Most Severe Single Contingency (MSSC) Impacts on Alberta Balancing Authority Area Operation

Observations and Information Sharing

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Executive Summary

The purpose of this paper is to summarize the issues identified by the Alberta Electric System Operator (AESO) as a result of its initial review of current operating practices that take into account the Most Severe Single Contingency (MSSC) to ensure the overall reliability of the Alberta Interconnected Electric System (AIES). This paper is being made public for information purposes.

The AESO operates the AIES in compliance with Alberta Reliability Standards (ARS), ISO rules and various other industry standards. This operation must take into account, among other requirements, the consequences of the MSSC in terms of supply to the AIES. As the AIES continues to grow and expand, the generation supply market is considering the installation, as evidenced by system access service applications, of larger generating units, some much larger than the current largest single generating unit of 466 MW. The installation of larger generating units would have some operational consequences which must be managed in real-time.

Since 1985, the AIES has had a strong electrical interconnection with British Columbia (BC) via a single 500 kV AC transmission circuit in parallel with two 138 kV AC transmission circuits. This AC interconnection with BC was further enhanced with the commissioning of the 230 kV AC transmission line to Montana in 2013. The reliability of the AIES has been enhanced by having the AC interconnection to BC and through it, a connection to the larger western interconnection.[1] Alberta, by virtue of this interconnection with other systems within the WECC, is able to minimize frequency deviations following supply contingencies as the supply shortfall is immediately made up through increased import power flow. This form of operation is typical of many balancing areas including the four examples (ISO New England, Manitoba Hydro, PJM, and ERCOT) presented in Section 4 of this paper.

The AESO will be required to adjust its operating procedures, in particular intertie operations, with the addition onto the AIES of larger generating units or a combination of generating units. The addition of larger generating units would possibly result in a reduced level of available transfer capability (ATC)[2] on the AC interconnections. The AESO would potentially also be required to procure an increased volume of contingency reserve in order to ensure the AIES would continue to be operated in a manner that provides a satisfactory level of service and in compliance with reliability standards.

1 Background

The AIES continues to grow at a significant pace and includes new generating units of varying sizes and technologies. The AIES has a current installed capacity of 16,159 MW[3] made up of predominately coal-fired (6,271 MW) and gas-fired (7,151 MW) generation. The current largest single generating unit is a coal-fired unit rated at 466 MW.

1.1 History

Prior to 1985, Alberta was weakly connected to the BC (and subsequently WECC) system via two 138 kV transmission lines. The 500 kV AC interconnection has provided Alberta, among other benefits, a significant level of power frequency stability. Prior to the commissioning of the 500 kV AC interconnection, the AIES routinely (up to several times per month) experienced underfrequency excursions upon the loss of any interconnected generator greater than 100 MW. The loss of a generator greater than 100 MW typically led to the tripping of the 138 kV interconnection with BC and consequently an underfrequency event on the AIES. The loss of a 350 MW generator prior to 1985, for example, typically led to an

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[1] The AESO's *Consolidated Authoritative Document Glossary* (CADG) defines "western interconnection" as "the area comprised of those portions of western Canada, northern Mexico and the western United States in which members of the [Western Electricity Coordinating Council] operate synchronously connected transmission system".
[2] Per the CADG, ATC means "the remaining transfer capability the AESO determines can be commercially available for transfers over the interconnected transmission network over and above already committed uses".
[3] See the AESO's Load Demand display for details regarding the rating of individual generating unit on the AIES; – see http://ets.aeso.ca/ets_web/ip/Market/Reports/CSDReportServlet

underfrequency excursion below 58.9 Hz with various interruptible load contracts in conjunction with operating reserve utilized to support frequency recovery. Prior to 1985, the utilities in Alberta had a number of interruptible load contracts with several industrial customers that included underfrequency load shedding. This program was designed to avoid firm load shedding following the loss of the Alberta Balancing Authority Area MSSC. Frequency recovery was assisted through the application of the appropriate levels of operating reserve (including regulating, spinning and supplemental). In 2013, the Alberta AC interconnection to the other jurisdictions within WECC was further enhanced with the commissioning of the Montana 230 kV interconnection. Currently, when the BC interconnection is tripped or taken out of service, the Montana interconnection is also tripped or taken out of service, thus the loss of the BC interconnection and the Montana interconnection are considered a single contingency[4]. The AIES has an interconnection with SaskPower in the form of a +/- 150 MW DC back-to-back convertor station. However, the MSSC does not impact transfer capability on the SaskPower interconnection given that the interconnection is a DC connection. On this basis the SaskPower DC tie is not particularly relevant to the MSSC discussion.

1.2 Most Severe Single Contingency Defined

The word "*contingency*" is defined in the AESO's *Consolidated Authoritative Document Glossary* (CADG) as the "unexpected failure or outage of a system component, such as a generating unit, transmission line, circuit breaker, switch or electrical element". MSSC is not defined in the CADG, however, MSSC refers to the most severe single contingency generator or supply loss on the AIES which may occur as a result of a generator trip or the loss of a transmission line that subsequently leads to the simultaneous loss of generation. The MSSC on the AIES may vary, depending on generator unit output or transmission configuration, and is closely monitored in real-time by the AESO system controllers. The MSSC is currently at a value of approximately 466 MW under a normal transmission system configuration. The MSSC could be less depending on the status of the generator (i.e., depending on the output to the system of the particular generator) or could be greater depending on the transmission system configuration.[5] The value of MSSC could also be larger if the MSSC is associated with a large import on the AC interconnections. However, depending on the availability and effectiveness of load shed service for Imports (LSSi), the effect of the loss of a large import can be mitigated through the application of LSSi (i.e., if the frequency drops below the LSSi trip setting) and shift the MSSC from being the AC interconnections to being a large generating source within the AIES.

1.3 Alberta Balancing Area Obligations and Compliance

The AESO is obligated to comply with ARS to ensure overall system reliability. A number of ARS refer to balancing area operations and monitoring of the MSSC. As referenced in BAL-002-WECC-AB-2 and BAL-002-AB-1 *Disturbance Control Performance* establishes a number of requirements and measures associated with disturbances involving supply loss. The purpose of this ARS is to ensure that the AESO is "*…able to utilize its contingency reserve to balance resources and demand and return interconnection frequency within defined limits following a disturbance resulting from a loss of supply*."[6] The AESO must "*…have access to at least enough contingency reserves to cover its most severe single contingency*".[7] In view of ARS BAL-002-WECC-AB-2 requirements, the AESO's balancing area contingency reserve levels exceed the MSSC under normal operating conditions. ARS BAL-STD-002-AB-0 – Contingency Reserve establishes requirements to ensure that the AESO has the necessary contingency reserve to meet the requirements of the Western Interconnection. ARS BAL-STD-002-AB-0 requires that 50% of the contingency reserve must be spinning. The AESO may meet these obligations through participation in a reserve sharing group as further described in Section 3.5. The amount of reserve the AESO carries at

[4] Since the flows on the BC interconnection would immediately be superimposed on the MATL interconnection following the loss of the BC interconnection and the combined BC and MATL flows would greatly exceed MATL rating, the MATL interconnection is automatically tripped to prevent equipment damage.
3[5]An example of a certain transmission configuration determining the MSSC includes the 500 kV Keephills-Ellerslie-Genesee area loop wherein an outage of a 500 kV line leaves the Genesee power plant on a radial connection.
[6] ARS BAL-002-AB-1 *Disturbance Control Performance* at section 1.
[7] Ibid. at section 3R3.

any given time is displayed on the AESO's web site in the Current Supply Demand Report.[8] The AESO has historically operated the AIES whereby following a trip of the AC interconnections at high imports, the AESO will reestablish frequency through the use of contingency reserve and other measures such as LSSi.

1.4 Alberta Balancing Area Operations

1.4.1 System Normal

Section 203.6 of the ISO rules, *Available Transfer Capability and Transfer Path Management* outlines the rules associated with establishing the Total Transfer Capability (TTC) and managing transfer paths. The simultaneous import TTC on the BC /MATL interconnection[9] is set taking into account Alberta's MSSC which may be associated with the loss of a generator or a transmission line which removes the large generating source and places the burden of the supply loss on the AC interconnection. The criteria being applied is based on the avoidance of loss of an AC interconnection as a result of the MSSC. A supply contingency internal to the AIES results in an immediate draw of power from the AC interconnections which would be superimposed on the already scheduled flow on those interconnections. If the combined flows (i.e., the scheduled flow and the immediate draw of power following the MSSC) were to exceed the AC interconnection capability the AC interconnections may trip and thereby compound the supply shortfall in Alberta potentially leading to automatic underfrequency load shedding. On this basis the AESO strives to preserve the AC interconnections by appropriately setting the simultaneous TTC to be able to accommodate the MSSC on the AIES. Please refer to ID #2011-01R *Available Transfer Capability and Transfer Path Management* for specific information regarding the impacts that the MSSC may have on intertie operations.

Planned transmission outages may result in the system being exposed to a single supply contingency that is larger than the MSSC under normal conditions. In such cases, the ATC is reduced through an increase of the transmission reliability margin[10] on the BC interconnection in order to ensure the interconnection is not lost in the event of the supply contingency. Restoration of interconnection schedules, and rapid frequency recovery following a supply contingency, is an important aspect of balancing area operations in order to ensure system reliability.

1.4.2 System Abnormal (elements out of service or supply emergencies)

Under abnormal system conditions, the import TTC on the BC and MATL interconnection is set while taking into account Alberta's MSSC. This may be associated with the loss of a generator or a transmission line which removes the large generating source and places the burden of the loss on the AC interconnection. The criteria being applied is to permit loss of an AC interconnection(s) as a result of the MSSC on the basis that a controlled separation scheme will trip the interconnection(s) in service. On this basis, the AESO strives to preserve the AIES off nominal frequency performance by appropriately setting the simultaneous import capability to be able to accommodate the MSSC on the AIES with the consideration of LSSi.

1.5 NWPP Reserve Sharing Arrangement[11]

The AESO is a member of the North West Power Pool (NWPP) Reserve Sharing Group and meets its obligations in regards to BAL-002-WECC-AB-2 *Disturbance Control Performance* and BAL-002-AB-1 through that arrangement. Attachment *K—NWPP Reserve Sharing Group Most Severe Single*

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[8] http://ets.aeso.ca/ets_web/ip/Market/Reports/CSDReportServlet
5 The BC/MATL interconnection is made up of two AC interconnections with Alberta; 500 kV and 138 kV to BC Hydro and 230 kV to Montana
[10] Per the CADG, "transmission reliability margin" means "that amount of transfer capability the AESO determines is necessary to ensure the reliable operation of the interconnected electric system taking into account uncertainties in system conditions and the need for operating flexibility".
[11] A copy of the arrangement can be obtained at http://www.nwpp.org/our-resources/NWPP-Reserve-Sharing-Group/NWPP-Reserve-Sharing-Program-Documentation

Contingency Tables (specifically Table 3) of the *NWPP Reserve Sharing Program Documentation*[12]—provides a listing of the typically reported MSSC in MW by members of the Reserve Sharing Group. The reported values of the MSSC range in size from 44 MW to 1,505 MW.

1.6 Underfrequency Load Shed Program

The AESO manages the Alberta underfrequency load shed program[13] in coordination with the NWPP and WECC and in compliance with ARS PRC-009-AB-0 *UFLS Performance Following an Underfrequency Event* and EOP-003-AB1-1 *Load Shedding Plans*. Firm load shed is set to begin when the system frequency drops to 59.1 Hz or if the frequency has not recovered to 59.3 Hz within 15 seconds or 59.5 Hz within 30 seconds of the initiating event. Therefore, the AESO strives to manage imports on the BC 500 kV interconnection such that following a single contingency trip of the tieline, underfrequency excursions on the Alberta system are limited to prevent firm load shedding by underfrequency protections. Similarly, when the Alberta system is operating islanded (i.e., separated from BC and Montana), the underfrequency load shed program is designed to limit large underfrequency excursions as a result of supply contingencies.

1.7 Typical System Response following MSSC Event

Appendix A provides some illustrative examples of dynamic response to various types of supply contingencies on the AIES. The examples illustrate the benefits (in terms of frequency stabilization) associated with strong AC interconnections.

2 Issue Identification

The AIES continues to expand in terms of load and generation additions with the most recent large generator addition applications involving gas-fired generating plants. Over the past number of years, the AESO has received a number of generator capacity increase requests. These requests were approved by the AESO as the units were proven compliant with the relevant generator capability standards. As a result, the MSSC reached its current level of 466 MW under normal operating conditions with all relevant[14] transmission facilities in service.

As the system and energy market grows, market participants are currently proposing the addition of generating facilities with unit sizes, or combination of unit sizes, exceeding the existing MSSC of 466 MW. These new proposed generation additions can be in the form of single electrical generators driven by two turbines (gas and steam) on a common shaft, or a combined-cycle configuration where the loss of a single gas-turbine may lead to the immediate loss of a combined-cycle train.

The AESO continues to assess, in collaboration with generation developers, the transmission system impacts of generating unit (or a combination of units) additions including the need for transmission reinforcements in order to enable the interconnection of the new generation. The result of this analysis culminates in the submission by the AESO of a needs identification document to the Alberta Utilities Commission for approval. The AESO has not placed any size restrictions on new generator proponents as the AESO continues to assess and establish the required transmission system enhancements to accommodate new generators, regardless of size. Where necessary the AESO may work with the new generator proponents to appropriately configure the interconnecting substation in such a way as to limit the impacts to the system as a result of generator forced outages.

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[12] http://ets.aeso.ca/ets_web/ip/Market/Reports/CSDReportServlet.

[13] The underfrequency load shed program is described in OPP-804 *Off-Nominal Frequency Load Shedding and Restoration* and is available from the AESO's web site at http://www.aeso.ca/rulesprocedures/9073.html

[14] Relevant transmission, as used in this context, are lines that provide redundant paths for large sources of supply

The AESO will be required to continuously adjust its operating procedures, in particular intertie operations and potentially quantities of contingency reserve, with the addition of ever larger generating units (or combinations of generating units) onto the AIES. The addition of larger generating units on the AIES will result in a reduced level of TTC on the AC interconnection.

3 Industry Practices Regarding MSSC

All balancing areas within North America, as required by North American Electric Reliability Corporation (NERC) standards, are required to monitor their MSSC and operating reserve levels and adjust their operating procedures accordingly as the MSSC values change in order to ensure reliable operations. The MSSC may vary from being a transmission contingency to a generating contingency. Balancing Areas with strong interconnections or simply large Balancing Areas are able to accommodate large values of MSSC more readily than entities with weak interconnections. Balancing Areas must carry sufficient levels of operating reserve in order to meet the NERC reliability standard requirements for control performance or frequency recovery. Information from the following organizations available through internet-based query has been examined in order to provide some examples of varying practices and magnitudes of MSSC.

3.1 ISO New England

ISO New England is considered a large interconnected system (about 13 major interconnections to systems in New York and Canada) and has a peak demand of approximately 28,000 MW and about 32,000 MW of generating capacity from approximately 350 generators. ISO New England's operating procedure, *OP 8-Operating Reserve and Regulation,*[15] describes the requirements for ensuring an adequate level of operating reserve is available on the system at all times. ISO New England indicates a typical MSSC magnitude of 1,200 MW. ISO New England typically acquires about 600 to 700 MW each of spinning reserve, supplemental reserve and replacement reserve. The largest single contingency in New England is generally the loss a nuclear unit or the power flowing from Hydro Quebec into New England over a DC transmission line.

3.2 ERCOT

The Electric Reliability Council of Texas (ERCOT) is the operator of the electric system in a majority of Texas having an approximate peak demand of 66,000 MW and a generating/supply capacity of approximately 75,000 MW. ERCOT has a number of HVDC interconnections and no synchronous interconnections with its neighboring jurisdictions. ERCOT has identified a MSSC of 1,375 MW[16].

3.3 Manitoba Hydro and MISO

Manitoba Hydro secures its contingency reserve through a contingency reserve sharing group agreement[17] with the Midcontinent Independent System Operator (MISO) and benefits from a 500 kV AC interconnection between Manitoba and MISO. Manitoba's MSSC is 1,000 MW (one of the HVDC poles interconnecting northern Manitoba generation with southern Manitoba load). MISO's MSSC is 1,500 MW.

3.4 PJM

The Pennsylvania-New Jersey-Maryland Interconnection (PJM) footprint is large and includes a number of large balancing authorities. In order to ensure compliance with NERC requirements for control

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[15] A copy of OP 8 may be accessed at http://www.iso-ne.com/rules_proceds/operating/isone/index.html
[16] Refer to http://www.ercot.com/content/meetings/fast/keydocs/2014/0307/CR%20Discussion%20Paper%20as%20of%20030514%201700.doc
[17] Some details of the arrangement is outlined in a 2010 presentation available at http://www.hydro.mb.ca/regulatory_affairs/electric/gra_2010_2012/Appendix%2056-Attachment_3.pdf

performance, various entities rely on reserve sharing arrangements. The MSSC may be as high as 1,300 MW for some balancing authorities. Some discussion regarding the management of operating reserve is available on the PJM website.[18]

4 Closing Remarks

In summary, the AESO has made a number of observations regarding MSSC. This paper is an information sharing piece and designed to make market participants, and to a lesser extent the public, aware of the current situation and possible future trends regarding MSSC. It is also designed to offer some context and history which should also assist in understanding the issues that have been identified.

The application of MSSC is not a scenario unique to Alberta – quite the opposite. As outlined above, it is a common issue across many jurisdictions as generators, as well as transmission interconnections, become larger and have a potentially greater impact on electrical systems.

The AESO is not suggesting any changes with respect to MSSC at this time, but anticipates that this paper may form the basis for future discussion with market participants and other stakeholders.

Should you have any comments or questions regarding this paper, please contact:

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[18] See the following link for some insights into PJM's overview of reserve requirements: http://www.pjm.com/~/media/training/nerc-certifications/RE1-reserve.ashx

APPENDIX A

Actual event recordings of AIES Frequency Response Following Major Supply Contingencies

CASE A: Figure 1 illustrates the AIES dynamic response following the loss of a large generator (approx. 390 MW) with the BC Interconnection intact. The generation loss is immediately made up by an increased import on the BC Interconnection resulting in a slight underfrequency excursion to approximately 59.93 Hz. The tie import schedule is restored within approximately 15 minutes through the deployment of operating reserve. MATL is out of service in the Case.

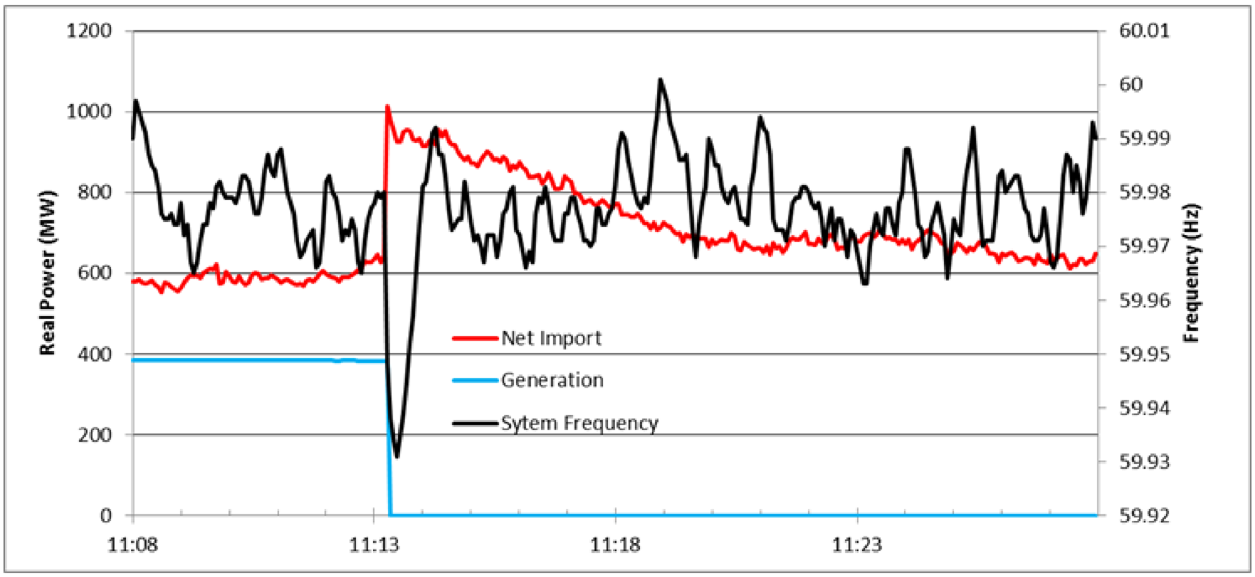

FIGURE 1: AIES Response following a supply contingency with the BC Interconnection intact.

CASE B: Figure 2 illustrates the AIES dynamic response following the loss of a large generator while the AIES is separated from the WECC system and operating as an island. The 425 MW generation loss results in an underfrequency excursion to approximately 59.55 Hz. The frequency is restored to approximately 60 Hz through the deployment of operating reserve within approximately 10 minutes.

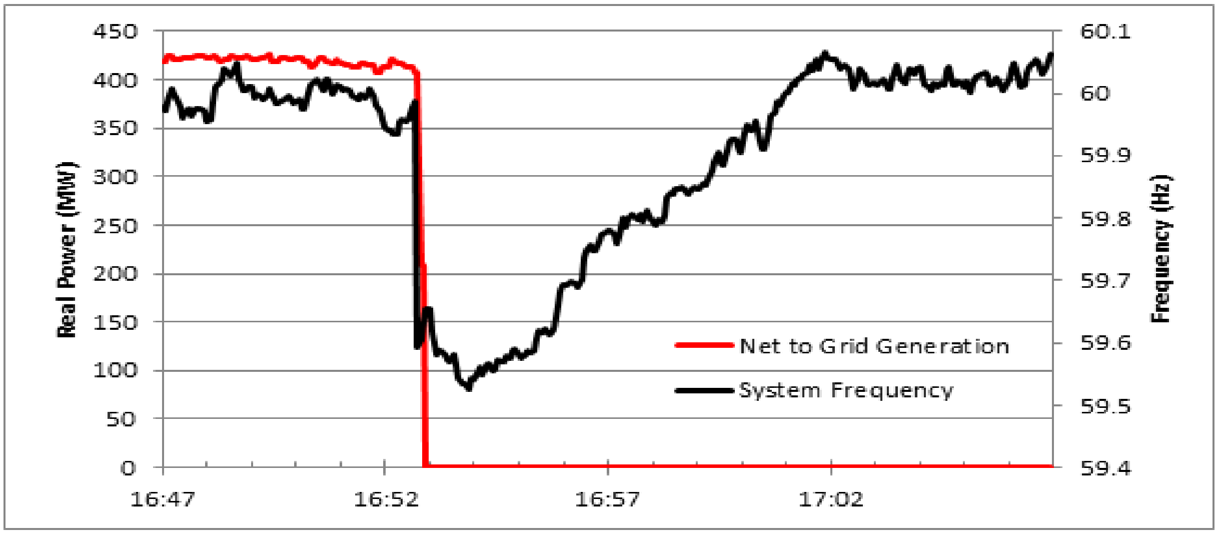

FIGURE 2: AIES dynamic response following a supply contingency with the BC Interconnection out-of-service.

CASE C: Figure 3 illustrates the AIES dynamic response following the loss of the AC Interconnections during import conditions. The supply contingency (approximately 450 MW) results in an underfrequency excursion to approximately 59.55 HZ which is restored to 60 HZ in approximately 12 minutes through the deployment of operating reserve.

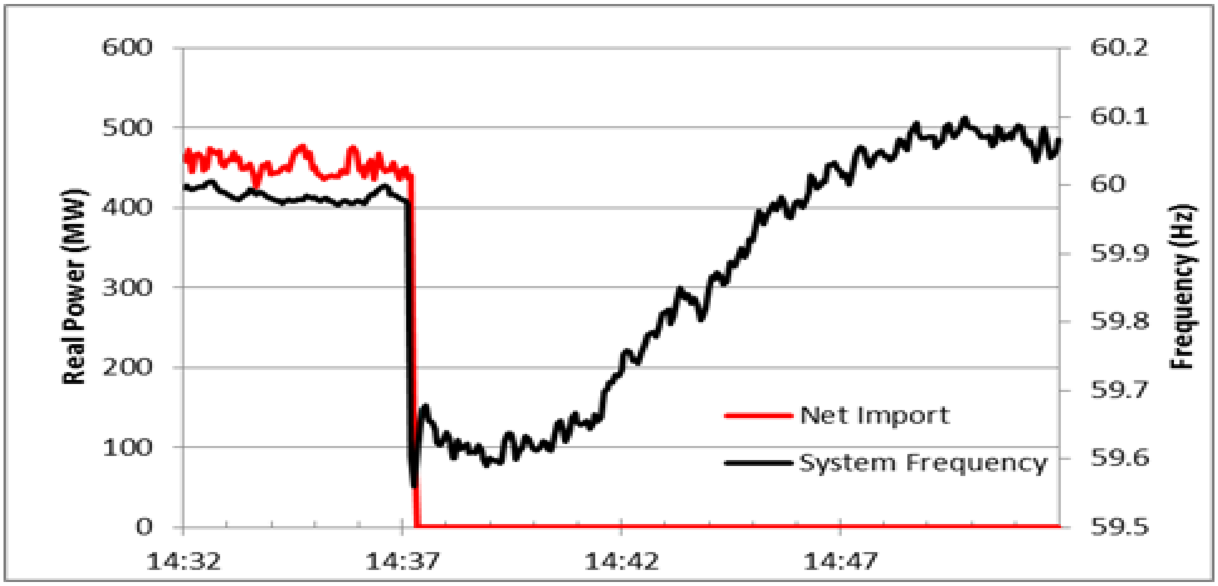

FIGURE 3: AIES dynamic response following the loss of a large import on the AC Interconnections