Suggested MDMS Phase 2 Study Scope Outline

Draft 06/03/17 ges

The purpose of the second phase Major Disturbance Mitigation Study (MDMS), hereafter MDMS2, is to investigate other types of potential major disturbances in addition to the major disturbances studied in the previous phase of MDMS (referred to as MDMS1). Specifically, a high level of wind and solar PV scenario was not studied in the previous MDMS1. Given the changing nature and scale of the disturbances brought about by the proliferation of inverter technologies due to renewable integration, it is critical for New York to investigate and develop mitigation methods to avoid and contain the impact of such disturbances to maintain the stability and resilience of the New York power system in the second phase of the MDMS. Additionally, the MDMS2 will explore practical implementation aspects of mitigation methods, including those investigated in the MDMS1 by utilizing the PMUs deployed in New York and the neighboring states.

The MDMS1 explored using PMU phase angle information from PMUs straddling New York's stability limited interfaces in an effort to predict impending dynamic (angular) instability of the New York system. Where a dynamic instability was predicted, controlled separation of key interfaces was tested to determine if the portions of the system could be stabilized. UFLS was simulated and where necessary, adjustments were made to achieve a stable result. This successful result was achieved using algorithms developed during the project which were implemented "on line" in stability simulations of the system. In addition, a concept was explored in an attempt to develop a fully independent and separate approach to achieve redundancy and security.

The MDMS1 results show promise but additional work building on these results is needed toward achieving building a New York state wide area protection system (WAPS) that can best mitigate the impact of major external and internal disturbances on the future New York system as well as avoiding any adverse impacts on its neighboring systems. Such a WAPS, using PMU based measurement to predict impending angular and voltage instability, must be highly secure against loss of customer load due to any misoperation of its own.

While the MDMS1 considered "industry standard" contingencies, a new evolving potential threat to system reliability emerges with increasing penetration of renewable resources and the impact of inverter technologies needed to integrate variable generation into the system.

The proposed MDMS2 project will reach beyond what was accomplished in MDMS1. In particular:

- Mitigation measures in addition to controlled separation will be considered
- A new topology where a Northeast Interconnection separated by HVDC from the remainder of the Eastern Interconnection will be tested.
- Substantial renewable penetration will be modeled and tested

In more detail, the potential areas of pursuit in MDMS2 include:

- **Consider increasing renewable DG penetration impact during and after major disturbances:** Although the impact of high penetration level of renewable generation during normal operation and fast cleared faults have been well studied, their impact during and after extreme/prolonged major disturbances have not been evaluated previously. With combined wind and solar PV installed capacity projected to exceed 15% of total installed capacity in New York state and its neighboring states in the next few years, and will reach a much higher level by 2030, the control and inverter reaction of these new types of generation resources to major system disturbances could be erratic and unpredictable, exacerbating the extent of the disturbances and leading to prolonged system recovery. An August 16, 2016 event in California taught a good lesson when 1178.33MW of solar PV scattered around hundreds of miles away dropped in response to a rather "normal" transmission line tripping and reclosing due to a forest fire.
- **Consider mitigation of voltage instability in addition to angular instability:** Major disturbances could also lead to situations where slow dynamic or voltage instability occurs. The high penetration level of renewable generation may further increase the possibility of voltage instability occurrence if the controls of the inverters are not "synchronized".
- **Consider additional extreme contingencies:** These events could include technical and human actions such as a terrorist attack, a gas pipeline rupture causing multiple gas fired plants out of services, or a severe weather event, which may result in the loss of a critical major substation, simultaneous loss of multiple transmission lines and generators, and so on.

The MDMS2 study will use forward New York state and surrounding regions transmission planning models in 2020 to 2030 with projected penetration level of renewable generation resources, and will consider other mitigation measures in addition to controlled separation of New York transmission system, such as:

- In addition to assess major disturbance mitigation methods primarily on the existing Eastern Interconnection topology, another system model will also be set up to explore major disturbance mitigation methods on a new topology where the Northeast is separated from the rest of the Eastern Interconnection by establishing a new, smaller synchronous interconnection which may be called as NorthEast Interconnection (NEI); this could possibly consist of New York, New England and the maritimes, and perhaps also Ontario. This regional synchronous interconnection NEI can be connected to the remaining Eastern Interconnection by means of asynchronous HVDC ties.
- Explore using existing SVC, HVDC terminal, and other FACTS device control systems of both existing and possible additional devices to stabilize post disturbance system or to increase synchronous torque and stability margin when the neighboring systems are

experiencing disturbances.

- Explore having WAPS directly interacting with controllers of the renewable generation resources for achieving desired mitigation effects for certain major disturbances

The MDMS2 study will further evaluate the feasibility and effectiveness of the contemplated mitigation measures to be implemented in the New York state WAPS under realistic implementation conditions, which include

- Simulation verification testing of proposed schemes should include latencies and delays of all devices in the chain of sensing and control including PMU's, data concentrators, computation delays, teleprotection delays, communication delays, relay delays and breaker operation delays.
- Include detailed modeling of TO transmission relay systems and UFLS.
- Consider suggesting modifications to TO relay systems which offer required reliability improvements.
- Develop redundancy concepts that would satisfy NPCC and NERC standards (e.g. NPCC Directory #7, NERC PRC-012-2) for wide area protection systems.

All told, this work requires a contractor with both very broad and in-depth expertise with regard to all aspects of system planning, protection and control, FACTS technology, PMU technology as well as dynamic and transient simulation capability. For reference, a summary of the MDMS1 findings (Attachment I) as well as the original scope of the MDMS1 (Attachment II) are provided below.

Attachment I – Overview of MDMS Project Final Report

MDMS Accomplishments

Filter/Prediction Algorithm

- Employs dual Kalman and Taylor series finite difference methodology-developed by this project
- Fully automated
- Tested PSS/E with dynamic stability cases
- Testing includes measurement noise and delays
- For stable cases- no false predictions
- For unstable cases- accurate, timely prediction

Mitigation Measures

- Controlled Separation of TEI (Total East Interface) and CEI (Central East Interface) tested
  - TEI “cleaner” but CEI lack of impact on J/K of interest
- UFLS operation simulated
  - Timing reduction required
- NY system successfully stabilized
  - Two very extreme cases
  - Requires UFLS operation
  - Requires reduction of UFLS timings

Added Security Measures Investigated

- Fully independent system using OOS relays
- PSS/e simulations indicated non-uniform response for all lines of the TEI so full confirmation not achieved
- Project scope limited further work in this area

Summary

- Instability Detection Algorithm Successful
  - Timely identification

- No false operations

- Mitigation Measures Successful
  - 2 Extreme Contingencies (1 Internal, 1 External)
  - Heavy Loading and Transfers
  - 2 Separation Interfaces tested
  - UFLS Required with modifications
- Full Redundancy Method Investigated
  - Based on completey separate approach
  - Shows promise but needs more work

Recommendations

- Enhanced expertise for future studies
  - System protection – in depth and current
  - HVDC/ FACTS modeling- controls to assist stabilization
  - NYISO AND TO commitment /involvement
  - NPCC and neighbor involvement/oversight
- Consideration of other approaches
  - Separation before the event by establishing new, independent synchronous interconnection in the Northeast
- Continuation of this research - funding
  - NYSERDA PON 3397 due 6/28?
  - Other?

Attachment II – Original MDMS Scope – Technical Sections

Task 2 – Review and Simulation Case Development

Task 2.1: The Contractor shall summarize the state-of-the-art analytical approaches on bulk power system phase angle stability and mitigation schemes of catastrophic disturbances for the New York bulk electric power system. The Contractor shall thoroughly review and analyze prior work including, but not limited to, the NYISO's controlled system separation scheme feasibility study report, the NYISO's 2003 blackout study reports, the New York control area defensive strategies study reports, the NYSRC working group meeting materials, and the Northeastern Power Coordinating Council oscillation study reports. The Contractor shall identify the pros and cons of the existing methodologies for proposing improved and/or new methodologies.

Task 2.2: The Contractor shall develop dynamic simulation cases for a wide range of disturbance scenarios for algorithm and methodology verification. The Contractor shall develop the dynamic simulation cases based on the existing NYISO's most recent representative system operating conditions in terms of generation dispatches, load levels, and transfer levels. The Contractor shall analyze disturbances consisting of those contingencies that are likely to cause instability, uncontrolled separation and possible major loss of load. The Contractor shall, in dynamic simulations, consider disturbance scenarios that consist of:

• Major External Disturbances – (1) extreme power flows through the NY system that result from cascading external transmission outages; (2) voltage collapse external to the NY system; and (3) "beyond criteria" losses of generation external to the NY system.

• Major Internal Disturbances – (1) extreme contingencies within the NY system, including the simultaneous loss of multiple transmission lines, multiple sequential loss of multiple transmission lines, multiple generation unit losses, (2) voltage collapse within the NY system, and (3) "beyond criteria" losses of generation within the NY system.

• Normal Disturbances – the single contingency events that the NY system is designed and operated to withstand and are included to test any control schemes that are developed in this study to insure that they operate properly.

Deliverables: Report detailing the findings and conclusions of the literature review, the dynamic simulations and disturbance scenarios.

Task 3 – Phase Angle Instability Detection and Mitigation Measures Development

Task 3.1: The Contractor shall develop algorithms for real-time and online detection of system angle instability. The Contractor shall utilize the capabilities of new measurement devices to design real-time and online algorithms that can predict impending phase angle instability in the New York power system. The Contractor shall take into account as many monitored system signals, including, but not limited to, generator phase angles and speed, electrical bus phase angles, electrical bus voltages, system frequencies, critical interface power flows, and circuit breaker statuses in defining proposed algorithms. The Contractor shall evaluate the performance of the proposed algorithms and verify their effectiveness in the dynamic simulations developed in Task 2.

Task 3.2: The Contractor shall develop mitigation measures to avoid adverse or even catastrophic impacts of large disturbances to the NY bulk electric power system. The Contractor shall improve the deficiencies of existing control schemes including, but not limited to, under-frequency load shedding, over-frequency generator settings, and controlled system separation. The Contractor shall investigate the coordination of the various protection systems and control schemes to develop effective mitigation measures for system stability improvements. The Contractor shall identify whether the system could suffer from reactive power deficiency or surplus following any mitigation scheme and develop corresponding reactive power compensation schemes. The Contractor shall evaluate the performance of the proposed measures and verify their effectiveness in dynamic simulations.

Deliverables: Report describing the developed detection algorithms and mitigation measures, compensation schemes. The report shall also include a description of the performance evaluation process and the verification of simulation results.

Task 4 – Testing of Algorithms and Mitigation Measures

Task 4.1: The Contractor shall test its proposed algorithm operations and mitigation measures against the disturbance scenarios developed in Task #3.

Deliverables: Report describing the major disturbance mitigation study test results and the analysis of these results along with findings, and conclusions.

Task 5 - Technology Transfer

Task 5.1: The Contractor shall conduct all technology transfer tasks to the Project Manager's satisfaction. Should the project's results differ from the expected outcome, the Contractor shall be allowed to modify the technology transfer plan, with the Project Manager's approval, to facilitate appropriate technology transfer activities.

Deliverable(s): Completion of all technology transfer activities approved by NYSERDA's Project Manager. The Contractor shall hold a workshop to present the results and findings.