Biggest Bang for the Buck

Evaluating Transmission Projects in an LMP Market

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Introduction

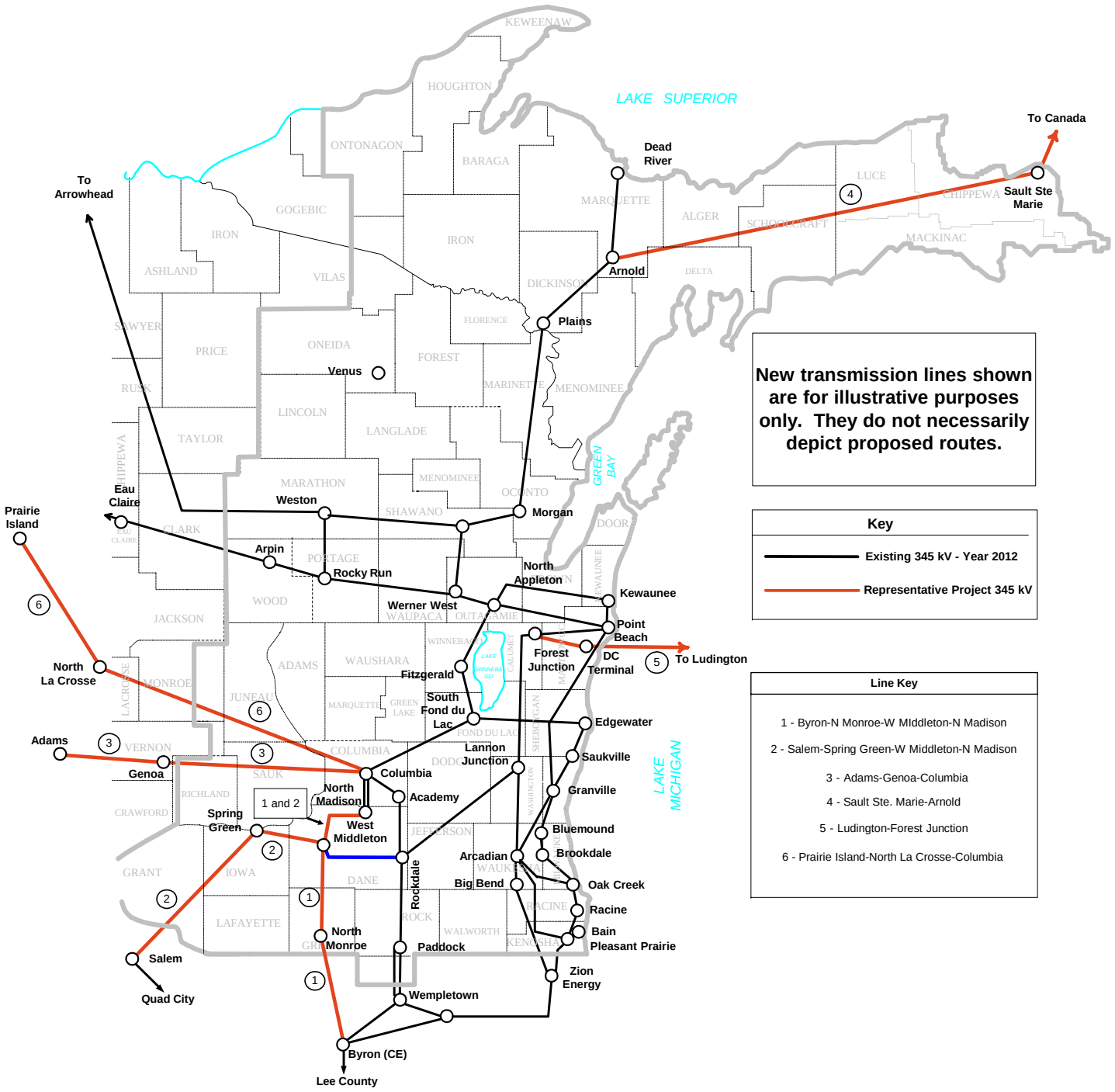
- American Transmission Company (ATC)
  - First, multi-state, transmission only company
  - Serve most of Wisconsin and the Upper Peninsula of Michigan
  - Approximately $700 million in transmission assets
  - Approximately 9,000 miles of transmission lines
  - Peak demand of approx. 13,000 MW in 2004
  - Largest load centers: Milwaukee, Madison and Green Bay

Introduction

- Which transmission projects provide the biggest bang for the buck in an LMP market?
- Explore some key drivers and principles using ATC's "Access Initiative" PROMOD analysis
- Questions evaluated with PROMOD:
  - What is the best transmission alternative/direction for increasing the import capability into ATC?
  - What is the optimal level of import capability
- Transmission/Generation background

Introduction

- Alternatives studied with PROMOD:
  - Base Case
  - Base Case Plus Two Fixes (to relieve the 2 most limiting constraints).
  - South: Byron-North Madison
  - Southwest: Salem-North Madison
  - West: Adams-Columbia
  - West: Prairie Island-Columbia
  - Northeast: Sault Saint Marie-Arnold
  - East: Ludington-Forest Junction


LAKE SUPERIOR
LAKE MICHIGAN
GREEN BAY
To Arrowhead
To Canada
Dead River
Sault Ste Marie
Arnold
Plains
Venus
Eau Claire
Weston
Morgan
Prairie Island
Arpin
Rocky Run
North Appleton
Kewaunee
Werner West
Point Beach
DC Terminal
Forest Junction
To Ludington
Fitzgerald
South Fond du Lac
Edgewater
North La Crosse
Adams
Genoa
Columbia
Lannon Junction
Saukville
North Madison
Academy
Granville
Spring Green
West Middleton
Bluemound
Arcadian
Brookdale
Rockdale
Big Bend
Oak Creek
Racine
Bain
Pleasant Prairie
North Monroe
Paddock
Zion Energy
Salem
Quad City
Wempletown
Byron (CE)
Lee County
1 and 2
KEWEENAW
HOUGHTON
ONTONAGON
BARAGA
GOGEBIC
IRON
ASHLAND
VILAS
MARQUETTE
ALGER
LUCE
CHIPPEWA
SCHOOLCRAFT
MACKINAC
DELTA
DICKINSON
FLORENCE
SAWYER
PRICE
ONEIDA
FOREST
MARINETTE
MENOMINEE
RUSK
LINCOLN
LANGLADE
TAYLOR
MARATHON
MENOMINEE
OCONTO
SHAWANO
DOOR
CLARK
PORTAGE
WOOD
JACKSON
WAUPACA
OUTAGAMIE
WINNEBAGO
CALUMET
MANITOWOC
KEWAUNEE
ADAMS
WAUSHARA
MONROE
LACROSSE
JUNEAU
MARQUETTE
GREEN LAKE
FOND DU LAC
SHEBOYGAN
VERNON
COLUMBIA
DODGE
SAUK
WASHINGTON
RICHLAND
CRAWFORD
JEFFERSON
GRANT
IOWA
DANE
WAUKESHA
LAFAYETTE
ROCK
WALWORTH
RACINE
KENOSHA
LAKE WINNEBAGO
1
2
3
4
5
6
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
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

Analysis Mechanics

- Economic analysis mechanics
  - Run the Base Case for a given year (2012) using ATC's planned transmission topology
  - Add a transmission expansion alternative, like the Byron to North Madison (NMA) 345 kV line, and see how much the production costs decrease relative to the Base Case
  - Compare the "production cost" savings to the capital cost for the project to determine which alternative provides the biggest bang for buck

Cost Differences

- Calculating the production cost difference from PROMOD between the Base Case and the alternatives
- Using the cost difference tends to reduce the impact of inaccuracies in forecasts and other input data. Example
- Still should be diligent in reviewing input data and assumptions, such as:
  - Flowgate ratings
  - Generator mapping
  - Load forecasts (including interruptibles & DSM)
  - Nuclear plant relicensing

Cost Comparison

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

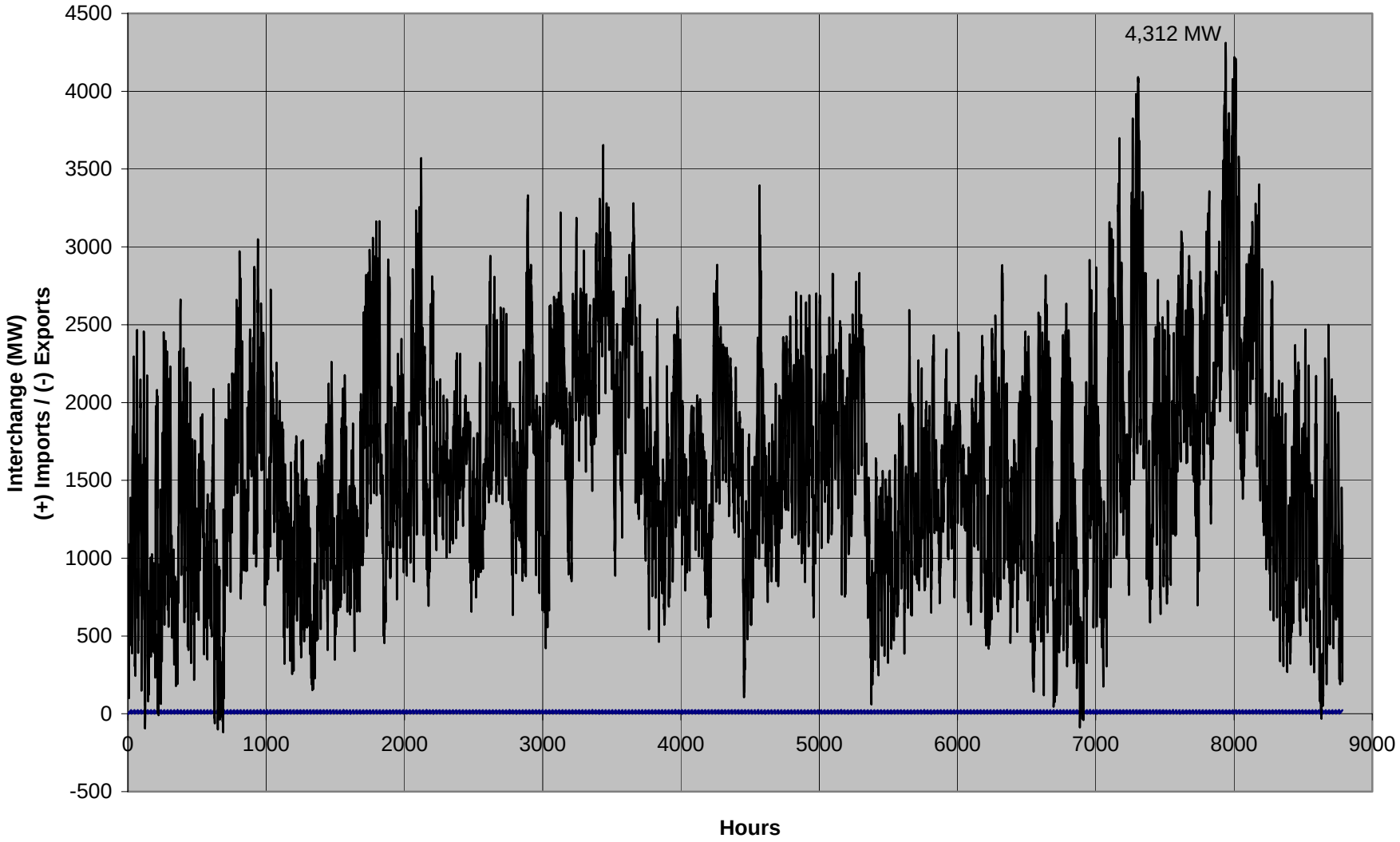
Capital Costs Versus "Production Cost" Savings

Project	Total Capital Costs (2003$ Mil.)	Approximate Annual Carrying Cost (2003$ Mil.)	"Production Cost" Savings[1] Relative to the Base Case (2003$ Mil.)	Net Imports Relative to the Base Case (GWH)
Base Case	$0	N/A	0	0
South: Byron–NMA	$143	$12.9	$37.1	4,107

[1] The "Production Costs" are calculated by adding the production costs plus purchased power costs minus the revenue from sales (at ATC's load weighted and generator weighted LMP values, respectively).

- PROMOD economic analysis:
  - Still being refined
  - Does not factor in other benefits like enhanced transmission system reliability and security--treated separately
  - Assumes that ATC bears all of the costs

Total Tie Line Flows Into ATC for the Byron-NMA Case - Baseline Scenario



Flowgates

- The transmission system is planned and operated such that it can withstand the outage of the most critical component--the “N-1” criterion
- Started with the MISO’s transmission flowgate list
- Made many changes to the MISO’s flowgate list to reflect the the transmission topology changes anticipated by 2012
  - Iterative process--each successive model run provides information to help refine the flowgate list

Shadow Price Case Study

- Shadow price--cost savings associated with increasing the flow capability (rating) on a constrained transmission facility (such as a line, transformer, etc.) by one MW
- The cost savings associated with relieving constraints (flowgates) with high shadow prices can be dramatic
- Case Study: Flowgate with a relatively high shadow price for the Byron-NMA alternative

Shadow Price Case Study

Sum of the Shadow Prices Across the Limiting Element for the Year for Byron-NMA[1]

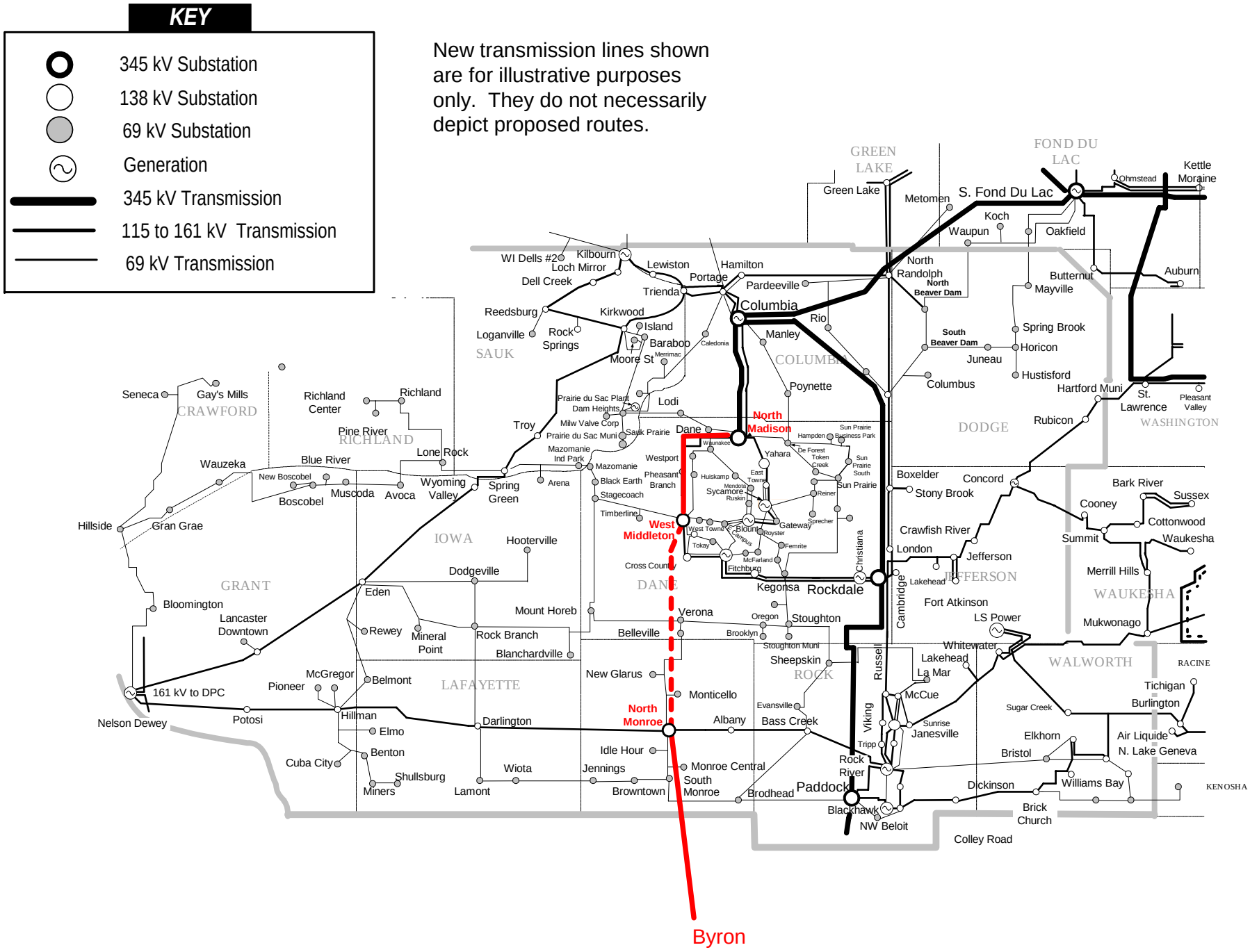
Limiting Element	Byron	Byron-NOM Fix
North Monroe 138/69 kV Transformer	$967,300	
Hilltop to Sherman St-115 kV	$91,960	$90,320
Tecumseh Rd 138/69 kV Transformer	$66,780	$80,420
West Middleton to Blackhawk-69 kV	$44,840	$56,830
South Fond du Lac 138/69 Transformer	$36,630	$23,630
Cassville to Nelson Dewey-161 kV	$13,640	$16,110
Rocky Run to Plover-115 kV	$10,350	$8,630
Cordova to Nelson-345 kV	$7,830	$9,210
Lakefield to Fox Lake-161 kV	$7,120	$8,120
Bain to Spring Valley-138 kV	$5,530	$8,830
Ramsey to Kansas-138 kV	$2,020	$4,810

[1] Values from the "FLOWGATE ANNUAL REPORT" table in the PROMOD "Report" file.

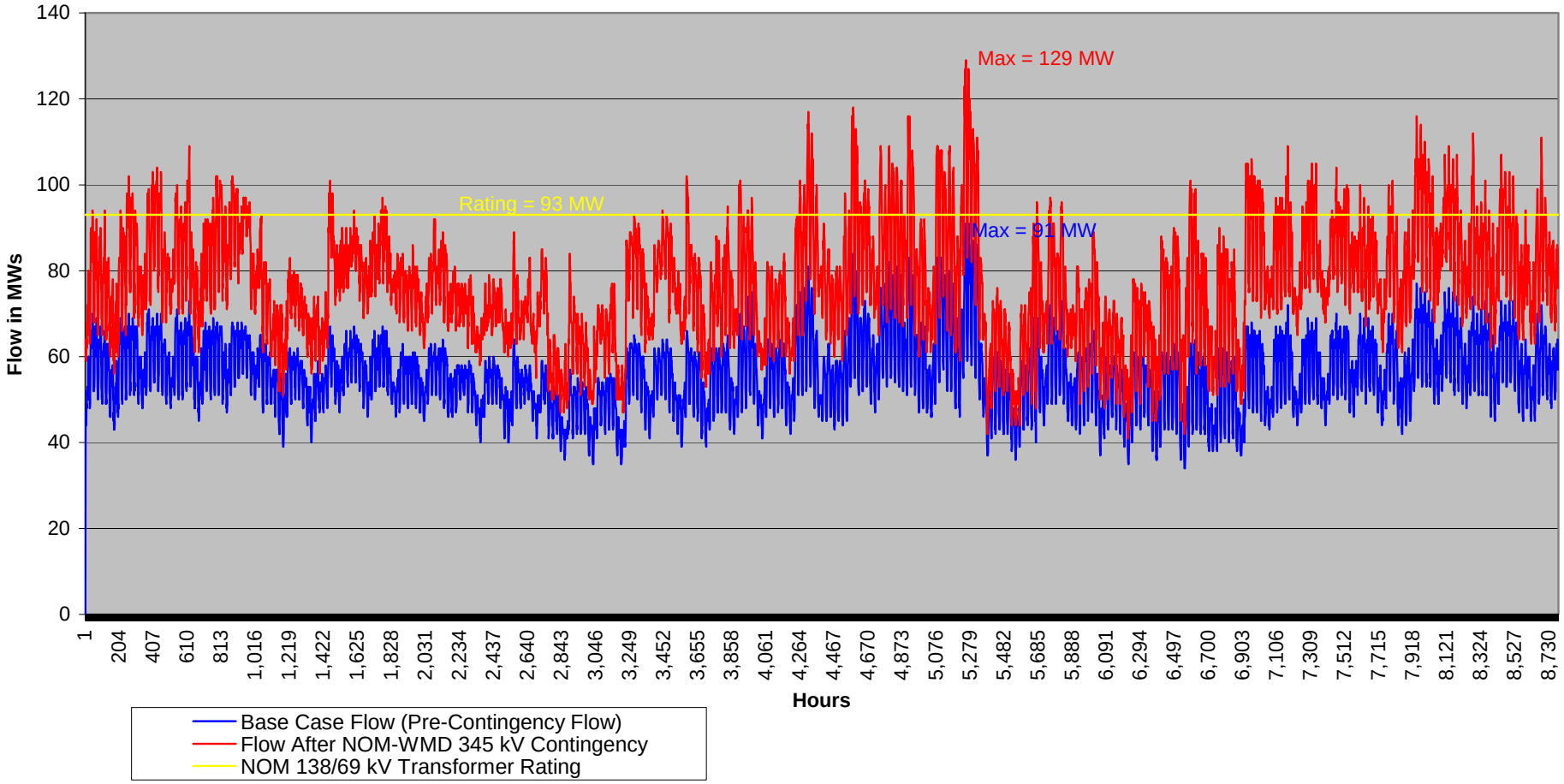
- What does the $967,300 shadow price sum on the North Monroe 138/69 kV transformer mean?
  - Increasing the flow capability (rating) on the transformer by a single MW would generate savings of almost $1 million

Shadow Price Case Study

- The rating on the existing North Monroe 138/69 kV transformer is 93 MW
  - If relieving this limiting element/constraint by 1 MW (to 94 MW) would saves $967,300, how much would a 5, 10, 30 or 50 MW increase save?
  - What is the maximum amount of power that wants to flow across the transformer in PROMOD?
  - Under what conditions do we see the maximum flow?
    - The North Monroe 138/69 kV transformer (limiting element) tends to overload for the loss of the North Monroe to West Middleton 345 kV line (single worst contingency) Flowgate


KEY
345 kV Substation
138 kV Substation
69 kV Substation
Generation
345 kV Transmission
115 to 161 kV Transmission
69 kV Transmission
New transmission lines shown are for illustrative purposes only. They do not necessarily depict proposed routes.
GREEN LAKE
FOND DU LAC
Green Lake
Metomen
S. Fond Du Lac
Ohmstead
Kettle Moraine
Koch
Waupun
Oakfield
North Randolph
North Beaver Dam
Butternut
Mayville
Auburn
WI Dells #2
Kilbourn
Loch Mirror
Dell Creek
Lewiston
Hamilton
Portage
Trienda
Pardeeville
Columbia
Reedsburg
Kirkwood
Island
Loganville
Rock Springs
Baraboo
Caledonia
Merrimac
Moore St
SAUK
Manley
Rio
COLUMBIA
South Beaver Dam
Spring Brook
Horicon
Juneau
Hustisford
Columbus
Poynette
Hartford Muni
St. Lawrence
Pleasant Valley
WASHINGTON
DODGE
Rubicon
Seneca
Gay's Mills
CRAWFORD
Richland Center
Richland
Pine River
RICHLAND
Prairie du Sac Plant
Dam Heights
Lodi
Troy
Milw Valve Corp
Prairie du Sac Muni
Sauk Prairie
Dane
North Madison
Hampden
Sun Prairie Business Park
W Junaker
Mazomanie Ind Park
Yahara
De Forest
Token Creek
Sun Prairie South
Sun Prairie
Wauzeka
Blue River
Lone Rock
Westport
Mazomanie
Pheasant Branch
Huiskamp
East Towne
Mendota
Sycamore
Ruskin
Reiner
Boxelder
Concord
Stony Brook
Bark River
Sussex
Cooney
Cottonwood
Summit
Waukesha
Merrill Hills
New Boscobel
Boscobel
Muscoda
Avoca
Wyoming Valley
Spring Green
Arena
Black Earth
Stagecoach
Timberline
West Middleton
West Towne
Blount
Gateway
Sprecher
Tokay
Campus
Royster
Femrite
McFarland
Fitchburg
Crawfish River
London
Jefferson
Lakehead
Fort Atkinson
Hillside
Gran Grae
IOWA
Hooterville
Dodgeville
Cross Country
DANE
Christiana
Kegonsa
Rockdale
Cambridge
JEFFERSON
WAUKESHA
Mukwonago
GRANT
Eden
Bloomington
Lancaster Downtown
Mount Horeb
Verona
Oregon
Stoughton
LS Power
Whitewater
Rewey
Mineral Point
Rock Branch
Belleville
Brooklyn
Stoughton Muni
Blanchardville
Sheepskin
Lakehead
La Mar
WALWORTH
RACINE
Russell
McGregor
Belmont
Pioneer
LAFAYETTE
New Glarus
ROCK
Tichigan
Burlington
161 kV to DPC
Monticello
McCue
Sugar Creek
Nelson Dewey
Potosi
Hillman
Darlington
North Monroe
Albany
Evansville
Bass Creek
Viking
Sunrise
Janesville
Elmo
Elkhorn
Air Liquide
Idle Hour
Benton
Tripp
Bristol
N. Lake Geneva
Cuba City
Monroe Central
Rock River
Dickinson
Williams Bay
Shullsburg
Jennings
South Monroe
Paddock
Brodhead
Miners
Lamont
Wiota
Browntown
Blackhawk
NW Beloit
Brick Church
KENOSHA
Colley Road
Byron

Flow on the 138/69 kV North Monroe Transformer (Limiting Element) in the Base Case and Under Contingency (Loss of the North Monroe-West Middleton 345 kV Line)



Shadow Price Case Study

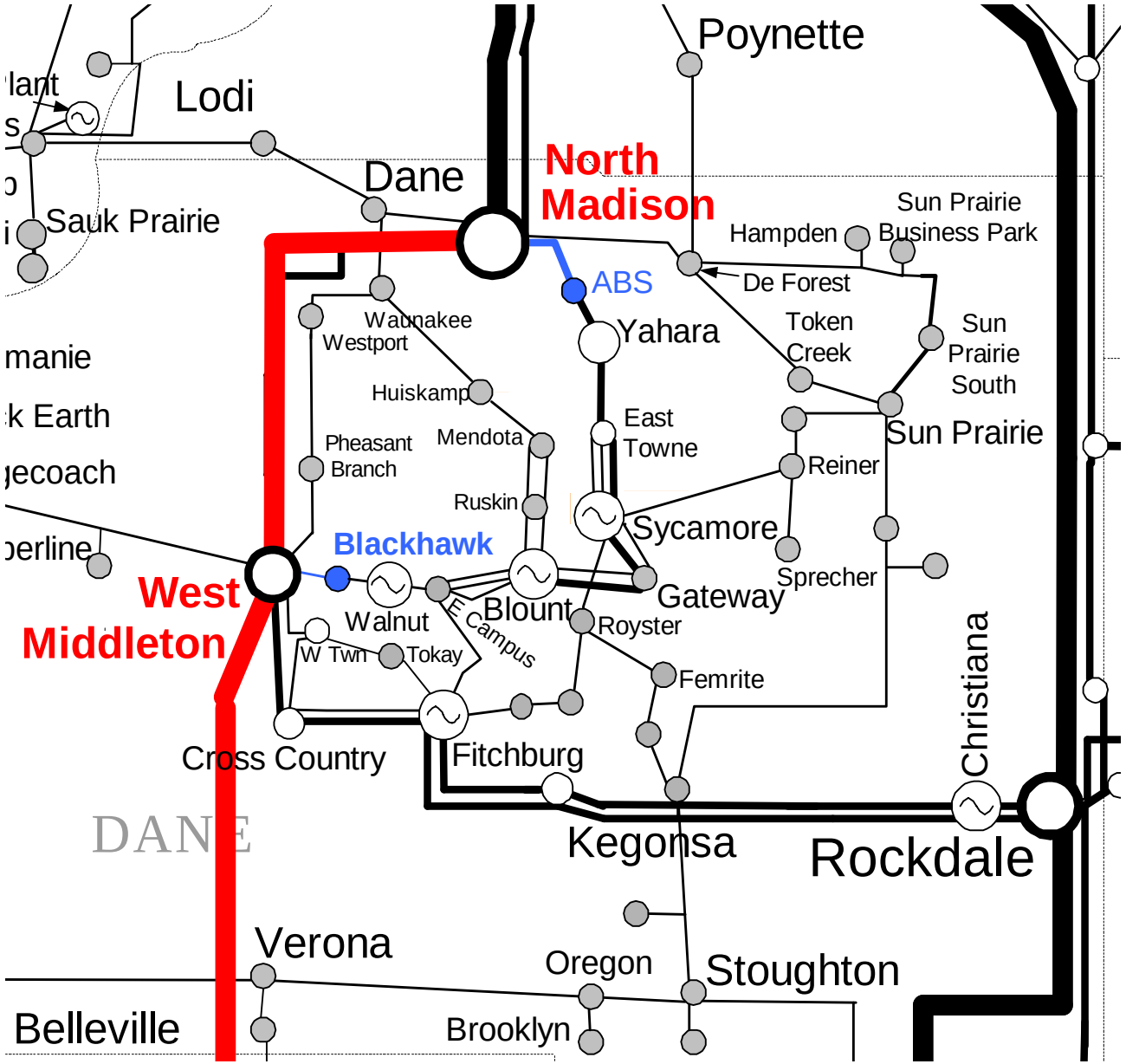
- The North Monroe 138/69 kV transformer "flowgate" rating only needs to be increased by 36 MW (from 93 to 129 MW) for it to no longer be an active constraint
- Because of increasing load growth in the area a second North Monroe transformer (~$1 million) has already been proposed
- Rating of the two transformers combined would roughly double to 186 MW

S.P. Case Study Conclusions

- A 1 MW increase in the flow on the North Monroe transformer would save $967,300
- Relieving the constraint completely, by adding a second transformer (~$1 million), saves around $10 million per year for Byron-NMA
- Other “downstream” lower voltage facilities might have to be upgraded
- Particularly important to have a complete set of flowgates and analyze their impact on the analysis—can have a major impact

Alternate Fixes Case Study

- There were other constraints/flowgates, with reasonably high shadow prices, that could also be "fixed"
  - Example: The West Middleton to Blackhawk 69 kV line tends to overload for the loss of the North Madison to ABS 138 kV line
- Would it be cost-effective to apply a fix for this constraint?


Poynette
Lodi
Dane
North
Madison
Sauk Prairie
Sun Prairie
Business Park
Hampden
ABS
De Forest
Waunakee
Westport
Yahara
Token
Creek
Sun
Prairie
South
Huiskamp
East
Towne
Sun Prairie
Pheasant
Branch
Mendota
Reiner
Ruskin
Sycamore
Blackhawk
Sprecher
West
Middleton
Gateway
Blount
E Campus
Walnut
Royster
W Twn
Tokay
Femrite
Christiana
Cross Country
Fitchburg
DANE
Kegonsa
Rockdale
Verona
Oregon
Stoughton
Belleville
Brooklyn

Alternate Fixes Case Study

- West Middleton (WMD) to Blackhawk is a 69 kV underground cable and as a consequence is difficult and relatively expensive to upgrade
- How else could we relieve this constraint?

Alternate Fixes Case Study

- Options for relieving the WMD-Blackhawk constraint:
  - Dispatch the lower-cost Blount units and the new University Plant more to "push back against the constraint"
  - The capacity factors show this occurring in PROMOD:

Capacity Factors for Select MGE Generators

Unit Description	Base Case Capacity Factor (%)	Byron-NMA Capacity Factor (%)
Blount:6	38.1	43.1
Blount:7	37.9	40.7
University Of Wisconsin Plant:GT	2.3	4.7

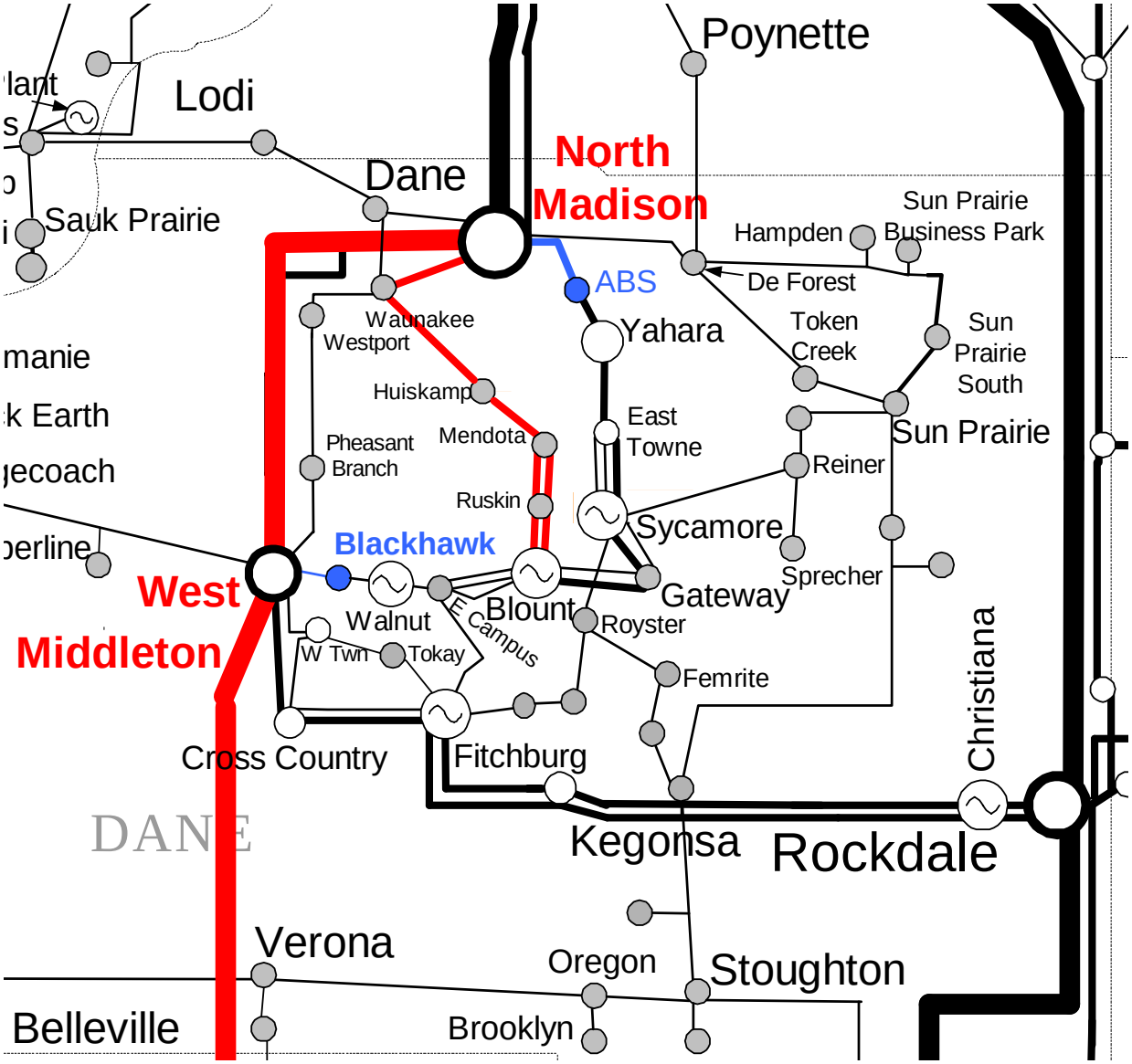
- Increase in capacity factors initially seems to be counter-intuitive

Alternate Fixes Case Study

- If it would be relatively difficult and expensive to “fix” WMD-Blackhawk, is there another transmission fix that could work?
- Instead of pushing back against a constraint with a power plant, could we “push back” by “fixing”/upgrading another transmission line?

Alternate Fixes Case Study

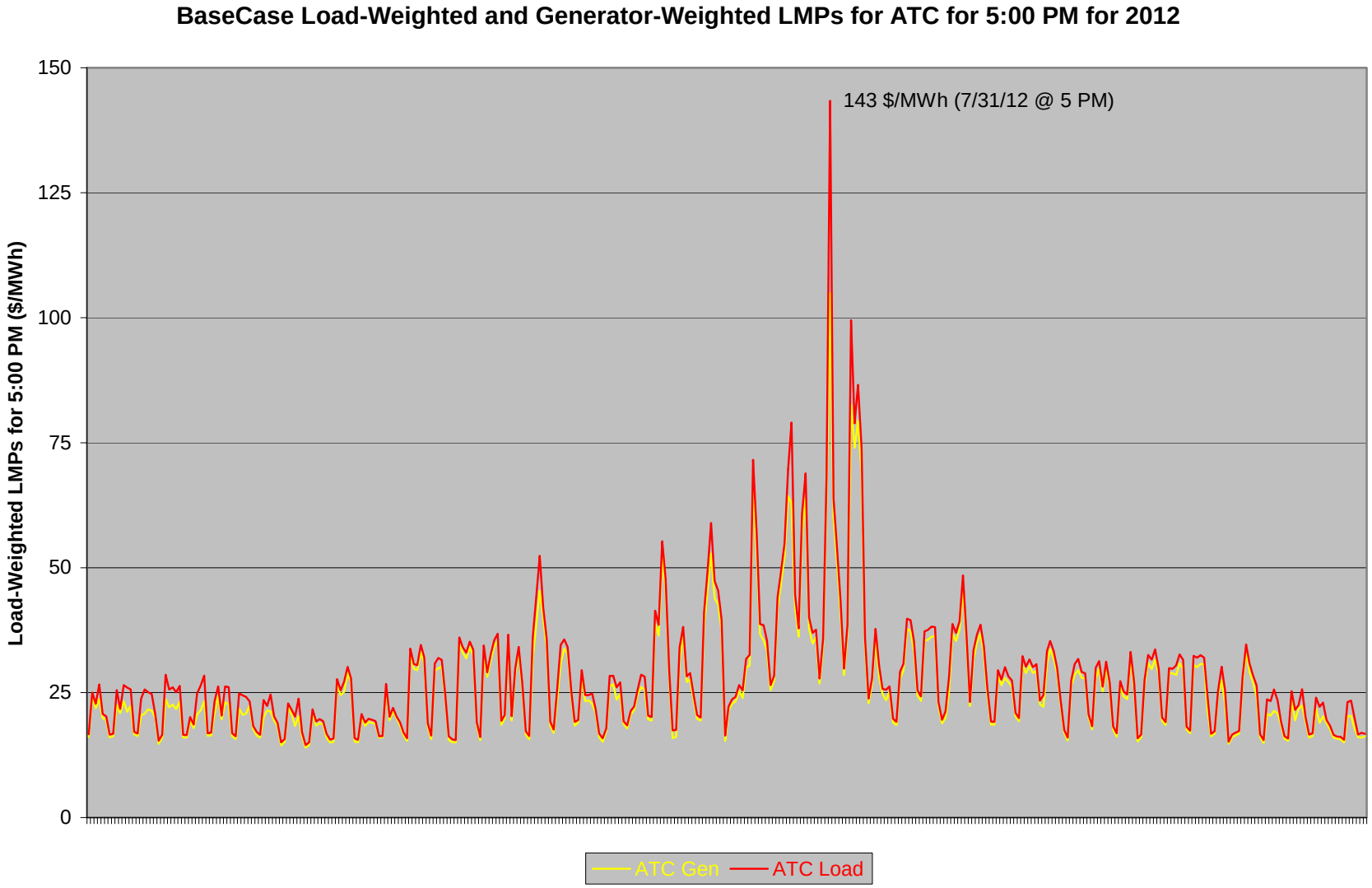
- ATC is planning to upgrade North Madison (NMA) to Blount from 69 kV to 138 kV to address low voltages, voltage stability and thermal overload problems in Madison
- Most of this line is overhead—less expensive and easier to upgrade
- Could this “reliability project” provide an additional benefit by “pushing back” on the WMD to Blackhawk constraint?


Poynette
Lodi
North
Madison
Dane
Sauk Prairie
Sun Prairie
Business Park
Hampden
ABS
De Forest
Waunakee
Westport
Yahara
Token
Creek
Sun
Prairie
South
Huiskamp
East
Towne
Sun Prairie
Pheasant
Branch
Mendota
Reiner
Ruskin
Sycamore
Blackhawk
West
Middleton
Sprecher
Gateway
Blount
Walnut
E Campus
Royster
W Twn
Tokay
Femrite
Christiana
Cross Country
Fitchburg
DANE
Kegonsa
Rockdale
Verona
Oregon
Stoughton
Belleville
Brooklyn

Alternate Fixes Case Study

- Desired effect—WMD to Blackhawk is no longer a significant constraint:
  - Relieving it helped increase the production cost savings for Byron-NMA
- Upgrading NMA to Blount may also have the additional benefit of lowering LMPs in downtown Madison—an area that could experience higher LMPs (and customer costs) due to transmission system congestion
- Conclusion: Fixing reliability issues may have other benefits like relieving constraints and lowering LMPs

LMP Case Study



LMP Case Study

- Observations:
  - Load-weighted LMPs greater than generator-weighted LMPs
  - Differ by congestion and loss components of the LMP
  - Nearly identical values during low load periods
- What is causing the load-weighted LMP values for to spike on 7/31/12 at 5 PM?
  - Is the load high?
  - Are there key generator outages?
  - Are there transmission outages?

LMP Case Study

- July 31, 2012 at 5:00 PM
  - ATC system is very close to its peak
  - ~ 800 MW of generation within the ATC footprint forced off-line (based on gen. forced outage rates)

Conclusions

- Flowgates are a major driver in PROMOD
- Constrained flowgates can be relieved in multiple ways
- Some output may initially seem counter-intuitive (capacity factor example)
- Useful to do sanity checks on capacity factors, line flows, shadow prices, etc.
- Generation and transmission background
- Access Initiative presentations and results:
  - http://www.atcllc.com/oasis/Customer_Notices/Access.html