

Evaluating the Hydro Wind/Solar Synergy Using Day-Ahead and Real-Time Interleaved Simulation

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June 26 2012

For FERC Technical Conference on Increasing Real-Time and Day-Ahead Market Efficiency through Improved Software



*PLEXOS® for Power Systems
Electricity Market Simulation*





MISO and Manitoba Hydro Wind Synergy Study

- **This study evaluates the potential of Manitoba Hydro system to provide**
 - Additional operational reserve capabilities to MISO
 - Flexibility of being used as a large-scale storage device to MISO
 - Possibility of eventually enabling transmission between MISO and Manitoba
- **The objective is to determine the value of increasing hydro storage and transmission to the renewable energy integration in MISO footprint**
- **Primary geographic area: Manitoba, Minnesota, North and South Dakotas**
- **Analysis started in June 2011 and scheduled to end in June 2013**

Problem Statement

- **Need to simulate MISO and Manitoba Hydro(MH) Day Ahead(DA) and Real Time(RT) operation to identify the benefits, such as revenue gained by MH and the production cost reduction in MISO from accommodating MISO load and renewable energy variability and forecast error.**
- **Both the hydraulic and electrical systems need to be modeled to simulate the hydropower operation correctly.**
- **Real Time simulation is more challenging than Day Ahead simulation in the production cost model due to:**
 - Huge amount of additional data needed
 - Forecast error and fixed unit commitment schedule
 - Co-optimization of Energy and ASM market



PLEXOS Simulation Tool Capability to the Solution

- **Mixed Integer Programming as the optimization algorithm**
 - The same algorithm used by Day-ahead and real-time market scheduling software in many ISOs: CAISO, MISO, PJM, etc.
- **Co-optimization of Energy, AS, DC-OPF, Pumped-storage, Energy-limited resources, etc.**
- **Intra-hourly optimization intervals**
- **User-defined operational constraints allowed**
- **Transparency: formulation of MIP can be reviewed and audited**
- **Cost-based or bid-based simulations**
- **Day-ahead and Real-time market interleaved simulations that closely simulate the real world market operation**

PLEXOS Simulation Process

- **Day-ahead Simulation Mimics MISO-MH DA scheduling**
 - 24-hour optimization window plus look-ahead at an hourly interval
 - Forecasted load and wind profiles
 - MH hydro storages are modeling in details
- **Real-time Simulation Mimics MISO-MH RT scheduling**
 - 5-minute optimization window plus look-ahead
 - DA unit commitment schedule is frozen except quick startup generators
 - 5-minute actual load and wind profiles
 - MH hydro generators are re-dispatched to accommodate the load / wind variability and forecast error. The bidding Q/P for MH hydro generators derived from the dispatch schedule and bus LMP from the DA simulation

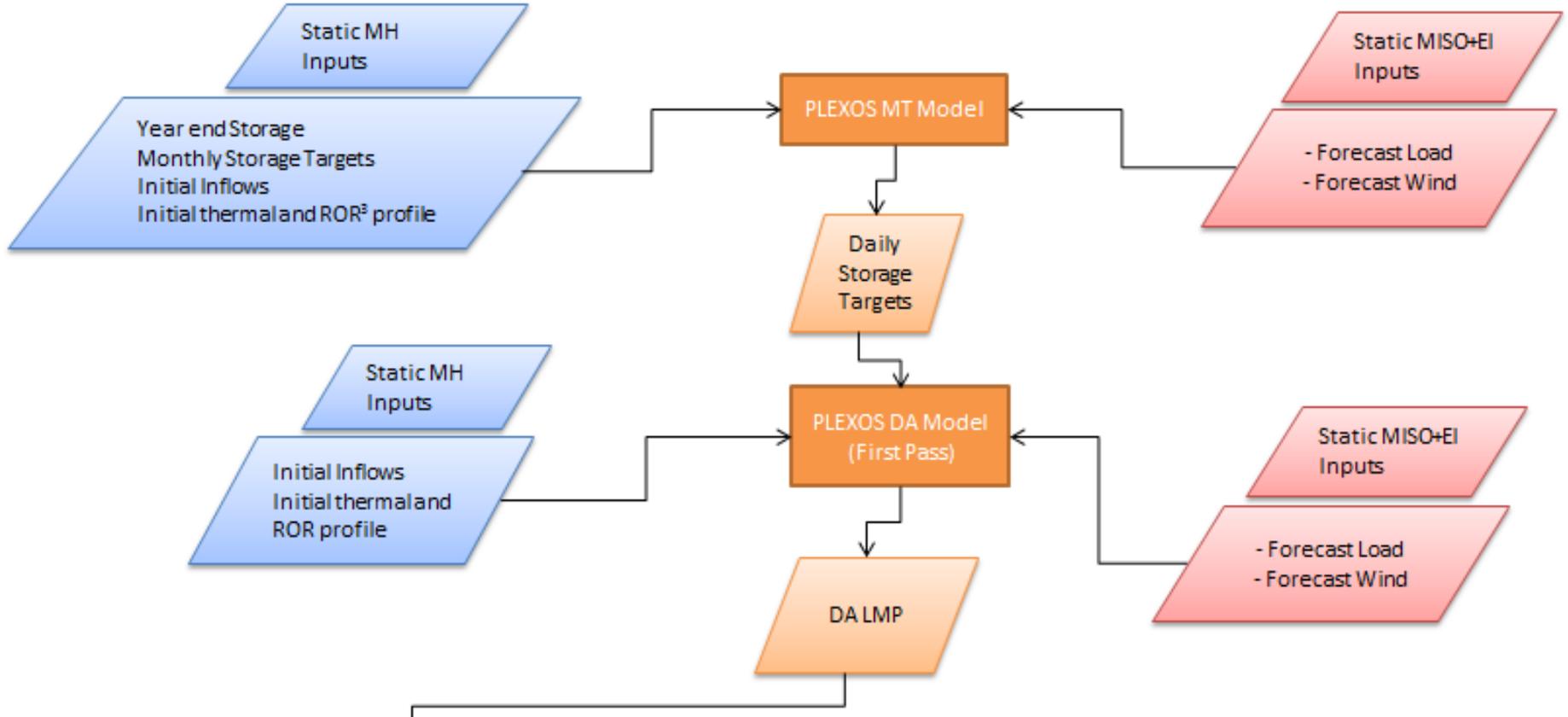
Process Flow Chart (Page 1)

STATIC MH INPUTS:

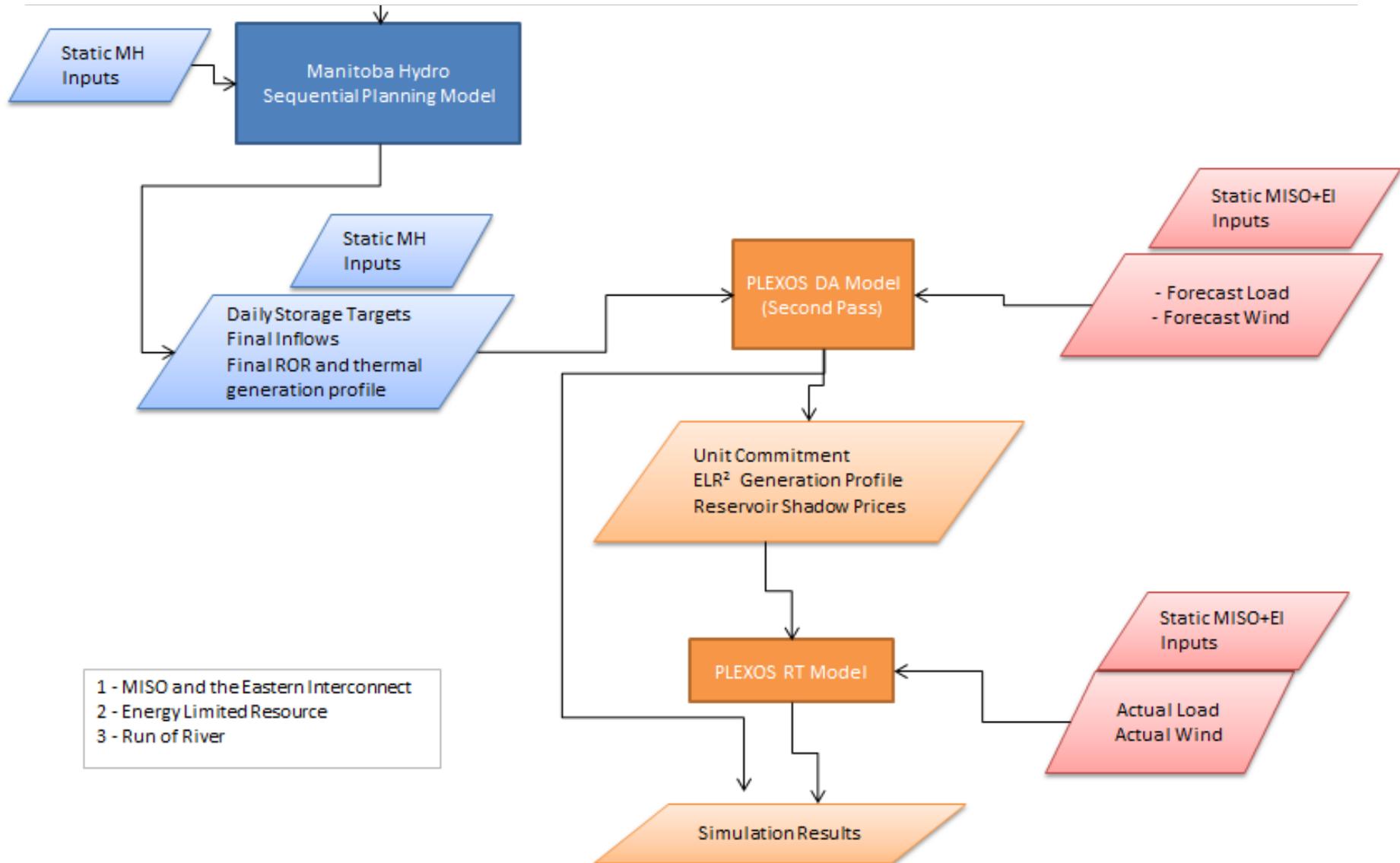
- Generation Characteristics
- Reservoir Size
- Reservoir Year Starting Storage
- Transmission System
- Load Profile

STATIC MISO+EI² INPUTS:

- Transmission System
- Non-Wind Generation Characteristics



Process Flow Chart (Page 2)

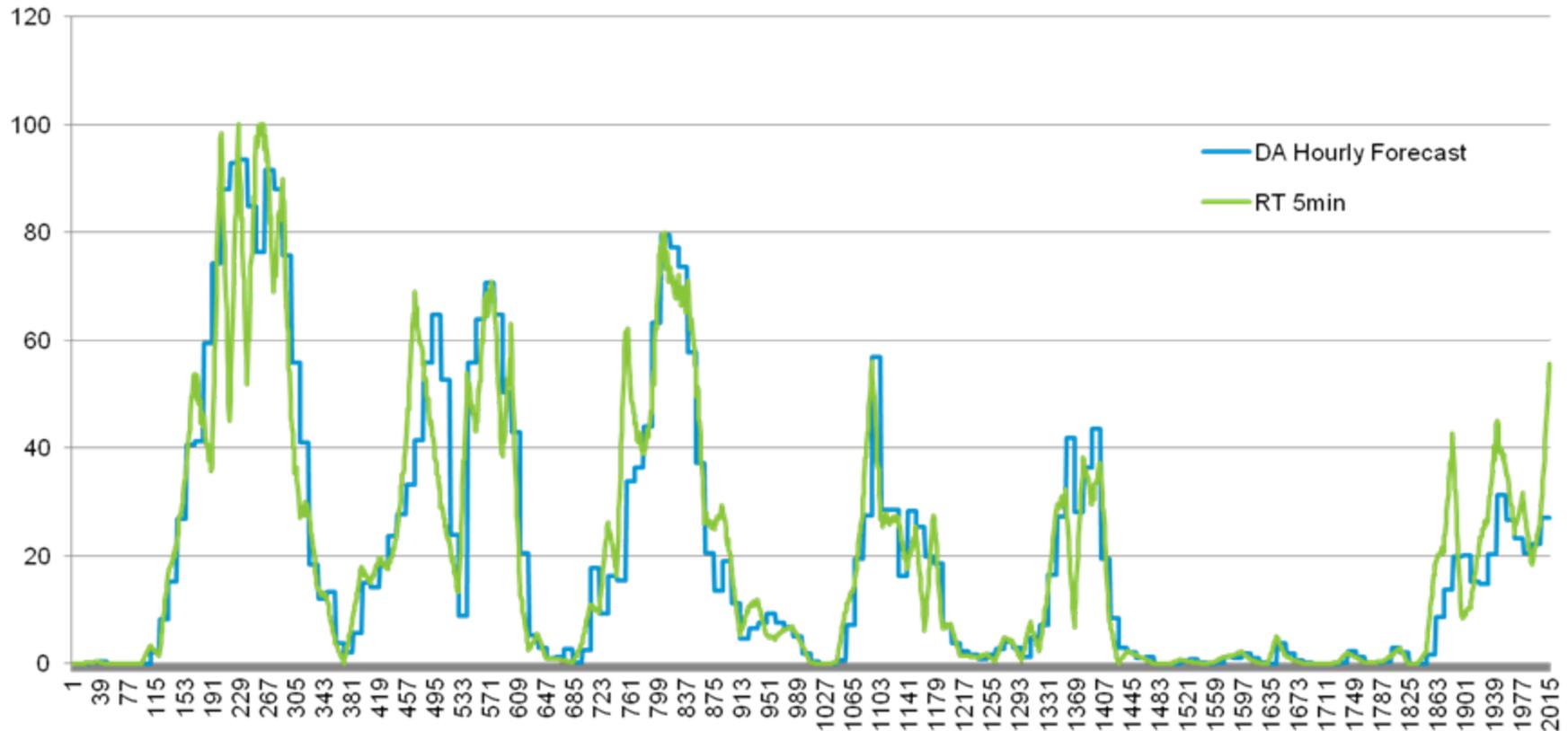


- 1 - MISO and the Eastern Interconnect
- 2 - Energy Limited Resource
- 3 - Run of River

An Example of DA Forecasted and RT Actual Wind Profiles



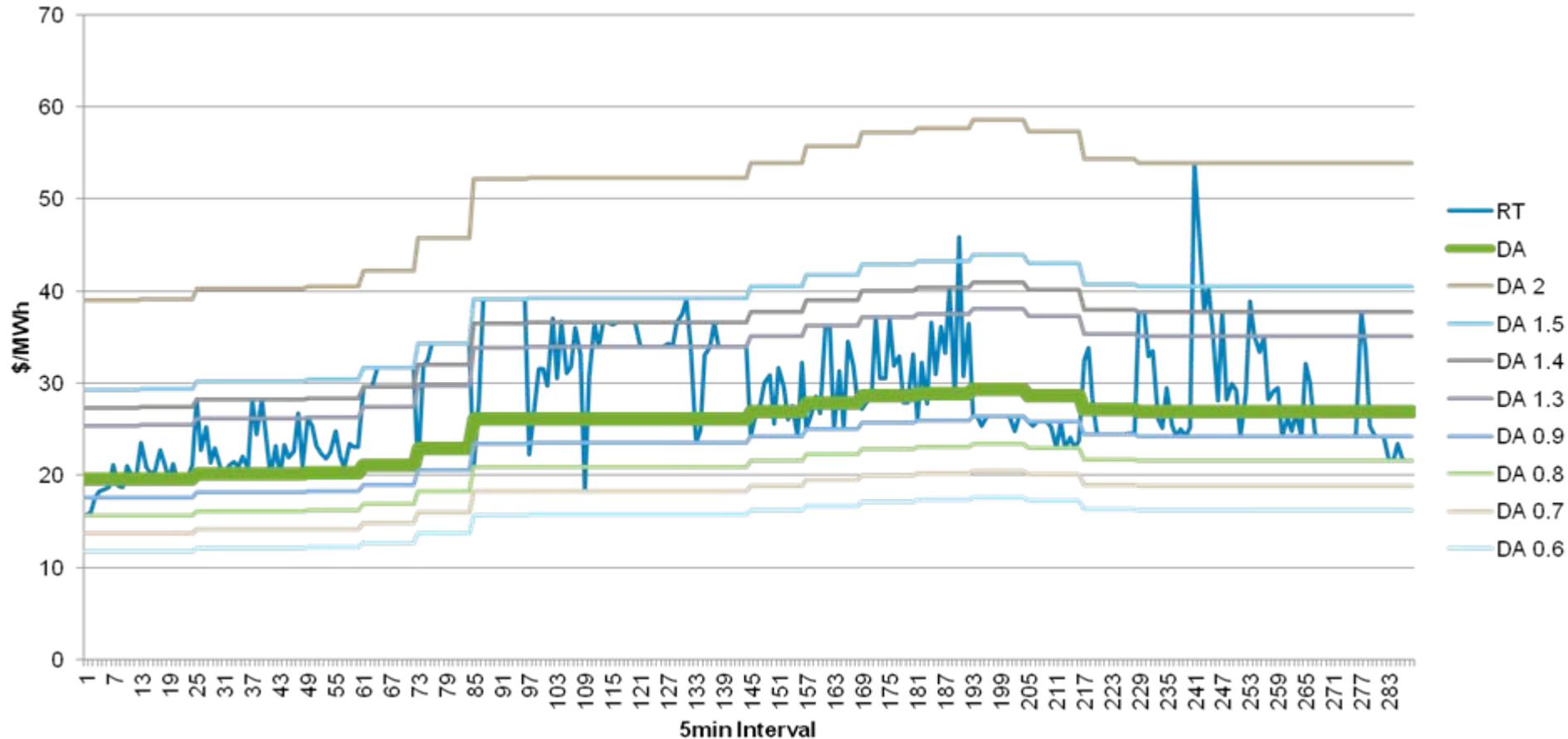
1 week, June 4th 2012, RT 5min Profile



MH Real Time Participation Benefits

- **MH's participation in the MISO RT market provides benefits to both MISO and MH such as**
 - Production cost savings
 - Load cost savings
 - Reserve cost savings
- **3 methods were used to analyze RT dispatch benefits**
 - Method 1: Participation fixed to DA schedule
 - Method 2: Participation based on the DA hourly price
 - Method 3: Participation based on the DA lowest export price
 - This method is the closest to real world MH operations

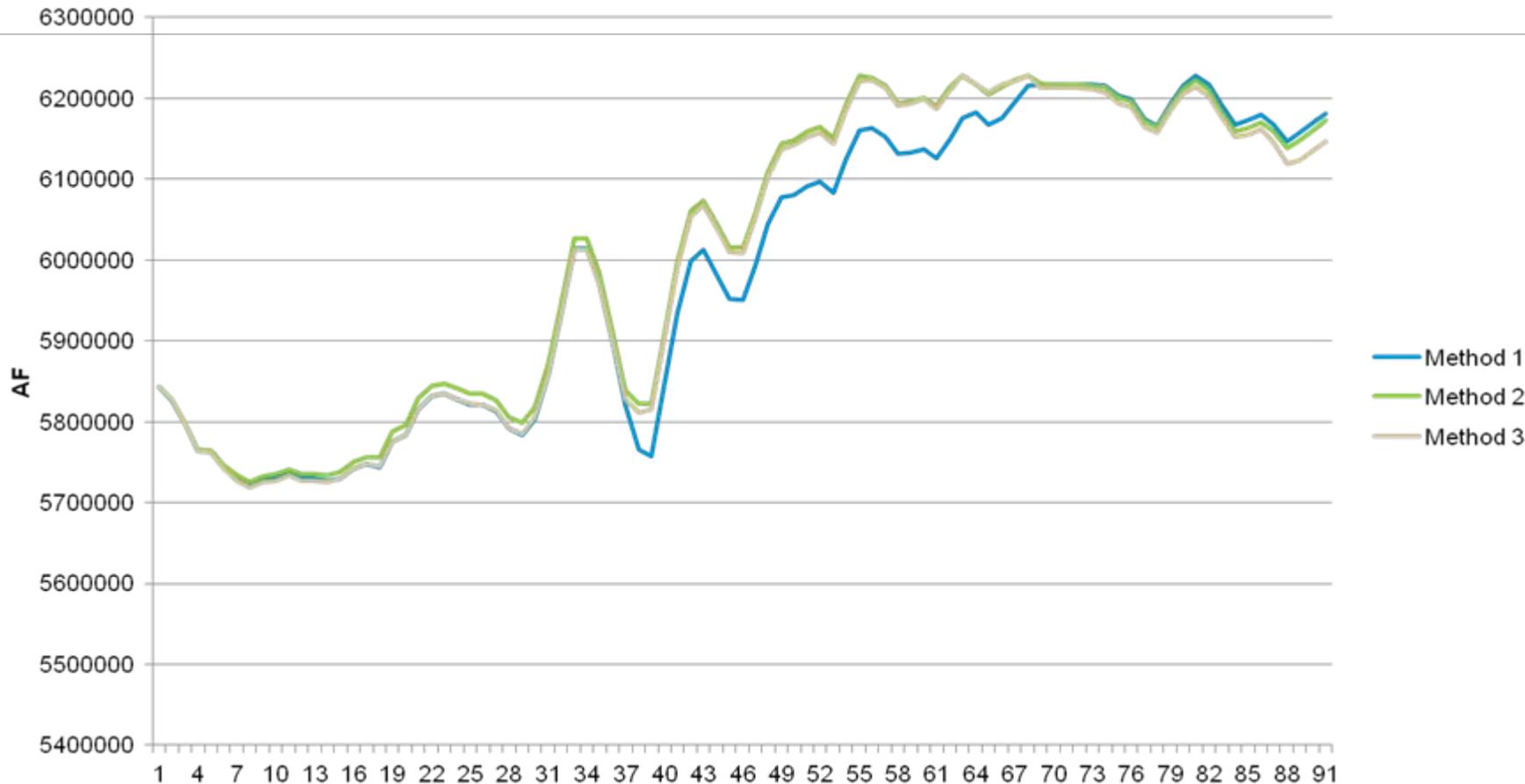
MH Hydro Generator Dispatch Offer Bands in RT simulation



- Each tier has an offer quantity associated with it

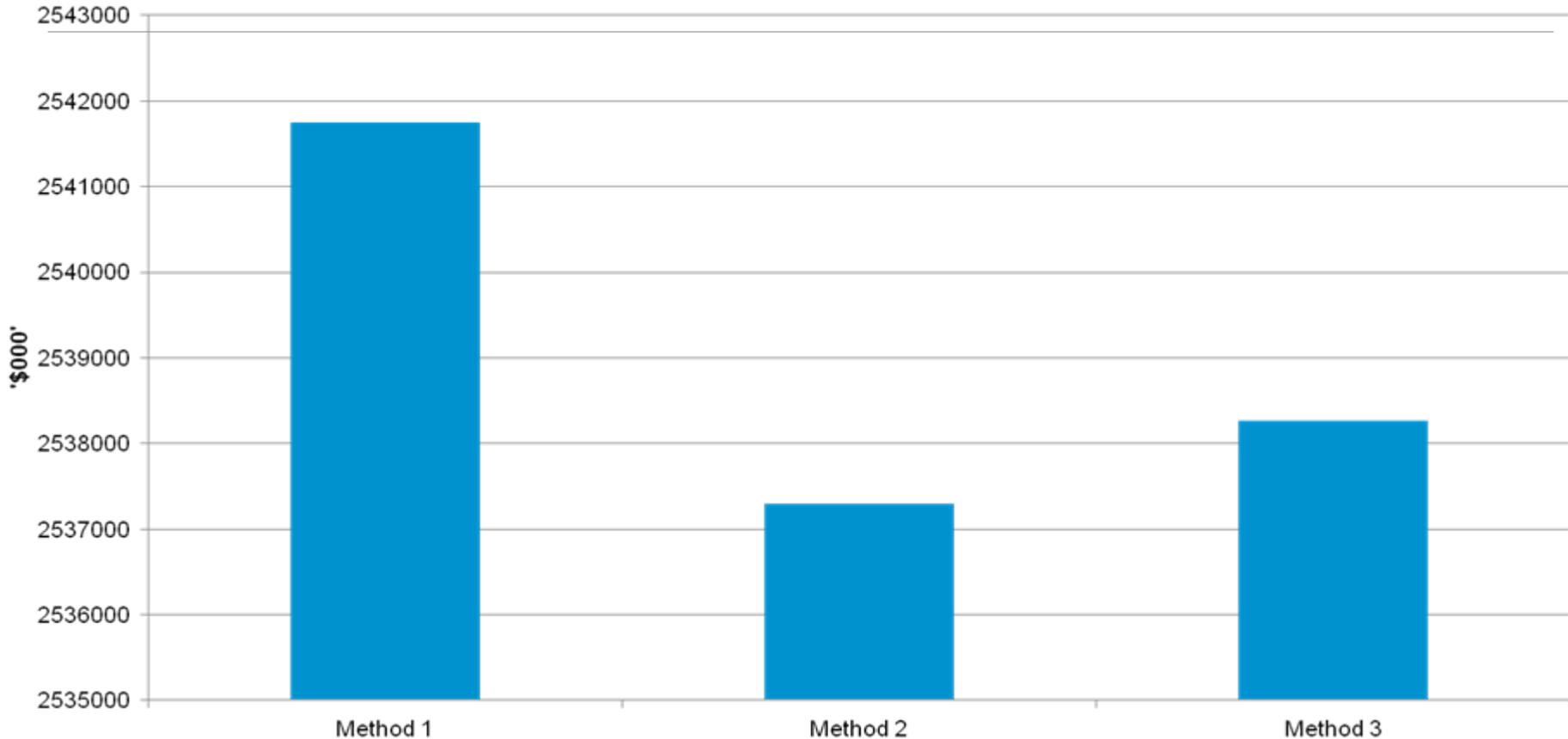


Water Target Comparison Grand Rapids (3 Months)



- Grand Rapids slightly under generates in the middle month, but makes it up by the end

MISO Production Cost Saving (3 Months)



- Production cost decreases by about \$3.5 Million between the no participation method and full participation after it has been adjusted for the difference in ending storage volume

DA/RT Interleaved Simulation Methodology

- **Day Ahead and Real Time simulations are performed simultaneously with the daily simulation solution exchange during the simulations**
- **What information is transferred from DA to RT?**
 - Daily unit commitment schedule
 - Day ahead LMP price
 - Daily generation profile
- **What information is transferred from RT to DA?**
 - 5-minute generation status
 - Hydro reservoir status
 - The generation status at end of the day as the initial condition for the next daily DA simulation

Hydro Generation Dispatch from DA-RT Interleaved Simulation





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