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Transmission Constraint Management at ISO New England

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Introduction

- Existing Transmission Constraint Management has been built incrementally over decades for traditional power systems
- Dramatic changes in operational environment
  - Increasing level of uncertainty and complexity
  - Higher penetration of intermittent resources
  - Fundamental change in generation mix
  - Greater security challenges for the Electric grid that blends physical grid, communication, hardware and software
- Operating uncertainties of the future grid
  - Extended set of contingencies (uncertainties)
  - The increasing probability of cascading events
  - The increasing impact of more frequent extreme weather events
- All these trends require significant changes in the Transmission Constraint Management. This presentation discusses four areas of the improvement

Shifting from Reliability-based to Risk-based dispatch.

Online Cascading Analysis as a practical approach

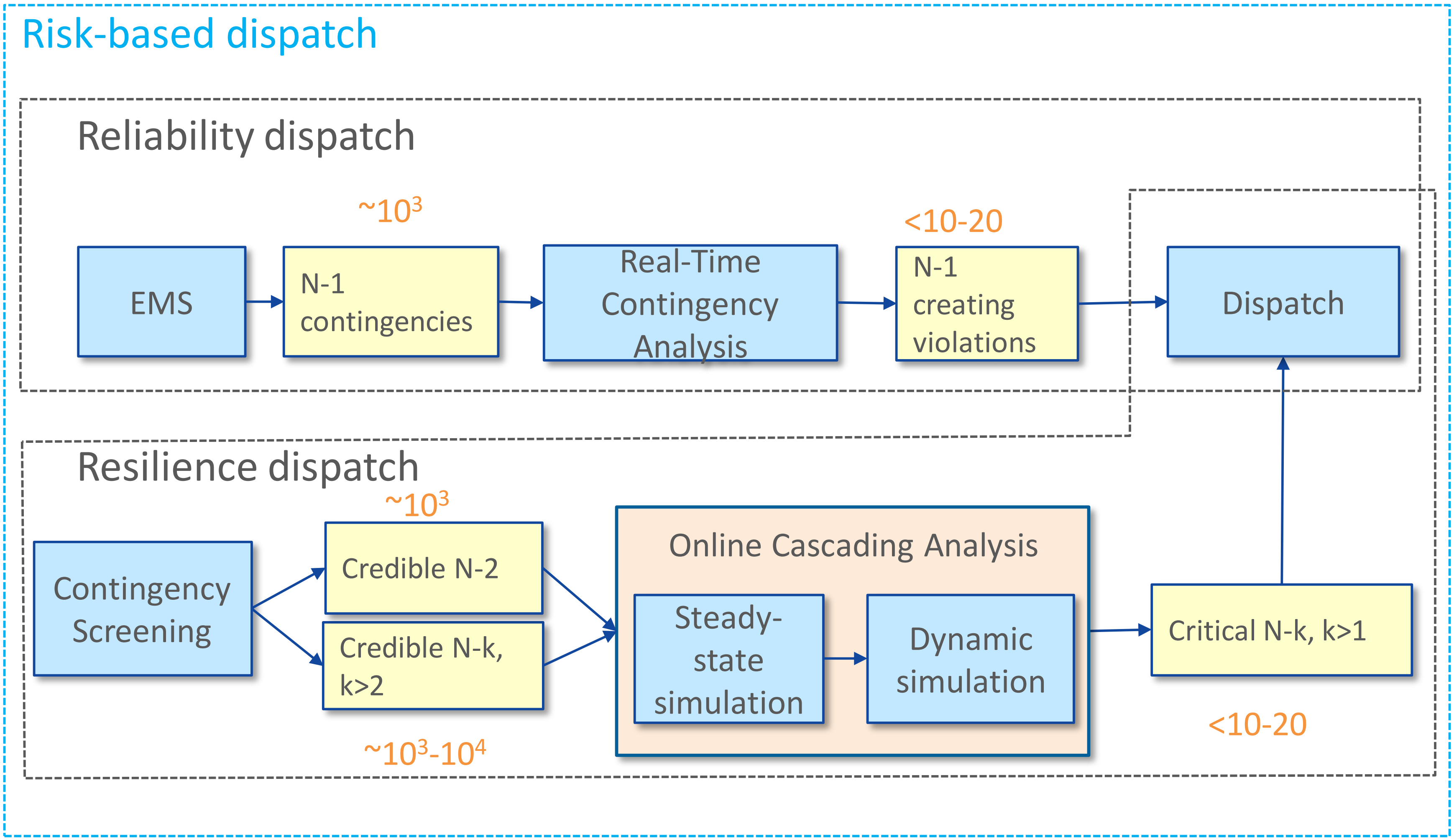
Need to look beyond N-1 security

- Traditional dispatch is based on N-1 security concept and preventively mitigates thermal, voltage and stability violations assuming 100% probability of contingency
- Applying the same approach for N-k, k>1 is prohibitively expensive
- “Violation” itself does not indicate actual risk to the system, such as MW of lost generation and load
- N-k, k>1 events can be secured by using risk-based approach

Risk = Impact_of_event x Probability_of_event

- *Impact_of_event* can be expressed as MW of lost generation and load
- Only high-risk N-k events need to be mitigated
- Online Cascading Analysis is a practical way of estimating *Impact_of_event* and identify high-risk initiating N-k events

Example of a Risk-based dispatch

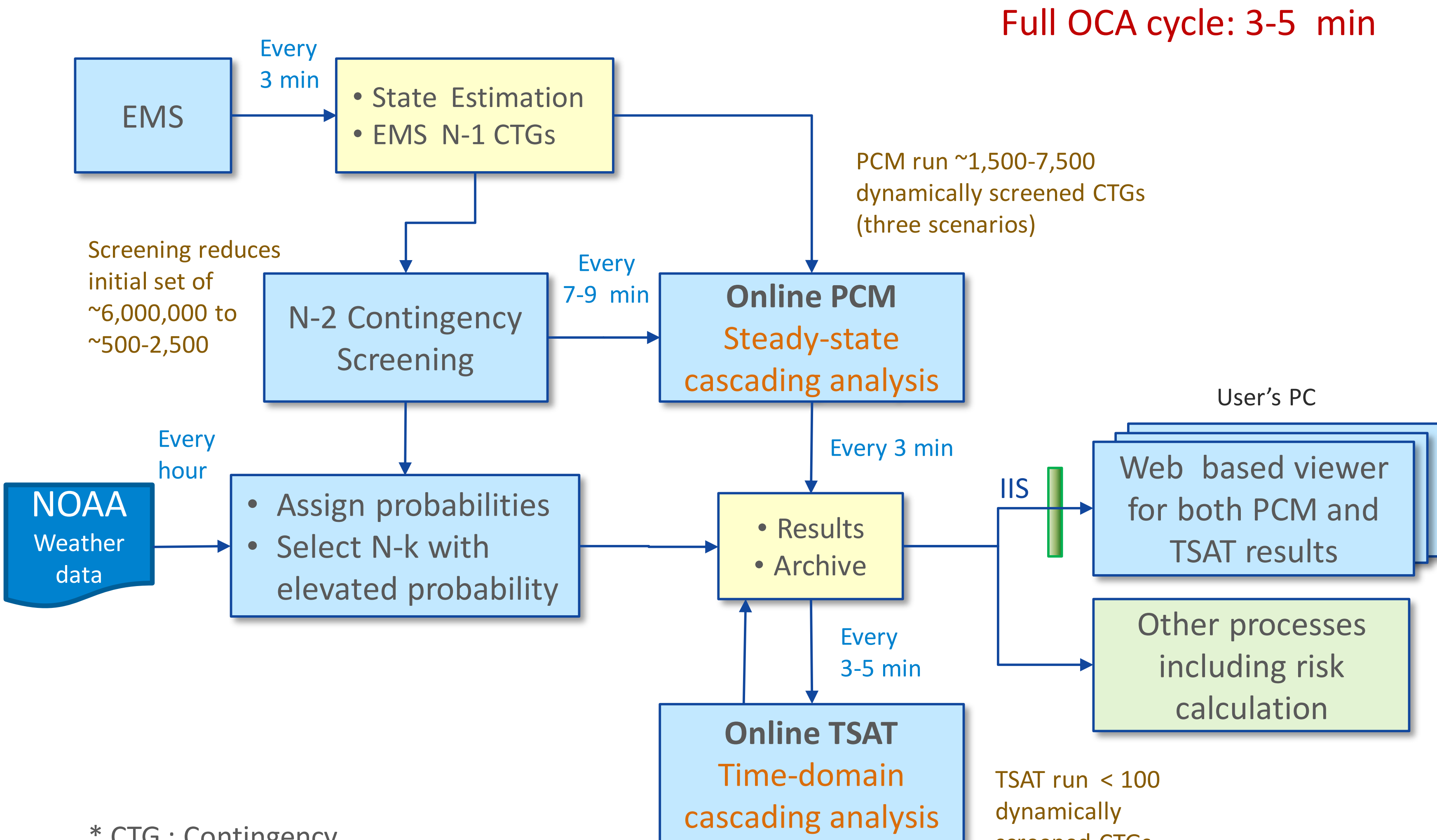


Online Cascading Analysis (OCA)

- OCA is used to *dynamically* identify high-risk N-k contingencies
  - Need to mitigate only these contingencies in addition to N-1
  - Integrated with the ISO-NE EMS and runs 24/7
- Identified by the OCA high-risk contingencies are mitigated via regular dispatch*
  - "N-1 stuck breaker" and N-2
  - N-k with elevated probabilities related to weather conditions

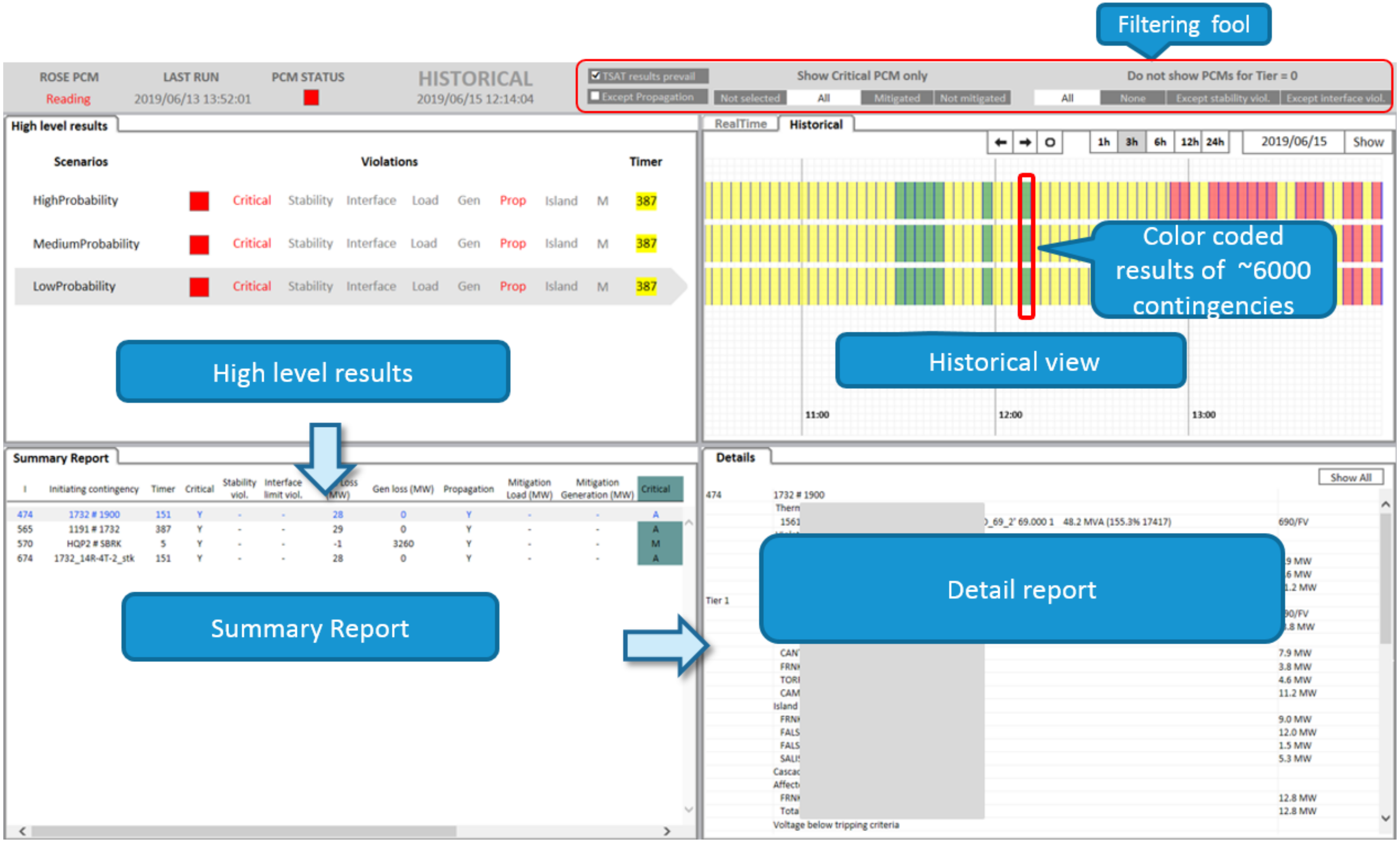
* Mitigation is not implemented yet in the existing pilot OCA process

OCA Data Flow

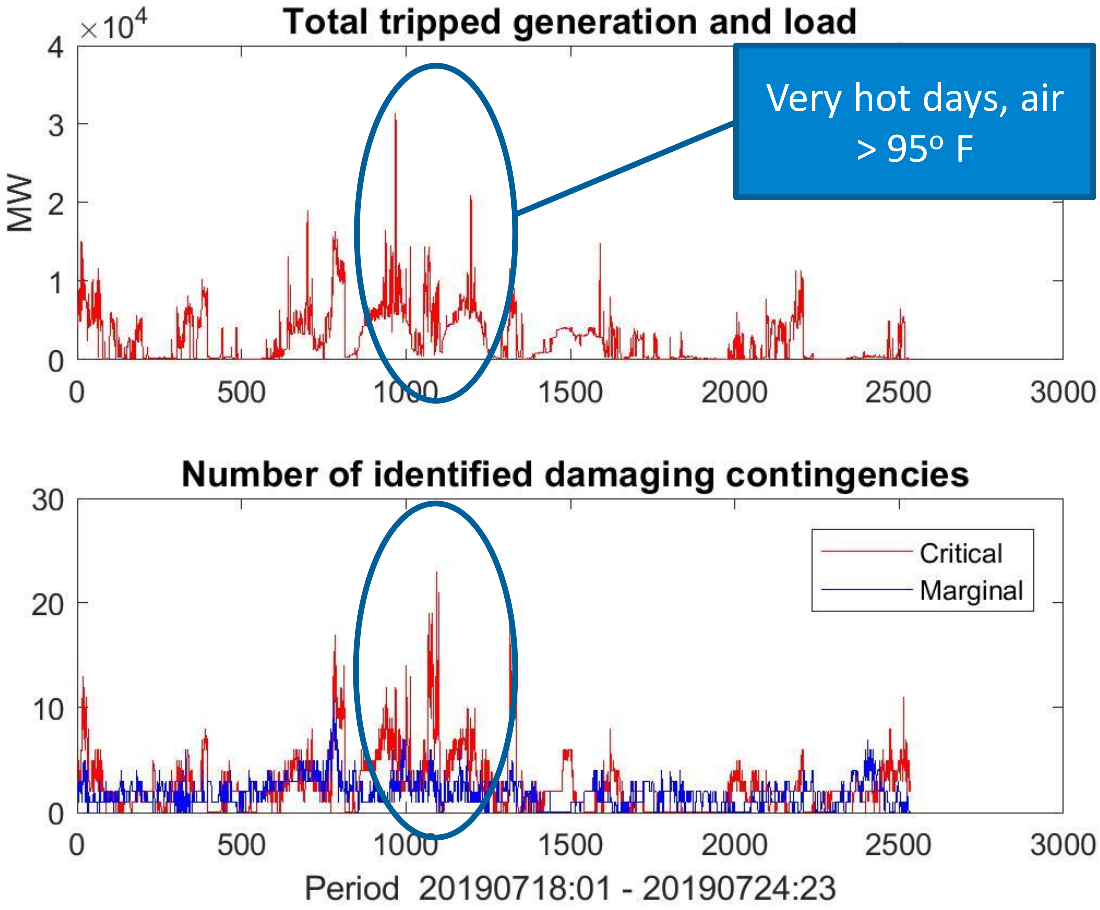


* CTG : Contingency
PCM: Potential Cascading Mode

OCA Display


Filtering fool
ROSE PCM
Reading
LAST RUN
2019/06/13 13:52:01
PCM STATUS
HISTORICAL
2019/06/15 12:14:04
TSAT results prevail
Except Propagation
Show Critical PCM only
Not selected
All
Mitigated
Not mitigated
Do not show PCMs for Tier = 0
All
None
Except stability viol.
Except interface viol.
High level results
Scenarios
Violations
Timer
HighProbability
MediumProbability
LowProbability
Critical
Stability
Interface
Load
Gen
Prop
Island
M
387
High level results
RealTime
Historical
1h
3h
6h
12h
24h
2019/06/15
Show
Color coded results of ~6000 contingencies
Historical view
11:00
12:00
13:00
Summary Report
Initiating contingency
Timer
Critical
Stability viol.
Interface limit viol.
Loss (MW)
Gen loss (MW)
Propagation
Mitigation Load (MW)
Mitigation Generation (MW)
Critical
474 1732 # 1900 151 Y - - 28 0 Y - - A
565 1191 # 1732 387 Y - - 29 0 Y - - A
570 HQP2 # SBRK 5 Y - - -1 3260 Y - - M
674 1732_14R-4T-2_stk 151 Y - - 28 0 Y - - A
Summary Report
Details
Show All
474
1732 # 1900
Tier 1
Detail report
Voltage below tripping criteria

OCA Statistics on MW Outages



- Estimated MW impact of critical N-2 and Stuck Breaker initiating events
- Statistics for July 18-24, 2019

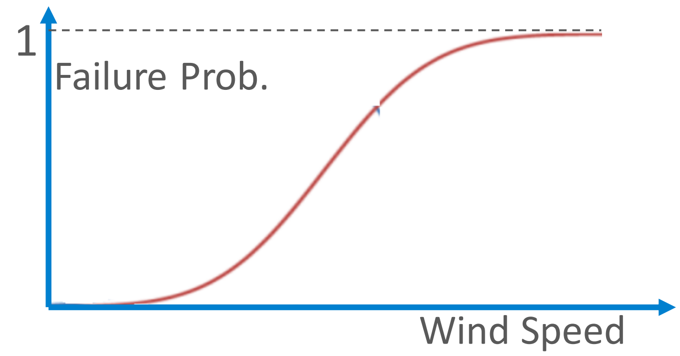
Extreme Weather Impact Monitoring

Extreme Weather Impact (EWI) Monitoring

- The tool performs real-time weather impact assessment, including predicting future equipment outage probabilities due to severe weather conditions, using:
  - Weather data on wind, ice-rain, lightning, etc.
  - ISO operational data, including network topology, load flow, etc.
  - Fragility curves of transmission structures (towers and conductors)
  - Machine learning models to account for uncertain impact factors.
- The tool calculates the probabilities of
  - N-2 and “Stuck breaker” contingencies
  - Identifies N-k, k>2 with elevated probabilities
- The calculated contingency probabilities and identified N-k are fed into the OCA process

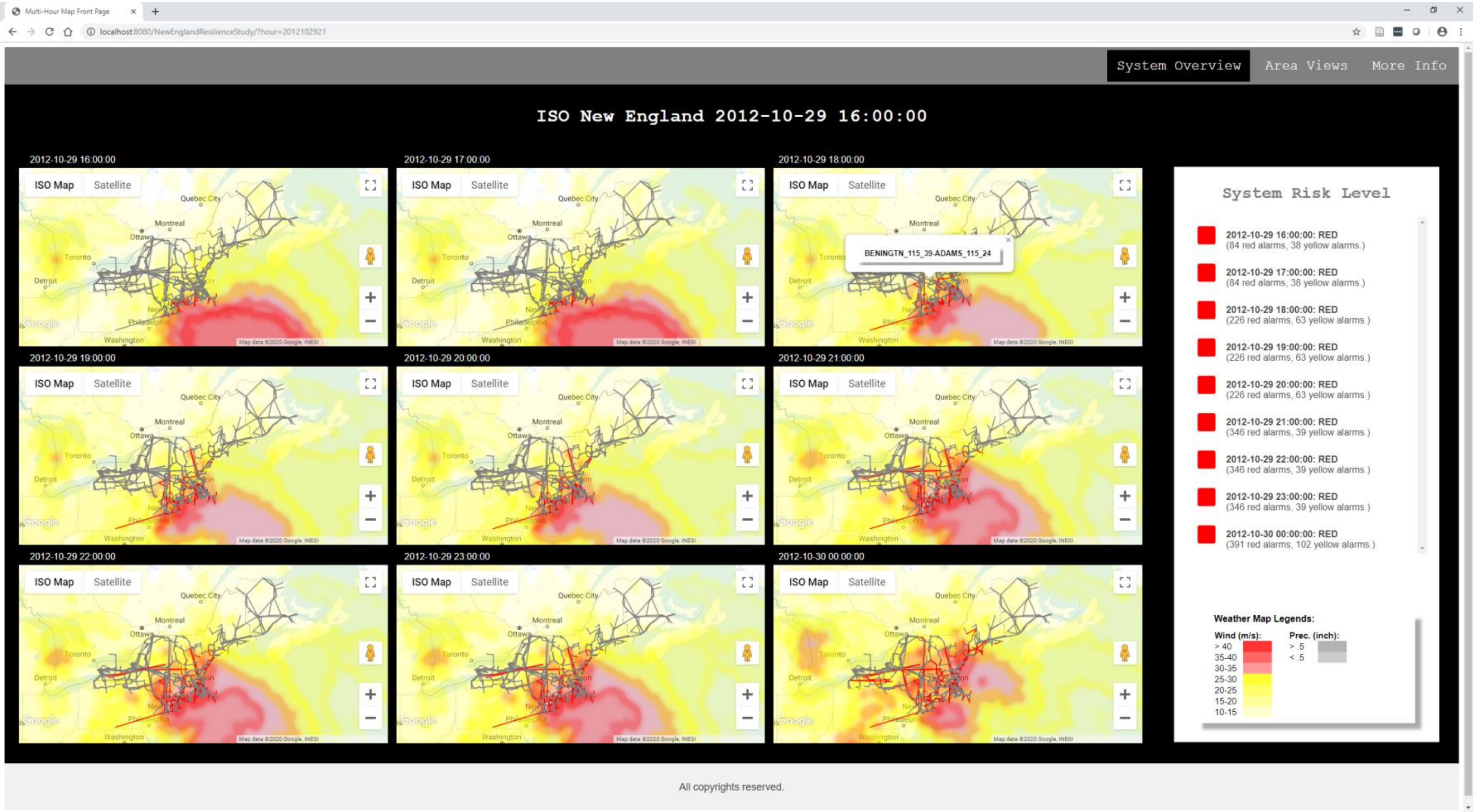
Main Methodologies for Computing Failure Probabilities –Structural Failures

- Conditional failure probabilities of the power transmission equipment subject to weather conditions
  - Develop fragility curves based on the finite element models of transmission structures (towers and conductors)



  - Train deep learning models with utility outage data to study other factors such as tree trimming schedules.
  - Collaboration with university civil engineering experts.

9-Hour Look-Ahead EWI Assessment (Hurricane Sandy, 12/29/2012)



Online Calculation of Interface Limits

Objective

- Interface limits are used as a proxy transmission constraint to enforce the stability-, voltage- and N-1-1 thermal-based limitations
- Majority of stability- and voltage-based limits are calculated offline (months before the real-time)
  - Thermal limits are typically calculated once a day
- Issues
  - Potential inconsistency in modeled and actual real-time system state creates inaccuracy in limits
  - Offline calculated limits are typically conservative
  - A lot of effort to account for uncertainties in offline studies
- Solution: online calculation of as many as possible interface limits

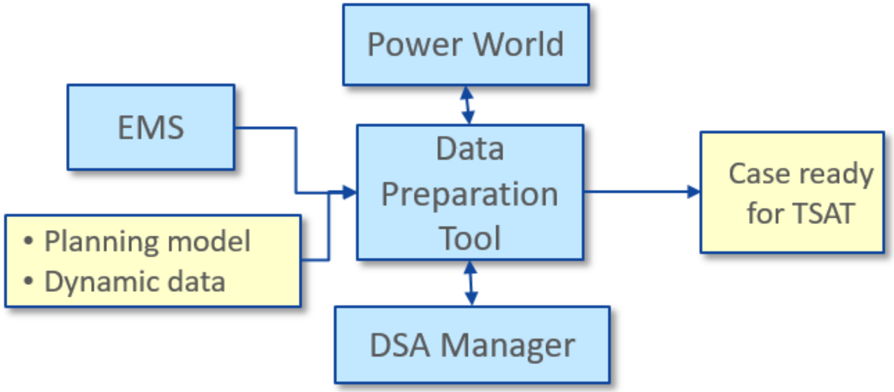
Challenges

- Deficiencies of Real-Time EMS model for voltage and stability studies
  - Lack of modeling of sub-transmission and distribution parts
  - Lack of dynamic data (available in planning model)
  - Lack of modeling of external areas for dynamic studies
- Software tools
  - Multiple commercial tools can be used for online studies
  - Powertech Labs VSAT and TSAT are the ISO-NE tools of choice
  - “Black box” dynamic models from the PSSE planning model should be converted to standard models for the use in TSAT
- Operators’ Concern of being overly-dependent on the automated tools for the limit calculation and losing the skills doing it manually when the software is unavailable

VSAT Implementation: steady-state limits

- Online calculation of voltage-based N-2 limit for Connecticut interface was implemented in 2016.
  - Complex design with five scenarios including 2D nomograms
  - Accumulated experience and lesson learned
- Future plans
  - Extend for other voltage-limited interfaces
  - Add calculation of thermal N-1-1 limits
  - Optimize EMS – VSAT interaction to make the setup flexible and scalable to serve ISO-NE needs

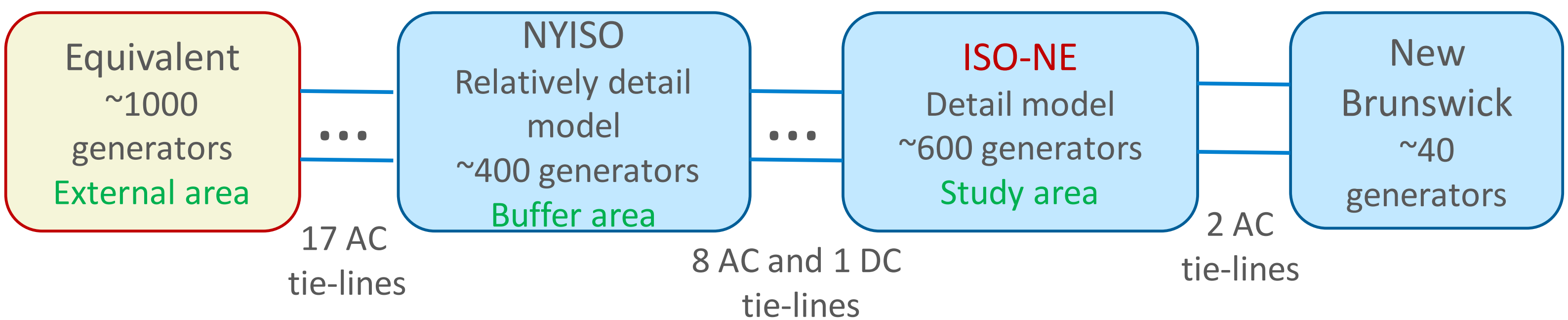
TSAT Implementation: stability limits



- The framework to use TSAT with EMS model has been established
- The framework is used for
  - Pilot calculation of stability interface limits; run cycle 15 min
  - Online Cascading Analysis; run cycle 3-5 min
- Future plans
  - Staged implementation of online calculation of stability limits. Easy to implement limits come first.
  - Systematic identification and elimination of obstacles for online calculation of stability limits
  - Development of adaptive, PMU-based dynamic equivalent for the external system

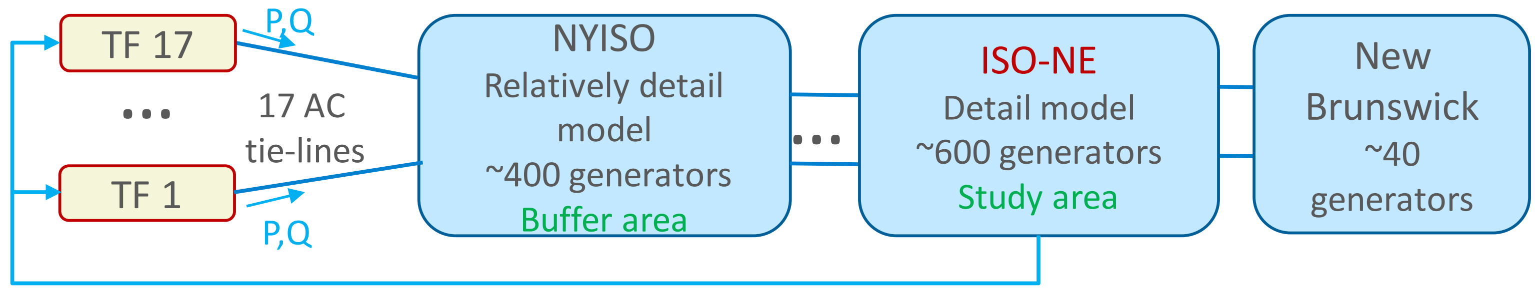
Existing Dynamic Equivalent

- Number of generators in the Eastern Interconnection (EI) model > 8,000
- DYNRED software was used to create equivalent of EI beyond NYISO
  - Equivalent preserves modal structure of inter-area oscillations
  - Modal structure changes over time and a static equivalent is not always accurate to model inter-area oscillations for Study Area (ISO-NE)



Desired Dynamic Equivalent

- Each of 17 tie-lines between NYISO and EI is replaced by a Transfer Function (TF)
  - Input for TF: measurements from ISO-NE or NYISO
  - Output of TF: MW and Mvar flow in tie-line
- TF is periodically updated online by using PMU measurements
- TF can be modeled as User Defined Model in TSAT



Transmission Operating Guide Formalization

Transmission Operating Guide (TOG)

- TOG is a paper document defining a process (type of lookup table) to select stability-based interface limit value as a function of power system state.
  - Number of stability TOGs ~200

- TOG is created offline by converting results of stability studies into a type of lookup table
- TOG limit is used as a transmission constraint

ISO new england	TOG – Stability Guide Owner Services	Revision Number: 8
	Technical Lea	Effective Date: Apr
	© ISO New England Inc. 2019	Valid Through: Ap

Table 1 - New Brunswick – New England Interface,

IROL ☒ SOL: ☐

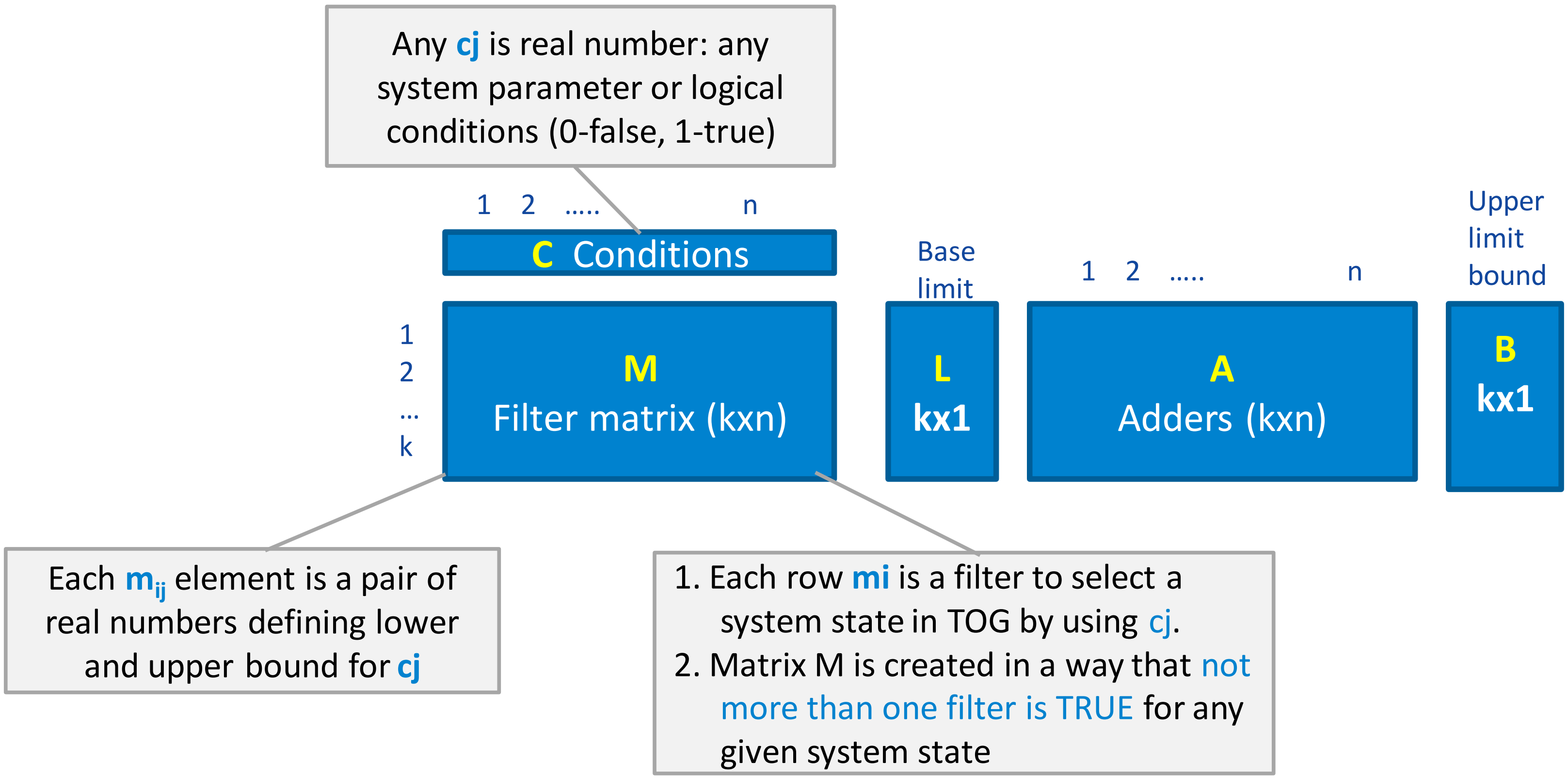
Equip OOS	Contingency	Related Facilities/Interface	Required Actions	Reasons for Required Actions
	New Brunswick 5	New Brunswick – New England Interface	Base transfer limit MW.	To prevent system split in Northern Maine, Or To prevent unacceptable Maine transient voltage sag.
		Chester SVC In-service with	Add **MW** to base transfer limit.	
		New Brunswick largest load	Add **MW** to base transfer limit.	
			The final New Brunswick – New England Interface stability transfer limit must not exceed **MW.**	

Deficiency: TOGs are paper documents not allowing automated translation of limits into other processes using TOGs

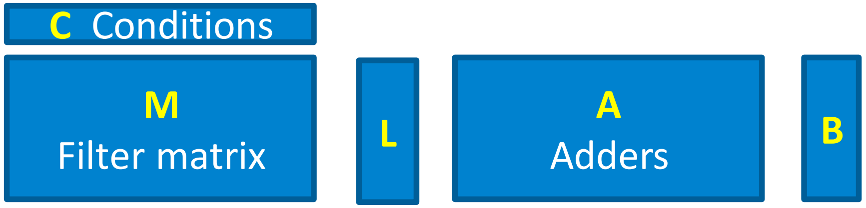
- Significant manual efforts to use TOG's limits in other processes
- A possibility of different interpretation of TOG by different people

Formalized Description of Limits in TOG

- A developed structure allows representing any existing paper TOG in a digital format, including data and logical conditions



Calculation of Limit



For any power system state:

Step 1: Calculate values of Conditions $c_j, j = 1, \ldots, n$

Step 2: Find the row *i* which has $f_i = TRUE$. Set *i=0* if all $f_i = FALSE$

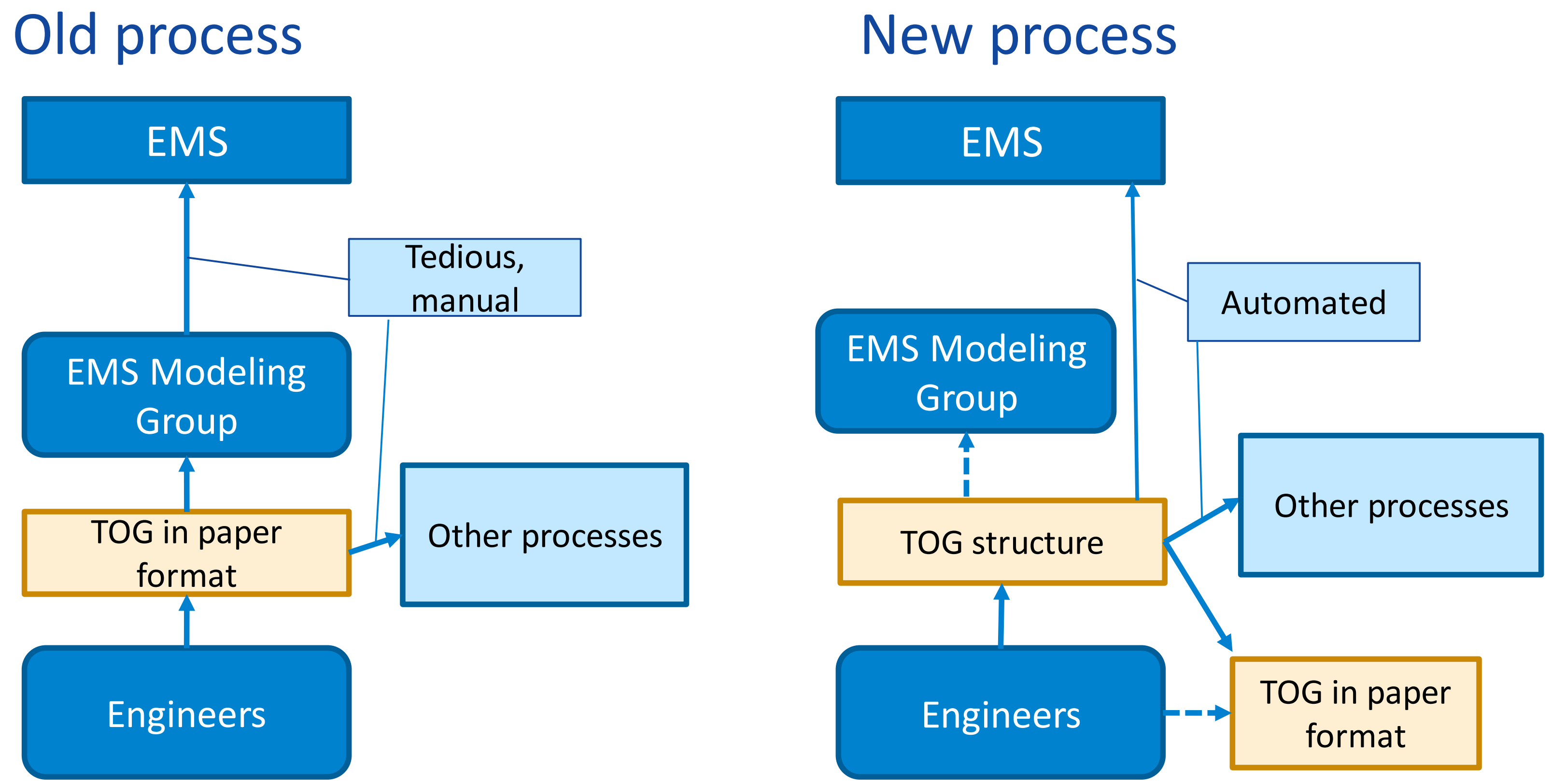
$$f_i = \begin{cases} TRUE, & \text{if} \quad m_{ij}^{\min} < c_j < m_{ij}^{\max} \quad \text{for } j = 1, \ldots, n \\ FALSE, & \text{otherwhise} \end{cases}$$

Step 3: Calculate limit value

$$Lim = \begin{cases} \min\{(l_i + \sum_{j=1}^{j=n} c_{ij} \cdot a_{ij}),\ b_i\} & \text{for } i \neq 0 \\ 99999 & \text{for } i = 0 \end{cases}$$

Fully formalized process allowing automated calculation

Use of TOGs



- Drastic improvement efficiency of the TOG utilization.
- Automated conversion of TOG-related study results (hundreds) into TOG structure by using the Decision Tree technology.

Conclusion

- Future Electric Grid with an increasing level of uncertainty and complexity calls for significant changes in the Transmission Constraint Management
- The Risk-based operations provide a unified framework for reliability and resilience metrics
- Online Cascading Analysis is a practical approach to measure the impact of initiating events including the events caused by severe weather conditions
- Moving offline calculation of interface limits online is an efficient way to manage uncertainties

Questions