Attachment #11.2
Return to Agenda

MDMS2 Project Status Report

Update 6/14/19

General:

Task 4 (testing) is complete. The final face to face meeting was held at the NYISO on May 23. A presentation of the project is planned for the July EC meeting. A brief overview:

- **Created stressed cases from 2022 base case**
- **Modeled projected inverter-based resources (IBR) with protections in the stressed cases**
- **Re-dispatched resources with a high level of IBRs to stress the targeted interfaces**
- **Assessed the impact of IBRs during contingencies and after the controlled system separation (CSS) actions**
- **Created a Northeastern Interconnection (NEI) case**
- **Evaluated NEI's ability to withstand NEI internal contingencies**
- **Improved/developed instability detection/ prediction algorithms using PMU voltage measurements to estimate contingency location**
- **Improved the performance of a continuously run true two-stage Kalman filter MDMS2 algorithm under high level of noise**
- **Investigate additional mitigation measures, such as HVDC modulation, capacitor tripping, and immediate load shedding**
- **Implemented and tested an Angular Instability Mitigation Scheme (AIMS)**

Progress vs SOW:

Task 2-Review Prior Work and Simulation Case Development

Task 2.1 **Prior Work** - Completed

Task 2.2 **Case Development –**

The 2022 base case has been received from the NYISO. The case is being updated to include DER Inverter based resources per the Gold Book. This includes behind the meter resources as well as BES connected resources. The base case, as received, does not contain UFLS modeling. Quanta to check with the NYISO. First, the updated case **without DER resources** added will be stressed with EC 12 to check for instability as was observed previously with the2015 model. Then testing will be performed with added DER per the NYISO gold book and the IBR queue.

Extensive updates and testing of the modified 2022 base case have been performed the previous period. First, the base case was tested using the complete set of 73 NYISO extreme contingencies. Of these roughly 20 of the cases could not be solved for a variety of reasons including problems with contingency definition errors and problems with user defined FACTS models. These were resolved with help from the NYISO and stable results werw achieved for all of the extreme contingencies.

At that point the case , as dispatched was lightly loaded with regard to key interfaces. To add stress, existing wind generation was increased from 11% to 55% to increase the loading of the interfaces with Central East loaded at 88%. The EC 12 case was run and showed the same instability as was observed with the MDMS project using no mitigation actions. Various other exploratory tests were performed to validate the behavior of the 2025 model. The next step was to add DER consistent with expectation, as outlined below and perform further tests.

With regard to Inverter Based Resource Models to be used in simulations, existing PSS/E models will be used as follows:

- Grid connected utility-scale IBRs:
  - Wind: generic Type 4, version 2, wind generator (WT4G2) and electrical control model (WT4E2)
  - Solar: generic generator/converter interface (REGCAU1), electrical controls model (REECBU1) and plant controller (REPCAU1)
    - Note: NERC PRC-024-2 voltage ride through settings will be used, which is coordinated with the Category II setting of the IEEE Std 1547-2018.
    - Note: Momentary cessation will not be modeled for utility-scale IBRs per NERC guidance
- BTM Solar IBRs:
  - Converter model (REECAU1) connected in parallel with the composite load model
  - Category I of the IEEE Std 1547-2018 voltage ride through settings will be used to model the worst-case scenario to evaluate the impact caused by the loss of IBRs during major disturbances.
    - Note: Momentary cessation could not be fully modeled with current PSS/E generic model REECAU1 or REECBU1. Both models are unable to fully model the Category III settings of the IEEE Std 1547-2018.
- Base Dispatch:
  - Utility-Scale Wind will be dispatched at **10%** of the installed capacity (note per recent NYISO presentation, July capacity factor is 15%)
  - Utility-scale Solar will be dispatched at 15% of installed capacity
  - BTM Solar will be dispatched at **15%** of installed capacity (per recent NYISO presentation BTN solar is running at 17% in July)
  - A sensitivity case will be created to dispatch BTM Solar at **80%** of the installed capacity for evaluating the impact at high IBR output condition.

Impact of selected contingencies on inverter based resources will be evaluated as a next step. Impact of the selected contingencies is currently under investigation.

During the recent DER workshop it was confirmed that there is a limitation of existing PSS/E inverter-based resources (IBRs) models. It has confirmed by modeling experts attending the workshop that existing PSS/E standard models are not capable of allowing such resources to be controlled during the simulation runs, which is consistent with Quanta's initial assessment. Developing a customized model would divert too much resource and efforts away from the main tasks of this project, and there is a high risk the developed model may not function as desired. Considering this, it was agreed that exploring the possibility of controlling IBRs as a new mitigation measure for major disturbances will be postponed until appropriate PSS/E models become available.

A separate case was developed to model **the Northeast Interconnection** which includes NY, New England, the Maritimes and Ontario. This Interconnection will be connected to the rest of the Eastern Interconnection using HVDC ties.. Impact of selected contingencies on inverter based resources will be evaluated as a next step for this configuration also.

Task 2.2 simulation testing is now complete. Results have been obtained for the full Eastern Interconnection topology (EI) as well as fir the Northeast Interconnection Topology (NEI). For the EI, cases without and with IBR's were performed. IBR's associated with DER were dispatched at a high level (3430 MW wind, 1870 MW of BPS solar and 2900 MW of behind the meter solar) to stress the case.

Relative to the EI topology:

1. Four extreme contingencies were tested:
    - Internal - NY transmission loss
    - External - Ontario transmission loss
    - External - NE (Loss of 2000 MW)
    - External -l PJM transmission loss

   For each of the contingencies tested, the appropriate interface was stressed at levels on the order of 90%.
2. Results for the extreme NY contingency remain unstable while the results for all of the external contingencies are stable. Note with the 2015 model tested in MDMS1, the external Ontario contingency was unstable. Results indicate that NY additions included in the 2022 model being used in MDMS2 make the NY system more robust.
3. With the addition of the IBR's associated with DER, it was assumed that if the voltage in a given area went below 90%, the DER in that area would stop generating due to momentary cessation.

   The internal NY contingency case remained unstable while the external contingency cases remained stable . Note that DER were lost for the NY case but remained online for the external cases. Generally, the addition of IBR's has little impact on the performance of these extreme contingency cases.

Relative to the NEI topology:

1. Three extreme contingencies with IBR's added were tested:
   - Loss of large NY generation (2600 MW)
   - External - Ontario transmission loss as above for EI
   - External – NE (loss of 2000 MW)
2. Of interest is that the results were stable for the loss of the 2000 MW in New England but were unstable for the other cases.
3. In Task 3, mitigation measures to be tested for this topology will include modulation of the connected HVDC power levels to see if this measure can stabilize the configuration for the contingencies that produce unstable results.
4. Attempts at a complete implementation of the NEI by introducing a back to back tie at Ramapo have been unsuccessful to date but effort in this area will continue. Due to resource constraints and the complexity of getting the case to work, this has been abandoned in order to concentrate on Task 4.

Task 2 **Reporting**

A report on Task 2.1 has been released. A report on Task 2.2 (Case Development) has been issued and released. This completes the reporting on Task 2.

Task 3- Instability Detection Algorithm and Mitigation Measures development

Task 3.1 **Algorithm Development**

The MDMS instability detection algorithm and associated test cases were transferred from Enernex to Quanta via the NYISO secure site. Cases run on Quanta's computer matched those performed by Enernex for MDMS validating the correct transfer of code. Improvements to the instability detection process are under consideration including sampling before the event, wider separation of PMUs, algorithm simplification plus use of local protection to achieve additional security.

In addition, a concept of detecting severe external events using PMU data from neighboring areas is under development. The concept will involve preventative action that can be taken by operators for slowly evolving situations as well as automatic actions for rapidly evolving events and contingencies.

The Python scripts (program code that simulates the instability detection algorithm and mitigation measures) developed during the MDMS project will be moved from MDMS cases to stressed 2022 cases with added inverter-based resources for algorithm testing and validation on the 2022 cases.

The MDMS1 algorithm was reviewed in detail. The work included running the algorithm before the event to see its response as MDMS1 simulation testing only considered post fault operation. Issues associated with operation during the fault indicated some potential shortcomings in the response of the MDMS1 algorithm. Additional work involved implementing and testing a Kalman filter/predictor algorithm to overcome some of these difficulties. Testing involving angle difference included: spacing PMUs bracketing an interface with wider geographic spacing as well as averaging pairs of PMUs on either side of an interface. In addition, the concept of looking at PMU data at strategic single locations, as opposed to angle differences, is also being tested. Work continues and further results will be presented at the March 7 face to face meeting.

Results for task 3.1 presented at the March 7 face to face meeting are summarized as follows:

- It was confirmed that the MDMS1 algorithm is not suitable for continuous running on a precontingency basis as it is prone to major prediction errors relating to the angle discontinuities that arise in fault situations.
- The 2 Kalman filter predictor method was developed and tested. Improvements were made to improve performance under fault induced discontinuities.
- Various PMU combinations and locations were tested in search of enhanced predictability and redundancy. It was shown that moving the PMUs further from the interface enhanced predictability. PMU redundancy was also explored.
- The random noise model used in MDMS1 was reviewed and the amplitude judged to be excessively large. Quanta suggested reducing the one sigma value from 5.7 degrees to 1.14 degrees based on amost likely source being due to harmonics generated by inverters connected to the BPS. Further verification is best done using real time digital simulators along with actual PMUs.
- Use of local relays for redundancy was also discussed with some potential issues identified. A writeup of limitations of this approach will be included in the report along with another concept of attaining the required redundancy.

Task 3.2 **Mitigation Measures**

Work continues. Work on reviewing CSS measures as well as generation tripping at strategic locations has begun. Further results will be presented at the face to face meeting.

Results presented for Task 3.2 at the face to face meeting are summarized as follows:

- The worst case internal extreme contingency was used in all the preliminary testing discussed below.
- For the 2022 model with inverter based resources and CE loading, Tripping various combinations of generation in the Oswego area was explored. 9M PT 2G has the biggest single impact on stability and tripping it post contingency can stabilize the system for this contingency.

- CSS of TEI under CE loading with UFLS was performed with the MDMS1 case (2015) to establish a basis for comparison. Validation results matched those obtained for MDMS1.
- Then the 2022 model with inverter based resources with CE loading was tested. Results indicated that CSS with UFLS could not stabilize this system. Note for this case, inverter based DERs in the area of the fault are **not** tripped due to low voltage.
- The above retested but with some IBRs retained and stable results were obtained.
- HVDC modulation on the DC ties was tested and shown to be a stabilizing influence.

Task 3 **Reporting**

A draft report has been issued (partial 3.1) on the assessment of the MDMS work . Some shortcomings and potential improvement areas were noted. Final drafts have been completed.

Task 4- Testing

Task 4.1 Testing of Detection Algorithms and Mitigation Measures

The concept of using PMU voltage magnitude information has been added to the detection algorithm in order to provide an indication of fault location in relation to a given critical interface. Given this information, angle information across the interface can then be used to determine an appropriate mitigation measure. This concept will be implemented and tested with stability runs.

The algorithm for determining the appropriate interface for a CSS mitigation was implemented and tested using Python code to automate the PSS/e stability simulations. The overall scheme is referred to as the Angular Instability Mitigation Scheme (AIMS). The EC12 case was used for the "proof of concept" testing.

- **The MDMS2 phase angle algorithm was actively predicting angle trajectories for 22 PMU locations**
- **The voltage based contingency location algorithm was monitoring PMU voltages at the 22 locations**
- **Upon detection of a fault, the location with the deepest voltage depression provides an estimate of the fault location**
- **In this case the Total East interface was selected as the interface for CSS.**
- **The testing verified successful operation of the AIMS for 2 cases:**
    - **EC 12 for 2025 with IBRs. For this case the Central East interface is heavily load with IBRs to the North of the interface. AIMS performed as intended but in spite of the mitigation, the system could not be stabilized.**
    - **The case above, which simulates delayed clearing due to a stuck breaker, is an extreme contingency. To test AIMS for a less extreme case, the clearing time was reduced to a normal value. Again, AIMS performed as designed and stable results were achieved.**

The development of the AIMS concept is a substantial achievement of this project. Future work could involve extending AIMS to include other mitigation measures, in addition to CSS, like generation rejection and/or DC modulation and/or other control schemes throughout the NYCA.

Task 4-**Reporting**

A report for Task 4 is in progress and a draft should be available soon.

Task 5-Technology Transfer

The major portion of technology transfer has been achieved through involvement of the team members (the NY TOs and NYISO Operations) in monthly status meetings as well as the face to face meetings. Detailed technical reports for the various tasks have been uploaded and shared vie the NYISO operations secure econnect site. In addition the plan is to prepare 1 or 2 transaction/conference papers on the impact of inverter based resources on power systems under extreme contingency conditions.

Task 6- Final Document

The individual task reports will be used as the basis to draft a non-CEII final document.