ELECTRIC POWER RESEARCH INSTITUTE

A Controlled System Separation Scheme and Related Dynamic Studies for New York State Transmission System Using Synchrophasors

(Proposal for DOE FOA-0000036)

Prepared by

George Smith, NYSRC EC

and

Kai Sun, EPRI
ksun@epri.com
650-855-2087

June 25, 2009

A. BACKGROUND

Presently, power systems are being operated closer to security limits than before in order to meet the requirements of rapidly growing electricity market. There is a higher probability that unexpected tripping of system elements may cause cascading outages or inter-area out of step in a power system and even lead to unintentional system separation. That may create unsustainable electric islands, where large-area power outages will happen. When system separation is unavoidable, the control center separating the system in a controlled manner (e.g. performed by an automatic separation program controllable by the system operator) can generally form electric islands with a better chance of surviving if in each formed island, imbalance of generation and load and instability of generators are strategically avoided to the minimum degree. Meanwhile, the under-frequency load shedding (UFLS) program can arrest frequency decline within each island.

Recent studies performed by the dynamics (SS-38) working group of the NPCC have determined modifications to the UFLS program required to arrest frequency decline within sub areas or islands within the NPCC. The concept assumes that the system will form islands automatically although at present there is no protection system within the NPCC for controlled separation. The Defensive Strategies Working Group (DSWG) of the NYSRC has been working on ways to mitigate the impact of major disturbances on the New York Control Area (NYCA). A main objective to determine the best way to utilize synchrophasor technology to enable controlled system separation, i.e. active formation of electrical islands, around and/or within the NYCA to minimize any adverse impact resulting from major disturbances and ensure prompt system restoration.

In a power system, the two issues are important for controlled separation:

- Where? That is to determine separation interfaces to form islands. Coherent generation groups, load/generation balance, and other security criteria, e.g. avoiding overloading of any transmission line within islands, need to be considered to determine separation interfaces. In addition, consideration should be given to whether the separation interfaces are topologically fixed or adaptive to changes of (1) power-flow profiles or (2) coherent generation groups. Due to topological characteristics of the system, generators tend to form coherent groups oscillating with each other under disturbances. Those coherent generation groups can be studied offline using, e.g. slow coherency analysis technology. However, the actual out-of-step mode may not be angular separation between all those offline identified groups, e.g. perhaps only one or two groups become out of step from the rest ones. Therefore, the separation interfaces should be able to only separate actual out-of-step groups. If two generation groups that are offline identified keep coherent, they could be put into the same island. Thus, separation devices should be installed at all potential separation points, which are able to isolate any single coherent generation group identified offline. The actual separation interfaces will be a set of separation points depending on the actual out-of-step mode.

- How? Determine conditions/criteria for determining the **need** to take actions and what actions or what interface **locations** require separation. The control action will primarily be the result of differential synchrophasor measurements taken at two or more points in the system. The measurements will reflect the emerging instability ("out of step') of coherent generation groups with regard to each other. The controlled separation criteria may involve rapid processing of differential angle rates or even accelerations of differential angles. As such, the approach may require dedicated distributed processing power at key locations. Note – synchrophasor measurements will be required from areas surrounding the NYCA.

- When? That is to determine when, in the out of step cycle, the separation needs to occur after the separation interfaces are already decided and the need for a separation is determined by the separation criteria. Generally, controlled separation could be implemented when out-of-step of coherent generation groups is credibly predicted. Synchrophasors can help monitor oscillations between coherent generation groups and predict the time when out of step may occur. Based on that information, the separation timing should be reasonably proactive in order to minimize adverse transient reactions and the chance for equipment damage. In the event that out of step conditions can not be predicted ahead of time, the best time for separation during the out of step cycle needs to be determined. Therefore, to answer the question "When", first, synchrophasors should be available at critical locations to monitor oscillations and predict out of step, and second, separation criteria need to be developed to determine the need for controlled separation.

In addition, some other issues (e.g. how to design and coordination of separation devices to create designed islands) also need to be addressed.

Since 2008, EPRI has launched multi-year base projects to investigate and develop technologies that can help perform controlled system separation and reduce the impacts of cascading outages and out-of-step of generators. In 2008, industry practices and the state-of-the-art technologies in this area were investigated. EPRI is performing both analytical and simulation studies to develop a synchrophasor-based controlled separation scheme that integrates appropriate and practical technologies to address key separation issues especially "Where", "How" and "When".

B. SCOPE OF WORK

The objective of this work is to develop a controlled separation scheme for New York state transmission system, which will address where, how and when to separate the system.

EPRI project team will perform both analytical and simulation studies to address the following issues for New York state transmission system:

1. Potential separation points in New York state transmission system.

According to coherent generation groups, which can be identified offline, as well as typical power-flow profiles, the separation points that can isolate each coherent generation group and minimize generation/load imbalance will be determined to address issue "Where". The profiles considered in the analysis will include N1 generation/load profiles and N2 import/export scenarios. Those potential separation points will be the locations to install separation devices. It is also possible that actual separation points could be online determined among those potential ones according to the out-of-step mode. This possibility for "adaptive" separation points will be considered in the study.

2. Recommended synchrophasor locations

The proposed controlled separation scheme will utilize synchrophasors to online monitor generator oscillation and determine the timing of controlled separation. Existing synchrophasors in New York state transmission system will be sufficiently utilized. EPRI project team will also perform a study on locations of new synchrophasors that can help improve the performance of the scheme.

3. Criteria for determining the need for separation and the interface(s) where separation needs to occur

The actual out-of-step mode needs to be predicted online using synchrophasor data. According to the predicted out-of-step mode, actual separation interfaces can be determined by combining the separation points that can disconnect out-of-step generation groups. This scope includes developing criteria and an appropriate real time control/protection algorithm that are able to online determine the need for separation and the interface(s) where separation should occur. The developed criteria and algorithm will address issue "How" and afford a high degree of security for the New York Control Area. "False operations" should be avoided for all normal contingencies. The developed criteria and algorithm will utilize real-time synchrophasor data and may be deployed at the control center for the purpose of online oscillation monitoring and enabling/disabling the separation function.

4. Performing controlled separation in a timely manner.

Once the need of separation is determined, the timing of separation will be the point in the out of step cycle when the actual command to separate is triggered. EPRI project team will develop the criteria for determining the right timing of separation (i.e. addressing issue "When") in order to minimize the stresses on the system and minimize the potential for equipment damage. The developed criteria may be embedded into separation devices that are installed at potential separation points and can be coordinated using real-time synchrophasor measurements.

5. Coordination with the UFLS program and other remedial actions

EPRI project team will validate the controlled separation scheme by dynamic simulations and study how to coordinate it with the UFLS program and other remedial actions.

C. TASKS TO BE PERFORMED

The following tasks will be performed by EPRI project team:

Task 1: Review Previous Study Results and Collect System Data

Task 1.1: Review existing NYCA defensive strategies and related study results.

Task 1.2: Obtain and analyze system data including, e.g., power-flow data, dynamic data, a critical contingency list, and security criteria. Dynamic data should give an adequate consideration to existing protective relays, e.g., at backbone network and special protection schemes, e.g. UFLS program, in order to credibly simulate system behaviors in pre-separation stages and early stages of system separation.

Task 2: Determine Potential Separation Points

Task 2.1: Study coherent generation groups in New York state transmission system.

Task 2.2: Determine the separation points that can isolate each coherent generation group with matched load under the base study condition.

Task 2.3 Determine the how the base separation points vary as functions of generation/load and import/export variations

Task 3: Determine Synchrophasor Locations

Task 3.1: Review the information on existing synchrophasors in New York state transmission system.

Task 3.2: Based on the results of Task 2, determine the locations of synchrophasors for monitoring oscillations between coherent generation groups and predicting out of step. This will include locations in systems bordering the NYCA. Depending on timing, it may be necessary to determine these locations based on best engineering judgment as the allocation of locations may precede completion of this phase of the study.

Task 4: Develop Separation Need and Location Criteria

Task 4.1: Develop an algorithm to online determine the need for a separation and which interface(s) need to be involved in the separation according to the current generator oscillations monitored by synchrophasor measurements in real time. This to be done with consideration given to predetermined “fixed” interfaces.

Task 4.2 Explore the feasibility of determining floating or “adaptive” interfaces so as to minimize loss of load due to generation/load imbalances.

Task 5: Develop Separation Timing Criteria

Task 5.1: Develop separation timing criteria to determine the timing of controlled separation utilizing real-time sychrophasor measurements. EPRI project team may refer to the NPCC Document A-11, “Special Protection System Criteria”, and give consideration to coordinating controlled separation with existing special protection systems in NYCA.

Task 6: Validate the Scheme and Study its Coordination with the UFLS Program

Task 6.1: Validate the developed scheme on defined separation scenarios of New York state transmission system by means of dynamic simulations. The August 14, 2003 blackout simulation base case developed by the NPCC SS-38 working group will be used as a base. This base will include all modeling changes developed during the course of the blackout study. The “how” and “when” criteria and related algorithms will be included in the dynamic simulations. The objective of the base simulation is to determine the effectiveness of the controlled separation scheme had it been implemented prior to the 2003 blackout.

Task 6.2 Validate the **dependability** of developed scheme for a variety of other potential major disturbances originating outside of the NYCA. These will include uncleared faults and multiple outages outside all boundaries of the NYCA. This will include sensitivities for pre contingency variations in generation and load.

Task 6.3 Validate the **dependability** of the developed scheme for the most severe “beyond criteria events” that may occur within the NYCA. EPRI project team will work with NYISO to define such events, e.g. loss of an entire station or multiple line outages.

Task 6.4 Study the **operational security** of the developed scheme for major “within criteria events” to make sure that separations (misoperations) do not occur for stable situations.

Task 6.5: Study its coordination with the UFLS program and other existing remedial actions. As part of Tasks 6.2 and 6.3, the NPCC UFLS program changes determined by the SS-38 working group will be implemented in the dynamic simulations to ensure proper coordination.

Task 6.6: Perform the risk-benefit analysis for a separation scenario to assess and discuss the consequences of a misoperation or failure to operate versus the rewards of successful system separation. Reference will be made to the SPS application criteria in the NPCC Document A-11, “Special Protection System Criteria”.

Task 7: Deliver Study Results

Task 7.1: Deliver a technical report to document the developed scheme and its validation results.

Task 7.2: Report study results by project review meetings

Task 7.3: Organize 1~2 technical workshops for technology transfer.

D. DELIVERABLES

The deliverables of this proposed work will include:

1) Technical report (possible progress reports or white papers)
2) 1~2 Technical Workshops

E. SCHEDULE

Task	Description	Start Date	Completion Date
1	Review Previous Study Results and Collect System Data	Month 1	Month 2
2	Determine Potential Separation Points	Month 3	Month 6
3	Determine Synchrophasor Locations	Month 6	Month 7
4	Develop Separation Need and Location Criteria	Month 8	Month 10
5	Develop Separation Timing Criteria	Month 11	Month 13
6	Validate the Scheme and Study its Coordination with the UFLS Program	Month 14	Month 26
7	Deliver Study Results	Month 27	Month 28