

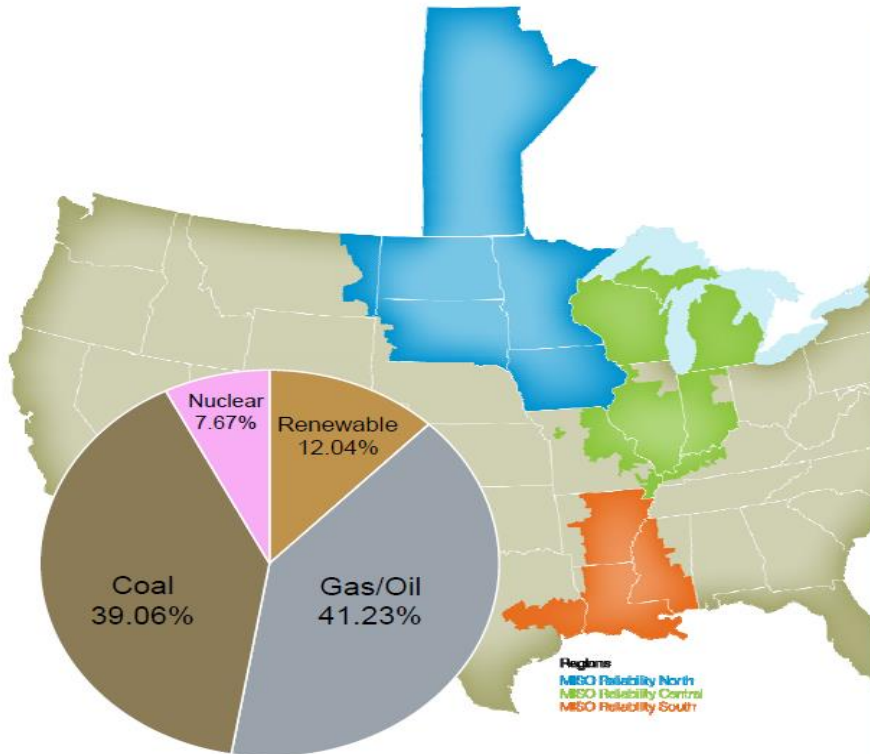
MISO Dynamic Stability Interface Limit Calculations

MISO Overview

- **MISO is an independent, non-profit, member-based organization committed to reliability. We serve as the reliability coordinator for the transmission of high voltage electricity via a security constrained economic dispatch across all or parts of 15 US states and Canadian Province Manitoba.**

MISO Overview Map

MISO Region



Key Statistics

Market Participants	408
MWs of Generating Capacity (Mkt)	179,514
Peak Load (MW)	133,181
Generating Units	1,401
Network Buses	45,098
Miles of Transmission Lines	65,800
Square Miles of Territory	900,000
States Served	15
	Plus Manitoba Province, Canada
Millions of People Served	42

MISO Roles

- **What does the MISO do?**
 - Provides market services for Energy, Operating Reserves, and Transmission Service in accordance with the Energy & Operating Reserves Market Tariff and Business Practice Manuals (BPM)
 - Provides reliable operation of the transmission system.

Scope of Operations

- Generation Capacity
 - 180,711 MW (market)
 - 195,231 MW (reliability)
 - 14,000 MW of Wind
- Historic Peak Load (set July 20, 2011)
 - 127,125 MW (market)
 - 133,181 MW (reliability)
- 65,800 miles of 69kV and higher transmission
- 15 states, 1 Canadian province
- Control Centers in Carmel, IN
Eagan, MN and Little Rock, AR
- 5-minute dispatch
- 2,452 pricing nodes
- 6,000 generating units in the network model
- State Estimator solving every ~ 90 seconds using 289,821 real-time measurements
- Real Time Contingency Analysis solving 8,300 “what if” contingencies every ~ 5 minutes
- \$37 billion settled annually
- 425 market participants serving 42+ million people

Reliability

- **MISO built and continuously refines its extensive network computer model of the MISO interconnected reliability region and surrounding systems.**
 - Alarming Tools
 - Automatic Generation Control Tool
 - Delta Flow and Voltage Tools
 - Flow gate Monitoring Tool
 - Generation Monitoring Tool
 - Real time Contingency analysis
 - Real time Stability Limit calculation Tool.

Key Stability Limited Flow gates:

- Minnesota area is generally stability constrained due to heavy import of power from generation in the coal fields of North Dakota and hydro generation in Manitoba.
- Various stability constraints such as North Dakota Export (NDEX), Manitoba Hydro Export (MHEX) and Minnesota Wisconsin Interface (MWEX) are monitored to protect reliability of the area.

MISO Dynamic Stability Interface Limit Calculation (DSA Tool):

- **Stability Limited Interface Limits are generally calculated using most limited scenario in the offline (planning time frame) process.**
- **This generally constrains the system capability as the studied scenario is a peak scenario.**
- **To improve the granularity of monitoring dynamic stability in real time we have implemented a Real-Time Stability Limit Calculation Tool which can determine safe operating limits in the operating horizon based on using MISO's state estimator model.**

MISO Dynamic Stability Interface Limit Calculation (DSA Tool):

- **MISO Real Time Operations implemented calculation of real time dynamic stability limits on interfaces using online TSAT/VSAT (DSA) tools in May2012.**
- **MISO Real Time Operations is currently running both Voltage Stability and Transient Stability studies for multiple stability limited interfaces and calculate limits on the interfaces.**
- **By taking advantage of the capabilities of the Real-Time Stability Limit Calculation Tool we reliably maximize system use.**
 - Online Voltage Stability runs every ~6 minutes and Transient Stability runs every ~15 minutes.

MISO Dynamic Stability Interface Limit Calculation (DSA Tool):

- **Analysis is performed for real-time system conditions captured by SCADA and solved by state estimator.**
 - MISO TO's/TOP's transient stability criteria are implemented
 - MISO TO's/TOP's critical contingencies are applied
 - Transfers for interface limits are analyzed.
- **The Tool monitors voltage and dynamic stability in real time and determines safe operating limits in the operating horizon.**

MISO Dynamic Stability Interface Limit Calculation (DSA Tool):

- EMS power flow models don't have dynamic data developed for .
- MISO EMS models didn't have detailed HVDC converter/inverter models , they are generally represented with Pseudo generators and pseudo loads.
- MISO EMS models didn't have step up transformers/station service loads modeled.
- Most of the generator dynamic data is generally acquired from planning power flow models.

MISO Dynamic Stability Interface Limit Calculation (DSA Tool):

- So We developed a “Power flow modification” process to convert and match EMS model to the dynamic data.
- Power flow modification data specifies the necessary modifications need to be made to the real-time power flow data to make the power flow suitable for online Dynamic Security Assessment.

MISO Online DSA- Real Time Operations – Pre DSA

- Before the use of online DSA we had Operating guides developed to monitor and manage the transmission constraints to acceptable limits to ensure reliable operation of the transmission system in real time.
- Limits are calculated from offline planning studies (Voltage Stability and Transient Stability) for various prior outage conditions and are adhered to these limits in real time.

MISO Online DSA- Real Time Operations – Pre DSA

- These prior outage off-line studies generally considers most limiting scenario (summer off-peak high simultaneous transfer) in the calculation of the limits on the interfaces.
- One set of limits for the duration of an outage can unnecessarily constrain the system capability.
- If multiple forced outages require a manual restudy of limits, it can be a time consuming task in Real-Time Operations.

MISO Online DSA- Real Time Operations – Post DSA

- With the availability of online DSA actual limits are being determined in near real time using the current conditions in the operating horizon for all types of system conditions rather than the most limiting condition that offline analysis is generally performed. This enhances the operation of system security.
- By taking advantage of the capabilities of the Real-Time Stability Limit Calculation Tool we can reliably maximize system use.
- When a forced outage occurs that potentially has stability issues we still adhere to offline planning calculated limits for the particular outage until the online DSA finishes its new run which includes the outage and calculates new limits.

MISO Online DSA- Real Time Operations

- If angular stability issues at particular generators are flagged in the simulation the displays highlight the generators and display real time mw with respect the limit from online DSA. Reliability Coordinators who are monitoring will implement generation reductions if the real time flow is greater than the limit.
- If voltage violations are flagged at particular stations the displays highlight the flow gate that is established for the particular violation and Reliability Coordinators implement MISO congestion management procedures to make sure the real time flow is below the limit identified on the flow gate.

User Defined Models Created For MISO Stability Limit Calculation Tool:

- **Manitoba Hydro's HVDC Link Control Model (CMHDC1 in UIP).**
- **Square Butte HVDC Link Control Model.**
- **Coal Creek HVDC Link Control Model (CCUDC2 in UIP).**
- **Miles City DC Link Model (CDCMC in UIP).**
- **Rapid City Converter Station Model.**
- **Manitoba Hydro DC power order reduction model (DCRED1).**
- **Dorsey Under Voltage Detection Models (SUVC in UIP).**
- **Dynamic Switching Models for Prairie switching capacitors (SWMH in UIP).**

User Defined Models Created For MISO Stability Limit Calculation Tool:

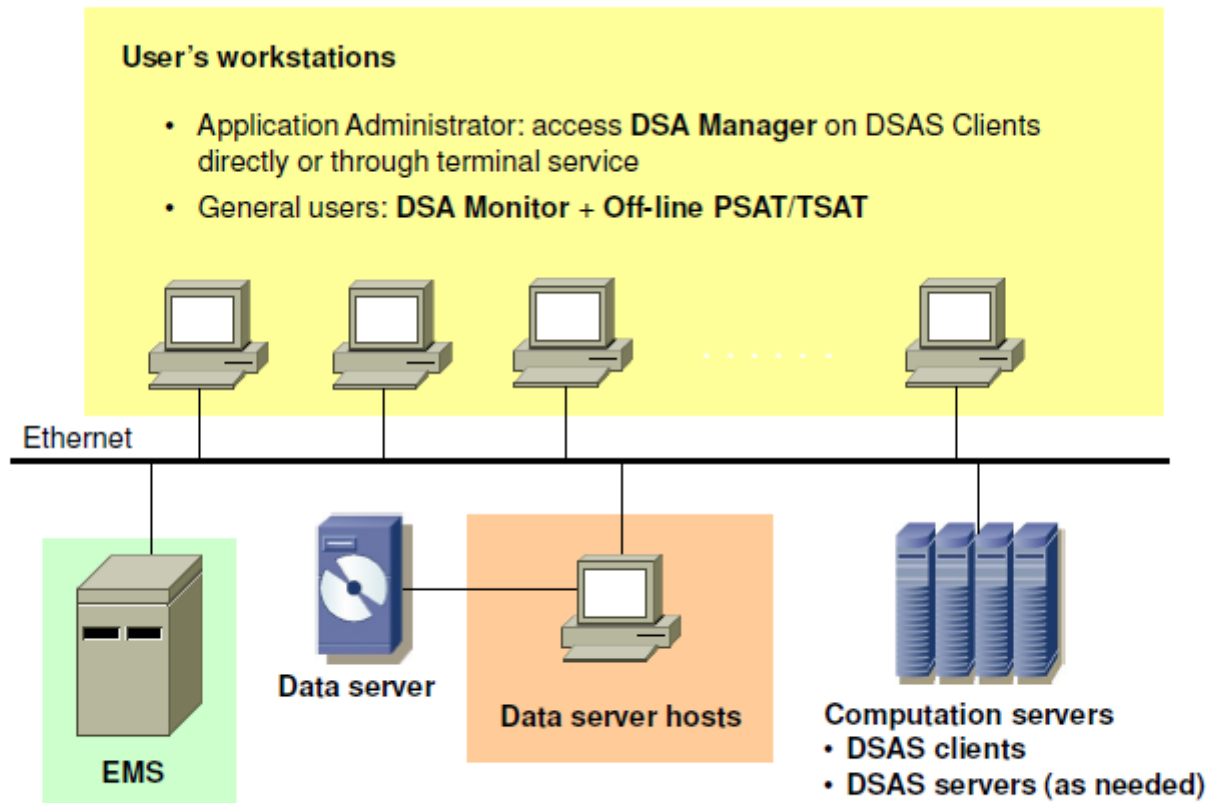
- **DC Reduction relay at Forbes (Delta Current Admittance Relay) on the Forbes-Dorsey 500 KV line .**
- **Fargo Static VAR compensator.**
- **Watertown Static VAR compensator.**
- **Forbes SVC.**
- **Fast Switched Shunt Capacitor models for Balta, Sheyenne, Eau Claire and Little Fork.**
- **Fast Switched Shunt Capacitor Models for Roseau and Ramsey.**

User Defined Models Converted For Online MISO

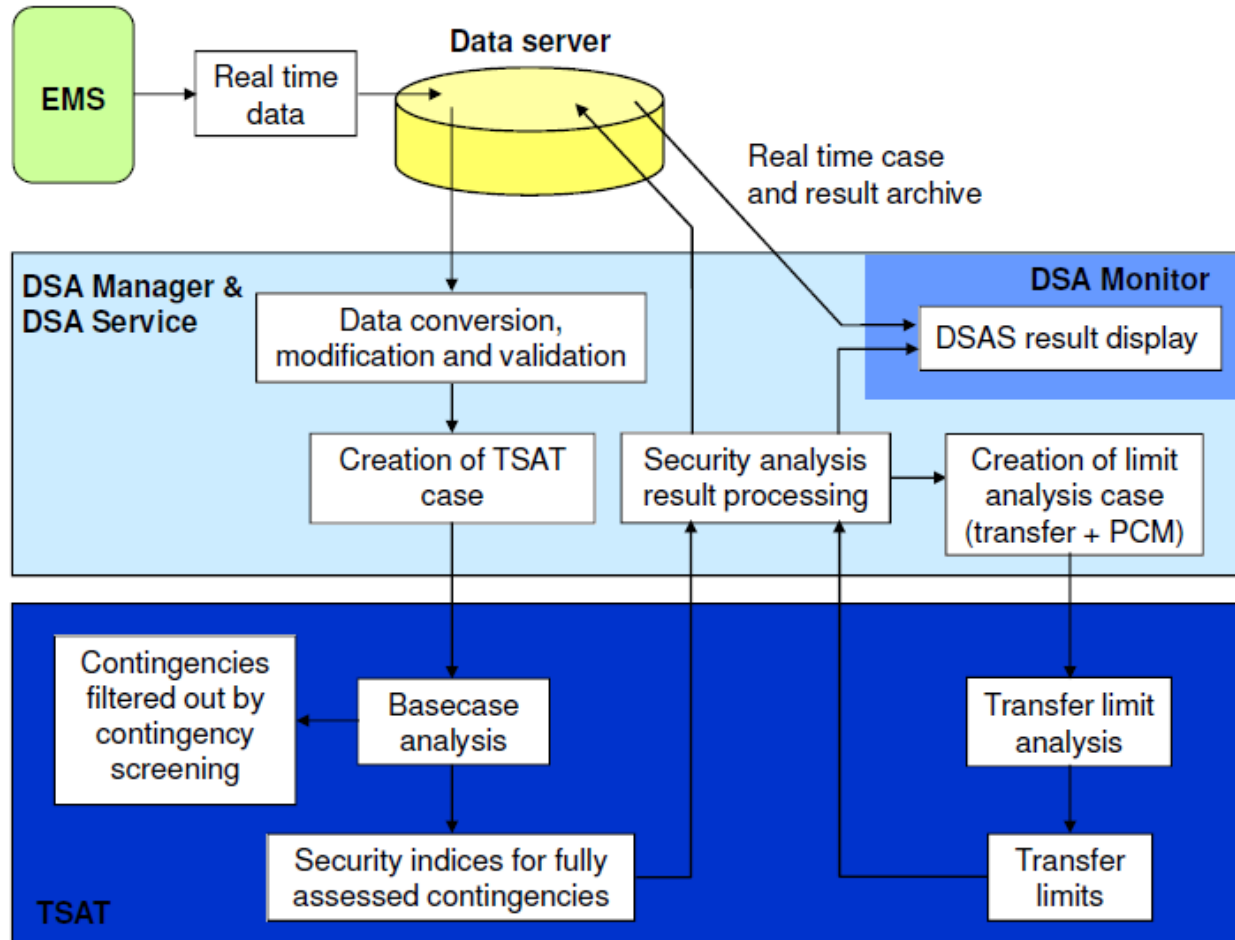
Online TSAT:

- **Fast Switched shunt capacitor model for Parkers Lake and Split Rock**
- **Lake Yankton user defined shunt capacitor model**
- **Dorsey Synchronous Condenser excitation and control system model for units 1-3**
- **Dorsey Synchronous Condenser excitation and control system model for units 4-6**

MISO Online TSAT/VSAT Architecture



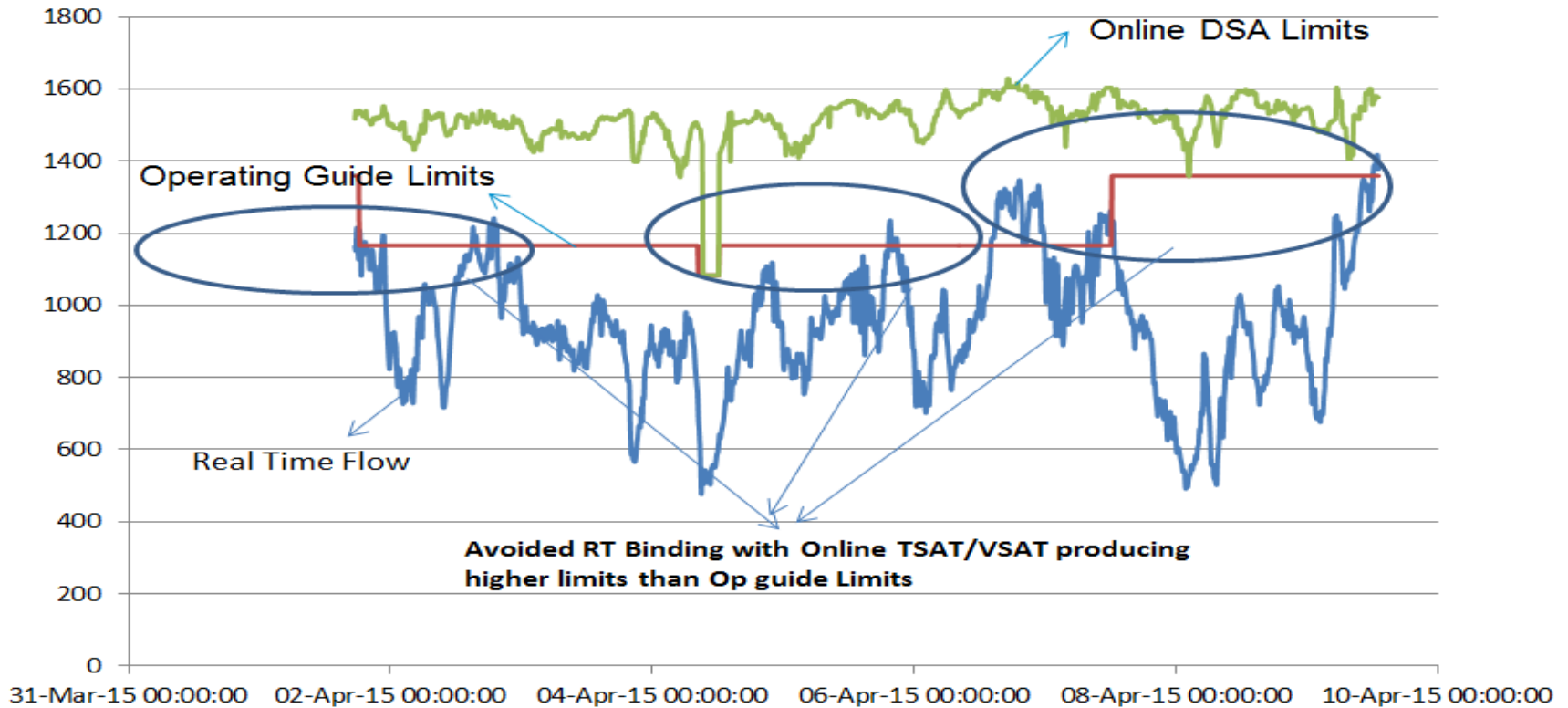
Architecture and Computation Flow:



Benefits of Online DSA

- Reduction in Real time Market binding with Higher Transmission Interface limits since we started using the limits from online TSAT/VSAT instead of Operating guide limits.

Limits from one of Stability Limited Interface



Benefits of Online DSA

- Higher amount of Wind generation that can reliably flow on through the AC System when it is not flowing on the HVDC system on which it has firm rights.
- Avoidance of arming generation tripping system protection schemes for various system conditions. Unnecessary tripping of generators, when reliability is not a risk, enhances the use of the transmission system.

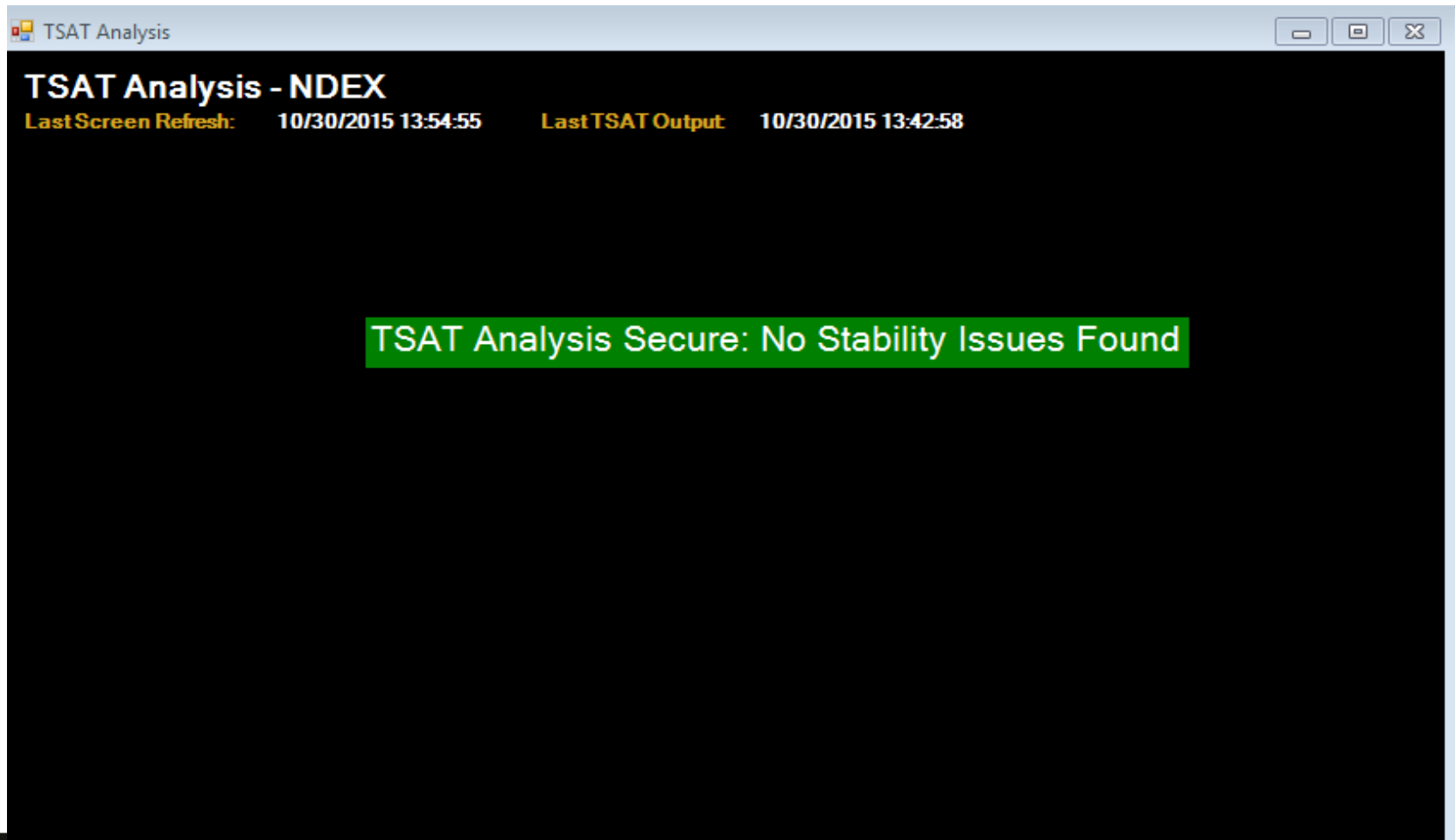
Benefits of Online DSA

- Real time Stability limits are also being calculated for multiple generators that encounter local stability limits.
- More real time wind added into the system than the old studies had studied, which the online stability tools accounts for in the studies.
- Limits are calculated for all kinds of system conditions rather than one peak condition operating guide limits are calculated

MISO Online DSA-Challenges

- **One of the main challenge was how to give reliability coordinators a quick understanding of Transient stability analysis results from the online DSA.**
- **Results from Online TSAT/VSAT were more suited for engineers who wants to look at all data to understand the results.**
- **So we developed a process to read the results and display all the relevant results in visual display for the control room operators.**

Real Time Displays:



TSAT Analysis

TSAT Analysis - NDEX

Last Screen Refresh: 10/30/2015 13:54:55 Last TSAT Output: 10/30/2015 13:42:58

TSAT Analysis Secure: No Stability Issues Found

Real Time Displays:



Questions?

– Raja Thappetaobula

- Senior Advisor
- MISO
- rthappetaobula@misoenergy.org
- 651-632-8460