



PROMOD Economic Analysis

Review, Model Updates & Case Study

February 14, 2005

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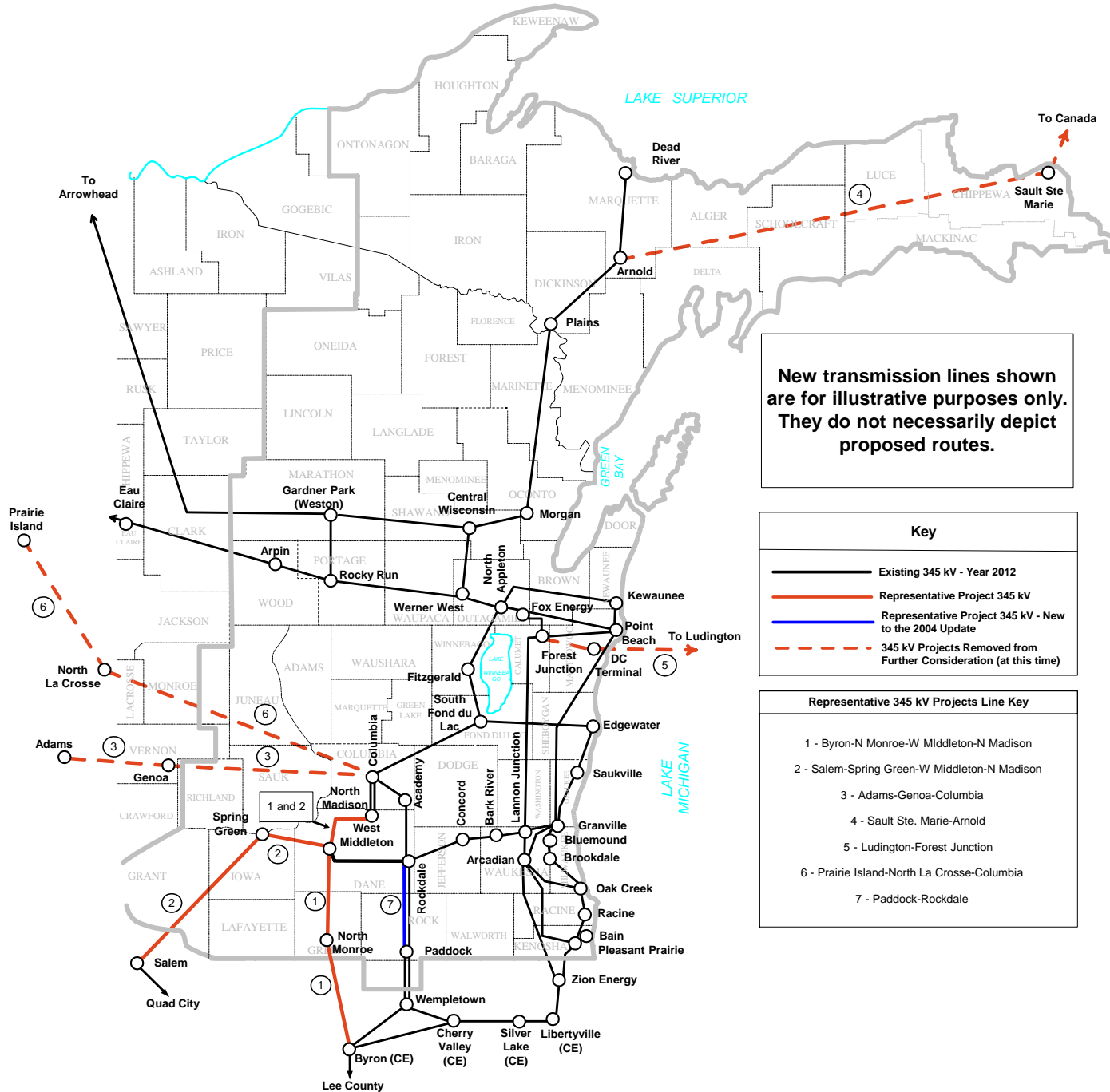
Review Results

- Compare the carrying costs for each alternative to the “production cost” savings from PROMOD

Costs for each Representative Project–Baseline Results From 12/04

Project	Total Capital Costs (2003\$ Mil.)	Approximate Annual Carrying Cost (2003\$ Mil.)	“Production Cost” Savings Relative to the Base Case (2003\$ Mil.)
Base Case	\$0	N/A	0
Base Case Plus 2 Fixes	\$20	\$1.8	\$10.0
South: Byron–NMA	\$221	\$19.9	\$14.6
South: Paddock–Rockdale	\$59	\$5.3	\$10.2
Southwest: Salem–NMA ¹	\$342	\$30.7	\$14.6

¹ Salem-NMA includes a fix for Salem to Maquoketa.



New transmission lines shown are for illustrative purposes only. They do not necessarily depict proposed routes.

Key	
	Existing 345 kV - Year 2012
	Representative Project 345 kV
	Representative Project 345 kV - New to the 2004 Update
	345 kV Projects Removed from Further Consideration (at this time)

Representative 345 kV Projects Line Key	
1	Byron-N Monroe-W Middleton-N Madison
2	Salem-Spring Green-W Middleton-N Madison
3	Adams-Genoa-Columbia
4	Sault Ste. Marie-Arnold
5	Ludington-Forest Junction
6	Prairie Island-North La Crosse-Columbia
7	Paddock-Rockdale



Introduction

- PROMOD analyses for 2005:
 - Focus efforts on alternatives showing the greatest promise
 - Analyze them in greater detail
 - Optimize them
 - Come up with at least 2 comprehensive packages
 - Refine the capital costs estimates
 - Do more sensitivity analyses
 - Work with MISO's Independent Market Monitor (IMM) to determine what facilities are required to address Narrowly Constrained Area (NCA) designation within the five year "forgiveness" window



Updates

- PROMOD and Data Updates
 - Latest version of PROMOD (8.7.0)—double checks the Unit Commitment to ensure generators are at least breaking even (increases PROMOD run times)
 - Update the natural gas fuel forecasts to the latest NewEnergy Associates (NEA) values—i.e. latest Platt's update
 - Include new units and plant updates that meet ATC's planning "inclusion" criterion, e.g. Sheboygan Energy Center
 - Do you have any updates for existing generators?



Updates

- PROMOD and Data Updates
 - Refine the automatic generator maintenance scheduling
 - Auto maintenance scheduling based on smaller regions/areas
 - More realistic time frames when maintenance can be scheduled
 - Replace ATC's portion of the transmission system model with the latest version and update the flowgates
 - Have been doing incremental updates
 - Complete resync with our latest TYA model
 - Update load shapes?
 - Most representative load shape year: **2001, 2002** or 2003?
 - Use existing load forecasts



Narrow Constrained Area

- Primary effects of being defined as a Narrow Constrained Area (NCA) by MISO
 - Congestion costs for resources outside the ATC footprint forgiven (e.g. Boswell for WPPI, Zion for We-Energies, etc.) for first 5 years
 - Lower threshold for bidding behavior to be considered anticompetitive by the MISO Independent Market Monitor (IMM)



Narrow Constrained Area

- Definition of a Narrow Constrained Area (NCA)
 - Area flowgates/constraints binding for at least 500 hours per year—based primarily on TLR activity
 - At least one supplier has generation resources that are “pivotal”, i.e. no other supplier’s generation can relieve the constraint
- WUMS and Northern WUMS defined as NCAs



Narrow Constrained Area

- IMM can remove NCA designation if constraints are expected to be binding less than 500 hours per year
 - Access alternatives could help to achieve this
 - IMM/MISO could probably use PROMOD to show that:
 - Constraints are binding less the 500 hours, and/or
 - There is no pivotal generation for the constraint
 - Some constraints become more active as import capability increases, however, with more import capability there would probably be a decrease in pivotal generation



MapAgent

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- Showing LMP contours with MapAgent
 - ATC has mapped loads in addition to generators—much better granularity for the ATC footprint
 - Demo of hourly LMP contours in MapAgent for the Base Case for August 7, 2012
 - Same day that we looked at previously
 - Loads are near their peak values for the year—not a “typical” hour
 - What would you expect the LMPs to be like?



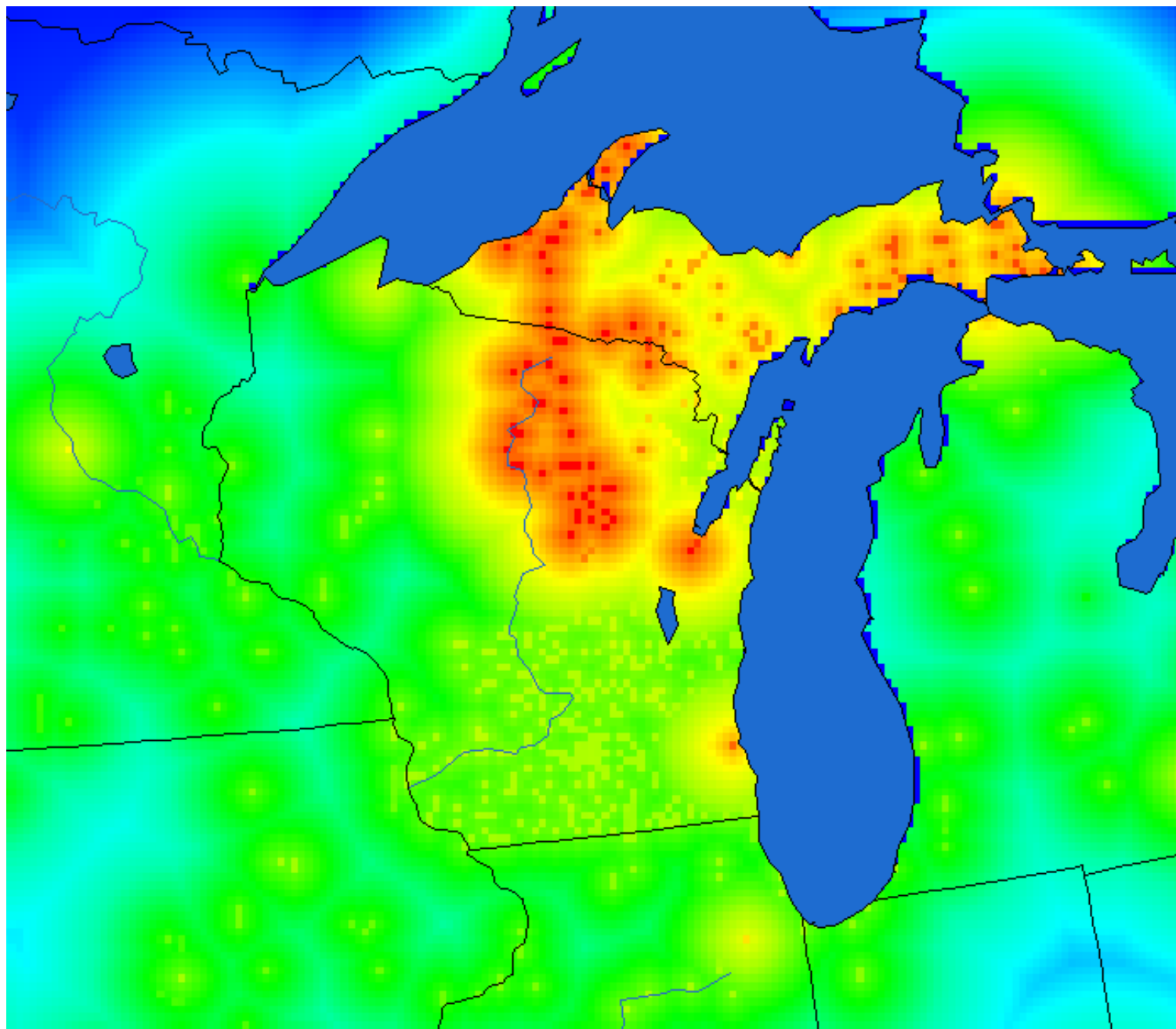
Case Study

- Rhineland Loop Case Study:
 - What is causing the Rhineland loop to be a “hot spot” on 8/7/12?
 - LMPs at 5:00 PM are as high as 2,500 \$/MWh!
 - Indicates that one or more flowgates is active in the area
 - What type of impact does this have on the economic analysis?
 - What can we learn from this case study concerning:
 - How LMPs are calculated
 - What drives LMPs

Base Case
LMP
Contours
(8/7/12 at
5:00 PM)

Key (\$/MWh)

- Less than 15
- 15 - 19
- 20 - 24
- 25 - 29
- 30 - 49
- 50 - 99
- 100 - 149
- 150 - 199
- Greater than 200





Case Study

- Let's start by looking at the flowgate shadow prices in and around the Rhinelander loop
 - A new tool, the PROMOD Analysis Tool (PAT), allows us to look at the details underlying the PROMOD results for any given hour(s)
 - Using PAT and examining the “worst” hour from MapAgent, 5:00 PM, we find that the Cranberry Loop flowgate has a relatively high shadow price of \$707
 - What does this shadow price mean?
 - What would it mean if the Cranberry Loop flowgate was active 1,000 hours per year at a similar shadow price?



Case Study

- The PROMOD summary results show that the Cranberry Loop flowgate is actually active only 41 hours/year
 - And the sum of the associated shadow prices is only \$15,510
 - How does this compare to other shadow prices we have seen?
 - What impact does this value have on the economic analysis and the “production” cost differences relative to the Base Case?
 - The sum of the shadow prices for Byron-North Madison (NMA) for this same flowgate is \$19,180—nearly the same as in the Base Case (the flowgate is active for a total of 42 hours/year)
 - Conclusion: The Cranberry Loop flowgate probably does not have a significant impact on the “production” cost differences relative to the Base Case



Case Study

- However, the Cranberry Loop flowgate and how the “market” responds provides an excellent example for showing what drives LMP costs, how they are calculated and how they relate to generation dispatch
 - It also shows the power of PAT to help us refine and, when necessary, debug our PROMOD analyses
 - Using PAT, we examined how much we would have to increase the rating on the Cranberry Loop flowgate to remove the constraint at 5:00 PM (one of the “worst” hours in MapAgent--similar approach to what we did for the North Monroe 138/69 kV transformer, but for a single hour)
 - It turns out that we only have to increase the rating by 10 MW to relieve the constraint completely



Case Study

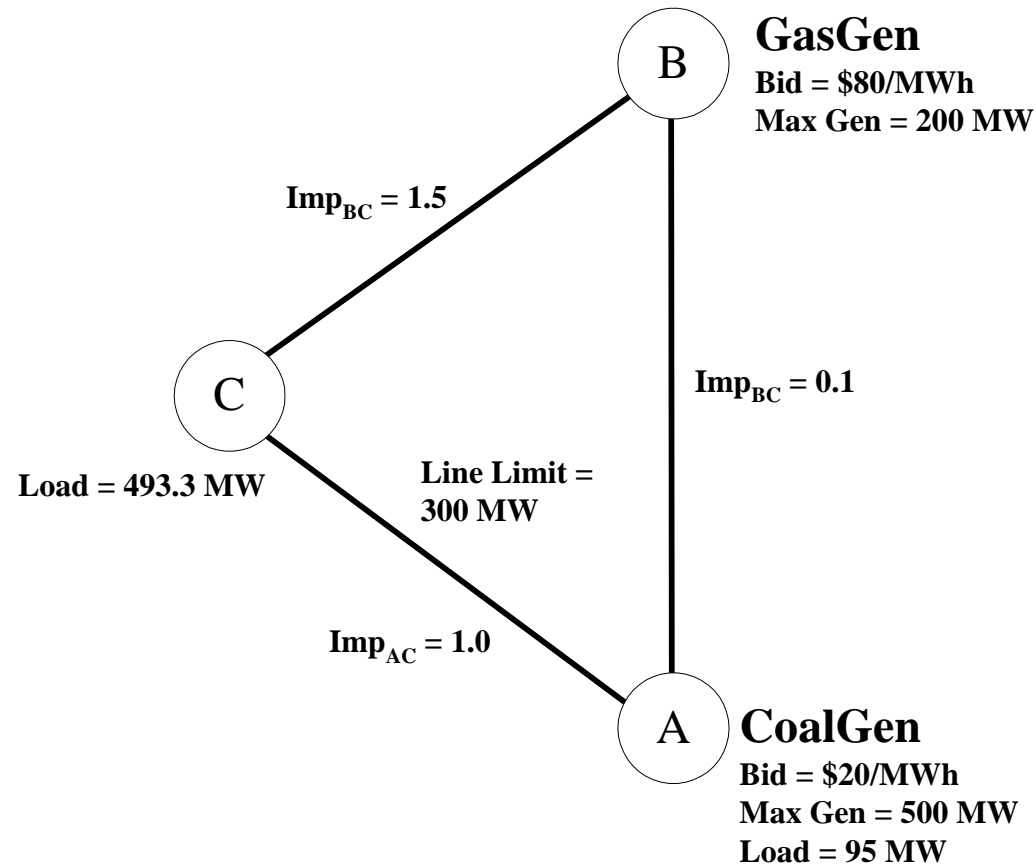
- How do the LMPs respond to relieving this flowgate?
 - LMPs in the area plummet from as high as \$2,500 to 60 \$/MWh!
- How is this possible?
- Let's look at a 3-bus example
 - To simplify our example:
 - Assume no transmission losses
 - Assume an intact transmission system (no contingencies)



Transmission Basics

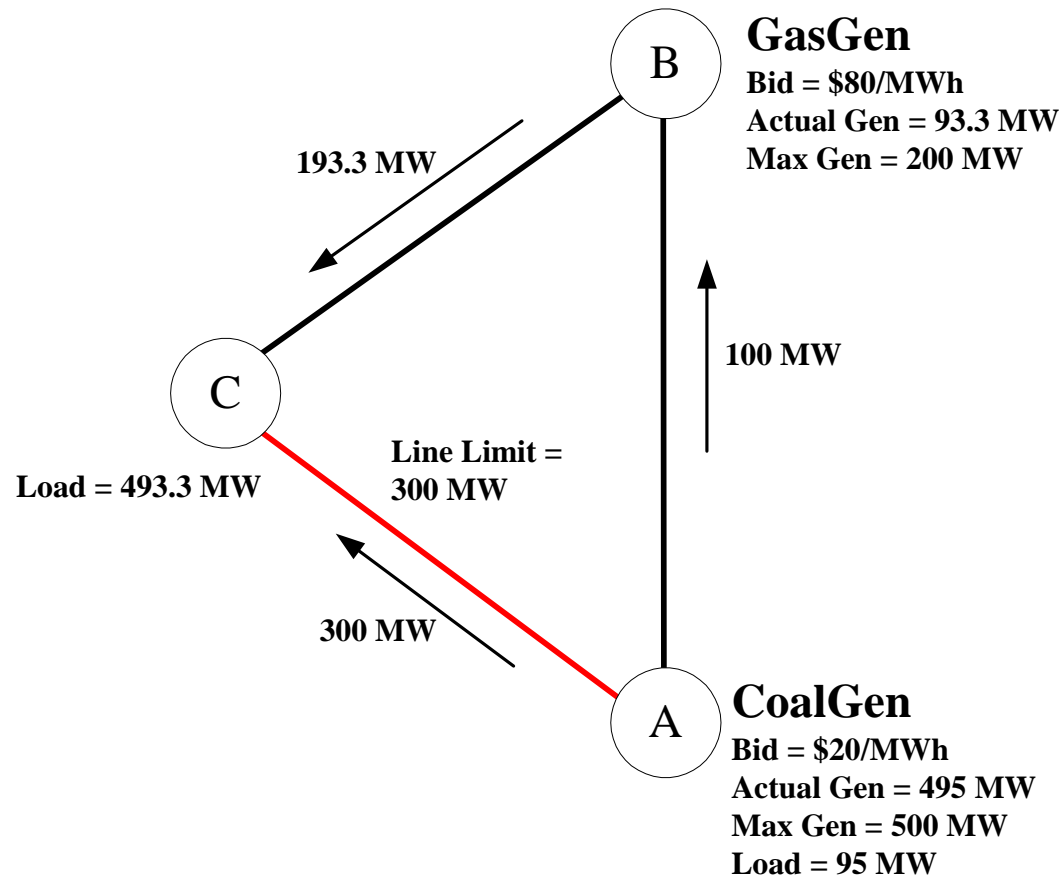
- Electric transmission flows are governed by Kirchhoff's laws, and determined largely by the characteristics of the grid and the location and amount of generation and load
 - Electricity will flow over all interconnected lines (between source and sink)
 - The magnitude of these flows will be determined by the characteristics of the grid (impedances/resistances) and the location of all net injections and withdrawals
 - Flows over lines or groups of lines generally, therefore, must be controlled by varying generation so that lines do not overload

Simplified Example-High LMPs



- What is the least cost dispatch?
- How does the “Line Limit” affect the generator dispatch?

Simplified Example-High LMPs



- Why isn't CoalGen dispatched fully?
- Line flows are function of the line impedances (resistances) and the power injections by the generators
- What is the LMP at node C? How is the LMP defined?



Simplified Example

- Any increase in the output of CoalGen overloads line A-C
- Instead of increasing the output of CoalGen, we have to **decrease its output by 15 MW!** (see the equations on the next slide for the details)
- To calculate the LMP at node C, how do we have to change the output of GasGen?

$$LMP_C = 16 * \$80 - 15 * \$20 = \$960$$

- The LMP at node C is the cost to serve the next MW of load, which is nearly \$1,000!
- May want to have an FTR to help offset the congestion costs

Simplified Example-High LMPs

- Why is the LMP at node C so high?
- From the line impedances, the impact of each generator's output on the line flows can be determined.
- Based on the impedances:
 - 61.54 % of CoalGen's output flows on line A-C
 - 57.70 % of GasGen's output flows on line A-C
- To avoid an overload, the change in the flow on line A-C must be zero

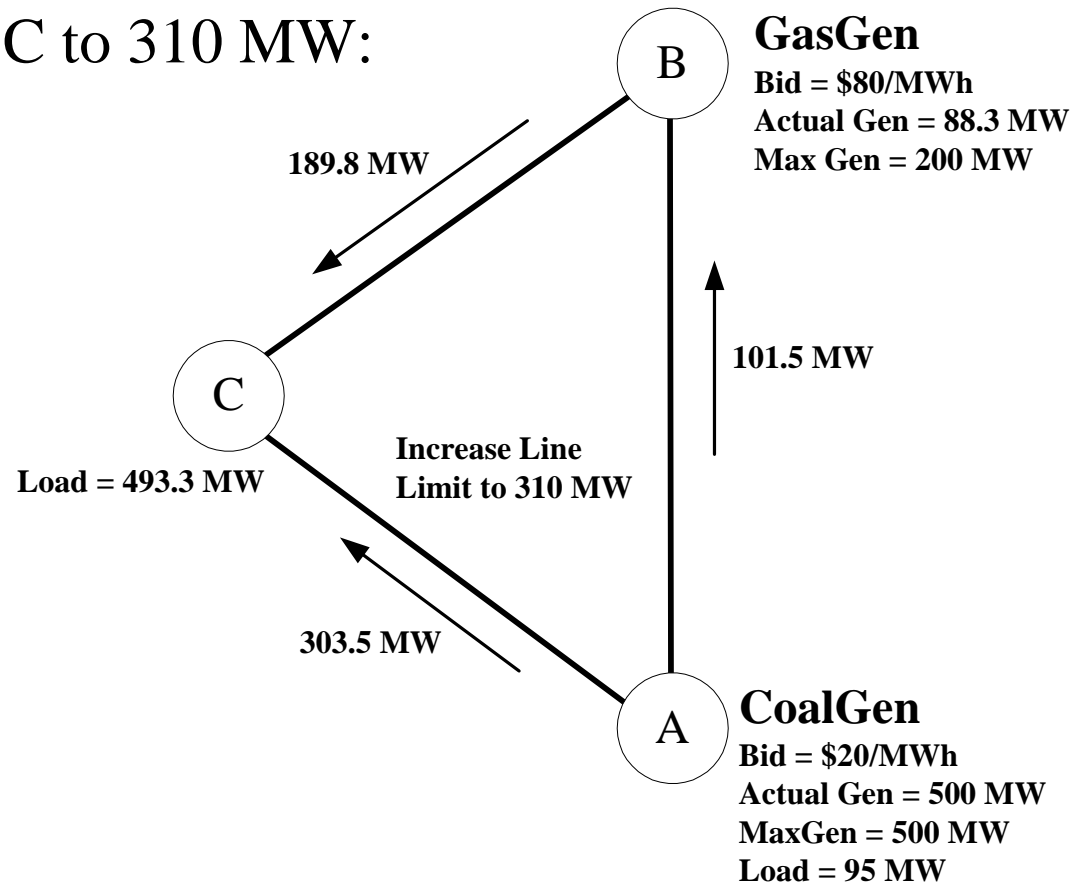
$$0.6154 * G_A + 0.5770 * G_B = 0$$

$$G_A + G_B = 1 \text{ MW}$$

- Two equations, two unknowns
- For zero impact on line A-C's flow, CoalGen (G_A) must decrease its output by 15 MW, while GasGen (G_B) must increase its output by 16 MW

Simplified Example-Unconstrained Transmission

Uprate line A-C to 310 MW:



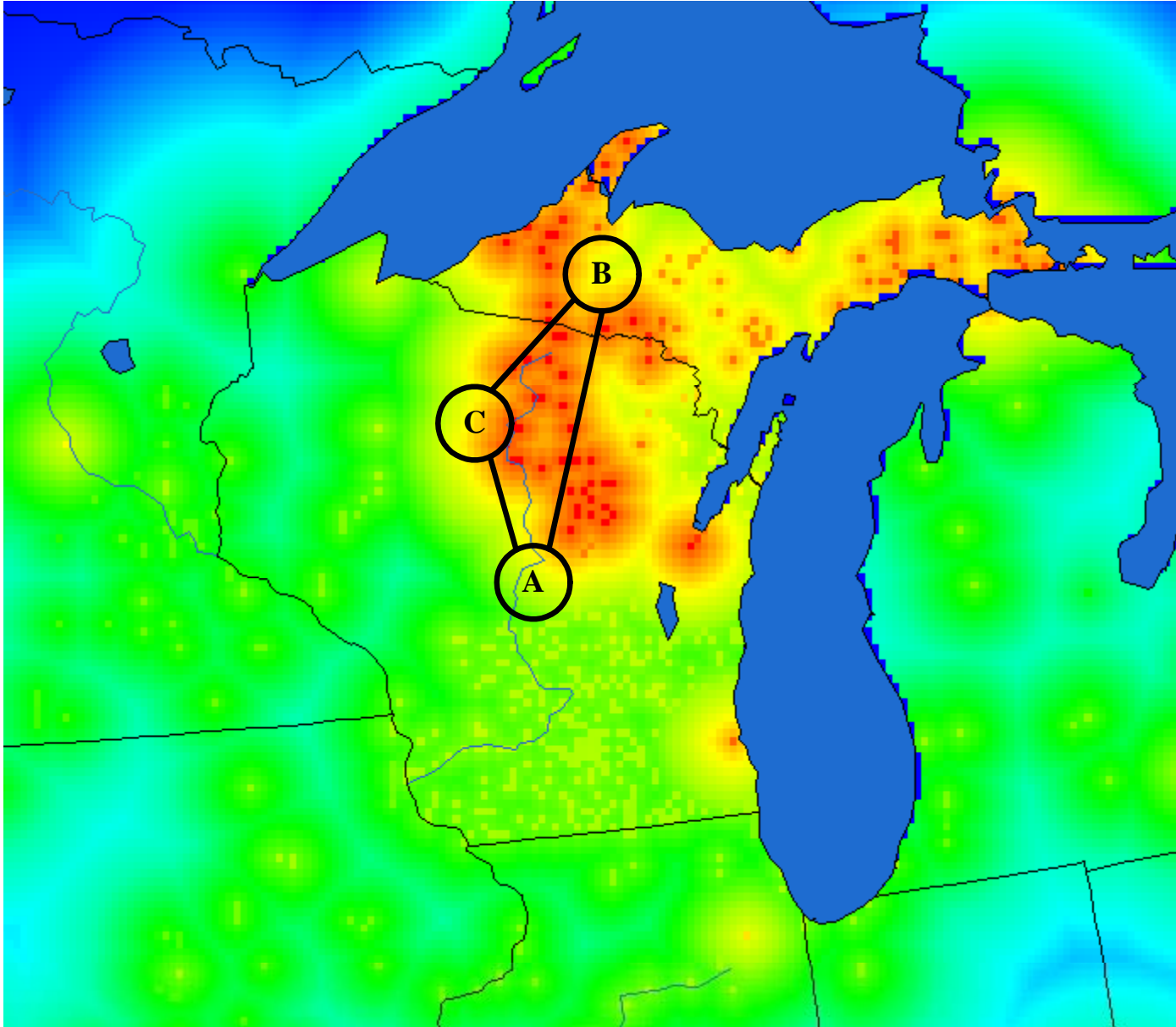
- After the uprate the transmission system is no longer constrained
- What is the LMP at node C?
- What is the marginal generator?



Case Study Observations

- How does our “simplified” example compare to what we were seeing in MapAgent and the PAT tool at 5:00 PM?
 - Weston 4’s output impacts the constrained Cranberry Loop flowgate. As a result this low cost coal-fired unit cannot be fully dispatched (similar to what we saw for “CoalGen” in our simplified example)
 - The PAT tool shows that Weston 4 is generating 462 MW (less than its maximum output of 500 MW)
 - The PAT tool also shows that the Cranberry Loop flowgate can be completely relieved by increasing its rating by just 10 MW, causing LMPs to decline dramatically to \$60/MWh
 - Output on Weston 4 increases to its maximum value—the coal plant is not setting LMPs (like in our simplified example)

Our “Simplified” and MapAgent Examples are Similar





Case Study Observations

- Be careful not to over generalize. Only looking at one “high load” hour in our examples.
- Actual system and interactions can be very complex because there are many generators and transmission constraints
- Important to have a “good” set of flowgates



Observations

- Moving from a screening level analysis (with seven alternatives) to focusing on several alternatives allows us time to refine our analyses and look at each alternative in much greater detail with tools like PAT
 - The Cranberry Loop flowgate was provided by the MISO to address voltage stability issues in the Rhineland area.
 - However, by 2012, with the new Cranberry-Conover line in place ATC's transmission planner for this area said that this flowgate should probably be replaced with the most critical thermal flowgate(s)
 - This change would probably not have a significant an impact on our economic analysis for similar reasons to those mentioned earlier



Observations, Cont.

- However, it is important to refine our analyses and to, for example, examine “downstream” lower voltage constraints more carefully, like we talked about in the North Monroe transformer Case Study. The Case Study that we just presented shows how PAT can be used to help accomplish this
- Our Case Study also re-illustrates how close the tie can be between generation and transmission when a flowgate is constrained in an LMP market



What's Next?

- Update/refine the generation and transmission portions of the model
- Focus analysis on a couple of alternatives and optimize them
- Use the PAT tool to further drill down into the details and refine our analyses
- Follow-up with MISO's IMM on the NCA designation
- Do sensitivity analyses