CONNECTING to the TRANSMISSION GRID in TODAY’S RTO WORLD

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Objectives

• Explain the need for a Straits “Flow-Control” device
• How did our RTO (MISO) play a role?

• Explain the need for the Benson Lake Static Var Compensator (SVC)
• How did our RTO (MISO) play a role?
ONCE UPON A TIME……

• There existed NO network connection across the U.P.
  – The 1998 Central U.P. (“CUP”) project established this
  – ARN-PER-ILK-HIA-STS…across the straits of Mackinac
    • 2-138kV Marine cables laid across the bottom of the “Straits”
    • Over to ITC-METCs McGulpin substation
  – Planning studies focus: “ON-PEAK” conditions
    • Ludington pump-storage facility off-peak operations not understood
      – Operates as 1500MW Hydro plant during ON-PEAK
      – Operates as 1800MW load OFF-PEAK (fill it’s reservoir)
      – Result: 3300MW “swing” in “bias” or “angle”
        » Hi flows West-East across this new network connection
        » Exceeded Real-Time SOLs on ILK & HIA equip
        » ATC SCO opened the network to alleviate the SOLs
The U.P
Straits of Mackinac
LUDINGTON
This was the very start of U.P. “Flow-Control” (ON or OFF)
  - This open or “U. P. Split” was established each evening around 2200 and was closed back up each morning after 0600…(Split during OFF-PEAK)

Over time, the prevailing bias across the Midwest overtook the Ludington-induced U.P. bias
  - “U.P. Split” was required virtually around the clock

One of 3 supervisory “U.P. Split” locations were employed:
  - At ILK by opening 69kv ILK-HIA lines 6912 and 6913
  - At HIA by opening the same two lines
  - At STS or MGP subs by opening the 2-Marine cables
ONCE UPON A TIME……cont’d

- “U.P. Split” location selected based on FLOW-SOUTH
  - If limited on Flow South, split further West (ILK)
  - If not limited on Flow South, split further East (HIA or STS)

- To CLOSE the “U.P. Split”
  - Required bias or angle across the open bkr < 40 degrees
  - ATC had to wait for these favorable network conditions
  - On-Peak period normally got the angle < 40 degrees…..
    - Until the bias across the Midwest overtook the U.P. bias
Normal Bias across Midwest

MKN HVDC
Existing configuration

• Bias across U.P. created when Ludington transitioned from full Generation(approx 1500MW) to full Pump Storage(approx 1800MW) --- A 3300 MW swing
Existing configuration cont’d

• Over time – “Ludington” bias gave way to a 24/7 prevailing bias across the Upper Midwest Region
  – Bias is normally from West to East across the region
  – Approx. 98% of this flow is seen south of Lake Michigan
    • Flow on the DC Cook – Dumont – Wilton Center 765 kV Path reflects the direction and magnitude of this bias
  – Approx. 2% of this bias would flow North thru WI, East thru U.P. and South across the Straits of Mackinac if network is closed
  – These flows exceed the system thermal and voltage reliability limits causing the U.P. to be “split” continuously for the past several years.
Closing the “split” to support Planned Maintenance

• Need to connect the system for reliable operation when transmission elements are out of service for scheduled maintenance.

• Need to reduce the system flows across the UP when the system is connected

• Requires MISO to perform significant re-dispatch
  – Needed to reduce angle across the open to allow for closure of “split”

• The HVDC will eliminate a Free-flowing AC system connection across the UP and the Straits of Mackinac requiring the large amount of re-dispatch

• MISO included Mackinac HVDC as part of it’s “Miso Transmission Expansion Plan for 2011…Referred to as “MTEP-11”

• Mackinac HVDC is a Reliability Device intended to meet the needs of the area around HVDC both North and South of the Straits of Mackinac
Candidates considered for MKN Flow-Control

- **Series Reactors**: very limited in control, consumes Mvars
- **Phase Shifting Trf’s**: Good….BUT need several to achieve angle/capacity needed long-term; don’t provide dynamic reactive support
- **Variable Frequency Trf**: OK…BUT Rating of single device is 100MW…not cost effective for MW rating desired; no reactive control
- **Line Commutating (Thyristor) converter**: requires reactive support – not suited for Weaker systems
- **Voltage Source Converter (IGBTs)**: Great on weaker systems, excellent Dynamic Reactive control capability –
- **THAT’S IT!!** Voltage Source Converter was chosen
IGBT SUB-Module
6 sub-modules per press-pack

EACH SUBMODULE CONTAINS: 8 IGBTs & 4 Diodes
6 submodules for each press-pack
6 submodules x 8 IGBTs = 48 IGBTs per press-pack

ABB 4.5KV - 2,000 AMP IGBT PRESS-PACK
CONTAINS 6 SUB-MODULES

Electrical connections
MACKINAC HVDC CONNECTED ACROSS DC

SOUTH CONVERTER DISCONNECTS CLOSE

- NORTH CONVERTER DC DISCONNECTS CLOSE
- HIGH-SPEED SWITCHES CLOSE SHORTLY AFTER
- ACTIVE POWER (MW) FLOW MAY NOW BEGIN

Tie To South - HVDC Pole 1 / Inverter 1 / Block 1
(West side of HVDC Building)

Tie To North/UP - HVDC Pole 2 / Inverter 2 / Block 2
(East side of HVDC Building)
BENSON LAKE SVC
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2018 WPUI RTO conference – UW-Madison, WI
HOW DID WE GET TO A SVC…HERE?

• Let’s Review:
  – “PRI Area” comprises the area around Marquette, MI
  – PRI Area/U.P. Load would normally be 330MW 24/7
  – PRI Area/U.P. Load consisted of:
    • 260MW of Mine Load – Tilden and Empire Mines near Marquette
    • Approx. 50 – 55MW of load for the rest of the U.P.
    • U.P. Load was met from two main sources:
      – PRI Generation – 5 units that produce approx. 280MW
      – Flow South Corridor – group of lines connecting U.P. to WI
      – NOTE: U.P. was “split” around the clock at either HIA or ILK until 2014
The May 10, 2011 U.P. BLACKOUT

• Scheduled outage of Morgan – Plains 345kv line 35321
• ATC/MISO established a mix of PRI generation and allowable FLOW-SOUTH per network studies
• Studies showed ATC could survive next single ctg:
  – Loss of one Plains-Amberg 138kv line

• ….And BTW: Plains – Amberg is a double ckt 138kv that use the same structures

• Outage was commenced after above pre-requisites were met
The May 10, 2011 U.P. BLACKOUT

• In early morning hours of 5/10/2011 a 93,000 amp lightening strike hit one of the towers that carries the Plains – Amberg 138kV double-circuits

• ....And BTW: grounding conditions were not very good along this double-ckt corridor due to makeup of the earth

• Instead of the lightening current going straight to ground it arced across the tower it hit and caused a loss of BOTH Plains – Amberg 138kv lines....NOT GOOD
  - ....And BTW: Auto-reclose of these lines was set too long, resulting in huge angle...preventing bkrs from closing to restore either of the PLA-AMB 138kV lines
The May 10, 2011 U.P. BLACKOUT

- With the Morgan – Plains 345kv line already out, loss of both PLA – AMB 138kV lines caused existing FLOW – SOUTH to over-stress the remaining lines that make up FLOW-SOUTH.
- The U.P. relaying sensed this unfolding and “Islanded” the U.P. by opening remaining lines that connect U.P. to WI.
- 4-1/2 minutes after the double-ckt trip of Plains-Amberg:
  - The Islanded area made up of PRI Area load and generation suffered a complete collapse

- An investigation was started to evaluate this event….. To prevent this U.P. event from EVER HAPPENING AGAIN!
• ATC Planning developed a plan to address several items:
  – PRI generation slated to retire around 2020
  – Need to replace PRI generation to meet the mine load
  – Need to enhance the FLOW-SOUTH issue to operate reliably without any PRI generation on line and survive the next contingency
  – Initial “Northern Plan” consisted of:
    • A new 345kV line from North Appleton to Morgan (ISD: Oct 2018)
    • A new 138kV line from North Appleton to Morgan (ISD: Oct 2018)
    • A new 138kV from Morgan to Stiles – In Service
    • A new 138kV line from Holmes to new Old Mead Road – in service
    • Expand the North Appleton sub…replace old 345kV with new 345kV-complete Oct 2018
    • Expand the Morgan Sub for additional lines-complete Oct 2018
    • Build new 130 mile 345kv line from Morgan to PRI area (hold up Post-contingent voltages for loss of the existing 345kV)
    • Price Tag: around $950,000,000.00 …..WOW!
The newly proposed Morgan-National 345

• New long MGN-NAT 345kv line based on planning studies to survive contingent loss of MGN-PLA 345 line post PRI plant retirement (may happen in near future)
• Studies also showed if a device were available to “Hold the voltage up” for the above contingency, we cold survive this without having to build this new, long, expensive 345kV line
• Would need to place this device at near Amberg sub for optimum results (Amberg approx. 10mi South of Iron Mtn, MI)
• ATC solicited bids from Areva, ABB FACTS, Siemens, Mitsubishi
  – ABB won the bid
• This final config to include Benson Lake SVC was included in the MISO MTEP-12
The benefits of SVC to power transmission

- Stabilized voltages in weak systems
- Reduced transmission losses
- Increased transmission capacity, to reduce, defer or eliminate the need for new lines
- Higher transient stability limit
- Increased damping of minor disturbances
- Greater voltage control and stability
- Power oscillation damping
BENSON LAKE Static Var Compensator-SVC

• Benson Lake SVC: located adjacent to Amberg sub
• SVC will act as a “Ready Source” to either absorb (0-75Mvar) or inject (0-150Mvar) the required reactive power from or to the ATC network to maintain the proper 138kv voltage:
  – During normal operation
  – In the event of the contingent loss of a major Transmission element….to hold the area voltage up…prevent collapse
  – Equipped with a “Automatic Gain Optimizer”
    • Always ready for “The Big Event”
    • Instantly adjusts for smaller events to prevent over-reaction
    • Automatically restores back to “ready for the big one”
EMS one-line of Benson Lake SVC
Questions on this presentation?