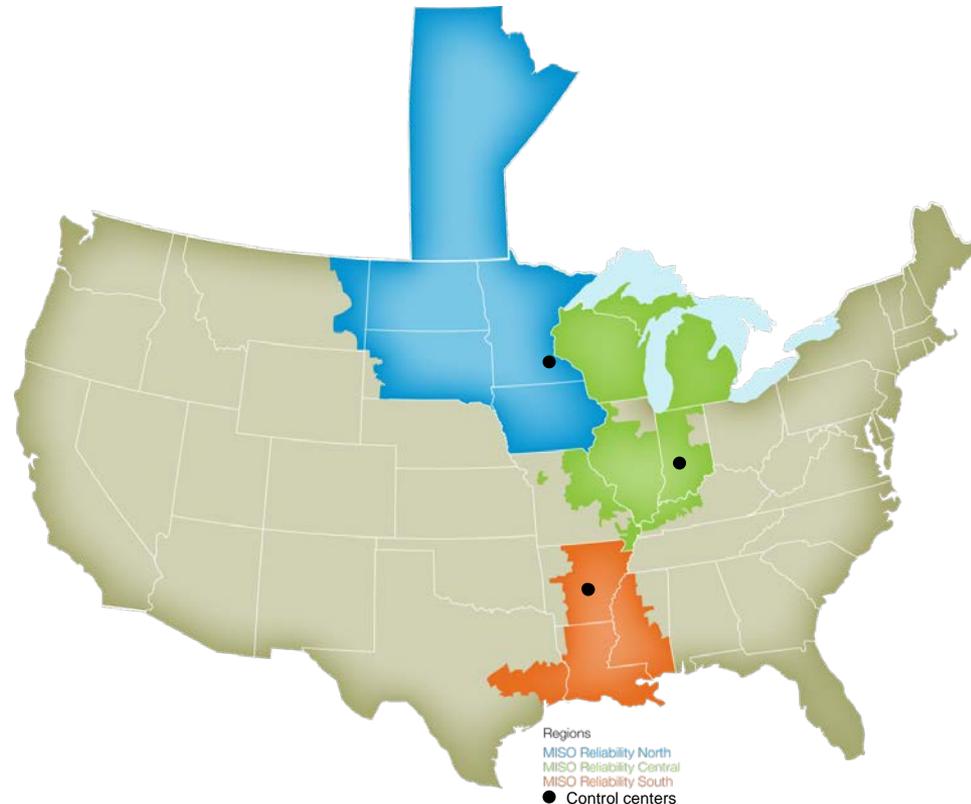
Journey of a Renewable MegaWatt – from an Interconnection Request to Real-time Market Dispatch

1st International Conference on Large-Scale Grid
Integration of Renewable Energy in India

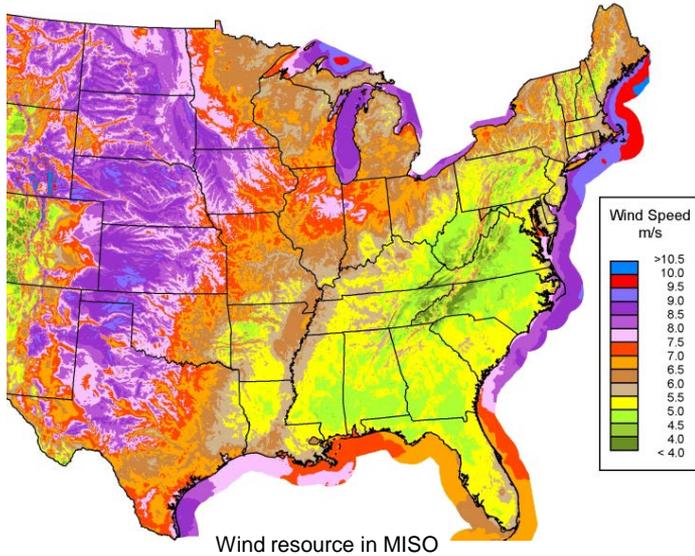
Durgesh Manjure, MISO Energy
September 7, 2017

MISO manages one of the world's largest energy markets

- Scope of Market Operations
 - US \$25.3 billion gross market charges
 - 437 market participants, 42 million customers
 - 5-minute security constrained economic dispatch
- Generation Capacity: 191,062 MW
- Historic Peak Load: 130,917 MW
- Wind generation capacity: 16,326 MW
- Instantaneous Wind Peak: 13,731 MW
- 65,800 miles of transmission
- Footprint: 15 US States, 1 Canadian Province

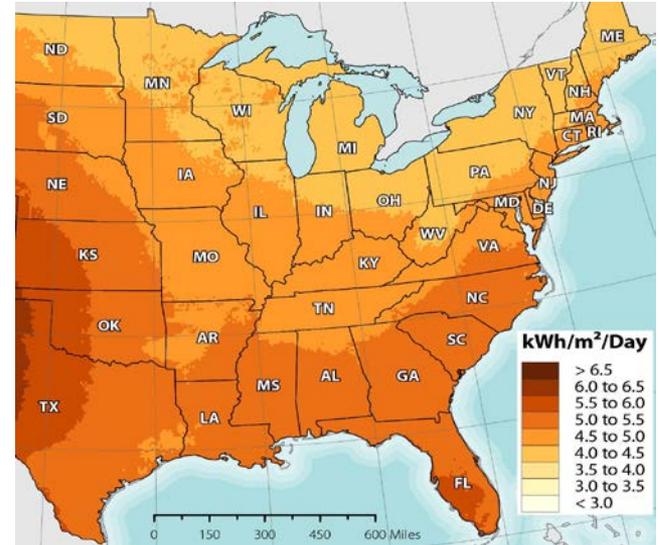


Rich resource and favorable policies have spurred renewable generation in MISO



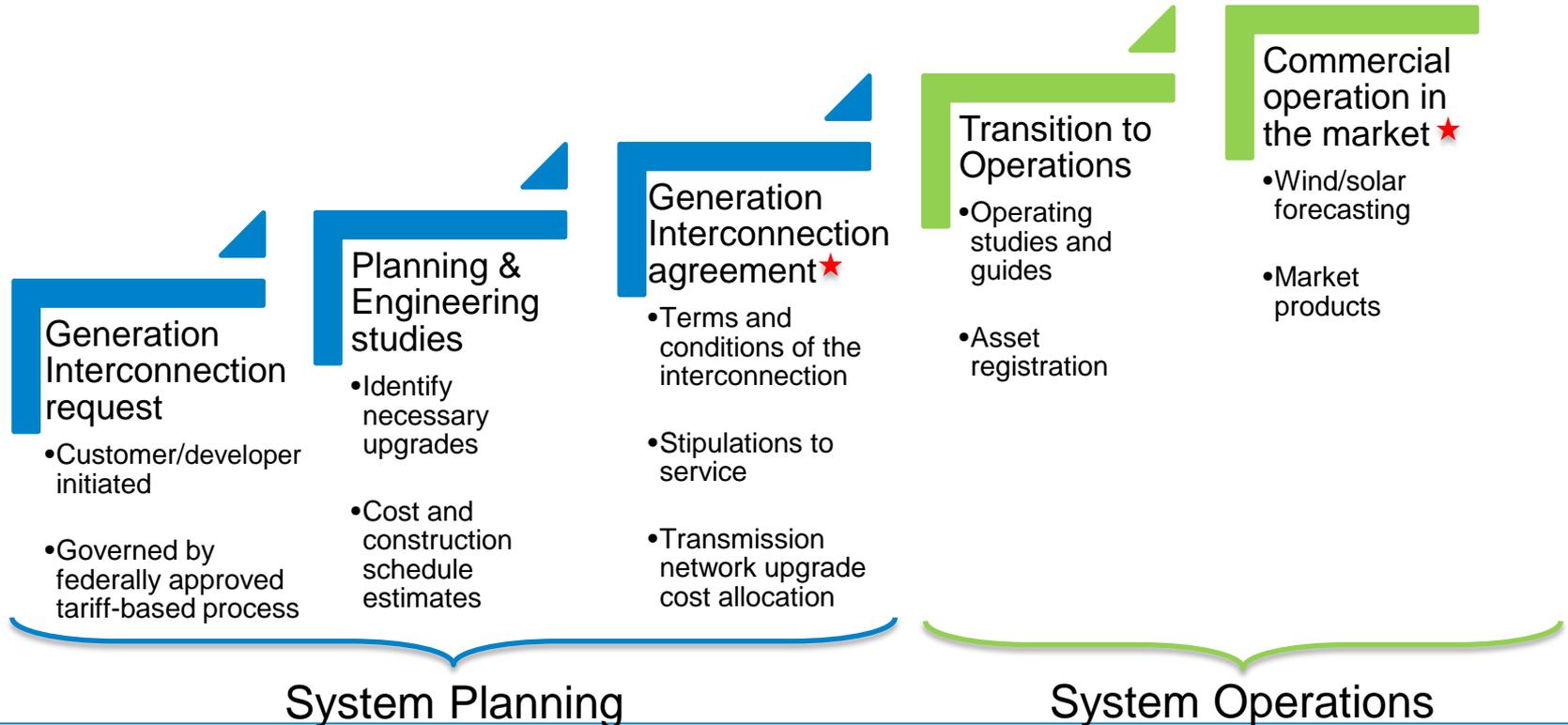
Wind
Installed: ~16,000 MW
In construction: ~2000 MW
In study: ~31,000 MW

Solar
Installed: ~200 MW
In construction: ~200 MW
In study: ~16,000 MW

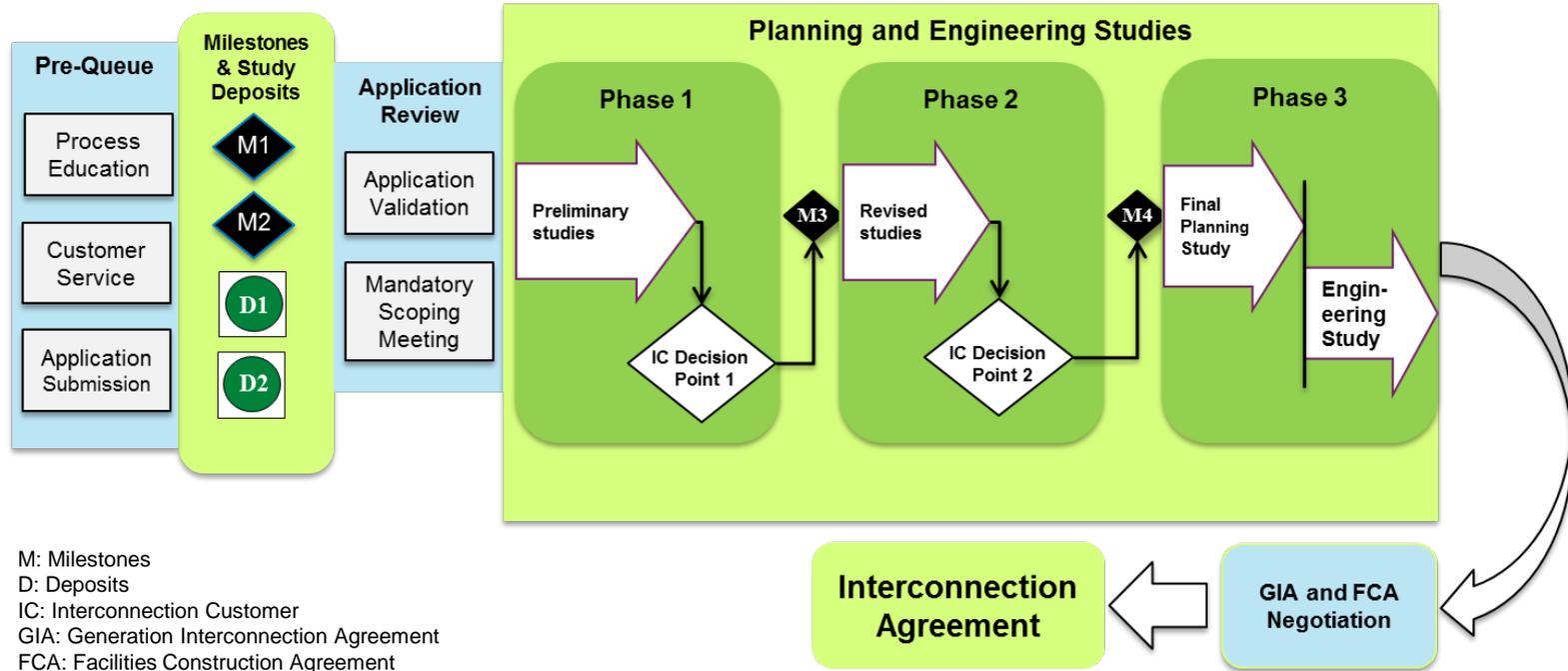


- Most states in the MISO footprint have mandates or goals for renewable energy
- Estimates for wind generation requirements are around 23 – 25 GW
- Solar generation development is just starting out

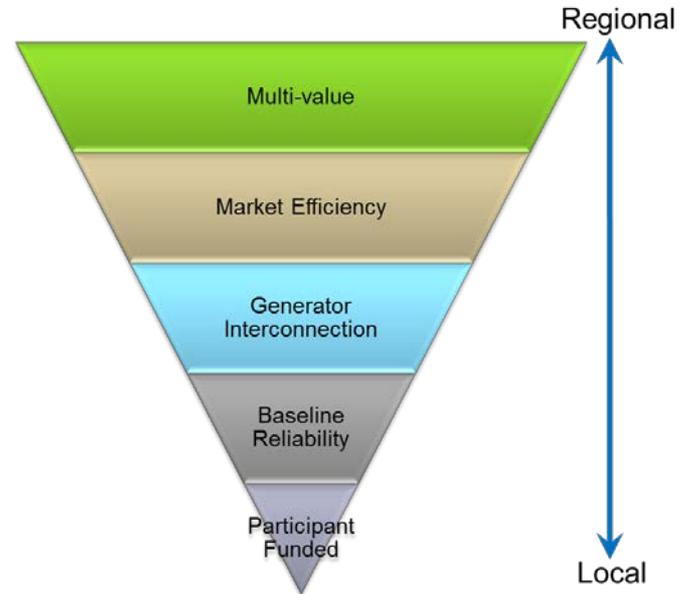
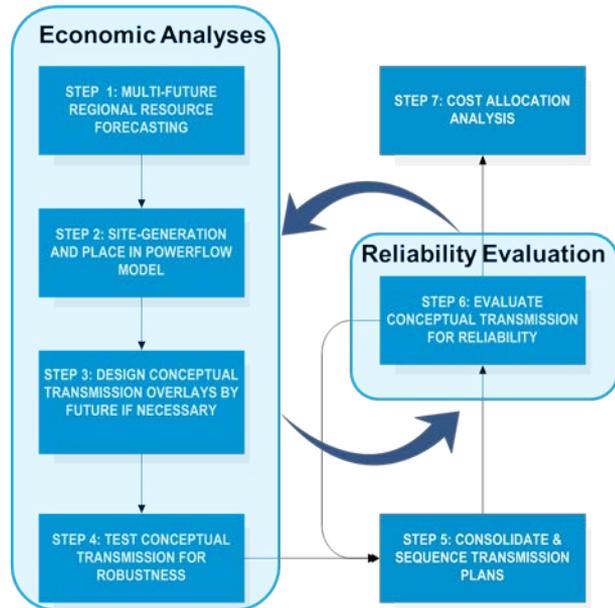
Renewable integration spans various aspects of both the Planning and Operations processes



MISO's *first-ready, first-served* GI process evolution was largely driven by requests to interconnect wind generation



Value-based transmission planning & equitable cost-allocation are key enablers of transmission development for large-scale renewable integration

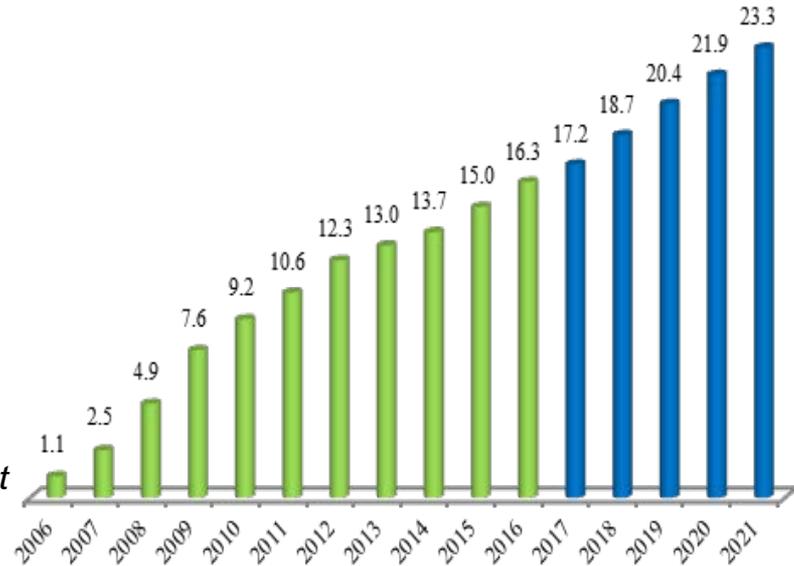


MISO's Planning process considers economic value as well as reliability benefits of transmission

MISO's tariff includes various categories of transmission projects to ensure costs are assigned commensurate with benefits

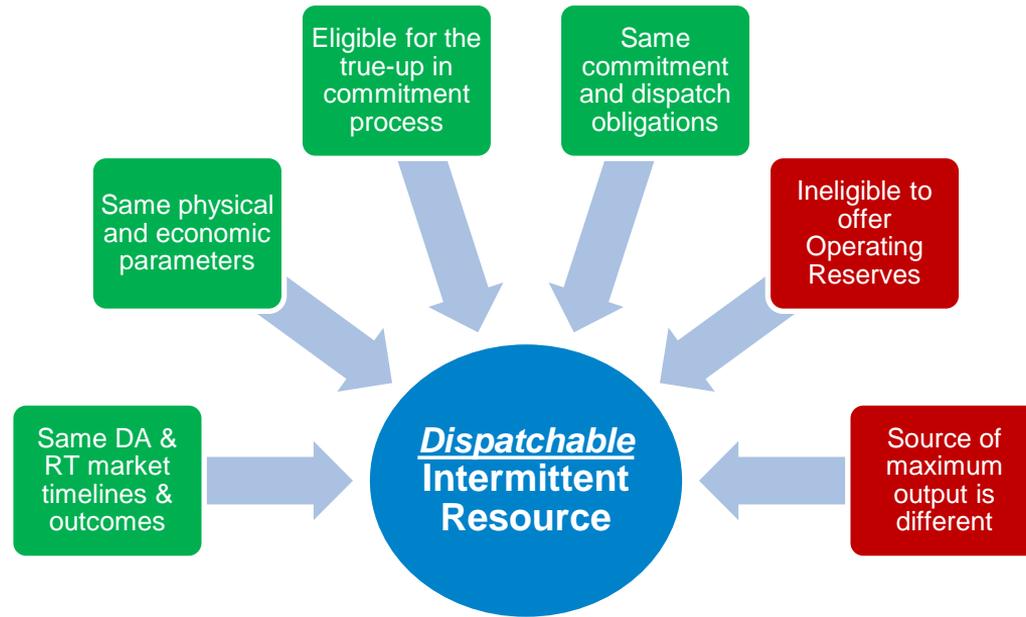
Rapid development of wind power adversely affected ability to maintain system reliability and economics

- Wind generation increased ~400% between 2007 and 2011, up to 10,000 MW
- High penetration of wind in areas with historically little generation
- Development of wind outpaced the necessary transmission development
- Original market design classified wind as an *'Intermittent Resource'* that could not be economically dispatched
- Difficult for the SCED to manage congestion with limited dispatchable resources in areas with high wind penetration



Growth of wind generation at MISO (in GW)
(actuals through 2016, estimates 2017 and beyond)

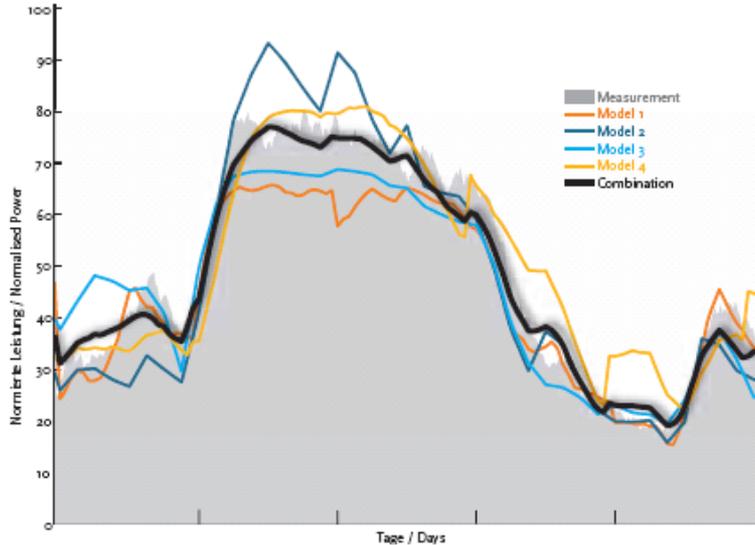
The solution was to make wind resources closely mimic traditional generator operation – DIR



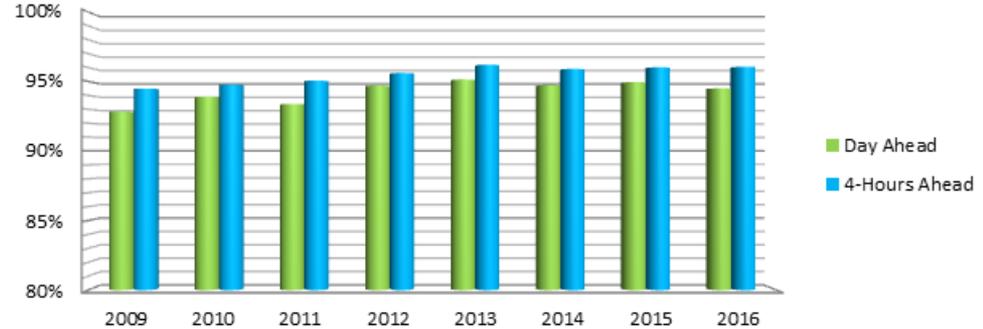
Ability to “dispatch” wind greatly enhanced congestion management, price transparency, and improved utilization of wind generation in the market

Wind forecast is a key enabler of the DIR product

MISO wind generation forecast is the weighted average of four independent forecasts – which improves accuracy

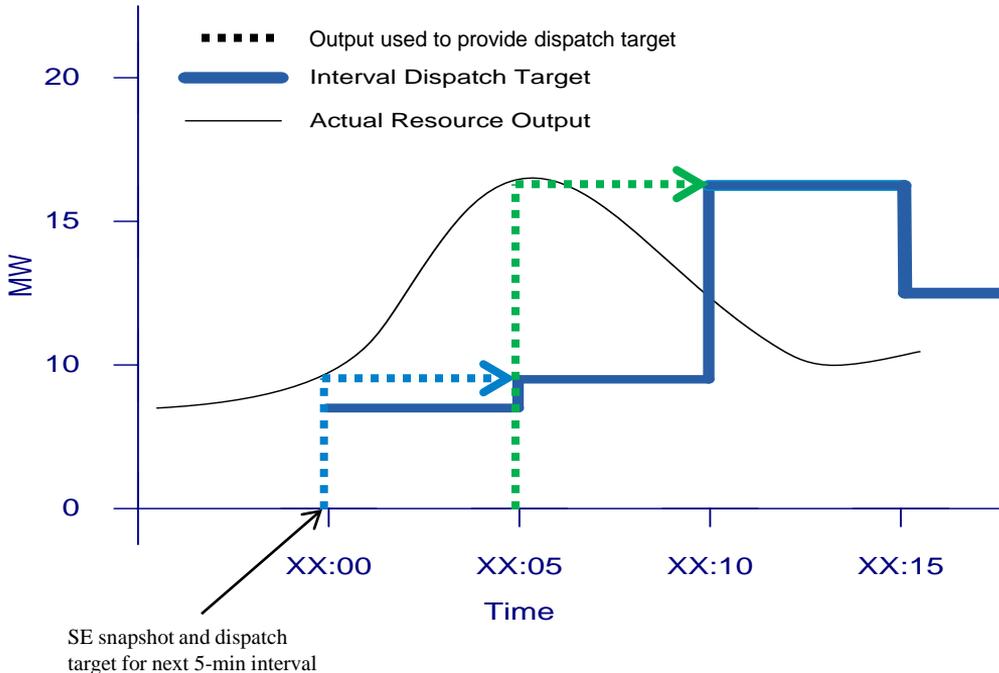


Accuracy of both the day-ahead and operating day (4-hour ahead) forecasts has consistently been over 93% and continues to improve



The effectiveness of “dispatching” wind in the market rests almost entirely on the accuracy of the wind generation forecast

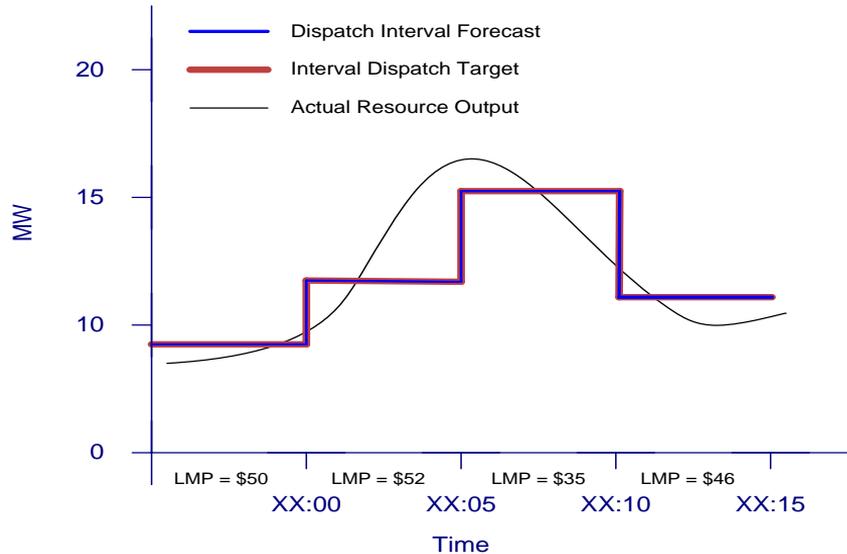
Pre- DIR, without a RT forecast, system unable to fully leverage benefits of wind generation



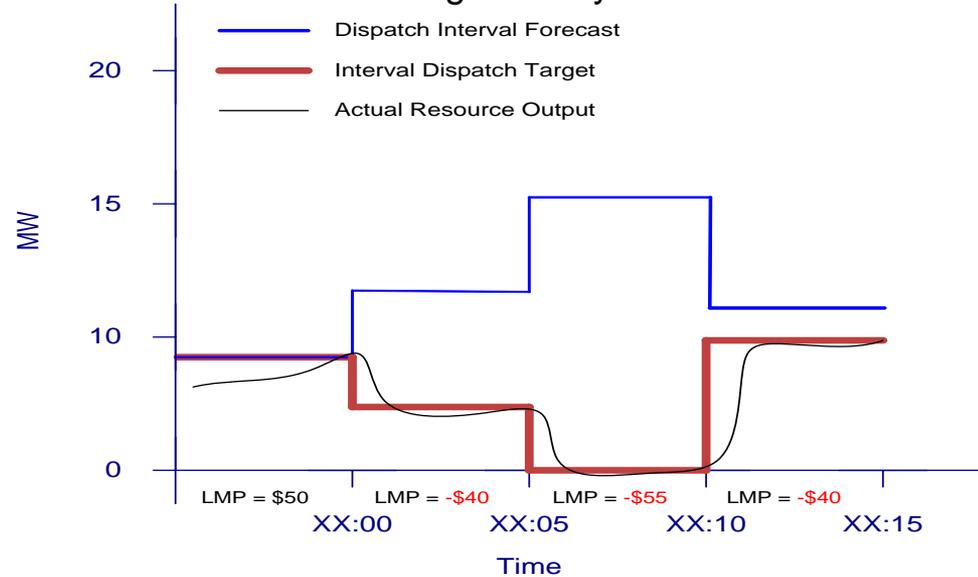
- UDS will issue a Dispatch Target equal to observed output at the time of the State Estimator snapshot for that case.
- Intermittent Resources
 - Cannot make real-time economic offers
 - Cannot set price
 - Are subject to RSG costs
 - Are ineligible to receive MWP

Granular forecast improves reliability and efficiency of wind & overall market dispatch

Unconstrained System



Congested System



- Forecast recognizes dispatch down situations
- When dispatched down, the forecast is based on the last actual before the dispatch down

In Summary...

- Robust Transmission Planning and System Operations processes are essential to effectively facilitate the journey of renewable resources from a conceptual project to a viable, commercially operating generating facility
- Significant penetration of renewable resources has been the primary driver for the evolution of both Planning and Operations processes at MISO
- Due to queue process enhancements, value-based transmission planning and improved market products, MISO is well-positioned for continued efficient & reliable integration of bulk quantities of renewables



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