XXXXX

Meikle Wind Energy Project

Interconnection System Impact Study

Report no.: T&S Planning 2015 - 067

November 2015

British Columbia Hydro and Power Authority

Acknowledgements

This report was prepared and reviewed by T&D, Interconnection Planning and approved by both Interconnection Planning and Transmission Generator Interconnections.

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Executive Summary

XXXXX, the Interconnection Customer (IC), is proposing to develop the Meikle Wind Energy Project in the Peace Region of British Columbia to deliver electric energy to BC Hydro (BCH). The wind farm will consist of a total of 61 (General Electric (GE) Type 3) wind turbine units with a total installed capacity of 184.5 MW. The Point of Interconnection (POI) is at BCH's Meikle Terminal Station (MKT), which is a new station to be built for connecting this wind project. An IC owned 4.2 km, 230 kV transmission line will be used to connect the IC's 230 kV Meikle Wind station (MKL) to the POI. The maximum power injection into the BCH system at the POI, after internal losses and loads, is 181 MW. The proposed Commercial Operation Date (COD) for this project is November 01, 2016.

This System Impact Study (SIS) is a re-study of the previous Meikle Wind Energy Incremental Project. The previous SIS was performed in 2014 for the wind farm which was proposed with 62 (Siemens Type 4) wind turbine units and documented in a study report (T&S Planning 2014-008). After completion of the 2014 SIS, a Facilities Study report (TGI-2015-A110-FS-R1) was delivered to the IC in early 2015. This SIS report updates the previous SIS study conclusions and also includes the findings of analytical studies based on the submitted PSCAD models arranged by the IC.

This report documents the evaluation of the system impact of interconnecting the proposed generating facility and identifies the required system modifications to obtain acceptable system performance with the interconnection of the proposed project. To interconnect the Meikle Wind Energy project and its facilities to the BCH system at MKT, this SIS has identified the following conclusions and requirements:

- The Meikle Wind Energy project can be accommodated without requiring any Network Upgrades in addition to the Network Upgrades that have already been identified in the previous System Impact Study reports (T&S Planning 2014-008 and ASP2010-T058) and the Facilities Study report (TGI-2015-110-FS-R1) for the Meikle Creek Wind Energy project. The 2014 report can be found in Appendix C.
- Control revisions to the GE turbine were provided for the study. Those revisions listed in Table 4 must be implemented in the turbine hardware prior to operation or unacceptable oscillations and weak system interactions may occur.
- Some technique to reduce the inrush current, associated with Transformer Energization, is required in order to meet the voltage sag requirements as per BCH's "60 kV to 500 kV Technical Interconnection Requirements for Power Generators."
- Abrupt opening of 2L313 at Sukunka Switching Station (SNK), for either protective or non-protective conditions, requires the implementation of a Direct Transfer Trip (DTT) to disconnect MKL with the existing intentional (1 cycle) delayed opening of 2L313 at SNK to avoid high Temporary Over Voltages (TOVs).
- Application of area sacrificial Surge Arrestors (SAs), rated at 180 kV with disconnecting capability, is recommended at the MKT line terminal.

The work required within the IC's facilities is not part of the Interconnection Network Upgrades. The Interconnection Facilities Study Report (TGI-2015-A110-FS-R1) provides more details with the interconnection requirements and associated cost estimates for this project.

Table of Contents

1. Introduction

The project reviewed in this Interconnection System Impact Study (SIS) is as described in Table 1 below:

Table 1: Summary of Project Information

Project Name	Meikle Wind Energy Project		
Interconnection Customer	XXXXX		
Point of Interconnection (POI)	Meikle Wind Terminal Station – MKT		
IC Proposed COD	Nov 1, 2016		
Type of Interconnection Service	NRIS	☒	ERIS ☐
Maximum Power Injection (MW)	181 (Summer)		181 (Winter)
Number of Generator Units	61		
Plant Fuel	Wind Farm		

XXXXX, the Interconnection Customer (IC), is proposing to develop a 184.6 MW wind generating facility near Tumbler Ridge in the Peace Region. The project was previously studied in 2014, and the SIS results are documented in the study report, T&S Planning 2014-008. Before the 2014 study, a SIS documented in ASP2010-T058 was performed for a similar project with lower installed capacity. Detailed interconnection Network Upgrade requirements upon the 2014 SIS results have been documented in the Interconnection Facilities Study (FS) report: TGI-2015-A110-FS-R1.

The previous application in 2014 consisted of 62 (Siemens units – Type 4) Wind Turbine Generators (WTGs) fed off of seven feeders. XXXXX has revised their application and changed the wind turbine manufacturer and technology type. The wind farm will now consist of 61 (General Electric units – Type 3) WTGs fed off of six feeders with a maximum power injection of 181 MW into the BCH system. The queue position remains unchanged from the 2014 project.

The newly proposed Meikle Wind farm consists of a total of 61 wind turbine units. There are 35 units with a capacity of 3.23 MW each and 26 units with a capacity of 2.75 MW each. All 61 wind turbines are proposed with Type 3 technology, i.e. Doubly Fed Asynchronous Generator (DFAG) units. The total power (184.6 MW) generated from all 61 turbine units will be collected, via six 34.5 kV feeders, at two 34.5 kV, 3000 A buses in the Meikle Wind station (MKL). Located at each 34.5 kV bus will be a 15 Mvar capacitor bank for a total of 30 Mvar of compensation. From the two buses, the power is stepped up to the 230 kV system through two 100 MVA, 240/34.5 kV (high side Y-gnd) transformer units. The power will then be transmitted through an IC owned 4.2 km, 230 kV transmission line to a to-be-built BC Hydro's (BCH's) Meikle Terminal Station (MKT) for connecting this wind farm, which is located 23 km from Tumbler Ridge Station (TLR). MKT is the wind farm's Point of Interconnection (POI). The farm's maximum power injection into the BCH system, after losses and internal loads, is 181 MW. The proposed Commercial Operation Date (COD) for this project is November 01, 2016.

Due to the addition of the switching station MKT, the present circuit 2L313 SNK-TLR will be sectionalized into two 230 kV lines, one between SNK and MKT which is still designated as 2L313 and one between MKT and TLR which is designated as 2L337.

There is significant load growth in the South Peace area and a major transmission upgrade project is already in the construction phase called Dawson-Chetwynd-Area-Transmission (DCAT) project. Figure 1 below illustrates the reconfigured Peace Region electrical system after the DCAT upgrades as well as the proposed IC connection. A new 230 kV station Sundance (SLS) is being built at the existing intersection of 2L312 (SNK – LAP) and 1L358 (BMT – CWD). The existing 138 kV circuit from SLS to CWD will be renamed 1L349. A 230 kV double circuit will be built from SLS to BMT and DAW. The 230 kV section from BMT – DAW will be operated at the 138 kV level. The two existing 138 kV lines, 1L358 (section from SLS – BMT) and 1L362 (BMT – DAW) will be decommissioned. The scheduled COD for the DCAT project is sometime in 2015.

As shown in Figure 1 below, the Meikle Wind Station (MKL) will be connected into the 230 kV system at the MKT station.

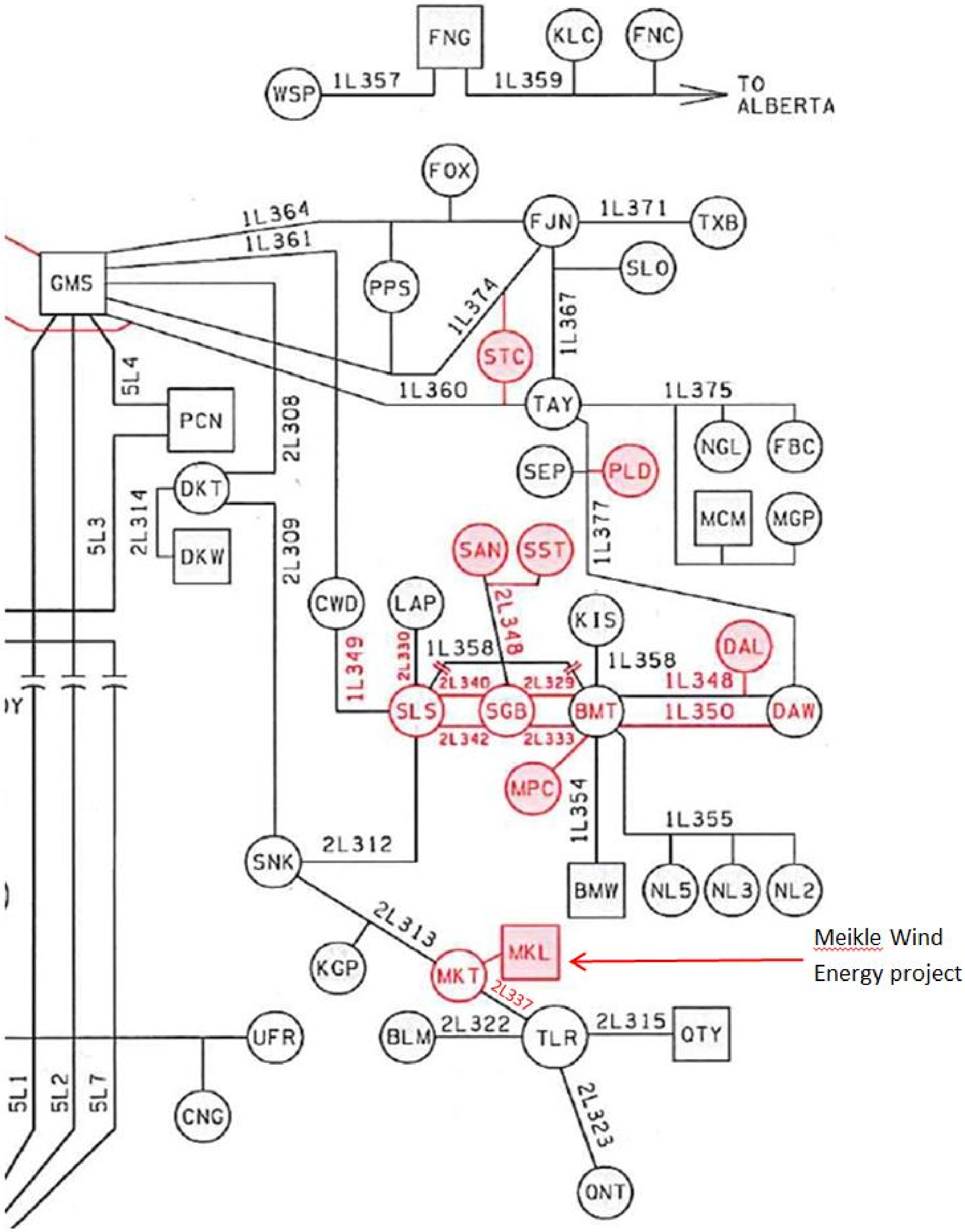


Figure 1: Peace Region (post DCAT) one line diagram with Meikle Wind Energy (MKL) connection

2. Purpose of Study

The purpose of this SIS is to assess the impact of the proposed interconnection on the BCH Transmission System. This study will identify constraints and Network Upgrades required for interconnecting the proposed generating project in compliance with the North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC) reliability standards and the BCH transmission planning criteria.

3. Terms of Reference

This study investigates and addresses the overloading, voltage deviation, and stability issues of the transmission network in the Peace Region as a result of the proposed interconnection for system normal and single contingency conditions. The studied topics include equipment thermal loading and rating requirements, system transient stability and voltage stability, transient over-voltages, potential harmonic resonances, protection coordination, operation flexibility, telecom requirements, and high level requirements for Local Area Protection Schemes (LAPS). BCH planning methodology and criteria are used in the studies.

The SIS does not investigate operating restrictions and other factors for possible second contingency outages. Subsequent network studies will determine the requirements for reinforcements or operating restrictions/instructions for those types of events.

The work necessary to implement the network improvements identified in this SIS re-study report have been described in greater detail in the Facilities Study (FS) report, TGI-2015-A110-FS-R1.

4. Assumptions

The studied power flow conditions include generation, transmission facilities, and load forecasts representing the BCH interconnection queue position applicable to this project. Applicable seasonal conditions and the appropriate study years for the study horizon are also incorporated. As a result, BC Hydro 2016 Heavy Winter (HW), 2017 Heavy Summer (HS) and Light Summer (LS) power flow base cases were selected for this study. The IC's latest data submission, as of April 2015, has been used in this study.

5. System Studies and Results

Power flow, short circuit, transient stability, and analytical studies were carried out to evaluate the impact of the proposed connection. Studies were also performed to determine the protection, control and telecommunication requirements and to evaluate possible over-voltage issues and remedies.

5.1. Steady State Power Flows

Steady state pre-outage (N – 0) power flows were prepared and single element (N – 1) contingency studies were conducted. This was to determine if the pre-contingency and post-contingency performance, including bus voltage deviations and facility loading levels, met the NERC Mandatory Reliability Standards (MRS) and WECC/BCH transmission planning criteria and system capabilities under different load conditions for 2016 heavy winter, 2017 heavy summer and light summer.

Pre-contingency study results (i.e. all elements in-service) have indicated that with a maximum injection of 181 MW from MKL and high levels of area generation, no transmission equipment overloads or unacceptable voltage conditions were observed due to the MKL project.

Single contingency (N – 1) study results have indicated thermal overloads on circuits 1L349 (SLS – CWD), 1L361 (CWD – GMS), 1L377 (DAW – TAY), 1L367 (TAY – FJN), and SLS transformer (230/138kV) under the contingency of circuit 2L308 (GMS – DKT) for the 2017LS and 2017HS system configurations. There were no unacceptable bus voltage conditions/violations in the transmission system observed.

This thermal overload issue was identified in the previous SIS for the Meikle Wind Energy Project and a generation runback or shedding Remedial Action Scheme (RAS) was proposed to mitigate any potential thermal overload concerns for this N–1 contingency and other more severe system disturbances. If the thermal overloads cannot be addressed in a prescribed allotted time, Direct Transfer Trip (DTT) signals may be needed to trip the IC’s entrance breaker and isolate the wind farm.

A summary of the study results are shown below in Table 2:

Table 2: Power Flow Results

Base Case	Contingency	Bus voltages (p.u.)				Power flows (MW / Amps %)							
		GMS 230	SNK 230	TLR 230	SLS 230	2L308 @ GMS	2L309 @ SNK	2L312 @ SNK	1L349 @ SLS	1L361 @ GMS	1L377 @ DAW	1L367 @ TAY	SLS TX (230/138)
2016 HW	All in-service	1.03	1.04	1.02	1.04	-198	58	215	37	-14	59	71	37
	2L308 (GMS - DKT)	1.02	1.03	1.02	1.03	n/a	-140	413	138	-104	150	122	138
	2L309 (DKT - SNK)	1.03	1.04	1.02	1.04	-140	n/a	274	67	-42	86	86	67
	2L312 (SNK - SLS)	1.02	1.03	1.02	1.04	-405	274	n/a	-76	107	-41	7	-76
2017 HS	All in-service	1.03	1.03	1.02	1.03	-202	62	220	29	-17	52	60	29
	2L308 (GMS - DKT)	1.02	1.03	1.02	1.02	n/a	-140	422	133	-108	144 (108% I)	112 (104% I)	133
	2L309 (DKT - SNK)	1.03	1.03	1.02	1.03	-140	n/a	282	61	-47	80	77	62
	2L312 (SNK - SLS)	1.02	1.03	1.02	1.03	-413	282	n/a	-86	107	-51	-6	-86
2017 LS	All in-service	1.04	1.03	1.02	1.04	-237	98	186	33	-24	56	45	33
	2L308 (GMS - DKT)	1.04	1.02	1.02	1.02	n/a	-140	424	155 (114% I)	-128 (109% I)	165 (123% I)	106	155 (101% I)
	2L309 (DKT - SNK)	1.04	1.03	1.02	1.03	-140	n/a	284	83	-69	101	71	83
	2L312 (SNK - SLS)	1.03	1.02	1.02	1.05	-415	284	n/a	-64	77	-31	-10	-64

Note:

Summer continuous rating of 1L349 is 133.6 MVA and winter continuous rating is 167.6 MVA
Summer continuous rating of 1L361 is 133.6 MVA and winter continuous rating is 143.4 MVA
Summer continuous rating of 1L367 is 124.3 MVA and winter continuous rating is 155.4 MVA
Summer continuous rating of 1L377 is 133.9 MVA and winter continuous rating is 174 MVA
Summer continuous rating of SLS transformer is 150 MVA and winter continuous rating is 178 MVA
Summer continuous rating of 2L312 is 420.3 MVA and winter continuous rating is 509.9 MVA

5.2. Transient Stability Study

A series of transient stability studies, under selected system operating conditions including the 2016 heavy winter and 2017 heavy summer and light summer load conditions, have been performed. The model of the generating project was based on the IC's data submission plus any additional assumptions where the IC's data was incomplete or inappropriate. The best available dynamic models, provided by respective manufacturers that represent the nearby wind farms in the area, were used at the time of the study.

Transient stability studies have been performed to assess the impact of 181 MW of maximum power injection from the Meikle Wind Energy Project on the transmission network in the vicinity.

No transient instability phenomenon and transient voltage violations have been observed based on the studied scenarios and contingencies, and the wind farm was capable of riding through the faults. A summary of the system stability studies for the 2017 light summer load condition is shown in Table 3 below:

Table 3: Transient Stability Study Results for Meikle Wind Energy injection of 181 MW (using 2017LS case)

Case	Outage	3Φ Fault Location	Fault Clearing Time (Cycles)		Max. Transient Voltage			IC Low Voltage Ride Through Performance	Min. Transient Voltage		
			Close End	Far End	SNK 230 kV	TLR 230 kV	SLS 230 kV		SNK 230 kV	TLR 230 kV	SLS 230 kV
1	2L308 GMS – DKT	Close to GMS	GMS 7	DKT 9	1.21	1.22	1.19	Acceptable	>0.95	>0.95	>0.95
2	2L308 GMS – DKT	Close to DKT	DKT 7	GMS 9	1.19	1.19	1.18	Acceptable	>0.95	>0.95	>0.95
3	2L309 DKT – SNK)	Close to DKT	DKT 7	SNK 9	1.18	1.20	1.17	Acceptable	>0.95	>0.95	>0.95
4	2L309 DKT – SNK)	Close to SNK	SNK 7	DKT 9	1.18	1.19	1.17	Acceptable	>0.95	>0.95	>0.95
5	2L312 (SNK – SLS)	Close to SNK	SNK 7	SLS 9	1.13	1.16	1.08	Acceptable	>0.95	>0.95	>0.95
6	2L312 (SNK – SLS)	Close to SLS	SLS 7	SNK 9	1.15	1.19	1.09	Acceptable	>0.95	>0.95	>0.95
7	TLR 25kV Fault	Close to TLR	TLR 35	N/A	1.12	1.15	1.13	Acceptable	>0.95	>0.95	>0.95

5.3. Analytical Studies

This study performs power system simulations to determine the influence the MKL wind farm has over the existing system and nearby customers. Balanced and unbalanced faults were simulated for contingency scenarios. Instantaneous phase and rms quantities for voltage, power flow, and other quantities were measured at locations throughout the wind plant and the surrounding system.

The proprietary models of the MKL wind farm equipment, arranged by the IC, were used in the PSCAD modeling. The scope of work was defined by BCH and studies were completed by XXXXX.

A detailed model representing the Peace Region wind farm equipment and surrounding network was created using proprietary models provided by the respective manufacturers. The models are capable of showing high speed control interactions between nearby Statcoms and other wind turbines. A modified plant control model for MKL wind turbines was incorporated in order to address a negative impact observed due to a nearby wind farm for certain critical contingencies. The modifications were effective to address the issue. In addition, there is a need to engage the manufacturer of the Statcom device at the nearby facility to revisit the protection settings for their device and to validate the observed marginal response under the critical contingencies.

5.3.1 Observations

GE Turbine Control Sensitivity for the Meikle Wind Project

Initial adverse results led to a re-assessment of the Meikle wind farm project, where the turbine manufacturer (GE Wind) provided an updated model along with additional settings.

These new settings included the modification to the power recovery characteristic after faults and volt/var ratio at the turbine level. In addition to this, the manufacturer included a representation of the plant level controller. The plant level controller included a substantial increase in the reactive-power-droop to avoid steady state (or low frequency) negative interactions with adjacent plant controllers.

The new wind plant control settings used in this new evaluation are presented in Table 4. These are the only control settings accessible in the model. The rest are embedded as a black-boxed model.

Table 4: Revised PSCAD Wind Control Settings used in the Meikle Wind model

Parameter	Setting
Vreg Proportional Gain (puQ/puV)	0.07
Vreg Integra Gain (puQ/puV/s)	0.7
Qdroop Factor (puV/puQ)	0.083
Qdroop Filter Time Constant (s)	0.2

The results corresponding to the same critical contingency (SLG on 2L308) which previously generated a sustained oscillation across the system was repeated with the settings provided above. With the new settings above, the Meikle Wind project is able to ride-through the fault without deteriorating the system performance when recovering. The results before and after the control setting changes are presented in Appendix B in Figure B-0-1, Figure B-0-2 and Figure B-0-3.

Transient Over- Power condition at a nearby wind plant

In addition to the results presented above, an existing wind plant nearby evidenced consistent over-power injection after the fault clearance. This will require further validation with the WTG manufacturer to verify its accuracy and therefore adjust the controls in order to prevent this condition. This is observed in 0Appendix B – Figure B-0-4. However, this was determined as not critical for the MKL plant performance.

Harmonic Impedance Scans

Using the PSCAD Harmonic Impedance measurement component, the positive sequence impedance, as seen from the MKT 230 kV bus, was plotted against frequency. Several network configurations were measured as described in Appendix B - Table B.3. Measuring the harmonic impedance of power electronic devices this way is imprecise since this is a passive response (approximate). Dynamic frequency response methods are possible but were outside the scope of the analysis.

The MKL wind turbines were approximated and represented with a 10% inductance to ground on wind turbine MVA behind the step-up transformer impedance. This assumption has a dominant impact upon the harmonic impedance scan results and are only useful for screening purposes. Based on the preliminary results, the following observations are made:

- For case 1 and 2, without the MKL wind farm in service, the resonances are located around the 7^{th} and 31th harmonic.
- The inclusion of MKL contributes to the increase in the overall shunt inductance. This increase reduces the resonance magnitudes and pushes them toward higher frequencies. This is observed in Figure B-0-7.
- The zero sequence impedance resonances, prior to the connection of the wind farm, were located at 5^{th}, 27^{th} and 37^{th}. These resonance points were moved to higher frequencies with noticeable reduction in their impedance magnitude.

It was also observed that for all simulated faults, the Meikle wind farm behaves stably and recovers from faults into the weakened system. Other wind farms in the area generally perform acceptably during the contingencies studied, recovering full power into the weakened post-fault system with no unstable behaviour. It was noted that a 3LG fault on line 1L361 caused strong voltage oscillations under heavy load conditions. The various voltage control elements in the system react strongly to combat these oscillations and oscillations are damped after approximately 5 seconds.

Frequency scans were performed on the system along with the wind farms. No abnormal system condition is introduced by the MKL wind farm.

5.3.2 Recommendations

The Analytical recommendations are as follows:

- Control revisions to the GE turbine were provided for this study. These revisions must be implemented in the turbine hardware prior to operation, or unacceptable oscillations and weak system interactions may occur.

- Random closing of the MKL 230kV intertie breaker to pick up one single transformer at MKL could produce significant voltage sags of around 20% at the POI that exceeds the maximum allowable voltage sag as per BCH's "60 kV to 500 kV Transmission Interconnection Requirements for Power Generators." Some technique to reduce the inrush current is required such as using a 230 kV energizing breaker having independent poles and point-on-wave (POW) closing that accommodates the current proposed layout of sharing two transformers with a single circuit breaker. POW closing requires the use of a special purpose, commercially available relay which estimates the residual flux in the core and takes into account the actual closing characteristics of the breaker to close each pole at a predetermined instant. If the POW device is out-of-service (OOS), sub-optimal transformer energization can be achieved by staggering pole closing or use of proper selection of HV disconnects and associated driver mechanisms. It is the responsibility of the IC to select the mitigation solution and provide evidence of meeting the interconnection voltage sag limits.

- Abrupt opening of 2L313 at Sukunka Switching Station (SNK), for either protective or non-protective conditions, requires the implementation of a DTT to disconnect MKL and maintaining the existing intentional (1 cycle) delayed opening of 2L313 at SNK in order to avoid high Temporary Over Voltages (TOVs).

- Any outage of 2L308, 2L309 or 2L312 will require arming (i.e. generation shedding made available) of MKL to trip so that the wind farm does not remain operational in an islanded mode following a contingency on the remaining 230kV tie to SNK.

- For the proposed and existing wind plants in the Peace Region, the most severe load rejection condition (around 250MW) is experienced when circuits to GMS like 2L308 and 2L309 are lost. To avoid excessive load rejection TOVs , especially following a severe multi-phase fault on BC Hydro and customer equipment and facilities where achieving coordinated system voltage control can be complex, fast shedding of all generating sources including the MKL plant at the 230kV system has been recommended.

- For system and equipment back up security in cases where misoperation and/or miscoordination of the generation shedding schemes occur and subsequent failure(s) of system Surge Arrestors (SAs) can occur randomly, application of area Sacrificial SAs with disconnecting capability is recommended at strategic locations. The sacrificial SAs are chosen at a lower level than those applied for equipment protection purposes to ensure they fail first due to thermal energy and thus avoid possible random and multiple failures. Furthermore, since the system must be restored quickly, the sacrificial SAs should be equipped with motor operated disconnects to isolate the failed SA. The suggested rating of the Sacrificial SAs for this 230 kV region with mostly 192 kV and 228 kV rated SAs is 180kV with maximum continuous rating of 245 kV. The suggested application of sacrificial SAs are at the line terminals of the generating source connection to the BC Hydro 230 kV system which otherwise would be equipped with standard SAs.

5.4. Other Issues

There are no updates for the requirements identified in the previous Meikle Creek Wind Energy project SIS report (ASP2010-T058) and FS report (TGI-2015-A110-FS-R1) for islanding, fault analysis, protection & control, telecommunication, black start capability, transmission line upgrades, and the Meikle Wind Terminal Station.

5.5. Cost Estimate and Schedule

The Interconnection Facilities Study report (TGI-2015-A110-FS-R1) provides greater details of the Interconnection Network Upgrade requirements and estimated construction timeline for the interconnection project, and no updates is needed within this SIS report.

6. Conclusions and Discussions

To interconnect the MKL project and its facilities to the BCH system at MKT, this System Impact Study (SIS) has identified the following conclusions and requirements:

- The Meikle Wind Energy project can be accommodated without requiring any Network Upgrades in addition to the Network Upgrades that have already been identified in the previous System Impact Study reports (T&S Planning 2014-008 and ASP2010-T058) and the Facilities Study report (TGI-2015-110-FS-R1) for the Meikle Creek Wind Energy project. The 2014 SIS can be found in Appendix C.
- Control revisions to the GE turbine were provided for this study. These revisions must be implemented in the turbine hardware prior to operation, or unacceptable oscillations and weak system interactions may occur.
- Random closing of the MKL 230kV intertie breaker to pick up either a single or MKL station transformer could produce significant voltage sags of around 20% at the POI that exceeds the maximum allowable voltage sag. Some technique to reduce the inrush current is required such as using a 230kV energizing breaker having independent poles and point-on-wave (POW) closing that accommodates the current proposed layout of sharing two transformers with a single circuit

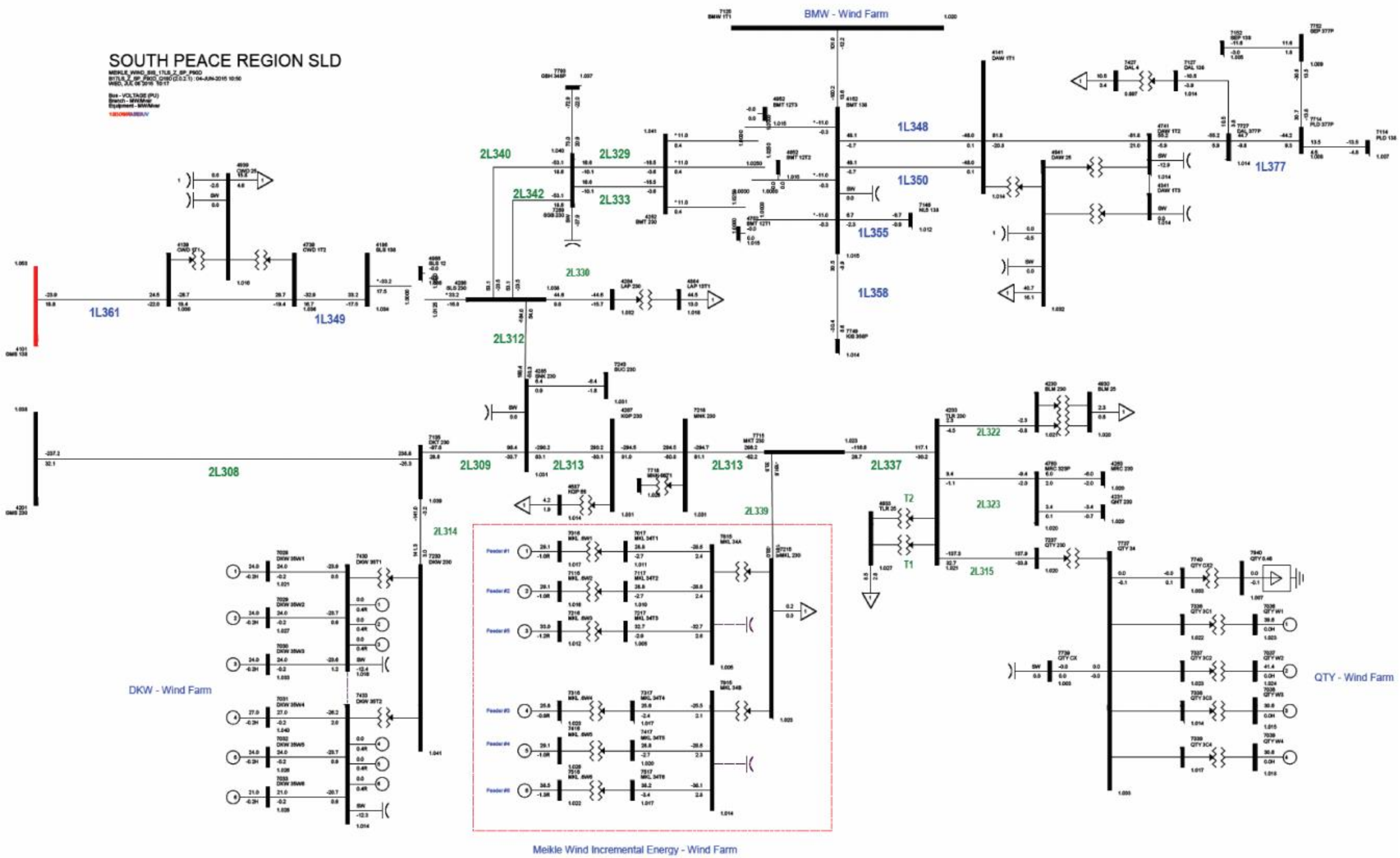
breaker. It is the responsibility of the IC to select the mitigation solution and provide evidence of meeting the interconnection voltage sag limits.

- Abrupt opening of 2L313 at Sukunka Switching Station (SNK), for either protective or non-protective conditions, requires the implementation of a DTT to disconnect MKL and maintaining the existing intentional (1 cycle) delayed opening of 2L313 at SNK in order to avoid high Temporary Over Voltages (TOVs).

- For the proposed and existing wind plants in the Peace Region, the most severe load rejection condition (around 250MW) is experienced when the circuits to GMS like 2L308 and 2L309 are lost. To avoid excessive load rejection TOVs , especially following a severe multi-phase fault on BC Hydro and customer equipment and facilities where achieving coordinated system voltage control can be complex, fast shedding of all generating sources including the MKL plant at the 230kV system has been recommended.

- For system and equipment back up security in cases where misoperation and/or miscoordination of the generation shedding schemes occur and subsequent failure(s) of system Surge Arrestors (SAs) can occur randomly, application of area Sacrificial SAs with disconnecting capability is recommended at the MKT line terminal for MKL. The suggested rating of the Sacrificial SAs for this 230 kV region is 180 kV with maximum continuous rating of 245 kV.

Appendix A – Area Single Line Diagram



Appendix B – Analytical Study Results

Table B.1: Summary of Contingency Cases

Case #	System condition	Area of Analysis
1	**DKY,BMW, QTY and Meikle (MKL) in service with full generation and low load condition**	
1.1	Post DCAT: 3G on 2L308	Transient and TOV responses at TLR, DKT and GMS 230kV line side
1.2	Post DCAT: SLG on 2L308	Transient and TOV responses at TLR, DKT and GMS 230kV line side
1.3	Post DCAT: 3G on 2L309	Transient and TOV responses at TLR
1.4	Post DCAT: 3G on 2L312	Transient and TOV responses at TLR, DKT and GMS 230kV line side
1.5	Post DCAT: SLG on 2L312	Transient and TOV responses at TLR, DKT and GMS 230kV line side
1.6	Post DCAT: 3G on 1L361	Transient and TOV responses at TLR

Table B.2: Results Summary of Contingency Cases

Meikel Wind Farm Transient Dynamic Response							
DKY, BMWM QTY and Meikle (MKL) in service with full generation and low load condition							
Case #	System condition	Case Summary					
		a) Meikle2_z16hw.sav			b) Meikle2_17ls.sav		
		Pass/Fail	SC MVA @ MKL 230kV POI	Notes	Pass/Fail	SC MVA @ MKL 230kV POI	Notes
1	Post DCAT: 3G on 2L308		580.86	2,3,4		457.63	3,4
2	Post DCAT: SLG on 2L308		580.86	1,4		457.63	4
3	Post DCAT: 3G on 2L309		578.11	1,4,5		456.53	3,4,5
4	Post DCAT: 3G on 2L312		847.4	1,4		809.94	1,4
5	Post DCAT: SLG on 2L312		847.4	1,4		809.94	1,4
6	Post DCAT: 3G on 1L361		1097.54	1,4,6		963.52	1,4
PINK	Problem case (May require mitigation)						
Yellow	Case exhibits undesirable behaviour, but may be acceptable						
GREEN	Acceptable Behaviour						

Note No.	Description
1	Normal operation
2	QTY wind trips due to overvoltage protection
3	QTY STATCOM blocked for aprox. 2s following fault clearing. STATCOM re-starts and continues providing reactive support after this period.
4	BMW trips off due to a hard coded 10 s tripping in the model (Simulation artifact, not real behaviour)
5	BMW over power after clearing the fault for 1 second
6	Strong voltage oscillations cause all reactive power controllers to activate. Damps after 5 seconds

Table B.3: Summary of Frequency Scan Cases

Case #	System Description	Area of Analysis
Part I - Normal system (no MKL) with 50% only of major loads in the GMS-TLR subsystem		Positive and Zero sequence impedances
1	Base Case 2016HW	
2	Base Case 2017LS	
Part II - Normal load (no MKL)		
3	2L309 OOS	
4	2L308 OOS	
5	2L312 OOS	
6	One 230kV circuit SLS-BMT OOS	
7	One 500/230kV Transformer at GMS OOS	
8	One 500/138kV Transformer at GMS OOS	
9	1L377 OOS	
10	1L361 OOS	
Part III - Normal load, Frequency scans at POI this time including MKL		
11	With no MSC caps in service	
12	With one 15 MVARs MSC cap in service	
13	With two 15 MVARs MSC cap in service	

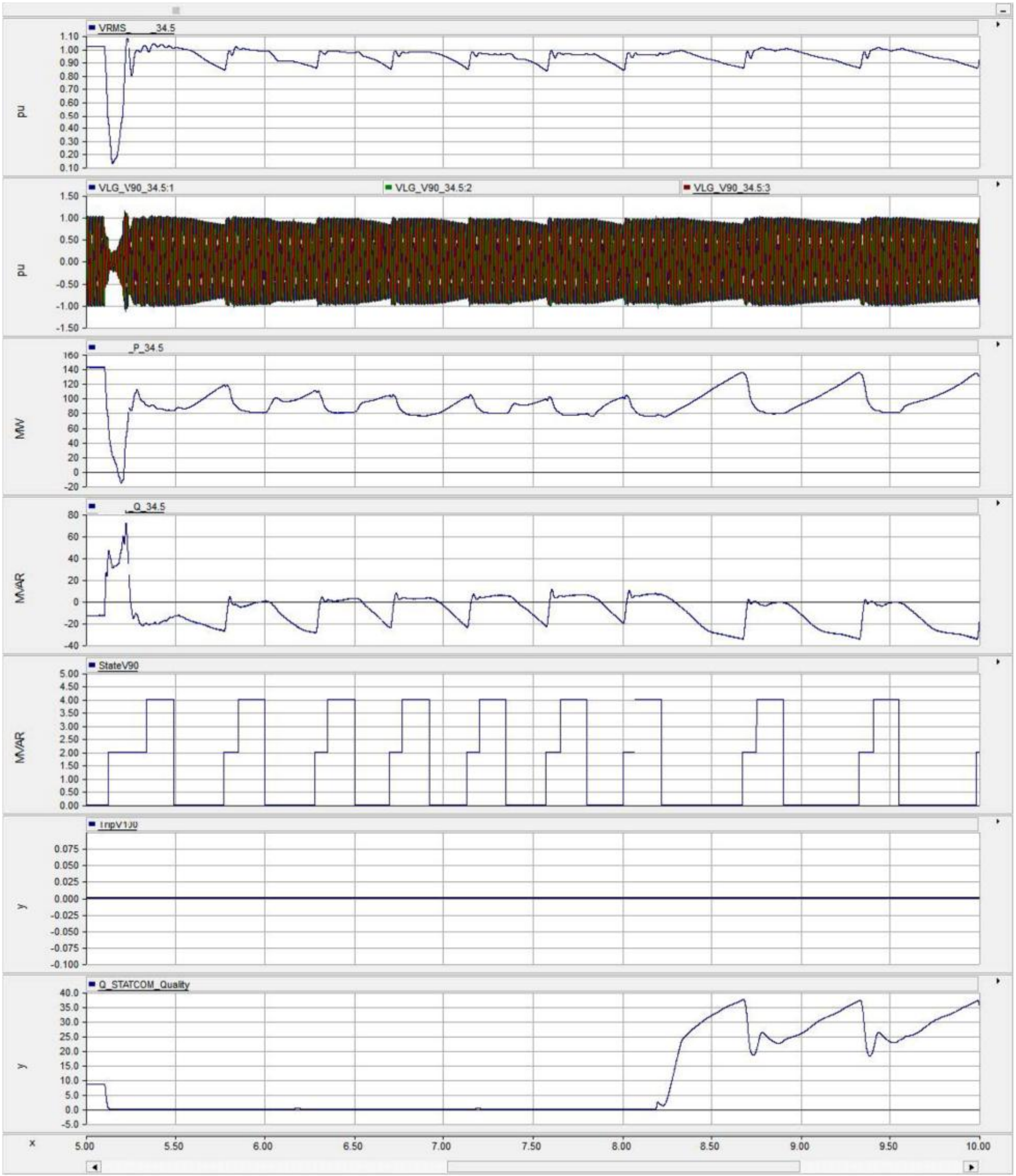


Figure B-0-1: Sustained voltage fluctuations at a nearby wind plant due to control mode cycling behaviour

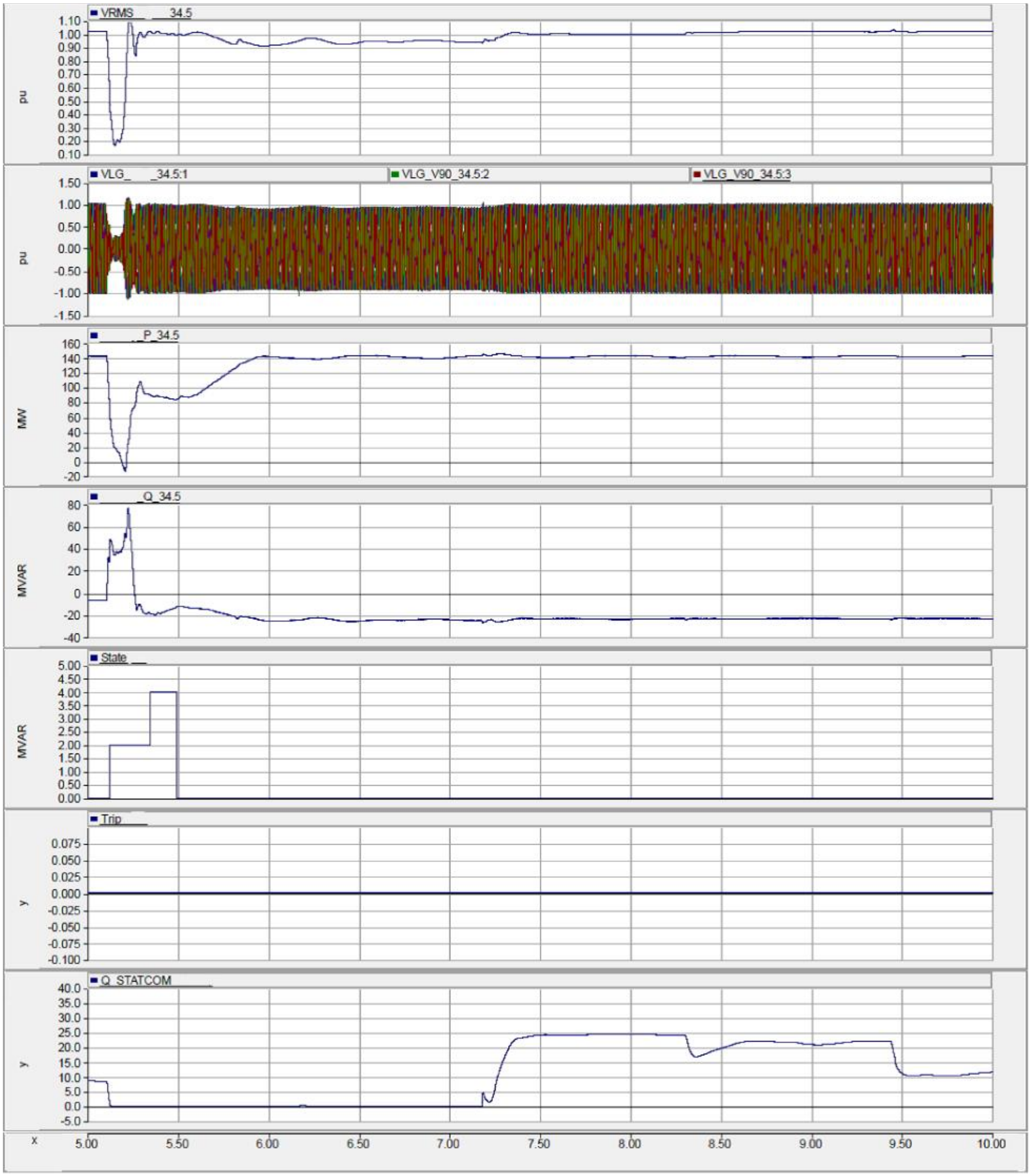


Figure B-0-2: Nearby wind plant *response using new settings at MKL provided by GE for case 1.2*

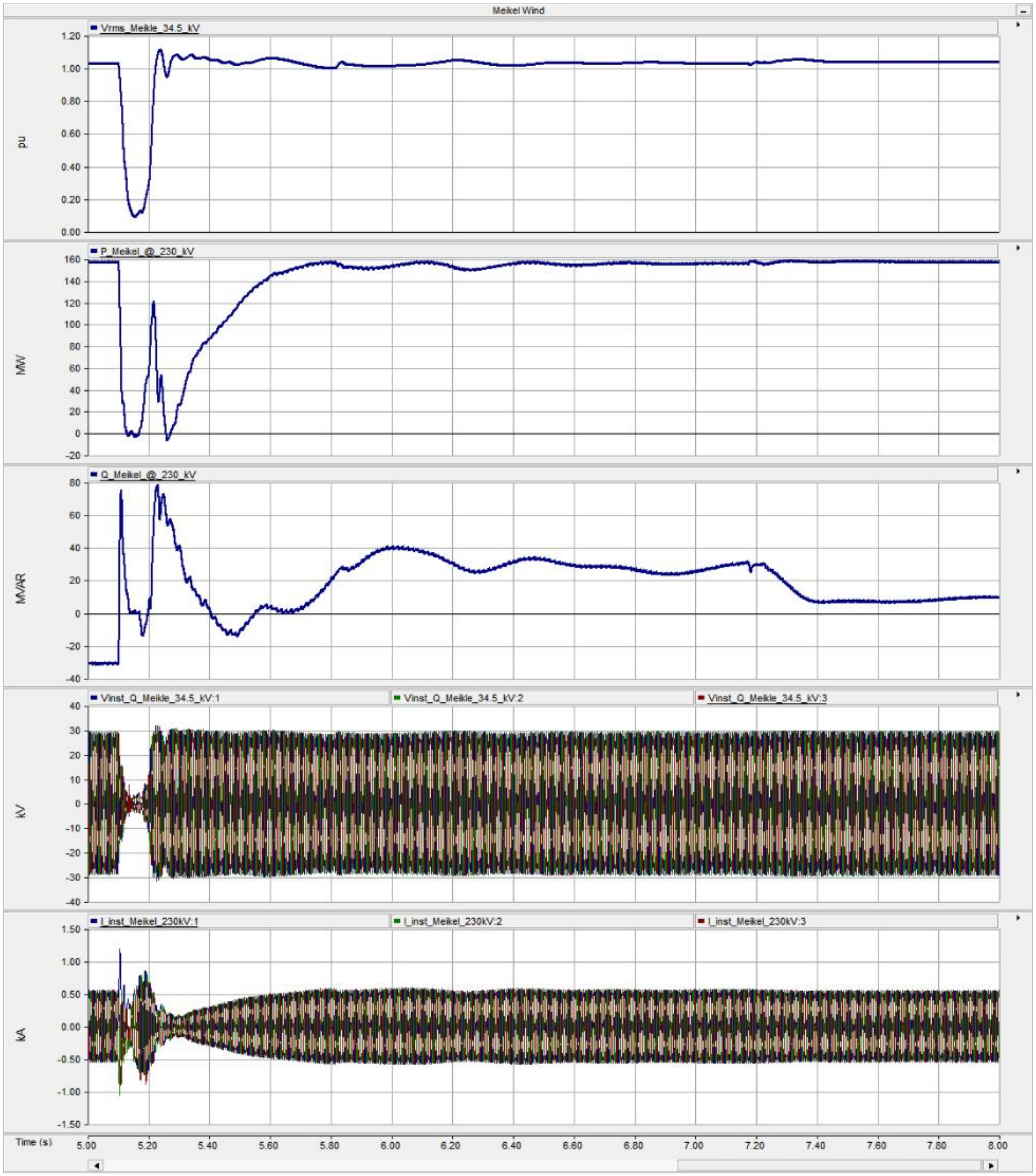


Figure B-0-3: MKL plant turbine response using new settings provided by GE for case 1.2

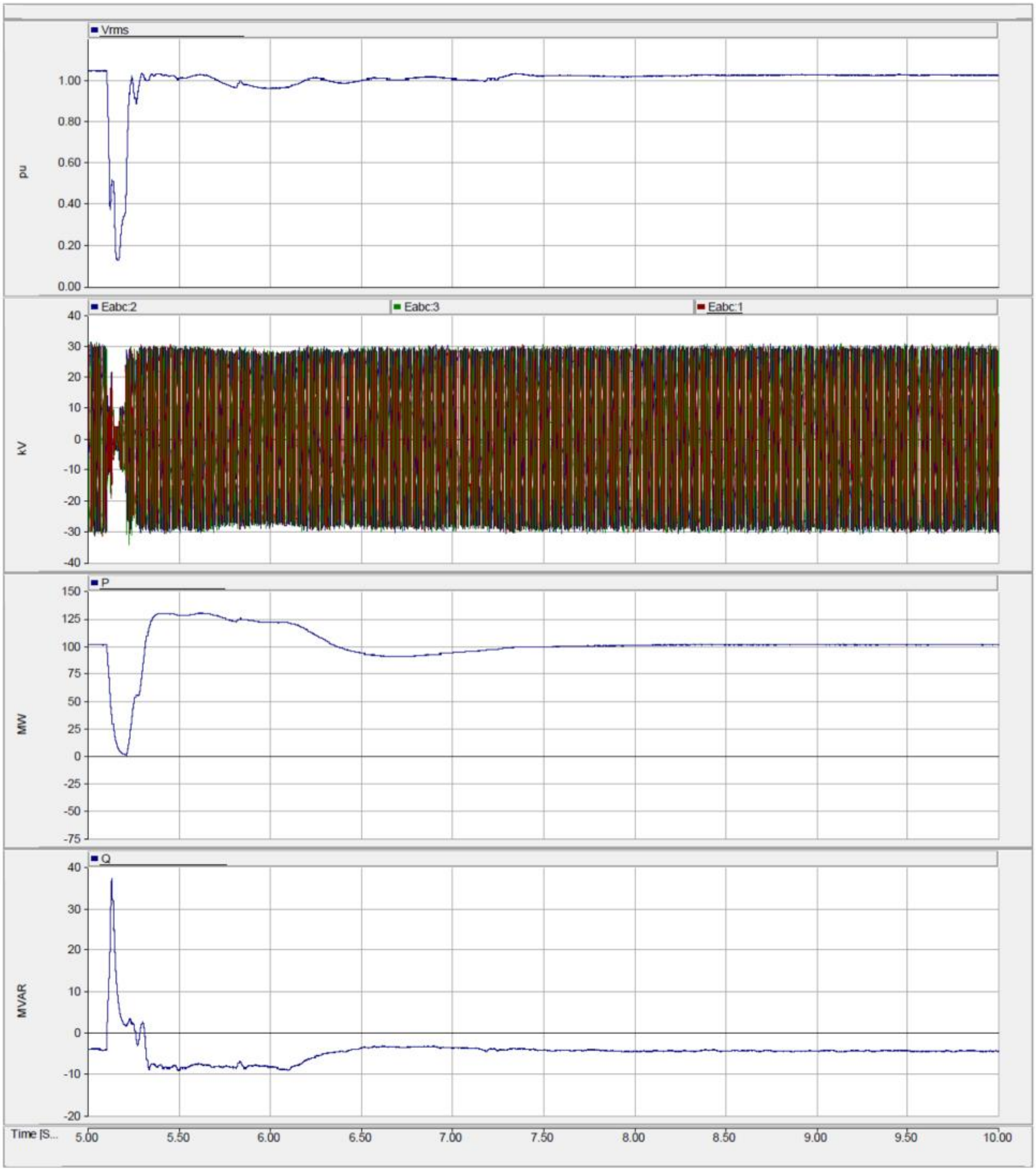


Figure B-0-4: Nearby Wind plant with over power behavior after clearing the fault for case 1.2

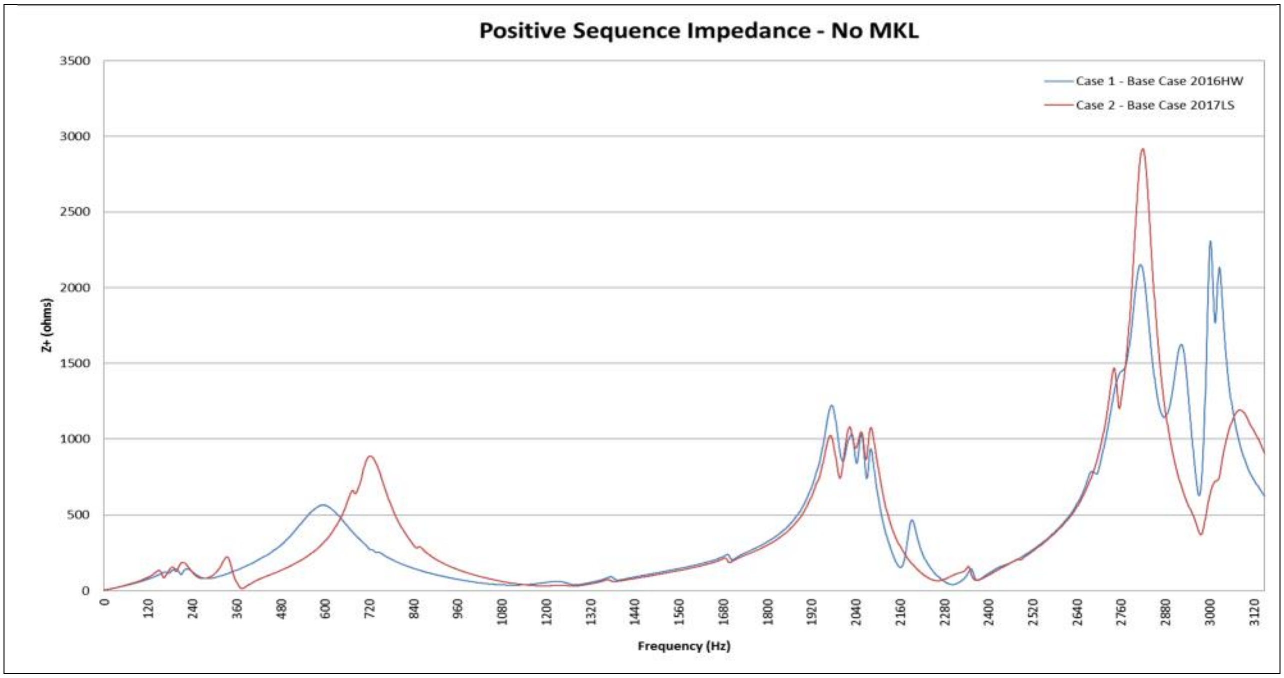


Figure B-0-5: Positive sequence impedance magnitude vs frequency for all studied cases without MKL

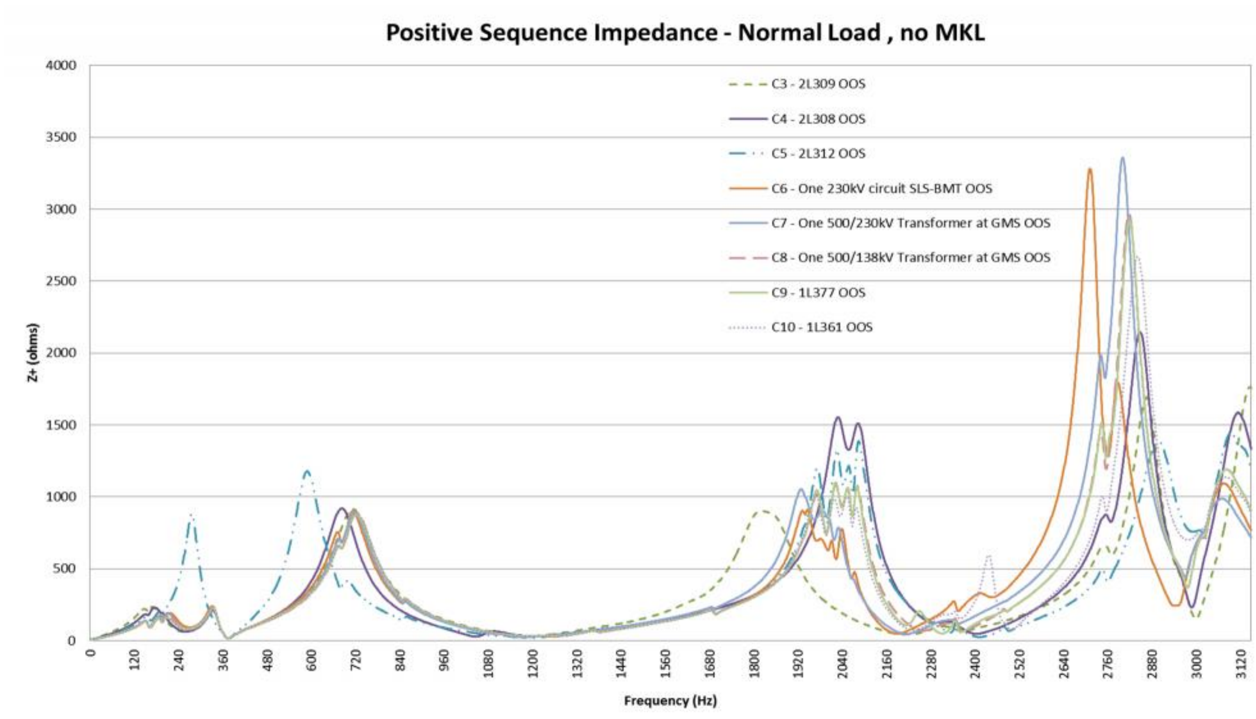


Figure B-0-6: Positive sequence impedance magnitude vs frequency for different contingencies without the inclusion of Meikle Wind

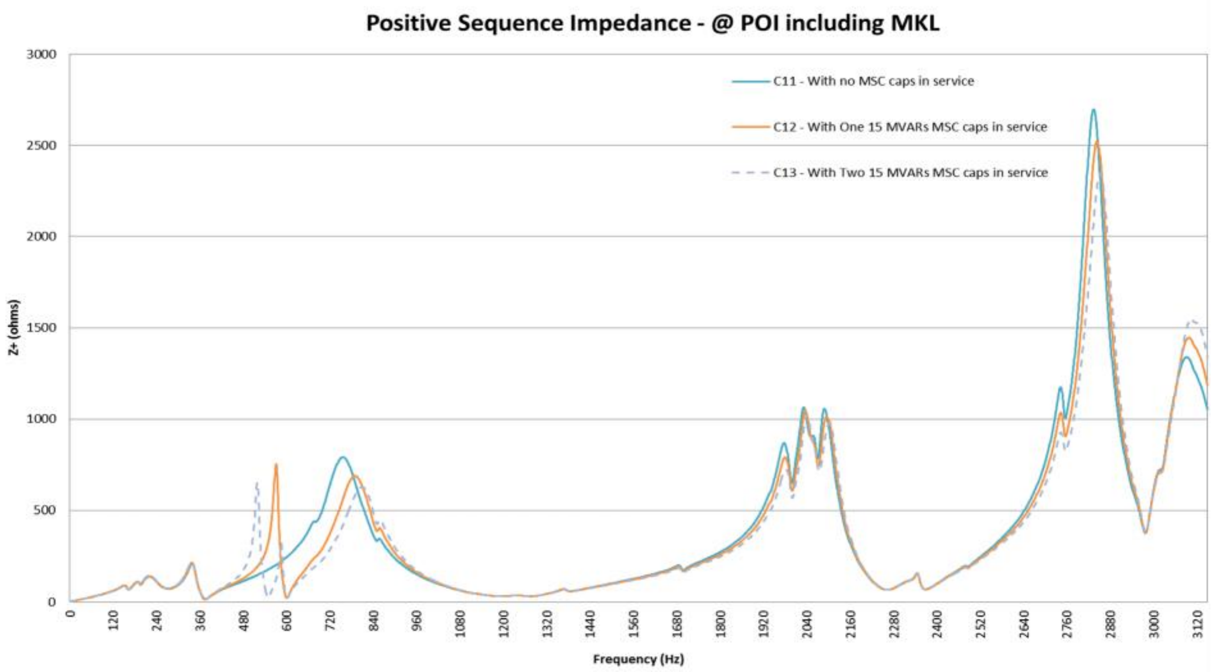


Figure B-0-7: Positive sequence impedance magnitude vs frequency for different configuration of MSC during the operation of Meikle

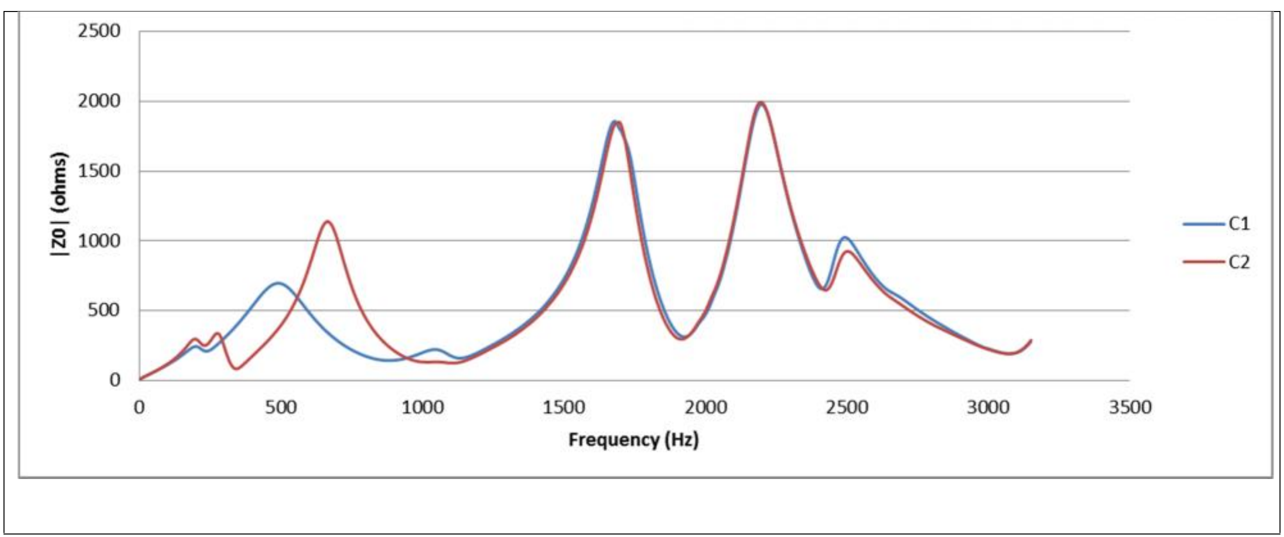


Figure B-0-8: Zero sequence impedance magnitude vs frequency for the case prior to the interconnection of MKL wind

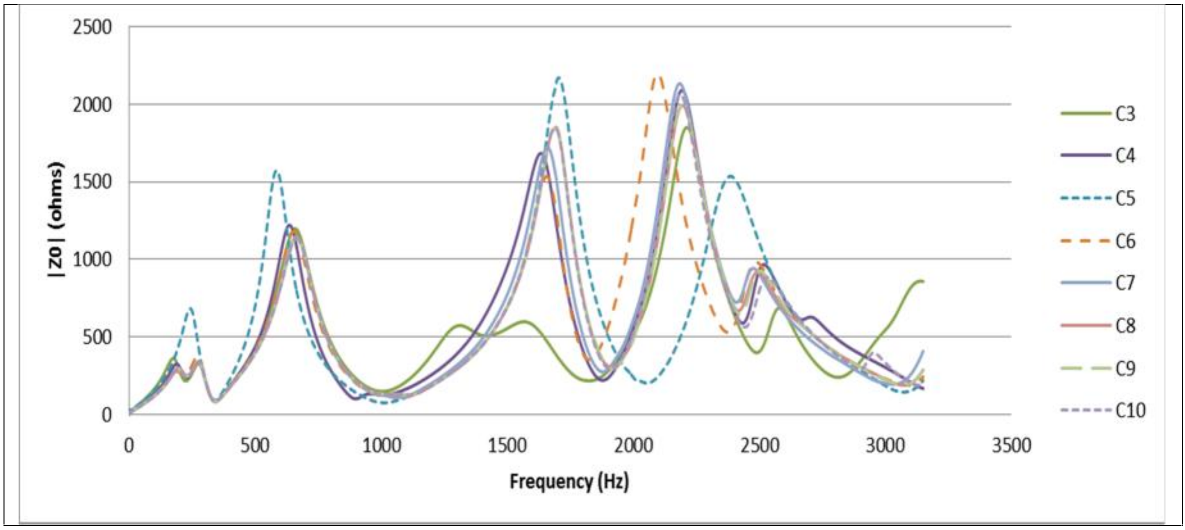


Figure B-0-9: Zero sequence impedance magnitude vs frequency for different contingencies without the inclusion of Meikle Wind

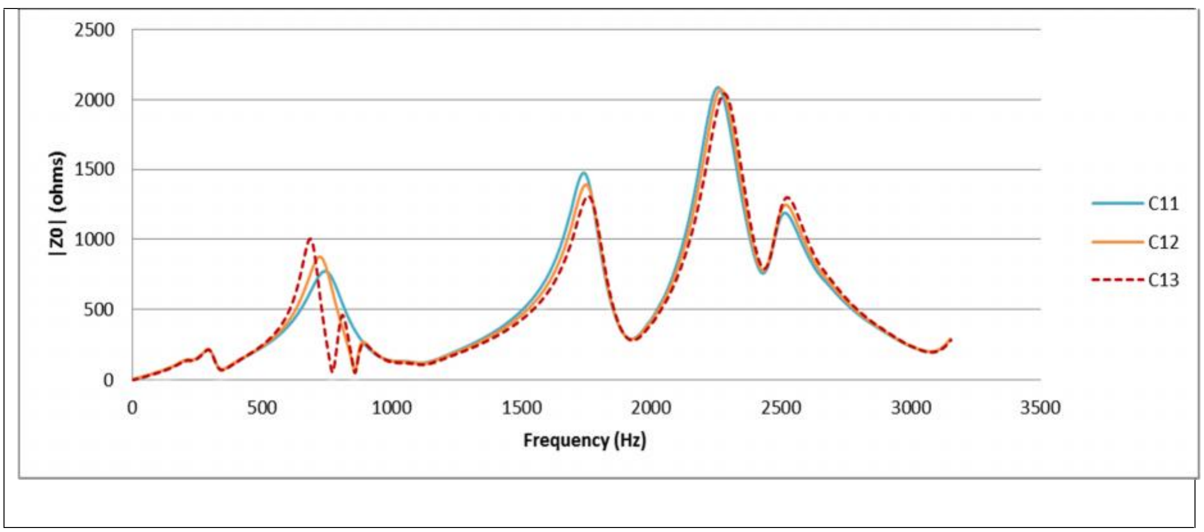


Figure B-0-10: Zero sequence impedance magnitude vs frequency for different configuration of MSC during the operation of Meikle

Appendix C – 2014 SIS Report

REDACTED

