The MDMS2 Project

Presentation to the NYSRC EC

Quanta Technology, LLC

With Comments by George Smith and George Loehr

July 12, 2019

NYSRC EC Meeting

Opening Remarks

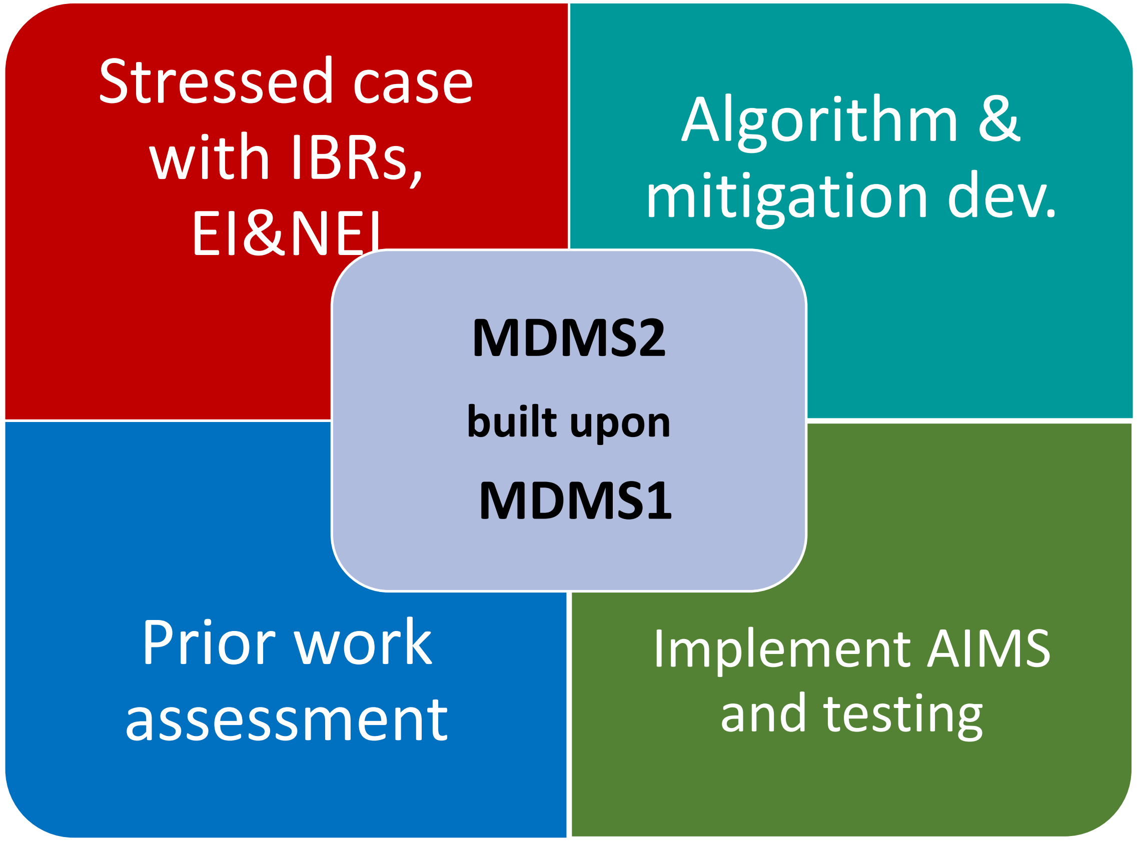
- **Brief history – prior studies**
- **Project participation**
- **Areas covered**
- **Accomplishments vs goals overview**

Agenda

- MDMS2 Project Overview
- Eastern Interconnection Topology
- Northeastern Interconnection Topology
- Project Accomplishments vs planned
- Conclusions and Recommendations

MDMS2 Project At A Glance

- **Project Title:** New York State Wide Area Protection Study (NYS-WAPS, a.k.a. MDMS2)
  - Primary funding by NYSERDA - PON 3379
  - Supported by NYSRC, NYISO, and New York State TOs
  - Started on 11/15/2017, and completed by 6/30/2019



- **Contractor:** Quanta Technology LLC
- **NYSERDA Project Manager:** Michael Razanousky

Background and Previous Studies

- Two of the many studies performed by New York State and NPCC since 2003 blackout led to MDMS2 project
  - NYISO Controlled System Separation (CSS) feasibility Study (CSSS)
    - 2015 base case, generator coherency, preliminary algorithm assessment
    - CSS was the only mitigation measure among those investigated that stabilized the EC12 case
    - Testing on individual runs with manual intervention.
  - NYSERDA Major Disturbance Mitigation Study (MDMS)
    - Same 2015 case from CSSS was used
    - Developed a two-stage Kalman filter plus 3-points Taylor expansion predictor to predict the Out-of-Step (OOS) condition
    - Demonstrated conceptually the algorithm can be used to detect OOS and take the CSS at TEI with UFLS to stabilize the NYCA
    - Automated the process using Python and PSSE.

MDMS2 Project Objectives

To enhance the reliability and resiliency of the New York electric power system during major disturbances by

1. Developing new and improving previously developed mitigation schemes that are feasible for near term field implementations – Task 3 and 4
2. Recognizing the impact of inverter-based resources on load and resources – Task 2, 3 and 4
3. Assessing the feasibility of implementing a New York State Wide-Area Protection and Control System (WAPCS) – Task 4
4. Leveraging the PMU system already deployed in New York State in WAPCS implementation – Task 3 and 4.

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- MDMS2 Project Overview
- Eastern Interconnection Topology
- Northeastern Interconnection Topology
- Project Accomplishments vs planned
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Discussion Topics for EI Topology

1. Base Case Modification and Testing
2. Addition of IBRs per NYISO Interconnection Queue and Gold Book estimates for 2022
3. Impact of 2022 IBRs to NYCA Reliability
4. MDMS2 Mitigation Scheme Development
5. Evaluation of Expanded Mitigation Options
6. Angular Instability Mitigation Scheme (AIMS) Implementation and Testing

1. Modified Base Cases

- The 2022 summer base case provided by NYISO was tested under the standard extreme contingencies (EC1 – EC73).
  - A stable and well damped system for the as-is dispatch in original the new MDMS2 base case.
- Modifications were made to the base case and the contingency files based on NYISO' input to address a few issues identified through the initial test.
  - **EC10, EC24, EC51, EC53,EC55, EC56C, EC56D, EC56E**: The contingency definitions were updated for these contingencies based on the changes in the network topology and PSAS syntax errors.
  - **EC36, EC60 and EC62 to EC73** – FACTS devices at Holtsville and Westwood were turned-off in the load flow and the case was reconverted for the dynamic simulations.
  - **EC12** – The generation of the Oswego units was reduced by 311 MW (through trial and error) from 1412 MW to 1101 MW to resolve the oscillation issues.

Selected Extreme Contingencies for EI Studies

- **Internal extreme contingencies**
  - EC12: Contingency with a stuck breaker at a major 345-kVsubstation, which could have a significant impact on NYCA under the high-power transfer across Central East Interface (CEI).
  - EC02: Loss of major generation resource within NYCA, which could have a major impact for Northeast operating as a smaller interconnection.
- **External extreme contingencies**
  - ExtDist1: Loss of one major 500kV substations in IESO, which could push more power into and through northern NYCA, and back to the Toronto area.
  - ExtDist2: Loss of major source in ISO-NE, including loss of HVDC lines with HQ, which could impact NYCA.
  - ExtDist3: Contingency involving the loss of a major 500kV substation in Northern PJM, which could impact the NYCA.

Created Stressed Base Cases

- Appropriate interfaces were stressed for the selected contingencies for evaluating NYCA system's response to these extreme contingencies
  - CEI-SBC: CEI interface is stressed for EC12 and EC02
  - ON-SBC: Increase flow from IESO to NYCA for ExtDist1
  - NE-SBC: Increase flow between ISO-NE control area and NYCA for ExtDist2
  - PJM-SBC: Interfaces between NYCA and PJM were stressed for ExtDist3
- IBRs are added to these stressed base cases to create the MDMS2 study cases CEI-IBR, ON-IBR, NE-IBR, and PJM-IBR.

2. Added IBRs to Stressed Base Cases

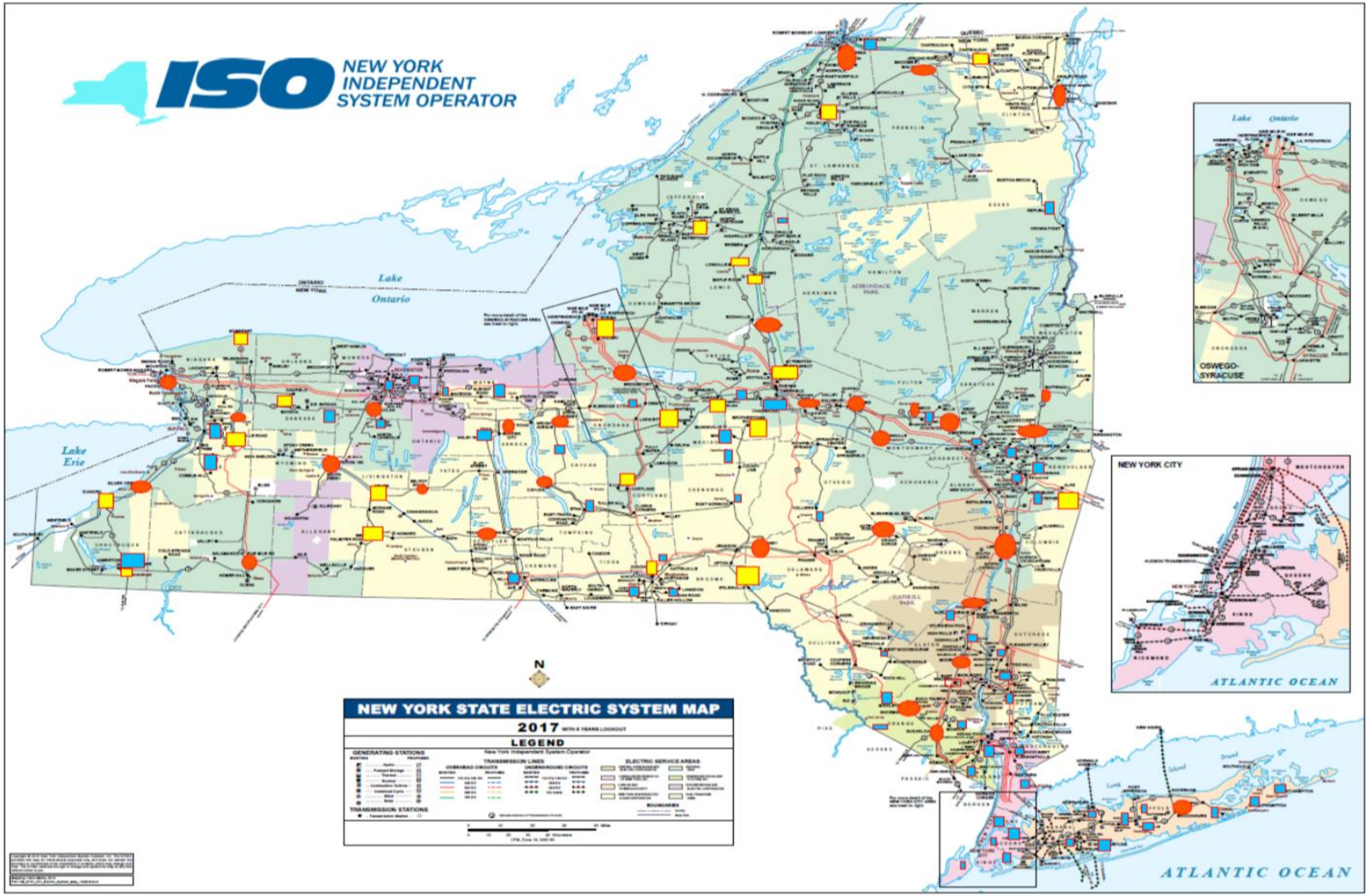
	2022 Base Case		Study Cases	
	Installed	Dispatched	Installed	Dispatched
Total IBRs	2,031	231	8,220	6,576
Utility Scale Wind	2,000	200	3,450	2,760
Utility Scale Solar	31	31	1,870	1,496
Behind-The-Meter Solar	-	-	2,900	2,320

	2022	2015
Total NYCA Generation	30,374	31,213
Net Import	2,731	3,772
Total NYCA Load	32,181	33,667

- IBRs dispatched in the study cases supply ~20% of the total NYCA load
- The study cases increased dispatched IBRs by ~27.5 times from the base case received
- All added IBRs are modeled with voltage and frequency ride-through capabilities

IBRs Map

- Utility scale Solar
- Utility Scale Wind
- Behind-The-Meter Solar



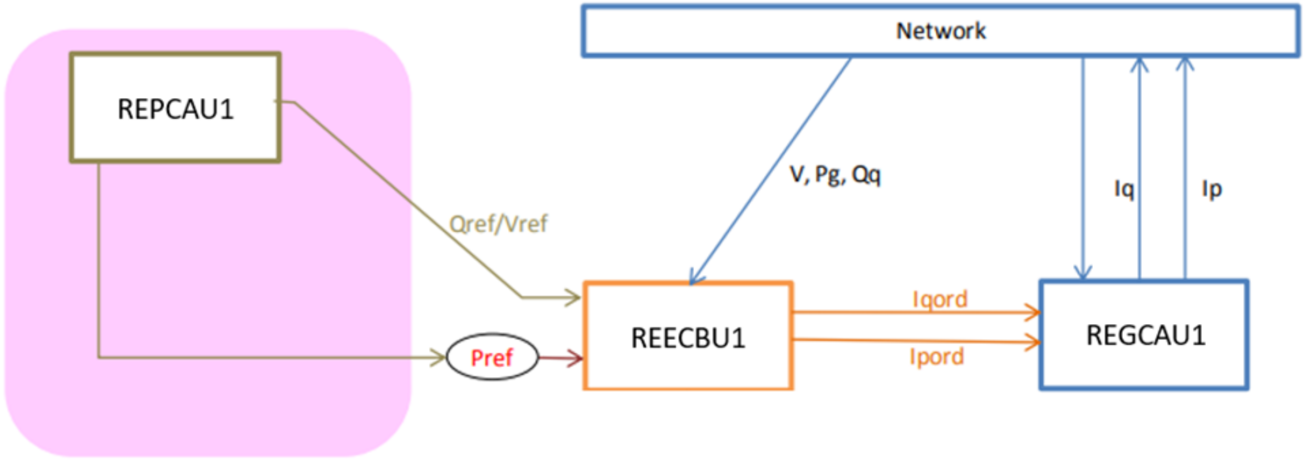
IBRs by The Zones

Zone#	Zone Name	BTM Solar-Total installed capacity (MW)	Solar Total installed capacity (MW)	Wind Total installed capacity (MW)
A	West	189	138	659
B	Genesee	151	58	0
C	Central	348	302	1215
D	North	27	330	600
E	Mohawk	205	140	861
F	Capital	325	508	120
G	Hudson	529	255	0
H	Millwood	41	0	0
I	Dunwoodi	67	0	0
J	NYC	334	0	0
K	Long Island	683	141	0
Total		2899	1872	3450

IBR Modeling – Utility Scale Solar

- Modeled as an aggregated plant (REGCAU1) with plant level active and reactive power control (REPCAU1) and electrical control (REECBU1).

- Ride-through capabilities are based on NERC PRC-024-2, which is coordinat with Category II of IEEE 1547-2018 standard.



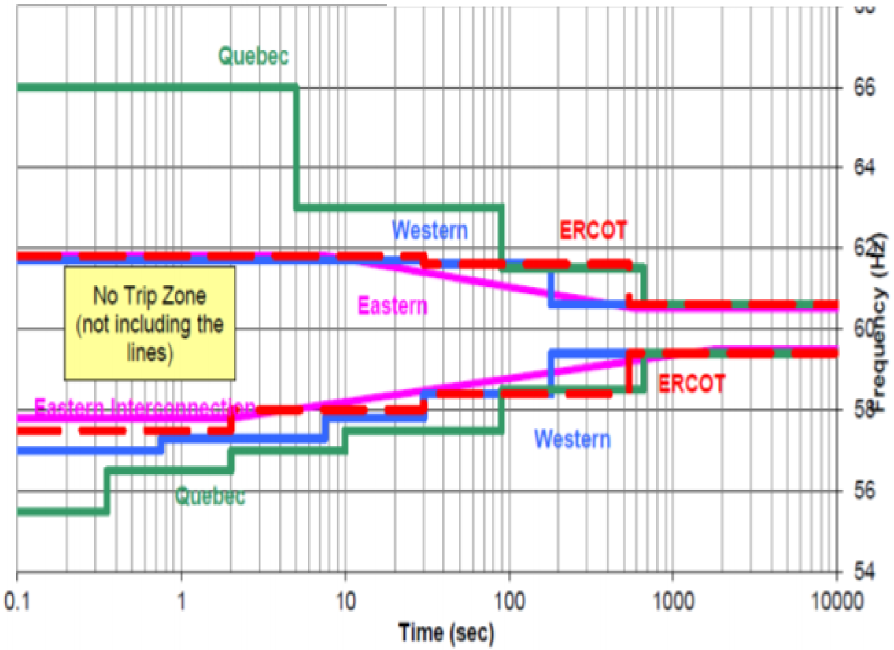


Figure 1: PRC-024-2 Frequency Curve

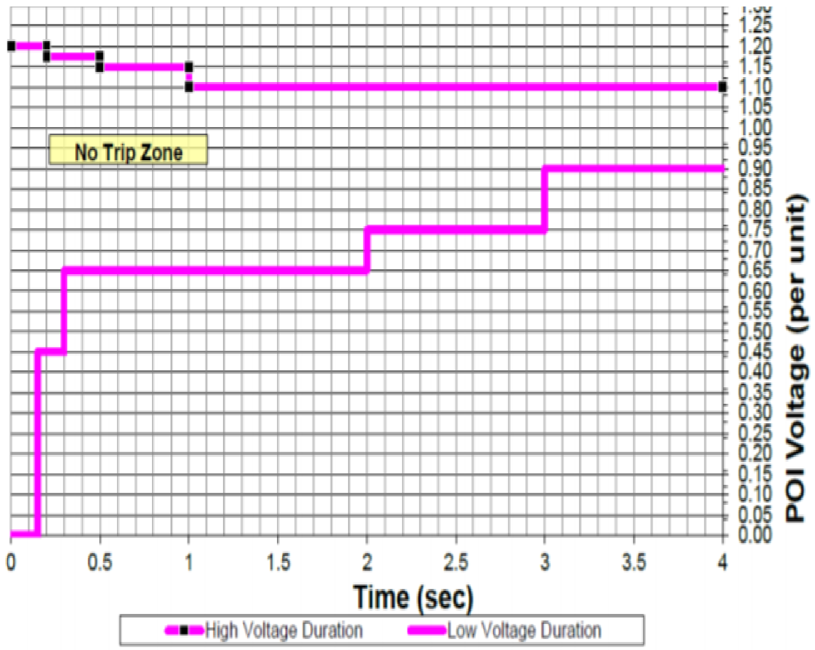
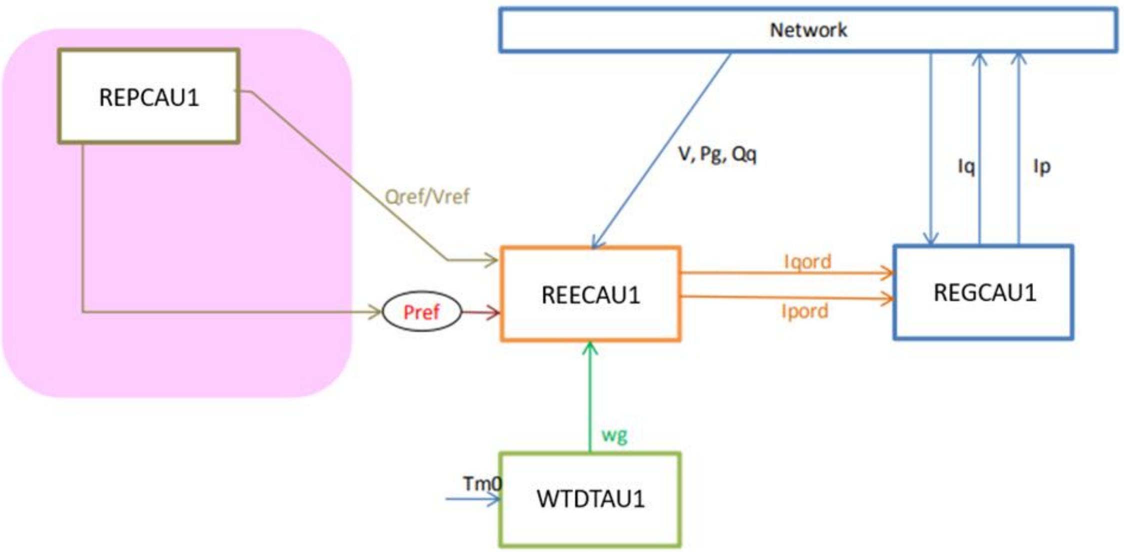
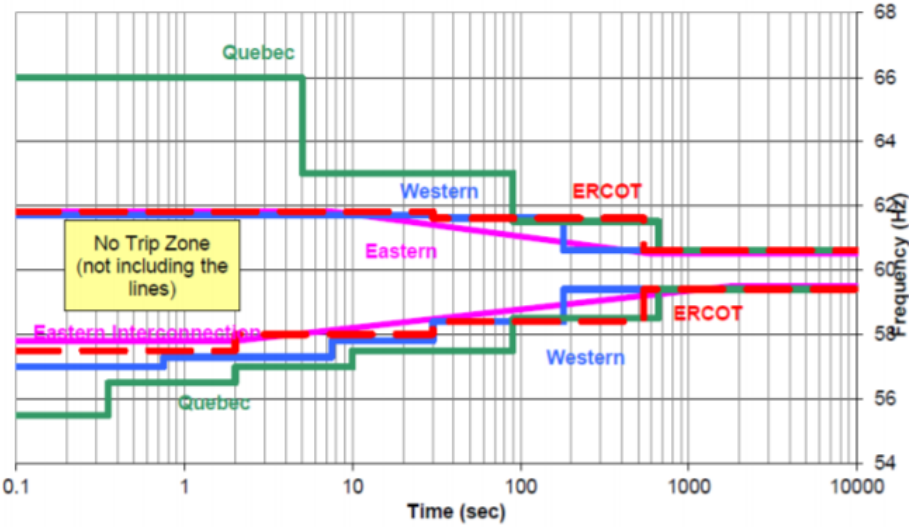


Figure 2: PRC-024-2 Voltage Curve

IBR Modeling – Utility Scale Wind



- Modeled as an aggregated plant (REGCAU1) with type-4 wind turbine drive train model (WTDTAU1), plant level active and reactive power control (REPCAU1) and electrical control (REECBU1).



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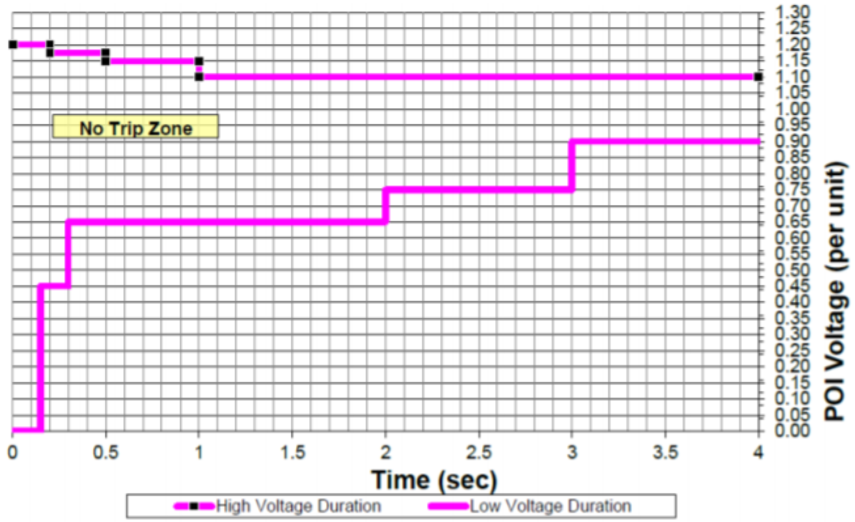
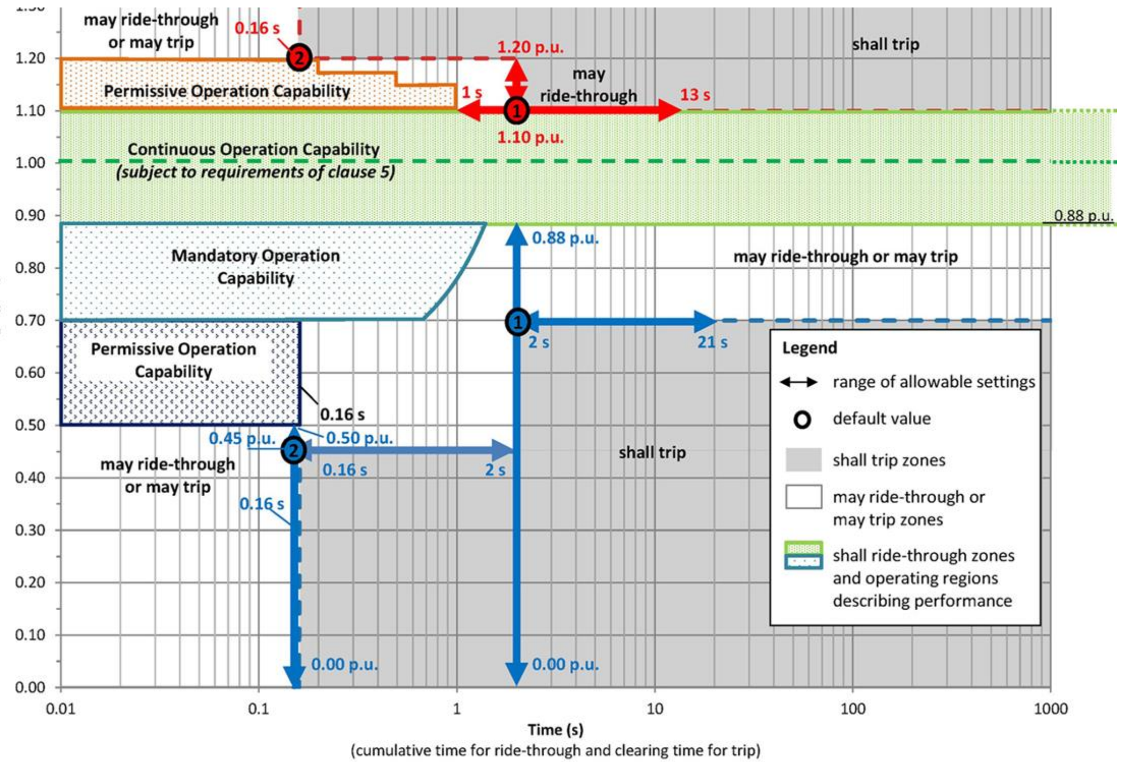


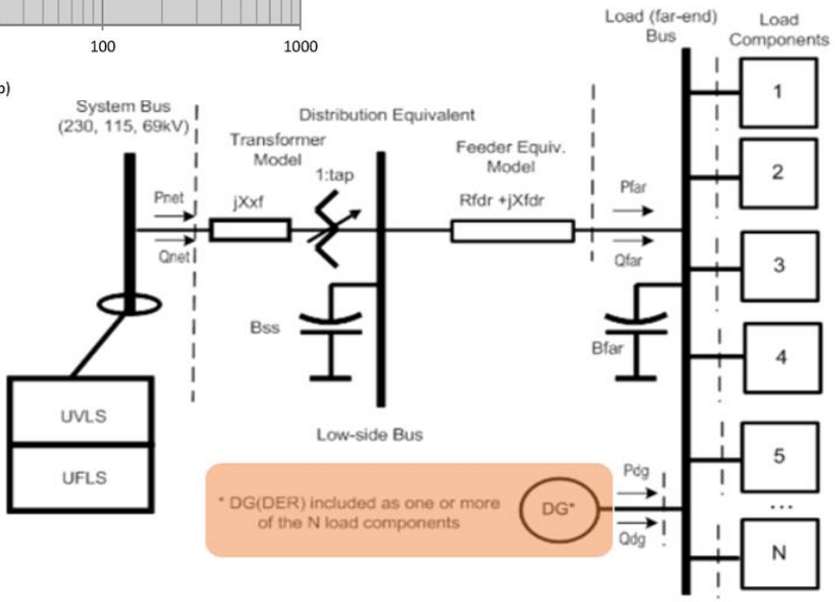
Figure 2: PRC-024-2 Voltage Curve

- Ride-through capabilities are based on NERC PRC-024-2, which is coordinated with Category II of IEEE 1547-2018 standard.

IBR Modeling – Behind-The-Meter Solar

- Behind-the-meter (BTM) solar
  - DER-A model was not available in PSS/E at the time
  - Modeled as an aggregated solar generator (REECAU1 or REECBU1) for distributed solar resources.
    - No momentary cessation
  - Ride-through capabilities are based on Category I of IEEE 1547-2018 standard as BTM solar are not under NERC's jurisdiction. Category I consistent with low penetration.





Key Results/Findings Summary – EI Topology

- Base case as received from NYISO
  - Other than a few initial issues later resolved, the case was very stable and well damped when subjected to all extreme contingencies (EC01 to EC73)

- Stressed base cases without added IBRs
  - Among the four selected extreme contingencies, only EC12 resulted in an unstable condition, which is similar to CSSS and MDMS1 results
  - The ExtDist1 did not cause instability as it did in CSSS

- Stressed base cases with added IBRs
  - Results are very similar to stressed base cases without added IBRs
  - Some IBRs are tripped near the location of the EC12 contingency
    - Impact of IBR tripping during the contingency on system stability appears minimal.

3. Impact of 2022 IBRs to NYCA System Reliability

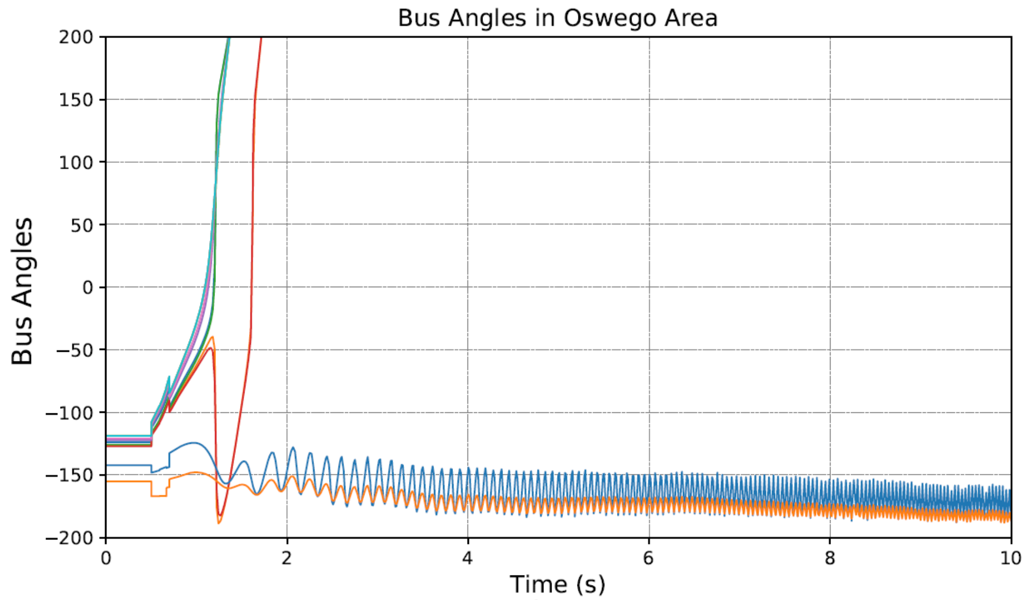
- During contingencies
  - IBRs will trip if abnormal voltage conditions caused by a contingency lasted beyond the ride-through curve
  - IBR tripping generally occur near the contingency locations (e.g. EC12)
  - IBR tripping shown to slow down the angle acceleration of nearby generators

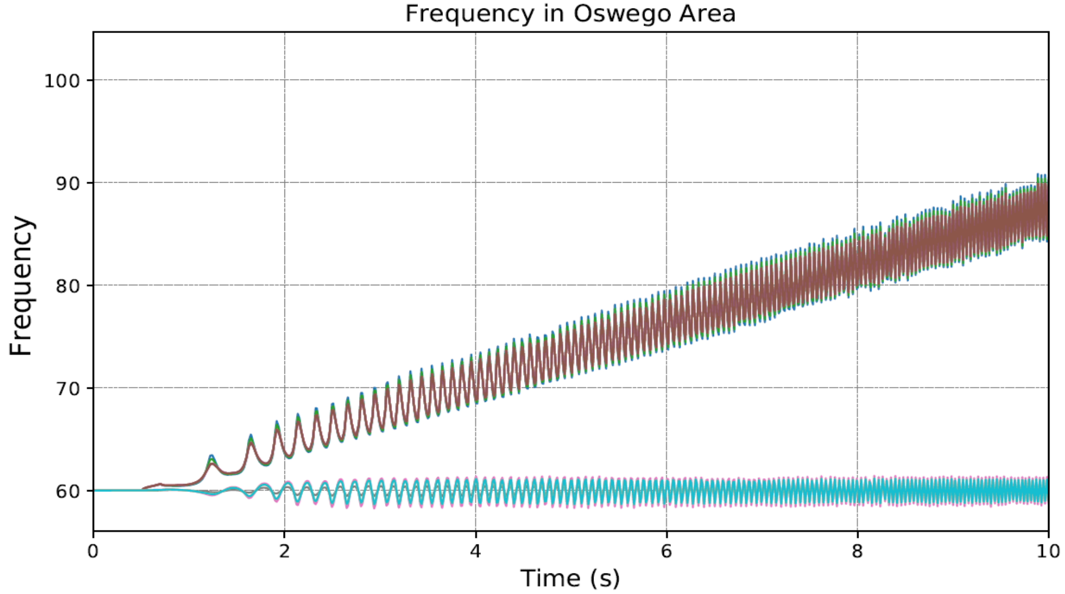
- After certain mitigation actions (e.g. CSS, HVDC modulation) are taken
  - IBRs will trip if there are long lasting abnormal voltage/ frequency conditions after those mitigation actions
  - **More load will be shed** as a result of additional IBR tripping in areas where load shedding is already happening to stabilize the system post mitigation actions.

IBRs will trip when abnormal voltage and/or frequency conditions lasted longer than their ride-through capability

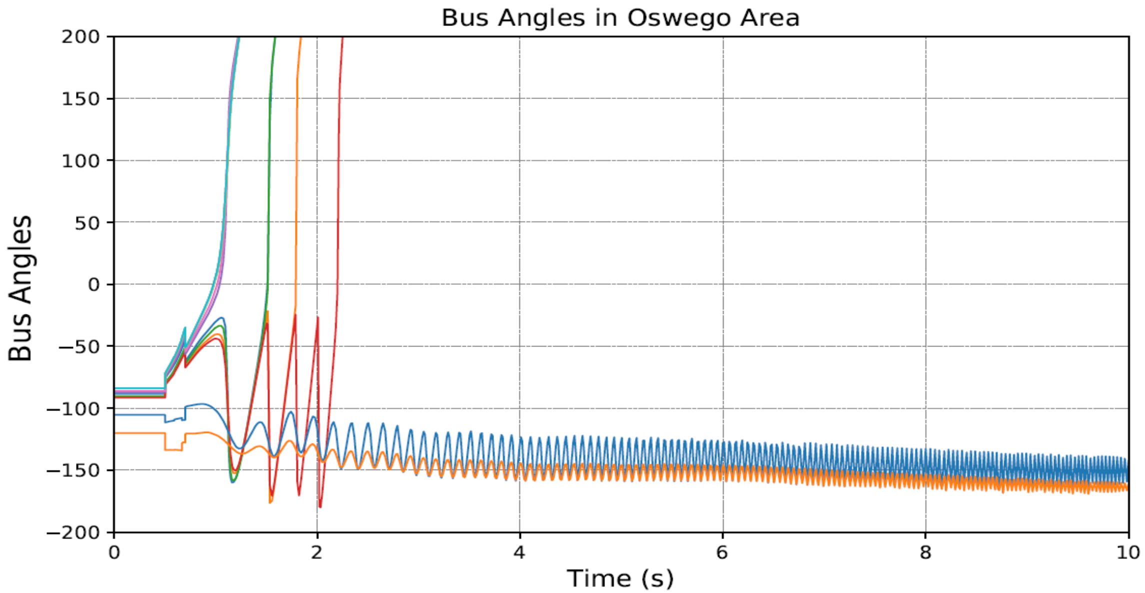
Bus Angle and Frequency Plots for IBR vs Non-IBR under EC12

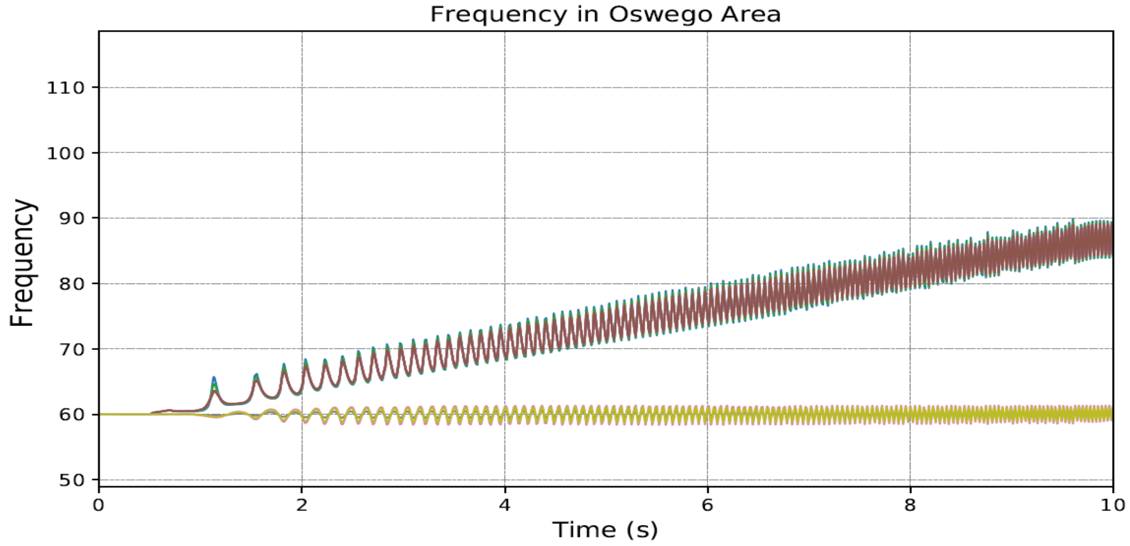
Non-IBR





IBR





4. MDMS2 Mitigation Scheme Development

- Updated MDMS1 algorithm towards practical implementation
  - Run algorithm continuously instead of starting after the contingency is cleared
  - Replaced Taylor's Expansion with 2nd order mechanical system predictor
  - Improved response to sudden changes
  - Moved prediction to individual location
    - Observability of generation locations

- Developed a new concept for estimating location and severity of a fault started extreme contingency
  - Use voltage magnitudes of all available PMUs
  - Location with the lowest voltage magnitude during the fault indicate the approximate location
    - Can be used to select PMU location for angle difference prediction
    - Can be used to select appropriate mitigation measures
  - Fault duration is an indication of the severity

Combined to make an angular instability mitigation scheme (AIMS)

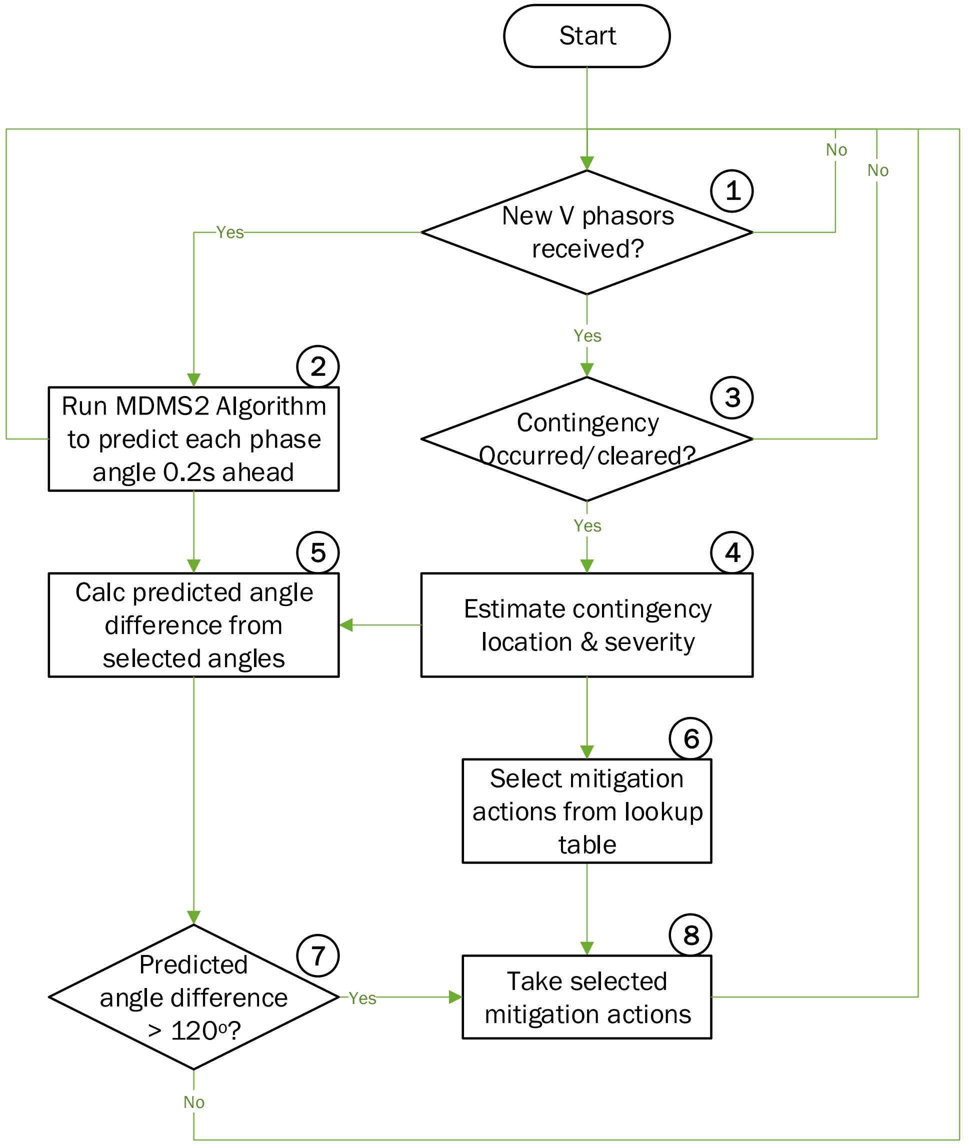
5. Evaluation of Expanded Mitigation Options

- **Generator tripping**
  - Effective (**<u>Only impact the generators that are tripped</u>**) where a small number of generators in a confined area are running away from rest of the system
  - Trip all generators in the area may create reactive power unbalance and voltage instability issues
  - Trip generators accelerated the fastest first is the key – The generator capacity/inertia ratio is a good indicator
- **HVDC modulation after CSS**
  - **Boost the imported power <u>help to reduce the amount of load shed</u> by UFLS after a CSS action**
- **Immediate load shedding after CSS**
  - **<u>Effective in reducing the amount of load being shed and avoid the wild frequency excursion compared to UFLS</u>**
  - Can be done when the amount of gen/load unbalance caused by CSS action and precise loads are known
- **Voltage/reactive power control**
  - **Tripping capacitors is effective where high voltage persists – <u>Help to avoid additional IBRs tripping</u>**
  - **Required as an integral part of any overall mitigation plan**

Choosing right mitigation actions reduces the impact of an extreme contingency

6. Angular Instability Mitigation Scheme (AIMS) Implementation and Testing

1. **AIMS Python scripts perform the AIMS functions every time a new measurement becomes available.**
2. **Run the MDMS2 angle prediction algorithm on all individual voltage phasor angles to predict their phase angles 0.2s ahead.**
3. **In parallel, the voltage phasor magnitude at all locations is monitored to detect if a fault related contingency has occurred or cleared – Occurred = a drop in one or more voltage phasors' magnitude to below 0.6 p.u.; and cleared = a sudden jump leads to the lowest voltage magnitude back above 0.6 p.u.**
4. **The PMU location with the lowest voltage magnitude during the fault is the estimated location of the contingency, and the duration of the fault is a measure of estimated severity.**
5. **Using estimated contingency location to select PMU locations from a lookup table for calculating the predicted voltage phase angle difference.**
6. **Using estimated location and/or the estimated severity to select the appropriate mitigation actions from a lookup table.**
7. **Trigger the mitigation actions when the predicted phase angle difference exceeded a threshold (e.g. 120 degree),**
8. **Execute the selected mitigation actions when triggered.**



CLSE enables AIMS to select the right mitigation measures and PMUs for angle difference prediction for each contingency – Critical for practical implementation

AIMS Logic Description

1. AIMS Python scripts perform the AIMS functions every time a new measurement becomes available.
2. Run the MDMS2 angle prediction algorithm on all individual voltage phasor angles to predict their phase angles 0.2s ahead.
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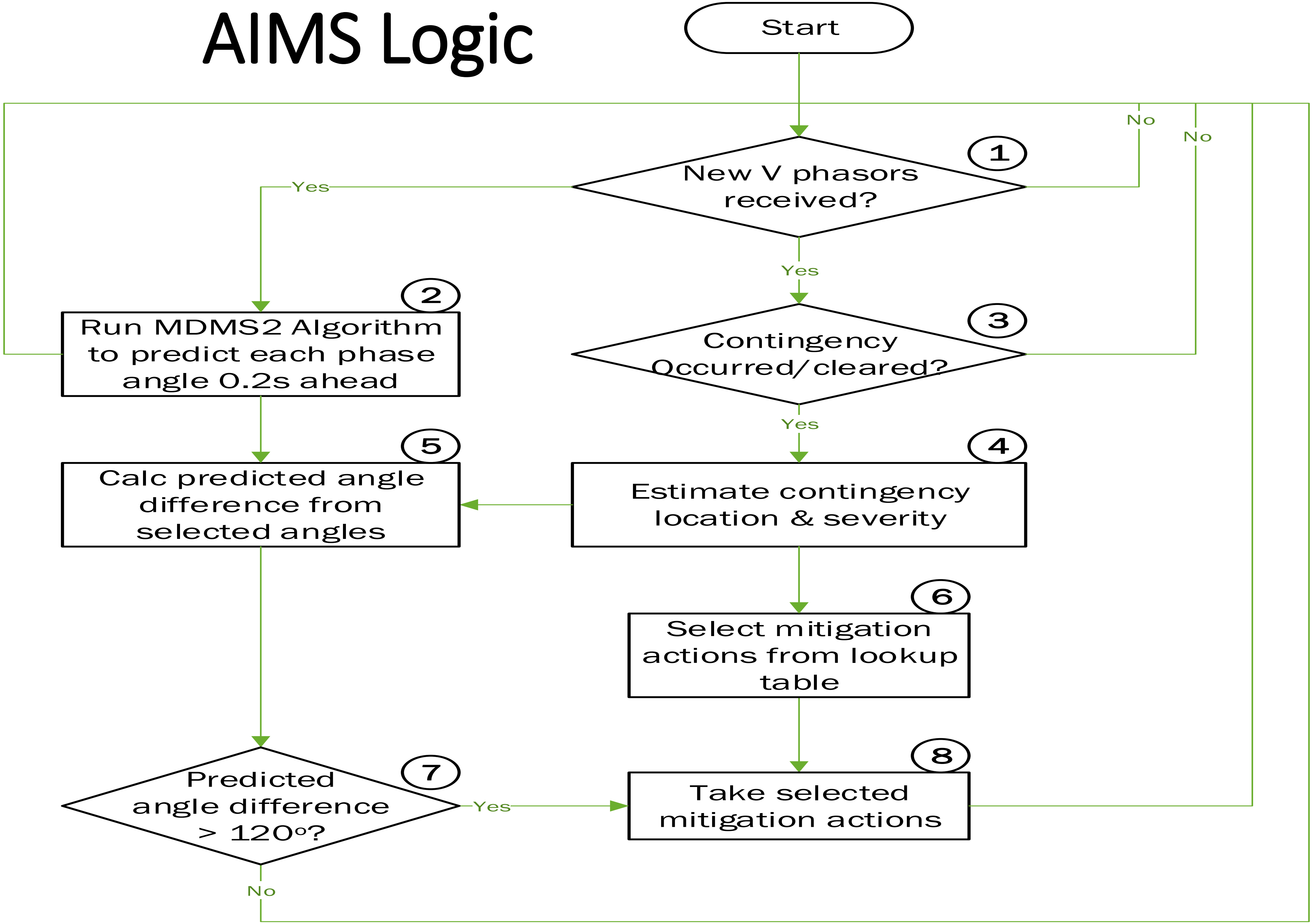
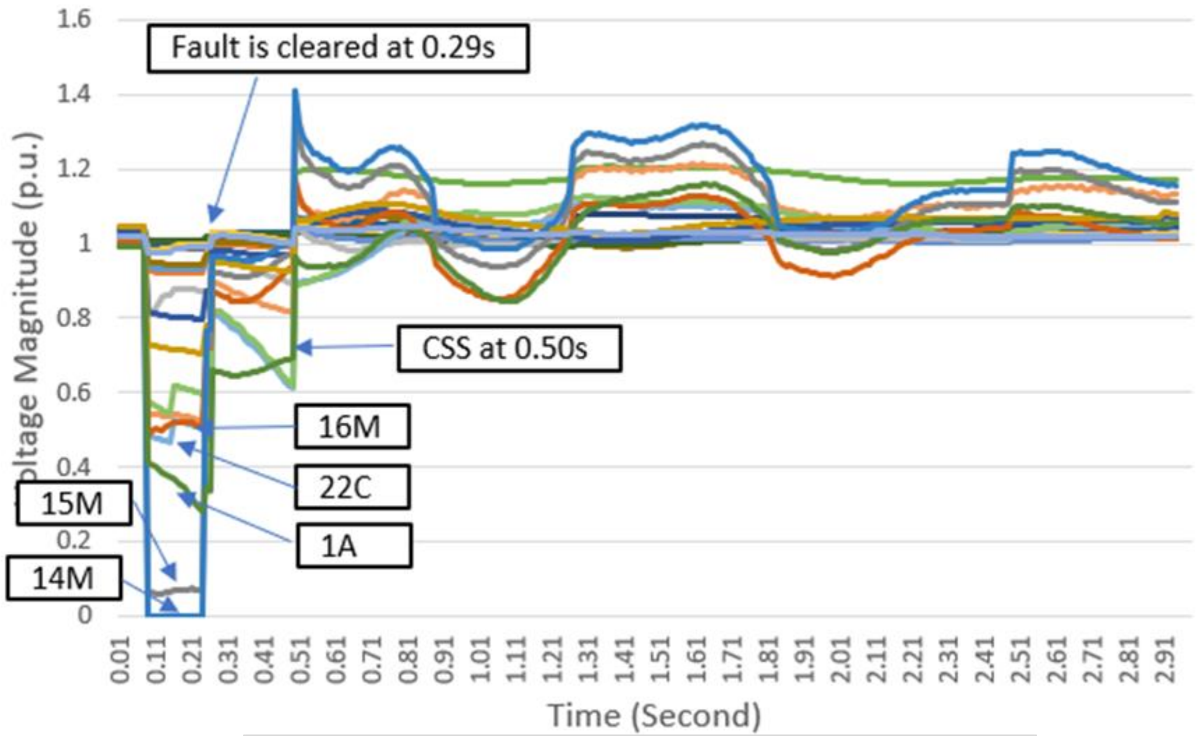
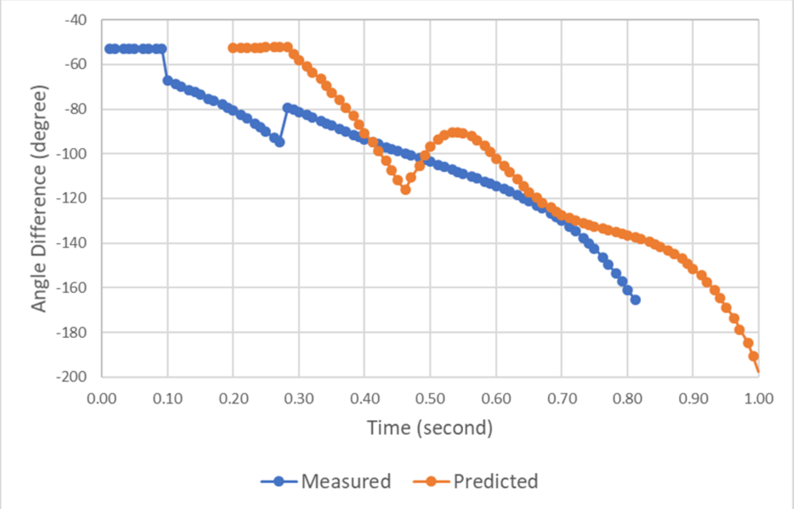
AIMS Logic



Start
1
New V phasors received?
Yes
No
No
2
Run MDMS2 Algorithm to predict each phase angle 0.2s ahead
3
Contingency Occurred/cleared?
Yes
4
Estimate contingency location & severity
5
Calc predicted angle difference from selected angles
6
Select mitigation actions from lookup table
7
Predicted angle difference > 120o?
Yes
No
8
Take selected mitigation actions

AIMS Operated Correctly to Stabilize EC12

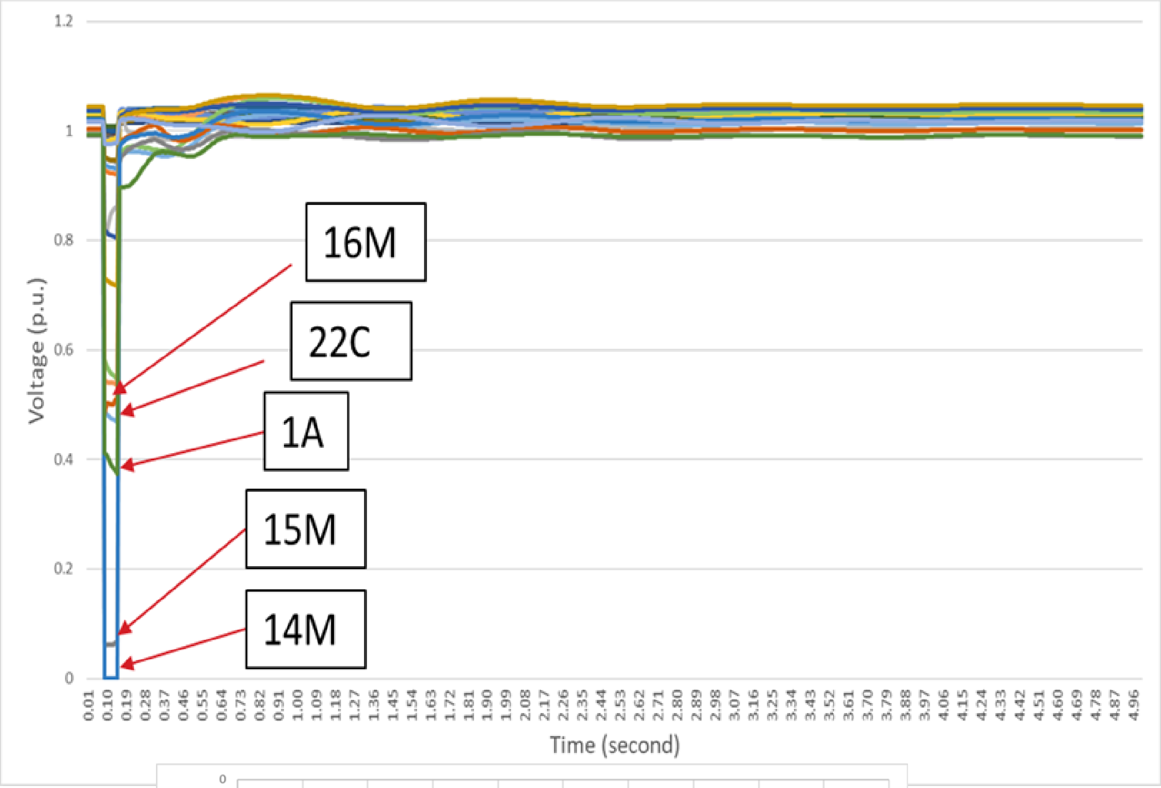


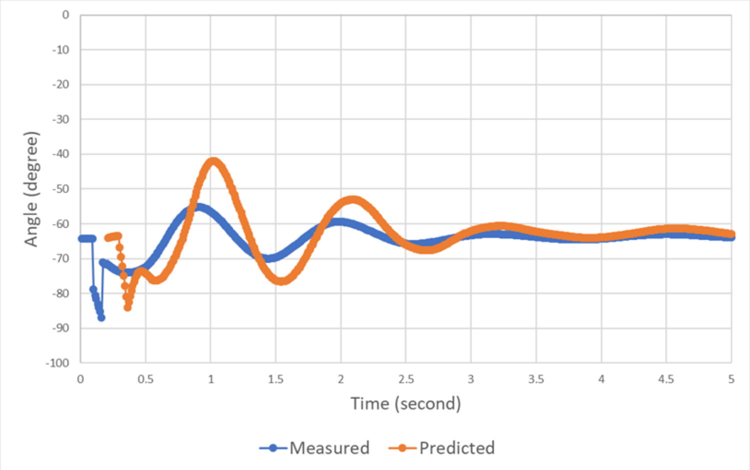


- t=0.1s, the fault starts;
- t=0.13s, the fault is detected by AIMS. The contingency location is estimated "at or near bus 14M". The information is used to perform the followings:
  - Select 2 PMUs from each side of the estimated contingency location to calculate the predicted angle difference.
  - Select CSS at TEI plus UFLS and capacitor as the mitigation actions when triggered.
- t=0.29s, the fault is cleared;
- t=0.32s, the fault clearance is detected by AIMS
- t=0.45s, the monitored average angle difference is predicted to exceed the threshold of -120 degrees at 0.64s.
- t=0.50s, the mitigation actions of CSS at TEI and capacitor tripping at selected locations are taken, which eventually stabilized the system

AIMS Did Not Operate for Stable Swing of CE14

- t=0.1s, the fault starts;
- t=0.13s, the fault is detected by AIMS. The contingency location is thus estimated as “at or near bus 14M”. The information is used to perform the followings:
  - Select 2 PMUs from each side of the estimated contingency location to calculate the predicted average angle difference.
  - Select CSS at TEI plus UFLS and capacitor tripping as the mitigation actions when triggered.
- t=0.19s, the fault is cleared after 5.5 cycles;
- t= 0.22s, the fault clearance is detected by AIMS. No mitigation action is taken since
  - The predicted angle difference has never crossed -120 degree threshold, and
  - The duration of the contingency indicated a normal fault clearing.





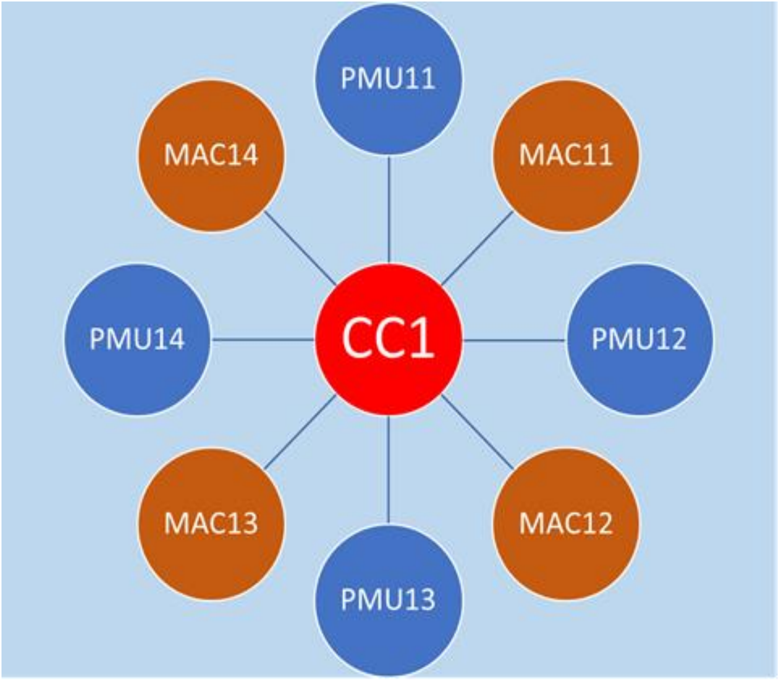
Local Validation or Supervision May Not Work

The concept of using local out of step relays in conjunction with a centralized PMU based scheme for validation and added security was originally proposed and contemplated in the MDMS1 study. This study further explored possible issues with this concept.

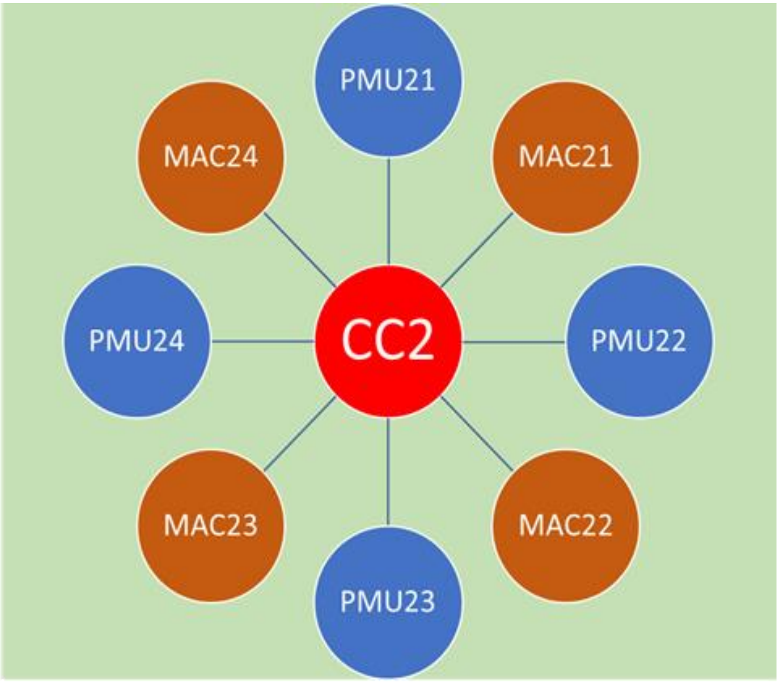
- **The Out-of-Step (OOS) system conditions that require a CSS action are system level problems, not localized ones, which require select right measurement data locations at the system level.**
- **Local OOS condition detection or prediction functions on all lines of an interface selected for CSS MUST be able to "see" the OOS condition at the same time in order for these lines to be tripped at the same time by the CSS command from AIMS.**
- **The measurements used by AIMS to make the CSS decision and the local measurements used to detect OOS condition on the lines are not the same → OOS detection functions on the lines of the selected CSS interface will not "see" an OOS condition the same as seen by the central controllers in making the CSS decisions.**
- **Typical out-of-step (OOS) detection function is based on the impedance measurement, which will only "see" an OOS condition if the "electrical center" of an OOS goes through its detection zone.**
- **Not all lines of a CSS interface are guaranteed to "see" the OOS conditions the same way as seen by AIMS.**

AIMS Implementation Considerations

- Dependability and Security
  - For increased dependability:
    - Use two redundant systems;
    - Send command multiple times.
  - For increased security:
    - Apply self-monitoring and blocking;
    - Take action based on commands from multiple central controllers.



System 1



System 2

AIMS Implementation Considerations

- Speed and Selectivity

  - Block all OOS line tripping depending on OOS condition and its reliable blocking schemes.

  - Ensure CSS actions occur before any possible line OOS tripping actions.

  - If the objective is to use CSS, not the generator tripping, to mitigate an imminent OOS condition, then the CSS operation must be taken before any generator OOS tripping actions.

Accomplishments for EI Topology

1. Modified base cases for dynamic simulation
   - Selected extreme contingencies (EC) for EI investigation
   - Created stressed base cases for selected extreme contingencies
2. Added projected inverter-based resources (IBRs) to stressed base cases
3. Evaluated NYCA under selected EC scenarios on stressed cases with projected high level of IBRs
4. Developed robust angular instability prediction algorithm
5. Evaluated additional mitigation measures including generator tripping, HVDC modulation, immediate load shedding
6. Developed and tested an overall Angular Instability Mitigation Scheme.

Conclusions for EI – Non IBR Case

- NYCA system remained stable and well damped under all the selected extreme contingencies except for EC12.
- Under EC12, the system becomes unstable due to the high west-to-east power transfers (the system is “stressed”).
- With the loss of major transmission lines, the western NYCA becomes generation surplus, causing the generators in the area to accelerate and, as a result the frequencies at the buses near/around the Oswego area in Zone C were found to be increasing.

Conclusions for EI – IBR Case

- The addition of the renewables did not show significant impact on the dynamic response of NYCA system when tested under the same contingencies.
- All of the contingencies tested, except for EC12, showed a stable and well-damped response.
- In addition to the synchronous generators, IBRs were found to be tripped under the EC12 by voltage and frequency protections relays
- Blocking IBRs from tripping under EC 12 would bring adverse impact on the system stability – resulted in an unstable (unsolvable) system condition.

Recommended Next Step Works for EI

- Assess the reliability in a carbon-neutral future NYCA grid
  - When 100% of electric energy are supplied by carbon-free energy resources by 2040
- Pilot implementation and testing of a centralized WAPCS with AIMS
  - Implementing centralized WAPCS with AIMS on a real-time platform and testing it under realistic real-time conditions in a hardware-in-the-loop testing setup
- Develop study cases with all protections (e.g., lines, generators, etc.) for proper WAPCS coordination studies
  - Ensure the operation of WAPCS is fully coordinated with all protections in the NYCA system.

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Key Results/Findings Summary – NEI Topology

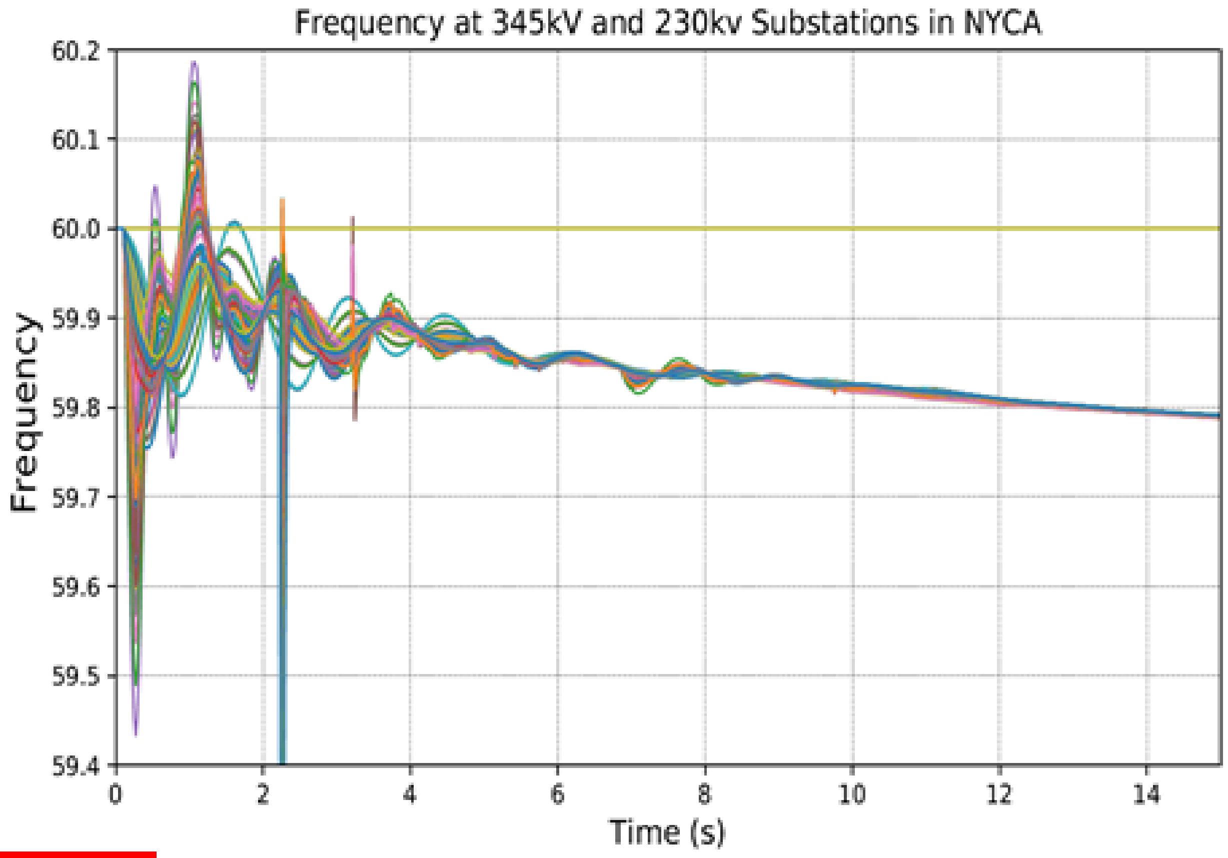
- The NEI case was created by disconnecting all AC tie lines between PJM and NYCA, and from IESO to Michigan, Wisconsin and Manitoba.
  - The CEI stressed case with added IBRs (CEI-IBR) is used, and
  - The HVDC connections with PJM and Hydro Quebec are not disconnected.
- In addition to EC02, ExtDist1 and ExtDist2 contingencies, a normal contingency CE22 was also run
  - CE22: 3-phase fault at one 345-kV substation in the Mohawk zone (Zone E) that disconnected a major 345-kV line carrying power from western NYCA to eastern NYCA

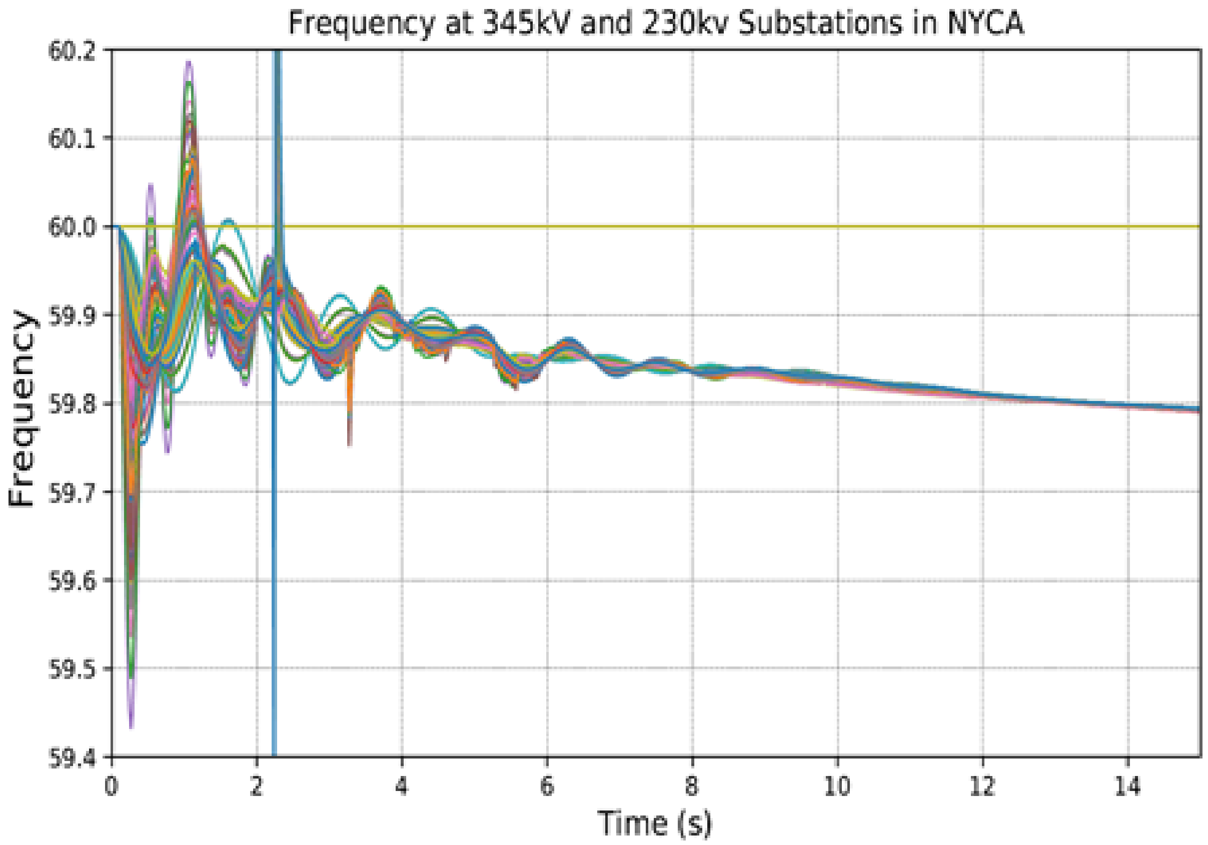
- Simulation results summary
  - EC02: NEI system stable but the system frequency did not recover back to nominal
  - ExtDist1: NEI system became unstable (Note that the system was stable for the same extreme contingency in EI topology)
  - ExtDist2: NEI system stable but the system frequency did not recover back to nominal
  - CE22: NEI system is stable and system recovered back to normal

Key Results/Findings Summary – NEI Topology

HVDC modulation as a loss-of-source mitigation measure for NEI topology

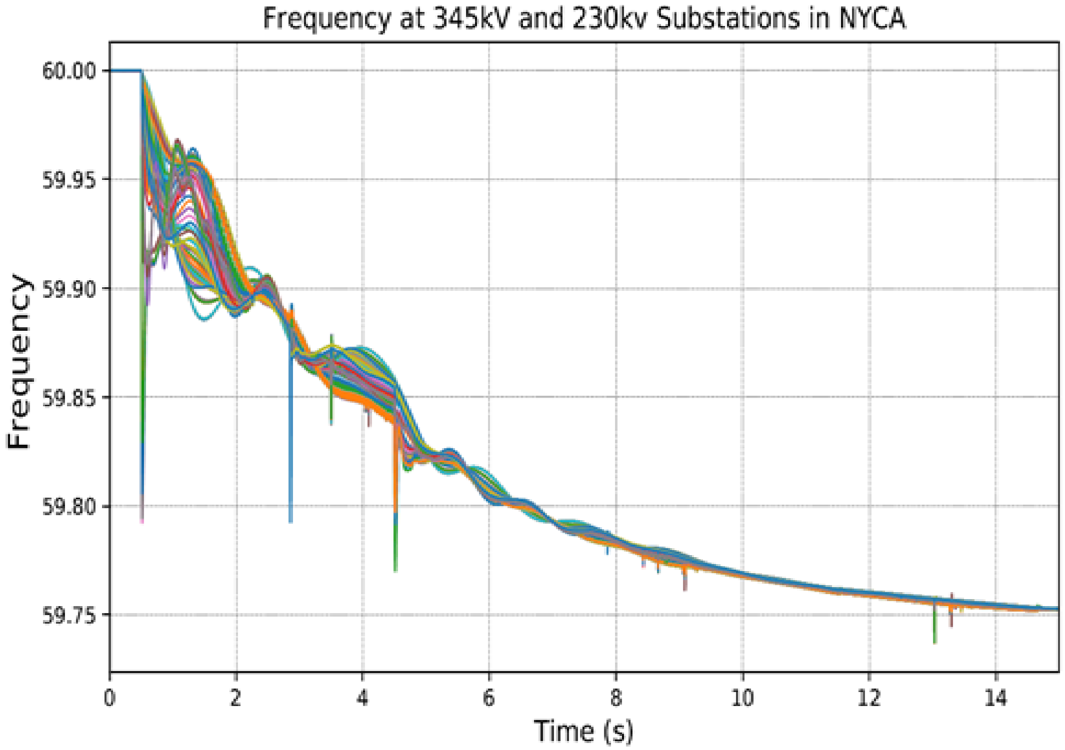
- EC02: Loss of source in NYCA, total loss of source is about 2,500 MW
  - Increase HVDC import at 25N and 26H by +500 MW each (+1,000 MW in total)
  - IBRs tripping: Lost additional 901 MW without HVDC modulation, and 841 MW with HVDC modulation
    - Net loss of source is 3,401 MW without HVDC modulation, and 2,341 MW with HVDC modulation

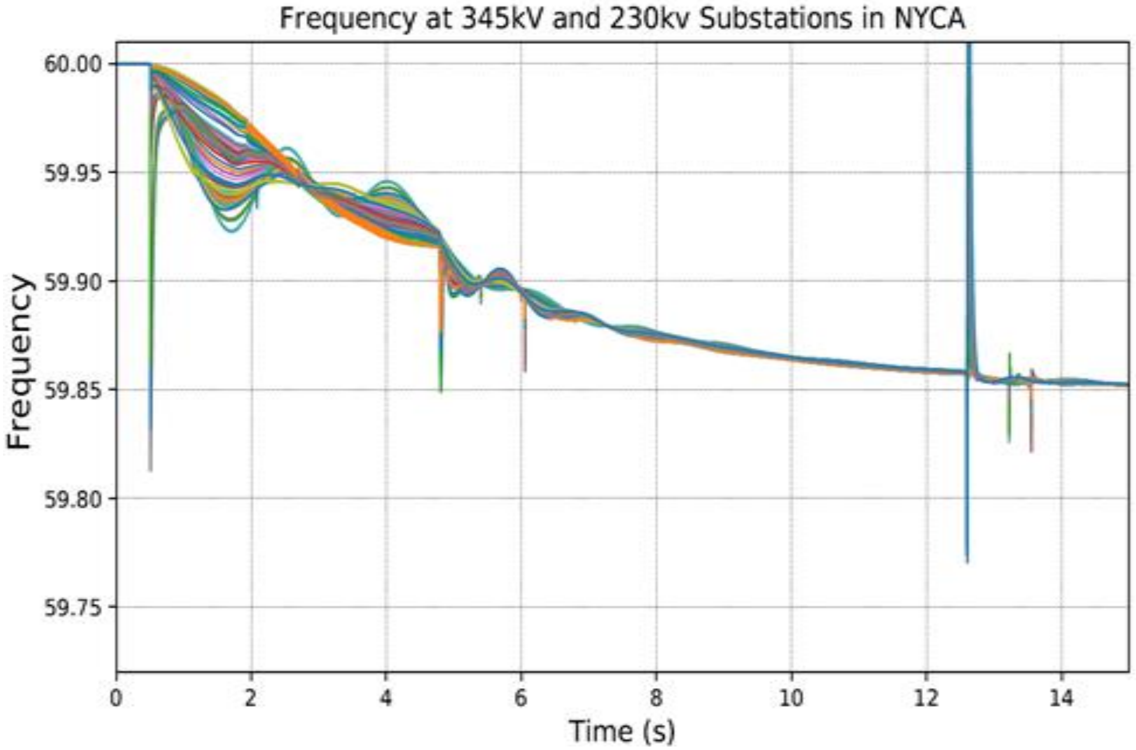




Key Results/Findings Summary – NEI Topology

- ExtDist2: Loss of major source in ISO-NE, total loss of source is about 2,000 MW
  - Increase HVDC import at Neptune and HTP by +500 MW each (+1,000 MW in total)
  - IBR tripping: 280 MW without HVDC modulation, and 120 MW with HVDC modulation
  - Net loss of source: 2,280 MW without HVDC modulation, 1,120 MW with HVDC modulation





Accomplishments for NEI

1. Selected NEI contingencies
2. Created NEI study cases
3. Evaluated NEI's dynamic performance under selected major contingencies
4. Explored mitigation actions for NEI.

Conclusions for NEI

- Under tested normal contingency condition, the NEI system remained stable.
- Under tested extreme contingencies, the NEI system
  - Remained stable similar to when NEI is part of the Eastern Interconnection under the extreme contingencies ExtDist2 and EC02
    - System frequency did not recover under EC02
    - System frequency dropped significantly under ExtDist2
  - Become unstable under the extreme contingency ExtDist1
    - Was stable in EI topology

Recommended Next Step Works for NEI

- The work and results under NEI topology indicate the need for further research/assessment to determine the viability of operating the NEI system reliably, when synchronously separated from the Eastern Interconnection. Important aspects should be further assessed include
  - Determining the new operating limits on the interfaces
  - Adding additional back-to-back HVDC connections that potentially could help to enhance the NEI system reliability
  - Making necessary changes in system operations (e.g. allow for a wider frequency range under normal system conditions), protection and controls.

Agenda

- MDMS2 Project Overview
- Eastern Interconnection Topology
- Northeastern Interconnection Topology
- Project Accomplishments vs planned
- Conclusions and Recommendations

MDMS2 Key Accomplishments vs. Planned Scope of Work

- Task 2 Planned
  - 2.1: Review and Summarize Prior Work
  - 2.2.1: Develop base cases with increased IBRs for Eastern Interconnection (EI) studies
  - 2.2.2: Develop base cases with increased IBRs for Northeastern Interconnection (NEI) studies

- Task 2 Accomplished
  - Reviewed 5 reports and submitted a comprehensive summary
  - Developed four stressed cases with high-level IBRs dispatched at 80% of the installed capacity for EI studies
  - Developed four cases with high-level IBRs dispatched at 80% of the installed capacity for NEI studies

MDMS2 Key Accomplishments vs. Planned Scope of Work

- Task 3 Planned
  - 3.1: Detection algorithm development – Improve MDMS1 algorithm, develop new algorithm
  - 3.2.1: Mitigation measure for EI – IBR control, HVDC modulation, may consider TO's relay modification if needed
  - 3.2.2: Mitigation measures for NEI – HVDC modulation only for unstable case

- Task 3 Accomplished
  - Made a few key updates to MDMS1 algorithm for practical implementation; developed a new contingency location and severity estimation method; developed AIMS
  - For EI: IBR control not possible due to model limitation; generator tripping; HVDC modulation, immediate load shedding
  - For NEI: HVDC modulation

MDMS2 Key Accomplishments vs. Planned Scope of Work

- Task 4 Planned
  - Verify the effectiveness and feasibility of developed detection algorithms and mitigation measures
  - Consider practical implementation factors (e.g. delays)
  - Evaluate the actions of Transmission Owner's relay systems and UFLS and the WAPCS system architecture with redundant design concepts

- Task 4 Accomplished
  - Implemented AIMS in Python scripts and the test results confirmed its effectiveness and feasibility
  - The 0.2s prediction time has taken into account the total delays of a PMU measurement based system
  - Evaluated a possible centralized system implementation with redundancy to address dependability and security, and speed and selectivity

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Executive Summary- Project Requirements

- Test stressed New York Control Area within the Eastern Interconnection (EI)
- Model projected inverter-based resources (IBR) with protections in the stressed cases
- Assess the impact of IBRs during contingencies and after controlled system separation (CSS) actions
- Test a hypothetical Northeastern Interconnection (NEI) representation to evaluate NEI's ability to withstand internal contingencies
- Improve/further develop instability detection and prediction algorithms, and implement and test Angular Instability Mitigation Scheme (AIMS)
- Investigate additional mitigation measures, such as HVDC modulation, generator and capacitor trippings, and immediate load shedding post CSS

Executive Summary- Key Discoveries

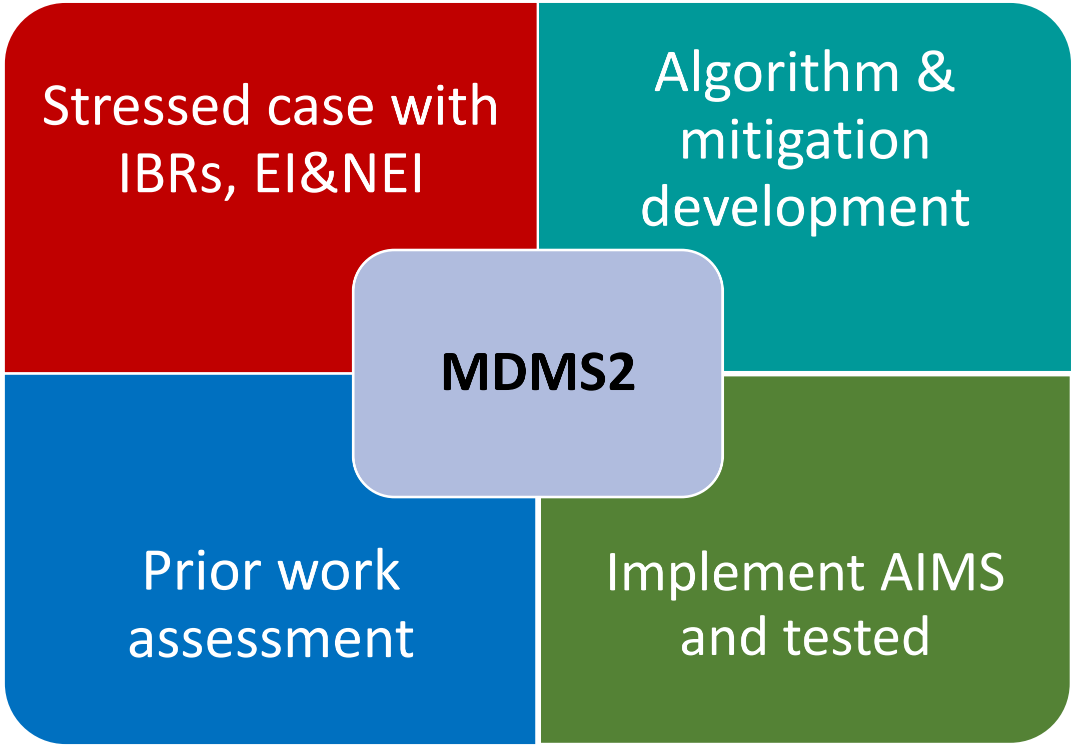
- Generator tripping, if done properly, can be an effective mitigation measure by itself without the need of load shedding as part of the NYCA CSS mitigation measures
- Immediate post-CSS load shedding can be effective as part of the NYCA CSS mitigation measures
- It is promising to use capacity/inertia ratio to dynamically select generators for generator tripping post disturbances
- HVDC modulation can be an effective Post-CSS mitigation measure
- PMU's voltages phasors can help locating disturbances and assessing severity
- Voltage control as part of the mitigation measures can help avoiding IBR trippings.

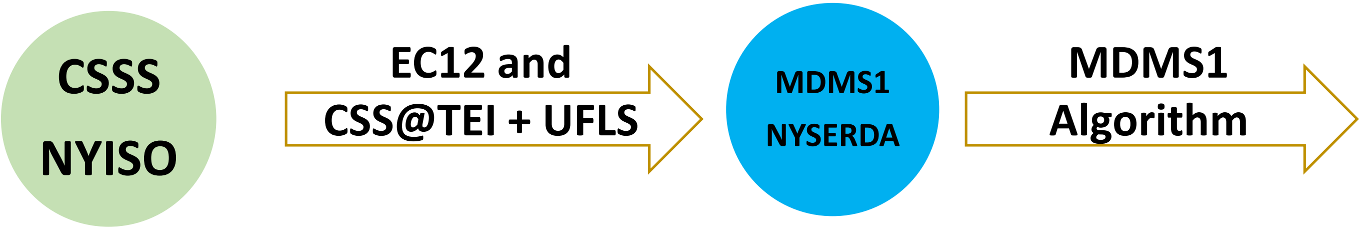
Executive Summary- Technical issues/challenges

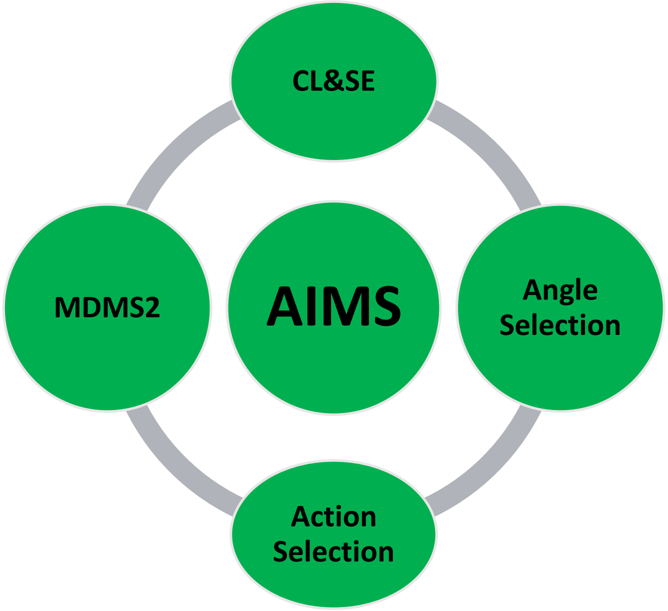
- Tuned and resolved numerous simulation/modeling issues related to EI, NEI, HVDC, IBR, protective actions and system balancing post CSS.
- Modeled high level of IBRs penetration to stress the NYCA system.
- Improved the performance of two-stage Kalman filter MDMS2 algorithm under high level of noises throughout disturbances
- Implemented a close-loop, PSSE-in-the-loop complex AIMS via Python scripts for testing and simulation.

Future MDMS Work

- MDMS2 project has achieved the target and beyond. However, more work is warranted before field implementation:
  - To assess IBRs impact to NYCA reliability in a 100% carbon neutral scenario
  - To further develop the disturbance location and severity estimation (CL&SE) concept and methodology so that it can work under different types of disturbances
  - To test AIMS on a real-time simulation system setup (e.g., Hardware-in-the-loop like the NYPA AGILe) with an AIMS pilot implementation on a real-time platform
  - To embrace generator and line protective relays for interactions and coordination.







Closing Remarks
Project Accomplishments

- **Forum for TO, NYISO and NYSERDA participation via monthly calls, face to face meetings and project reports**
- **Initial look at impact of IBR's**
- **Response of 2022 system to extreme contingencies and interface loading**
- **Advancement of protection concepts for NYCA**
- **Achieved <u>all</u> Project Objectives!**

Suggested Next Steps

- **System is changing with transmission additions as well as moving toward a carbon free future**
- **Focus should shift toward stability challenges facing the NYCA toward 2025, 2030 and beyond**
  - **Building future system base scenarios**
  - **Building and testing DER models specific to NY projections**
  - **Testing resiliency, identifying needs, informing rules.**