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COMMENTS REGARDING MISO MERCHANT HVDC TRANSMISSION

The Michigan based non-profit corporation, Citizens Against Rate Excess (MICH-CARE) respectfully submits the following comments and feedback pursuant to a request during the February 14, 2018 MISO Planning Advisory Committee meeting on the topic of Merchant HVDC (Item 03d).[1]

Introduction

The topic of Merchant HVDC raises many questions that need to be addressed. Our organization, funded by Michigan's residential ratepayers welcome and encourage this discussion in a broader context because we believe HVDC doesn't necessarily fall neatly into either the generation or the transmission categories. In general, we believe HVDC has a huge potential to reduce the construction of costly new generation facilities and economically bring green energy to markets at competitive prices. We appreciate the opportunity to submit the following thoughts and comments and would welcome the opportunity to have more in depth discussions with MISO staff and PAC members to fully vet these possibilities.

Summary of Position

While charging Transmission Service included in the MISO applicable Schedules for transmission to deliver or distribute power and energy from HVDC terminals is outlined in the HVDC Merchant presentation for PAC Review dated February 14, 2018, the possible offsetting revenues for those charges are not addressed. In our opinion, FERC should be asked to approve the full set of charges and ***potential revenues*** from MISO. Having just costs approved would be an undue burden on initial HVDC projects without a corresponding incentive for MISO to complete the potential revenue filing.

HVDC is not generation or transmission. HVDC is another class of power system components. HVDC systems can be designed and operated as business ventures to operate in multi RTO and utility environments. HVDC systems can be used to obtain revenue from the arbitrage of energy markets as well as delivering contracted capacity and energy.

Background

There are three classes of HVDC connections:

1. Embedded

[1] These comments were primarily prepared by former MISO engineer, Dale Osborn in consultation with 5 Lakes Energy Consultant, Douglas Jester, with limited editing by MICH-CARE's counsel, John Liskey. The funding for this effort was provided by the Michigan Utility Consumer Participation Board (see link below).
https://www.michigan.gov/lara/0,4601,7-154-10573_76244---,00.html

    a. Within a single Balancing Area-example the CU and Square Butte HVDC lines in MISO. There are MISO AC transmission with power transfer capability surrounding the HVDC line.
    b. Within single synchronous Interconnection and at least two HVDC terminals in two Balancing Areas in a single Interconnection. There are AC paths with power transfer capability surrounding the HVDC line. The MISO example of a generator in MISO exporting power to PJM would be one of these examples.
2. Connection
    a. Interconnection of Balancing Areas in two or more asynchronous Interconnections. HVDC back to back systems are an example. Hydro Quebec to New England is another example.
    b. Connection of generation to an HVDC line with possibly an asynchronous AC collector system for the generation. An example may be to connect 2,700 MW of wind generation in Kansas (Eastern Interconnection) for delivery to Colorado (WECC), The generation could in connected to the AC in Kansas or operate as an asynchronous island using Voltage Source Converter technology or Synchronous Condensers with Current Commutated HVDC technologies. Manitoba has this type of an arrangement in on Balancing Area. An extension of this concept would be to have the Kansas wind generation tapping the center of an HVDC line from Colorado to Indiana with HVDC terminals at the generation, Colorado and Indiana. Generation energy and capacity could be scheduled to both the terminals in Colorado and Indiana depending on the energy prices. If the generation terminal in Kansas was also connected to the AC system in Kansas, then capacity and energy could be scheduled to any of the terminals based on energy prices.

3. HVDC Networks
    a. No generation connected directly to the HVDC
    b. Generation connected to the HVDC
        i. Integrated generation connections with local AC
        ii. Islanded generation from local AC

HVDC Network Example – Macro Grid

An example of a HVDC network is the Macro Grid scenario in the NREL SEAM study. The NREL SEAM study for connecting the Eastern Interconnection to WECC indicates that a benefit to cost ratio of over 2.5:1 may occur from an HVDC network overlay. The study used a co-optimized generation and transmission expansion program to locate generation, including renewable generation. About 80% of generation expansion is renewable based on the choice of economic alternatives including gas fired generation. Carbon dioxide is drastically reduced as well with the NREL Macro Grid scenario.

One of the concepts of the Macro Grid is similar to MISO's PAC presentation approach. The number of HVDC terminals can be strategically and economically planned if AC transmission service is obtained to allow a high percentage of load in the Macro Grid footprint to be included in the cost of the Macro Grid. If the AC access transmission service is included in the cost of the Macro Grid, then the cost per MW for all participants in the Macro Grid is the same. Costs of the entire Macro Grid are distributed over all participants. Benefits are proportional to costs. Adding AC transmission service to HVDC projects is offset with benefits of being able to design economical HVDC networks rather than having terminals in every state.

The Macro Grid concept also includes wind, solar and gas generation connected to the HVDC systems. With Voltage Source Converter (“VSC”) terminals, large wind or solar plants might have generation collected by islanded AC collection systems. Wind and solar plants may be in the range of 1,500 MW to 3,000 MW. No transmission service other than the collector systems would be necessary. If the local area needed support, HVDC back to back systems or lower voltage HVDC systems could be used. The VSCs eliminate the need for short circuit strength to interconnect wind and solar plants.

Early results from the NREL SEAM study showed about 6,000 MW of additional transmission to Michigan by the year, HVDC lines with 3,000 MW of capacity looped in and out of Michigan would provide 6,000 MW of additional import capability. The present import capability into Michigan is about 3,500 MW.

(Note: the North American Renewable Integration study includes Canada, the US and Mexico. Transmission requirements for the NARIS footprint would add the Canadian HVDC interconnections for an efficient power system. NREL is coordinating and performing the NARIS study. HVDC Networks are included in the NARIS study.)

Embedded Example-Iowa to Michigan

Example of a hypothetical Embedded HVDC system possibly addressing congestion issues and delivering power and energy at the same time.

1. Single Balancing Area, (see par 1a on p1)- Iowa to Michigan
2. Single Interconnection (Eastern Interconnection), two Balancing Areas (MISO-PJM-MISO), (see par 1b on p1).

HVDC systems can be scheduled to delivery capacity and energy as either a source or sink independently of the AC power angle difference between terminals that determines the flow on the AC systems without Phase Angle Regulators. Incorporation of the HVDC scheduling may improve the economics of the AC power system operating in Market environments using a three-terminal trading hub. For the Iowa-Indiana (PJM) - Michigan (MISO) system, the energy prices would tend to converge within the cost of losses until the HVDC were fully scheduled. Strategic location of the HVDC terminals may mitigate congestion by producing counter flows due to the creation of synthetic generation and raising power angles in Indiana and lowering power angles in Iowa and mitigating congestion.

Figure 7 (p16) is a MISO LMP plot from August 28,2016 at 4 pm.

Figure 8 (p 17) of LMP plot for PJM and the Interchange Schedules and Actual flows. MISO has a higher resolution for LMPs than PJM. (Note: the colors of Figure 7 and Figure 8 do not represent the same values.)

Figure 9 (p 17) is another example like Figures 7 and 8, which shows potential energy sales from Iowa and Michigan to PJM for a three terminal HVDC line.

The actual PJM to MISO transmission is 985 MW versus the scheduled amount of 2,980MW. There is 1,995 MW of loop flow from PJM to counter market energy price differences. (Note: the good part of loop flow into PJM to maintain the energy balance in the PJM Balancing Area is from Duke and Carolina in the southeastern part of PJM.) The generation locations in PJM along Lake Erie and the Ohio River create high power angles and the transmission congestion in eastern Pennsylvania, indicated by the change in color of the LMP plot, cause the loop flow.

One hypothetical solution to the problems in Figure 7 and Figure 8 is to build an HVDC line from Iowa into Michigan with the terminal in Michigan east of the PJM AEP DuPont 765 kV substation. The energy prices in Michigan would be lowered for the conditions in Figures 7 and 8. The revenue to generation in Iowa would be increased as the export of energy from Iowa would reduce the generation pocket in Iowa.

(Note: if Merchants are to obtain revenue for congestion mitigation, the integral of the change in price versus power transferred the HVDC line curve would probably have to be constructed. The curve may be quite non-linear.)

KEY QUESTIONS concerning Transmission Service charges per the MISO Merchant HVDC proposal for PAC review:

1.) **Is there a plan with a schedule to include HVDC in the MISO operation and market systems?**

2.) **Does MISO have a plan for revenue to Merchants for lowering the price? If yes, how does it work for MISO? How would it work with ITC?**

3.) **What is the break down for the 2000 MW HVDC charges in Michigan? ITC has schedules in addition to MISO's?**

4.) **What is the break down for the transmission to access wind generation in Iowa?**

    a. **1000 MW of capacity to Michigan (850 MW capacity from Manitoba, 150 MW Wind Capacity Credit from Iowa). NITS transmission assumed in Michigan.**

    b. **1000 MW of HVDC transmission capacity used for energy arbitrage and wind energy aggregation?**

5.) **What would be the revenue process for a Merchant HVDC line for price convergence between MISO and PJM around HVDC terminals?**

6.) **For Load Capacity Diversity, please confirm if the stated assumptions are correct and that there would be no additional charges on the AC side for Load Capacity Diversity exchanges outside of the transmission expansion needed for the HVDC terminals to connect to the AC system.**

7.) **Is the Load Capacity Diversity transmission under the NITS for the AC system?**

8.) **Does the Load Capacity Exchange with HQ, reduce the MISO or ITC NITS costs of DTE if capacity and energy are scheduled on the HVDC system as not to load the ITC -MISO transmission beyond the reduced load reduce by the capacity exchanges with HQ or IESO?**

9.) **What is the break down for the 2000 MW HVDC charges in Michigan? Does ITC have schedules in addition to MISO's?**

10.) **What is the break down for the transmission to access wind generation in Iowa?**

DISCUSSION

An HVDC terminal in Michigan would increase the power angle in the Michigan area and produce counter flows to power through NIPSCO and counter flows to the PJM loop flow. ***The HVDC may produce benefits to MISO beyond the terminals.***

The power angles in Iowa would be reduced by the HVDC terminal exporting energy. Reduced power angles in Iowa would reduce the congestion between the Iowa generation pocket (figure 7 - dark blue area) and Illinois.

MISO economic studies could provide an estimate of the Iowa-Michigan potential benefits. In the case of proposed Merchant HVDC lines, the Merchant would do the studies. The business model assumed is that the Merchant may sell capacity on the line for 1000 MW and use the other 1000 MW of HVDC capacity for energy arbitrage.

Connection Example Michigan-PJM-Iowa by adding an HVDC terminal to an Embedded system

If wind generation were to be exported to PJM, a third terminal on the HVDC line east of NIPSCO would be a good choice. HVDC terminals west of NIPSCO would further add to the congestion in NIPSCO for power transfers east of Chicago.

If the HVDC terminal in Iowa was rated 2,000 MW, the HVDC terminal east of NIPSCO to PJM was rated 1000 MW, and the Michigan terminal were rated 2,000 MW then the PJM DuPont 765 kV bus may be a good interconnection location for the PJM HVDC terminal location. The HVDC line between the terminals could be rated at 2000 MW.

(Note: MISO economic studies probably cannot provide an estimate of the Iowa-PJM--Michigan potential benefits due to the loop flows from PJM contrary to market price difference signals. Actual versus simulated production cost bench mark studies results do not match well in the MISO-PJM dispersed area.)

The HVDC schedules change the power angle differences and associated power flow on AC transmission as well as converging the price differences. If there is sufficient HVDC capacity, the prices may converge within a few percent difference due to losses. HVDC systems can operate on energy market LMP differences. In addition to shift factors, the dispatch could calculate the price change that an HVDC schedule would produce. Price calculation computation would be doubled. Then MISO would determine the schedules on the HVDC and communicate the schedule order to the HVDC system. Then HVDC would be included in the dispatch as a controllable element.

HVDC for Load Capacity Diversity

Load Diversity is the hourly difference between two utility or groups of utilities loads. Load Capacity Diversity is the least Load Diversity on the peak hour between two parties for a sample of years. Nine years of hourly load data is used in the charts below. Load Capacity Diversity has the same probability of being available on peak as a gas fired generator.

The results below were produced by a MISO summer intern project. Individual utilities have larger Load Capacity Diversity potential than aggregated load groups such as MISO. HVDC systems allow schedules that can be made to deliver capacity as needed to specific terminals without a negative impact to the intervening AC systems.

(Note: Load Capacity Diversity cannot be added. The sum of two or more hourly loads for the peak period of nine years, then the hourly differences over the nine-year period are searched for the minimum Load Diversity on the peak hours for both participants.)

Michigan has the highest potential for Load Capacity Diversity exchanges of any area within MISO. Load Capacity Diversity Exchanges may use existing generation to supply generation on peak load from one utility or group of utilities and be supplied by another utility or group of utilities off peak. The net result is that half of the Load Capacity Diversity between two utilities or groups of utilities can be used for Resource Adequacy and reduce the need for new peaking generation from combustion turbines. Half of the Load Capacity Diversity should be able to be used by each party in the Load Capacity Diversity exchange for Resource Adequacy.

HVDC makes it possible to collect and deliver the capacity from the transacting parties. The receiving utility obtains delivery from an HVDC terminal and it looks like local generation with voltage support if the HVDC terminal is a VSC. Load Capacity Diversity potential exchanges increase with the east-west number of time zones of the participating load and north to south due to winter-summer peaking differences and load duration curve differences. Southern loads tend to have less peak to minimum load differences than northern loads.

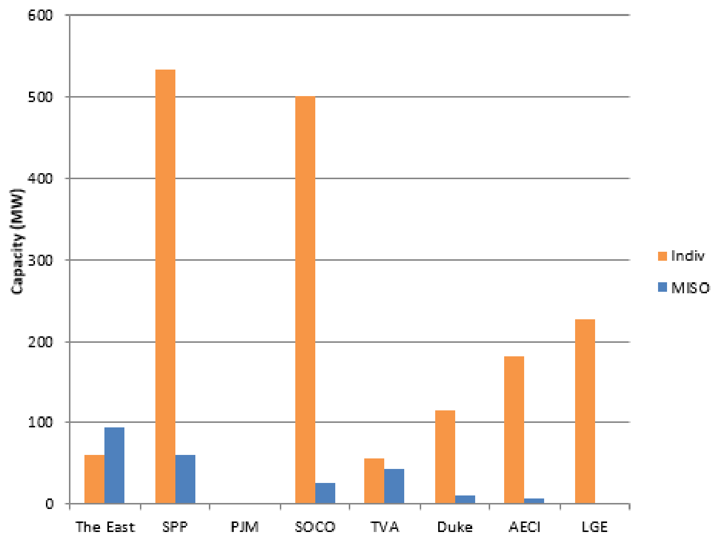
(Note: the generation and the transmission to deliver the generation used on the AC system is already covered by NITS or Transmission Service.)

The below charts indicate that Load Capacity Diversity may help support an HVDC line from the Southern Company to MISO North.

The Mountain and California plots indicate which utilities in MISO may benefit from an HVDC lines between the areas.

The most likely scenario for HVDC lines for Load Capacity Diversity are the Network studies by NREL or HVDC lines that could be integrated into a Road Map of a Network.

Consumers Energy – METC



Region	Indiv (MW)	MISO (MW)
The East	61	94.6
SPP	534	60.7
PJM	0	0
SOCO	502	26.3
TVA	56	43.1
Duke	115	10.1
AECI	182	7.4
LGE	227	2

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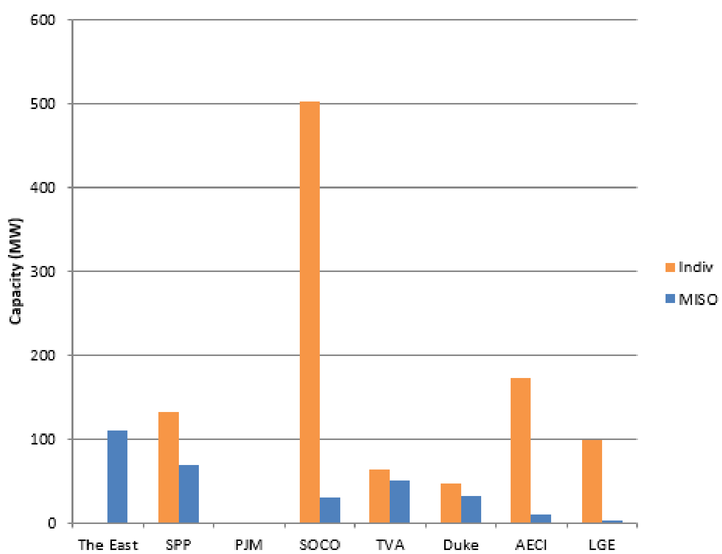
Detroit Edison Co



Region	Indiv (MW)	MISO (MW)
The East	0	108.9
SPP	132	68.3
PJM	0	0
SOCO	501.9	29.6
TVA	64	49.6
Duke	47	30.9
AECI	173	8.6
LGE	98	2.4

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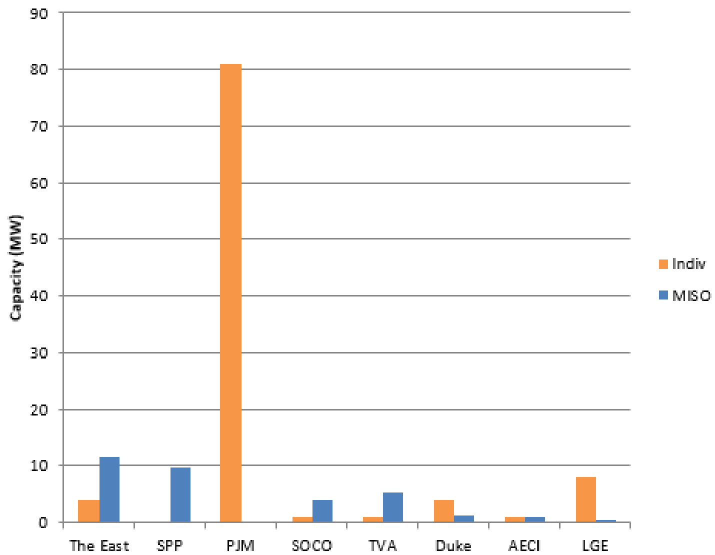
Southern MI Elec Power Association



Region	Indiv (MW)	MISO (MW)
The East	4	11.7
SPP	0	9.6
PJM	81	0
SOCO	1	4.1
TVA	1	5.3
Duke	4	1.2
AECI	1	1
LGE	8	0.3

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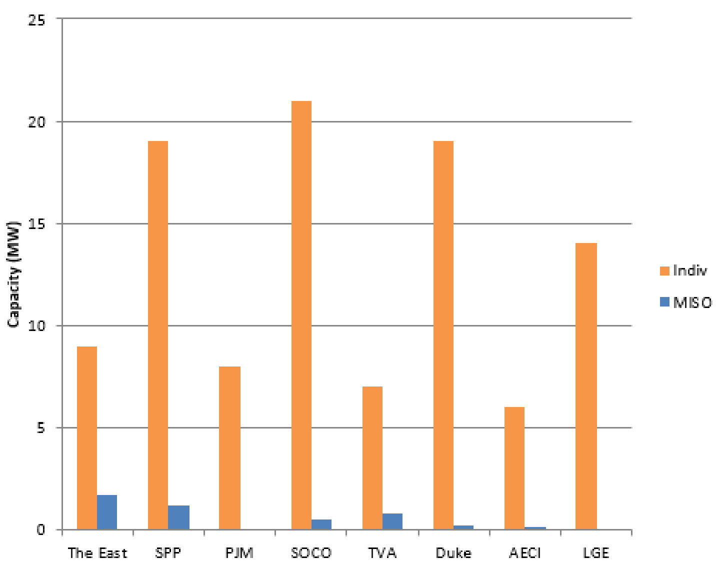
Upper Peninsula Power Co



Region	Indiv (MW)	MISO (MW)
The East	9	1.7
SPP	19	1.2
PJM	8	0
SOCO	21	0.5
TVA	7	0.8
Duke	19	0.2
AECI	6	0.1
LGE	14	0

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MISO Members

Member		Member		Member		Member		Member	
Alliant East		Detroit Edison Co		Entergy Texas		MidAmerica Energy Co		Southern Indiana Gas and Elec	
Ameren IL		Duke Energy Indiana		Great River Energy		Madison Gas and Elec		Southern IL Power Co-op	
Ameren MO		Dairyland Power Co-op		Hoosier Energy Rural Elec		MN Power and Light Co		South Mississippi Elec Power Association	
Alliant West		Entergy AR		Indianapolis Power and Light		Muscatine Power and Water		Southern MN Municipal Power Agency	
Big Rivers Elec Corp		Entergy Gulf States		Lafayette		Northern Indiana Public Service		Upper Peninsula Power Company	
Consumers Energy - METC		Entergy LA		LA Enrgy and Power Authority		Northern States Power Co		Wisconsin Elec Power Co	
Central LA Elec		Entergy MI		LA Generating/ Cajun Elec		Otter Tail Power Co		Wisconsin Public Service Corp	
Columbia MO Water and Light		Entergy New Orleans		Montana - Dakota Utilities Co		Springfield - City Water Light and Power			

The West

- **California (Cali)**
  - – Pacific Gas and Electric – Main
  - – Pacific Gas and Electric – Bay Area
  - – Pacific Gas and Electric – ZP26
  - – Balancing Authority of Northern CA
  - – Turlock Irrigation District
  - – Southern CA Edison
  - – LA Department of Water and Power
  - – Imperial Irrigation District
  - – San Diego Gas and Electric
- **Mountain (MTN)**
  - Mountain West
    - – WAPA – Upper Great Plains
    - – WAPA Colorado
    - – WAPA – Wyoming
    - – Public Service Company of Colorado
    - – Public Service Company of New Mexico
  - West Connect
    - – Arizona Public Service Company
    - – El Paso Elec
    - – Sierra Pacific
    - – Nevada Power Co
    - – Tucson Elec Power Co

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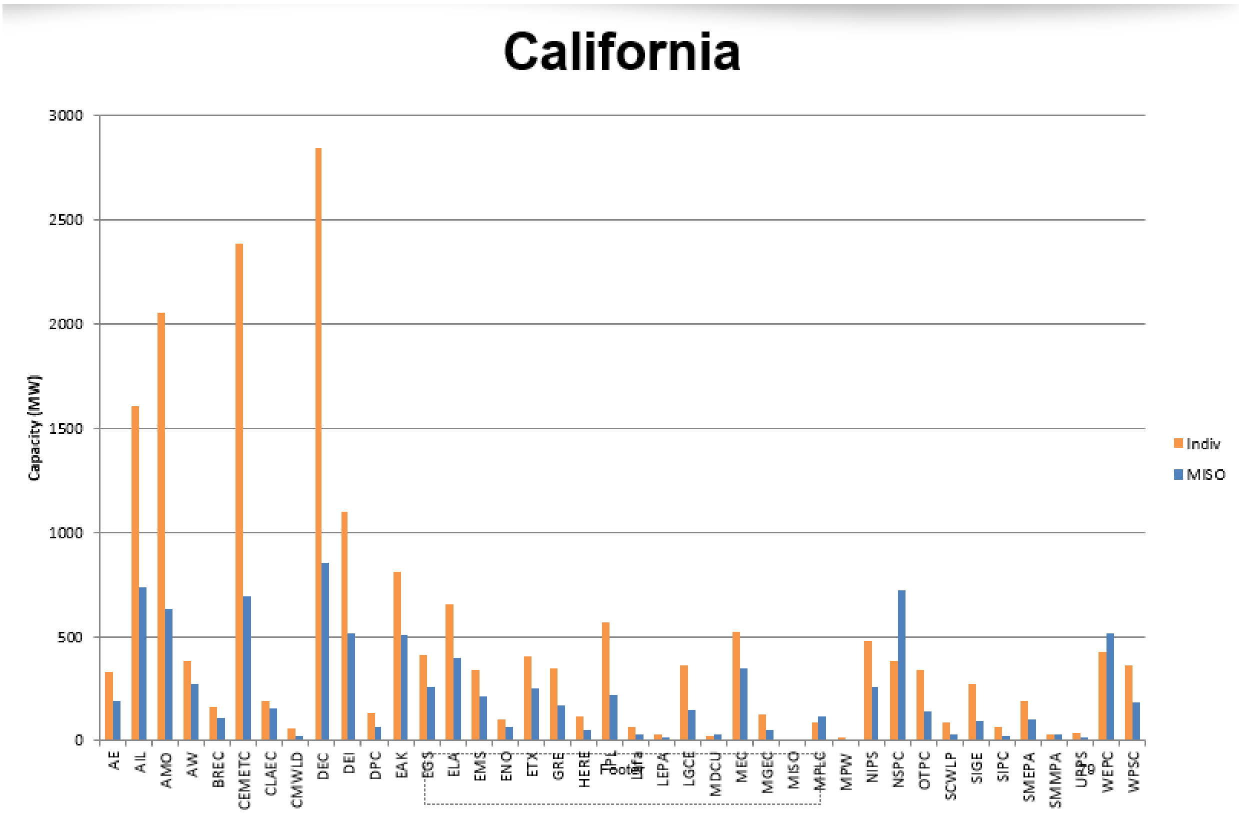
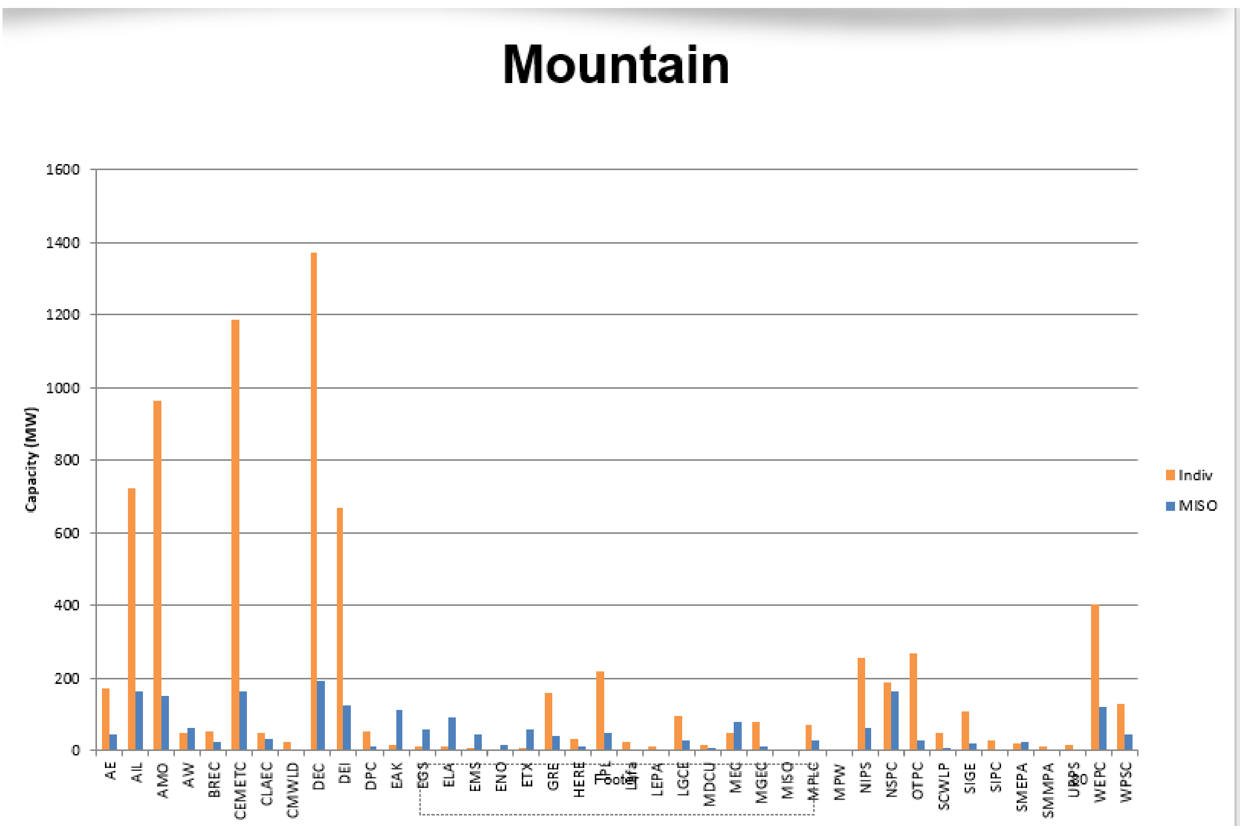

California
Capacity (MW)
3000
2500
2000
1500
1000
500
0
Indiv
MISO
AE AIL AMO AW BREC CEMETC CLAEC CMWLD DEC DEI DPC EAK EGS ELA EMS ENO ETX GRE HERE IPL Lafa LEPA LGCE MDCU MEC MGEC MISO MPLC MPW NIPS NSPC OTPC SCWLP SIGE SIPC SMEPA SMMPA UPPS WEPC WPSC


Mountain
Capacity (MW)
1600
1400
1200
1000
800
600
400
200
0
Indiv
MISO
AE AIL AMO AW BREC CEMETC CLAEC CMWLD DEC DEI DPC EAK EGS ELA EMS ENO ETX GRE HERE IPL Lafa LEPA LGCE MDCU MEC MGEC MISO MPLC MPW NIPS NSPC OTPC SCWLP SIGE SIPC SMEPA SMMPA UPPS WEPC WPSC

Connection Example- Detroit to Ontario and possibly on to Hydro Quebec.

Hydro Quebec has a difference of about 12,000 MW from winter peak load to summer peak load.

Michigan has 20,000 MW of summer peak load to 14,000 MW winter peak load.

Load Capacity Diversity for seasonal exchange may be an economic alternative for Detroit.

The maximum capacity Hydro Quebec HVDC line can accept using Frequency Response Obligation and Allocations of HQ and the neighboring RTOs and utilities is 2,265 MW delivered. The HVDC line rating for reserves and losses would be about 2,900 MW.

VSC converters could be placed on the 345 kV transmission system or broken into smaller poles or converters to supply power and voltage regulation strategically throughout the urban footprint. The HVDC terminals would be radial and may not qualify as transmission. HVDC cables might be laid in the rivers around Detroit to obtain access to Detroit loads like the Trans Bay cable in San Francisco.

The HVDC system delivering power to Detroit may also schedule low cost energy from HQ and if there is a terminal in Ontario, from IESO.

If the HVDC systems are not transmission, then Detroit Edison or Merchant HVDC may be the owners of the HVDC system. If HVDC is a third category of a power system besides transmission and generation, then DTE subsidiary ownership may also be an option.

The HVDC system may be self-scheduled by Detroit Edison or by a Merchant.

Since the connection is with a FERC non-jurisdictional utility and if the HVDC system is a third category the Michigan PSC may determine rate recovery.

Since HQ is asynchronous with MISO, HQ may qualify as an External Asynchronous Resource and own the HVDC line or part of it as a Merchant**. Perhaps an ITC-MISO-HVDC HQ line delivering capacity and energy to MISO could be through ITC. A determination would have to be made of the cost break down and to whom it would be paid after a breakdown of transmission service costs for ATC, ITC and MISO has been made.**

If wind generation were to be exported to PJM, a third terminal on the HVDC line east of NIPSCO would be a good choice. HVDC terminals west of NIPSCO would further add to the congestion in NIPSCO for Chicago east power transfers.

If the HVDC terminal in Iowa was rated 2,000 MW and the HVDC terminal east of NIPSCO to PJM was rated 1000 MW and the Michigan terminal were rated 2,000 MW then the PJM DuPont 765 kV bus may be a good interconnection location for the PJM HVDC terminal location. The HVDC line between the terminals could be rated at 2000 MW.

MISO economic studies probably cannot provide an estimate of the Iowa-PJM--Michigan potential benefits due to the loop flows from PJM contrary to market price difference signals. Actual versus simulated production cost bench mark studies results do not match well in the MISO-PJM disparate territory.

Connection Example- Upper Michigan Peninsula to IESCO at Sault Ste. Marie

The MISO Michigan Study identified a 325 MW import capability from IESO into the UP. However, the Reliability study phase of the Michigan Study limited power injections into the UP to 125 MW. A conceptual system with a 325 MW system at back to back HVDC VSC system on the Michigan side of Sault Ste. Marie may maximize the lower cost energy imports into the UP and Michigan while maintaining the HVDC separation of Lower Michigan from Upper Michigan.

A 230 kV AC line could possibly connect the Sault Ste. Marie HVDC terminal to the Mackinaw ATC HVDC back to back VSC system. The 230 kV AC line would feed multiple AC substations in the UP between the HVDC terminals and deliver 200 MW to the Mackinaw HVDC system.

Potential revenue would probably be calculated by the integral of the energy price difference versus HVDC price curve. Converting Mackinaw HVDC to a Merchant third type power component rather than transmission may be an option because a Merchant HVDC may be able to sell the full capacity of the HVDC terminal.

Assume that the MPSC provides an incentive to ATC to retain part of the potential revenue to use the Mackinaw HVDC terminal to transmit power from Michigan's Upper Peninsula to its Lower Peninsula. Controls would need to be modified to operate in a market mode with capacity limits for Reliability because the present controls are set to control power flow. Having two VSCs should reduce the contingency restrictions for the UP.

Voltage Source Converter systems

Commercial vendors have been willing to bid on Voltage Source Converter systems in the 2200 MW rating for six years. HVDC VSC systems in the 2000 MW range are large enough to address economic and market issues in MISO and surrounding areas.

Schedule 2 and VSC HVDC Characteristics

1. Voltage Source Converters have reactive power characteristics quite different from generators.

    a. VSCs regulate voltage 20-30 times faster than generators. VSCs are fast enough and have enough reactive power dynamic range to restore voltage before the first voltage swing. Presently several voltage swings pass before generators can restore voltage.

    b. Coordinated controls are required to relax the VSC output following a disturbance and add the dynamic reactive range back onto the system by coordination with fixed capacitors and probably the generators would need to be designed and implemented to obtain the value of the voltage regulation.

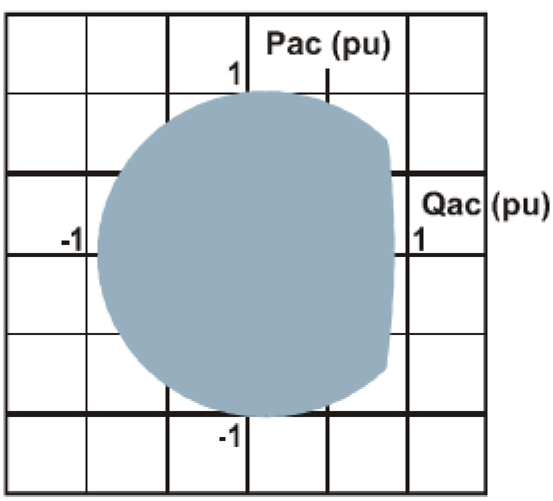
    c. The VSCs have a total dynamic reactive capability a zero power of about 140% of the rating of the VSC using both the leading and lagging reactive power characteristics. Typical designs would retain some the voltage lowering reactive power capability, about 40% of the converter rating. Multi step biasing capacitors would be used to provide a fast voltage recovery. The capacitors in total would be able to supply 60% of the VSC converter rating for of the dynamic voltage regulation. The VSC can schedule power and reactive power anywhere in the P-Q characteristic or biased P-Q characteristic. The VSC has the capability of a very large StatCon.

d. Dynamic reactive power placed in areas without voltage regulating generation, can increase the power transfer capacity of neighboring transmission. Would FTR credits be available if the VSC enabled a more efficient power system and markets? Static Var Compensators, the slower version of StatCon, have been used for years to increase the power transfer capability of transmission.

e. Some of the latest generation has a 95% power factor that has about a 30% of the generator rating for voltage boosting. Other generators have a 90% power factor rating and have about a 50% of the power rating of the generator available for reactive power production to increase voltage. A typical VSC could be designed for 100% of the power rating of the VSC as reactive power with biasing capacitors.

f. Biasing capacitors can be place on higher voltage lines near VSCs to move the power and reactive power characteristic curve that determines the operating region of the VSC such that VSCs can operate at full power while delivering reactive power for voltage regulation. The biasing capacitors allow the use of the dynamic reactive range of the VSCs.

g. Schedule 2 is written for generators and includes other equipment. The VSC may be other equipment, but VSCs can provide more than Schedule 2 includes as described above.



Simplistic Power-Reactive Power Characteristic of a VSC.

Figure 4

The reactive limit on the right side of Figure 4 is due to voltage limits on the converters. The entire reactive range can be used to provide dynamic regulation when combined with biasing capacitors. Figure 9 shows a typical generator characteristic. Generators can be limited in the leading reactive range due to stability and may not be able to use the entire reactive range.

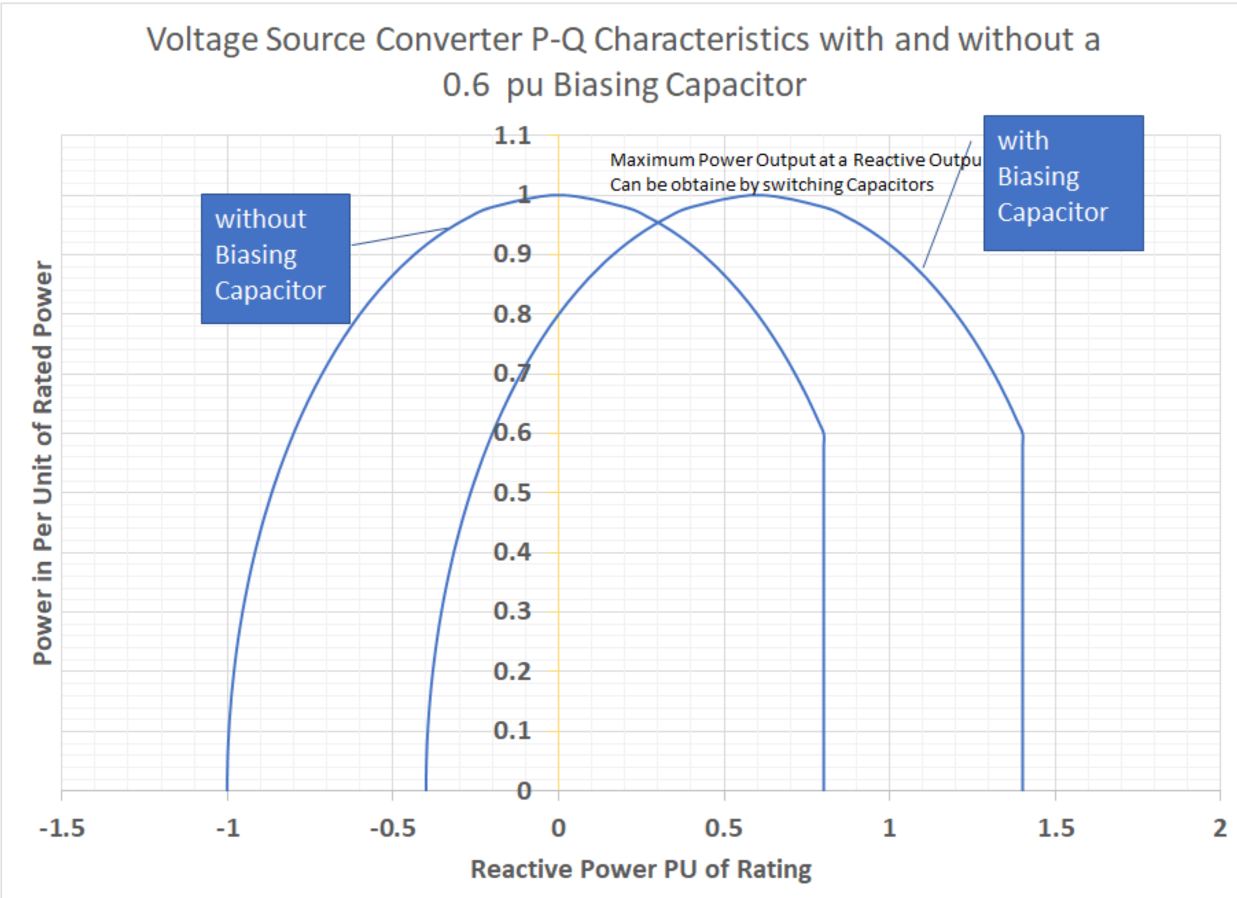


Figure 5

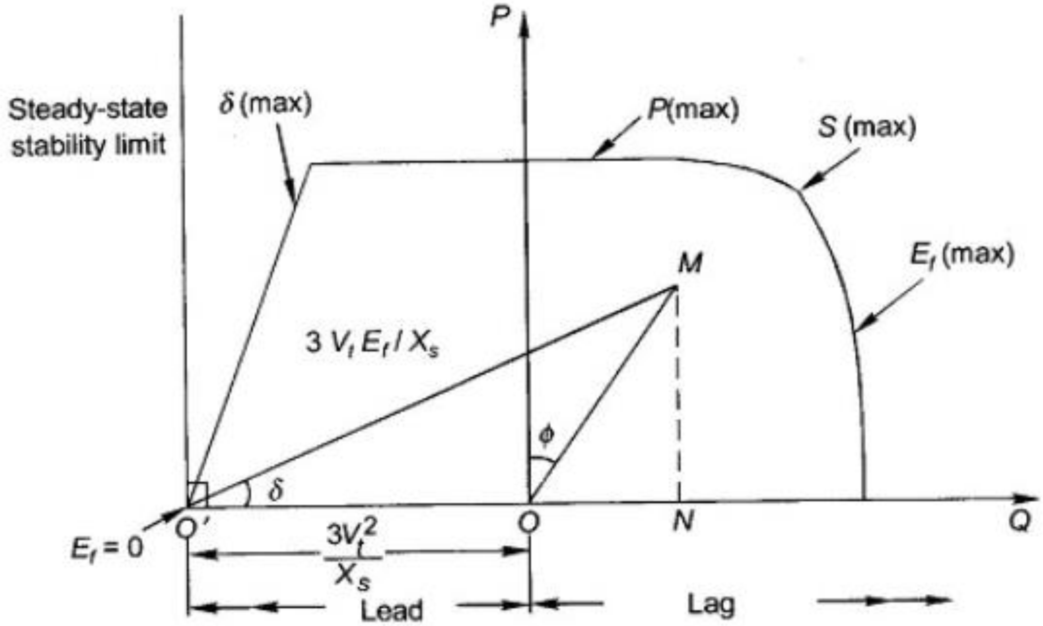


Figure 6 *Capability curve of synchronous generator*

Black Start

VSCs can be designed to black start an are without generation up to its rating including the voltage regulation if on terminal of an HVDC system is undisturbed.

The ramp rate of power for a VSC is to full rating, plus or minus, in less than 0.1 seconds with voltage regulation responding also. VSCs are fast enough to pick up blocks of load as it is switched onto the system. The rate of recovered load is much faster and more stable with VSCs than with break switched load and generator ramping.

The ramp rate on generators is rated in MW/minute. VSCs would allow generators to ramp at full capability. The VSCs would match load and generation with schedules that look like ramped load.

Probably, the power system in a disturbed area with a VSC could start faster than the present Black Start processes.

VSCs could be used to balanced load additions with generation by scheduling the power and reactive power needed.

Methods for VSCs to participate in the Black Start process and revenues for the participation should be developed.

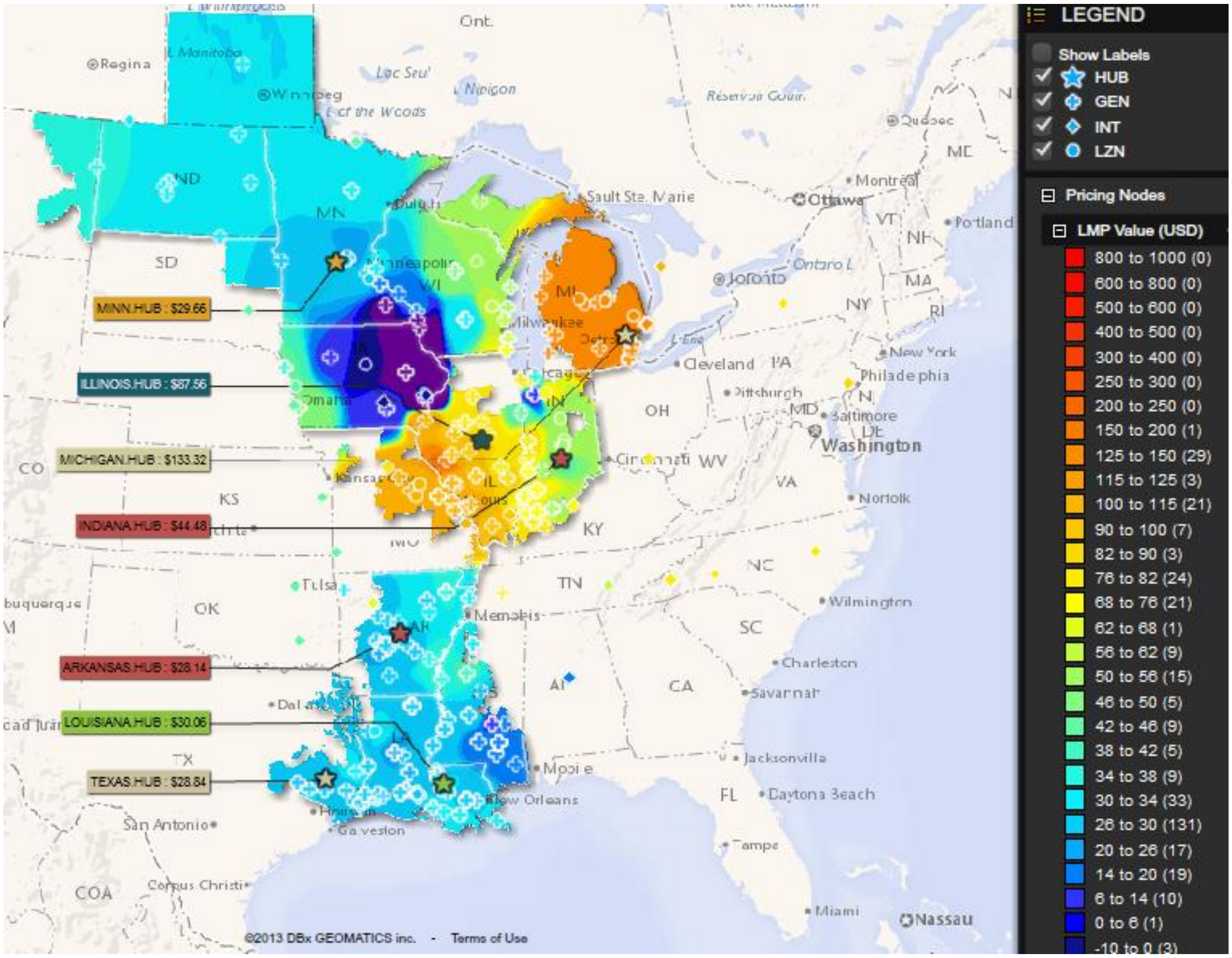

MINN.HUB : $29.66
ILLINOIS.HUB : $87.56
MICHIGAN.HUB : $133.32
INDIANA.HUB : $44.48
ARKANSAS.HUB : $28.14
LOUISIANA.HUB : $30.06
TEXAS.HUB : $28.84
LEGEND
Show Labels
HUB
GEN
INT
LZN
Pricing Nodes
LMP Value (USD)
800 to 1000 (0)
600 to 800 (0)
500 to 600 (0)
400 to 500 (0)
300 to 400 (0)
250 to 300 (0)
200 to 250 (0)
150 to 200 (1)
125 to 150 (29)
115 to 125 (3)
100 to 115 (21)
90 to 100 (7)
82 to 90 (3)
76 to 82 (24)
68 to 76 (21)
62 to 68 (1)
56 to 62 (9)
50 to 56 (15)
46 to 50 (5)
42 to 46 (9)
38 to 42 (5)
34 to 38 (9)
30 to 34 (33)
26 to 30 (131)
20 to 26 (17)
14 to 20 (19)
6 to 14 (10)
0 to 6 (1)
-10 to 0 (3)
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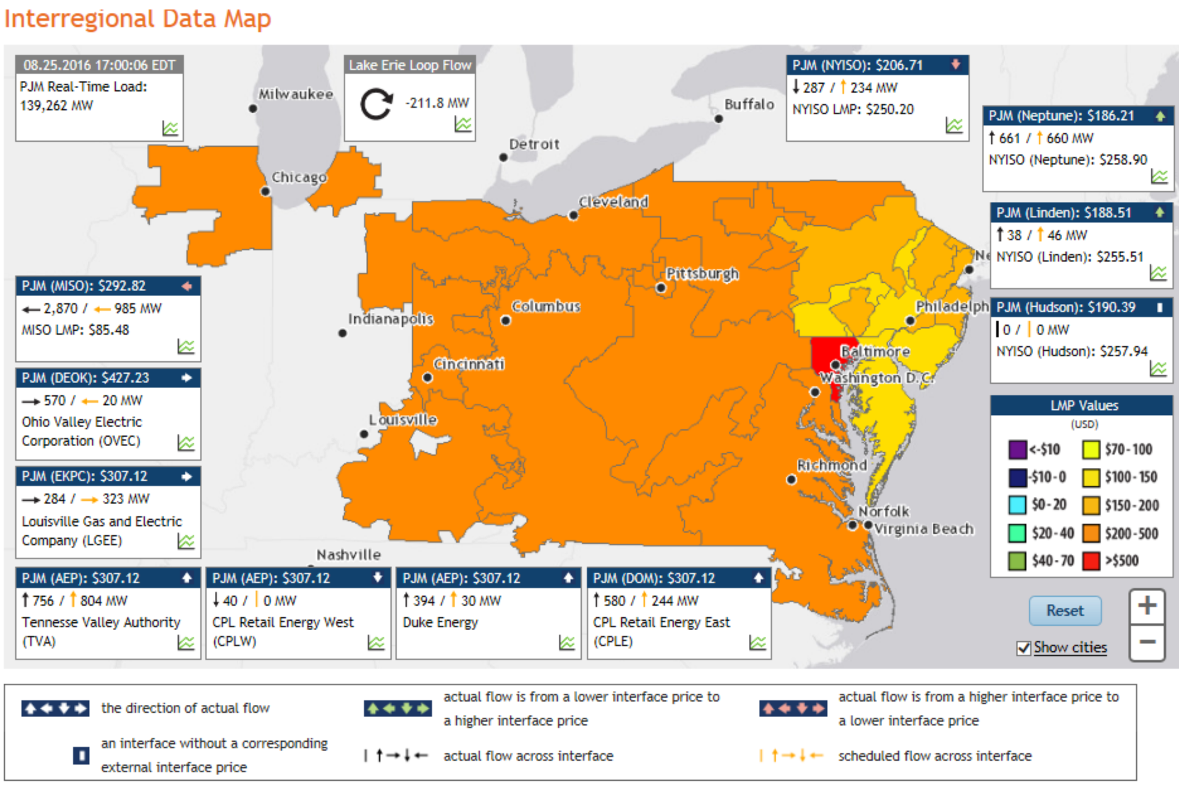
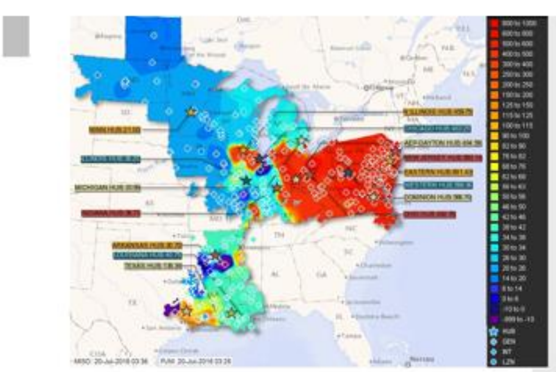
Figure 7



This map shows the flow of electricity into and out of PJM. The details are zone based showing the flow, interfaces, prices and the real-time load (MW).

Figure 8

MISO PJM 7-20-2015 3: 25 PM



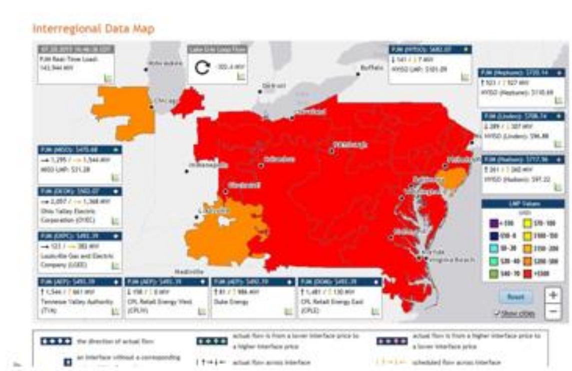


Figure 9