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WIND INTEGRATION STUDY – ISOLATED ISLAND

Technical Study of Voltage Regulation and System Stability

Date: August 18, 2012

System Planning Department

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1. Executive Summary

This study investigated the technical limitations of wind integration into the Isolated Island grid of Newfoundland and Labrador Hydro for the base years of 2020 and 2035. The focus of technical limitations was both voltage regulation and system stability constraints for extreme light loading and expected peak loading for the base years referenced. These results provided the maximum wind power penetration levels for the study years for both peak and light load conditions.

The 2010 "NLH Island Demand & Energy Requirements 2018 to 2067" was utilized as the basis for both peak and light load models. The extreme light load is based on approximately 26% of NP and NLH rural peak loading while the industrial customers loading was estimated at 78% of forecasted peak to account for loading coincidents.

Distributed wind generating plants were assumed to consist of 9 x 3MW Doubly Fed Induction Generators (DFIG), similar to that of the existing Fermeuse and St. Lawrence wind plants. Twenty (20) wind farms were modeled across the Island with the maximum output of each wind turbine plant at 25MW with VAR capability of +/- 13.5MVARs per plant (1.5MVARs per unit).

For the study years of 2020 and 2035, the following system additions have been added to NLH's current system isolated island model.

2020

1. New 230kV line from Bay d'Espoir to Western Avalon Terminal Station.
2. New 25MW wind farm added, assumed to be located at Bay Bulls with POI at Goulds 66kV bus.
3. Island Pond (36MW hydro – Kaplan unit).
4. Round Pond (18MW hydro – Kaplan unit).
5. Portland Creek (2 x 11.5MW hydro – Pelton unit).
6. New 125MVA transformer added at Oxen Pond Terminal Station.
7. New 20MVAR shunt reactor added at Bottom Brook 230kV bus.

2035

1. New 170MW CCCT at Holyrood.
2. Two (2) 50MW gas turbines at Hardwoods Terminal Station with a Brush generator of 165.9MVA rating for synchronous condenser operation.
3. One (1) 50MW gas turbines at Stephenville Terminal Station with a Brush generator of 165.9MVA rating for synchronous condenser operation.

Load flow analysis of the two base case years of 2020 and 2035 indicate that there are no steady state restrictions up to and including 500 MW of wind power generation for the Isolated Island option. 500 MW was the maximum steady state wind generation dispatch analysed due to the fact that NLH generation at extreme light load conditions approaches this value. The practical steady state limit during extreme light load conditions would be limited to 375MW due to other NUG generation dispatch of approximately 125MW.

Transient stability analysis of the two base case years indicate a maximum wind dispatch level of 225 MW and 300 MW for the 2020 and 2035 Extreme Light Load cases respectively. This is based on a sudden load increase of 15 MW causing a frequency decline to 59.6 Hz which was the pre-defined criteria for frequency deviation. There was no restriction up to and including 500 MW of wind generation for peak loading periods of 2020 and 2035. System events on the 230kV system such as three phase and line to ground faults that were cleared within normal operating times did not adversely affect operation of the wind generation due to the advances of the Low Voltage Ride Through (LVRT) capability. Table 1 below summarizes the resulting restrictions as a result of the transient stability analysis.

Table 1
Maximum Wind Generation Dispatch
Stability Analysis Results

Year	Extreme Light Load			Peak Load		
	Wind Generation Level (MW)	Wind Penetration Level (%)	System Inertia (MW.s)	Wind Generation Level (MW)	Wind Penetration Level (%)	System Inertia (MW.s)
2020	225	36.8	3340	500	28.5	7197
2035	300	43.8	3340	500	24.8	7509

Based on the studies conducted, the transient stability constraint is found to be the limiting factor in determining the amount of wind penetration during the extreme light load conditions. Thus, it is recommended that no more than 225MW and 300MW of net wind generation is dispatched during the extreme light load conditions during the years 2020 and 2035, respectively. However, the extreme light loading conditions are likely to occur for very short durations of the year, particularly during night hours of the summer season, when the wind generation profile is usually at its minimum. Thus, it is anticipated that the available wind generation under light load conditions is in close proximity to the wind penetration level limited by the transient stability constraint. It is recommended that historical wind data be obtained for potential wind sites across the island. This data can then be used to determine time and duration of minimal wind generation profiles coinciding with minimum system loading.

Overall analysis indicates that the current wind generation technology of the Doubly Fed Induction Generator (DFIG) model, similar to the Vestas V90 used in St. Lawrence and Fermeuse, provides voltage support on the island when dispatch is widely distributed (ie. wind farms are geographically dispersed) . As well, the control system of the DFIG model aids in frequency response control for the first 5-7 seconds during certain system events, such as loss of generation or sudden load increase. This is accomplished by converting the kinetic energy of the spinning turbine blades into excess power which, in turn allows time for conventional generation governors to respond to system conditions.

The analysis presented in this report does not assume time varying wind patterns and further analysis is recommended to simulate its effect on overall system frequency control. It is believed that high wind penetration levels on the island system could cause larger frequency deviations than currently experienced without additional fast acting counter measures. These could include high inertia synchronous condensers or high speed flywheel energy storage / regulation plants to minimize frequency deviations as a result of time varying wind patterns.

The analysis also highlights the importance of geographically diversifying wind farms to avoid simultaneous loss of nearby wind farms due to high wind speeds and subsequent system load shedding. In the absence of detailed wind surveys, it is recommended that future wind farm developments should be geographically dispersed to avoid the possibility of this event from occurring. As well, detailed study is recommended to investigate alternate solutions of avoiding under frequency load shedding due to loss of multiple wind farms. Possible solutions may include high speed flywheel energy storage systems and dispatch of fast response generation such as gas turbines during periods of predicted high wind and high wind penetration.

2. Introduction

This study will investigate the technical limitations of wind integration into the Isolated Island grid of Newfoundland and Labrador Hydro for the base years 2020 and 2035. The focus of technical limitations will be both voltage regulation and system stability constraints for extreme light loading and expected peak loading for the base years referenced. These results will provide maximum wind power penetration levels for the study years for both peak and light load conditions.

3. Study Parameters

3.1. Load Forecast

The 2010 “NLH Island Demand & Energy Requirements 2018 to 2067” load forecast was utilized as the basis for both peak and light load models. Appendix A outlines this forecast for NLH Total Requirements which consists of major customers and estimated losses. The NLH Annual Average System Generation Load Shape for the years 2008-2011 is illustrated in Figure 1. This load shape was used to estimate the system extreme light load NLH system generation that can be expected. Appendix B outlines the estimated

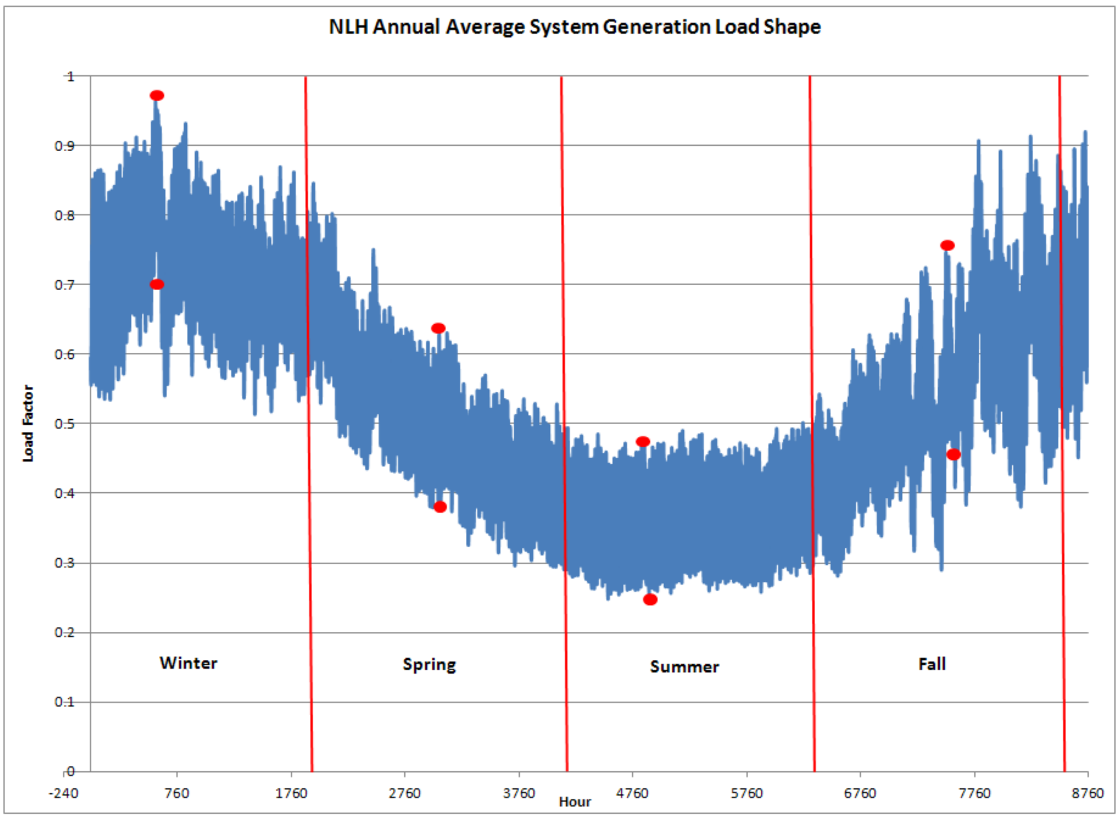


Figure 1
2008-2011 NLH Annual Average System Generation Load Shape

system loadings for the years 2014, 2020, 2030 and 2035. The extreme light load is based on approximately 26% of NP and NLH rural peak loading while the industrial customers loading was estimated at 78% of forecasted peak to account for load coincidence.

3.2.PSS®E Modeling – Wind Plants

PSS®E Version 32.1.1 was used for all analysis.

For study purposes, distributed wind generating plants were assumed to consist of 9 x 3MW Doubly Fed Induction Generators, similar to that of the existing Fermeuse and St. Lawrence wind plants. Twenty (20) wind farms were modeled across the island, as listed in Table 2. It is assumed that the maximum output of each wind turbine plant will be 25MW with VAR capability of +/- 13.5MVARs per plant (1.5MVARs per unit). Individual machines are not modeled in steady state or stability, but combined to act as a coherent group for analysis purposes. In steady state, normal dispatch will have all wind plants operating at unity terminal bus voltage, with VAR limits set at 0.96pf based on MW loading of the units.

Table 2
Listing of Distributed Wind Generating Plants Modeled on Island Grid

No.	Plant	Region	Bus #	Point of Interconnection (POI)	
				Location	Bus #
1	Doyles WG1	Western	1001	Doyles 66kV	201
2	Doyles WG2	Western	1002	Doyles 66kV	201
3	Stephenville WG1	Western	1003	Stephenville 66kV	204
4	Stephenville WG2	Western	1004	Stephenville 66kV	204
5	Massey Drive WG1	Western	1005	Massey Drive 66kV	115
6	Peter's Barren WG1	GNP	1006	Peter's Barren 66kV	121
7	Bear Cove WG1	GNP	1007	Bear Cove 138kV	134
8	Buchans WG1	Central	1008	Buchans 66kV	151
9	Springdale WG1	Central	1009	Springdale 138kV	113
10	Cobb's Pond WG1	Central	1010	Cobb's Pond 66kV	316
11	St. Lawrence WG1	Burin Peninsula	1011	St. Lawrence 66kV	372
12	St. Lawrence WG2	Burin Peninsula	1012	St. Lawrence 66kV	372
13	Sunnyside WG1	Western Avalon	1013	Sunnyside 138kV	223
14	Sunnyside WG2	Western Avalon	1014	Sunnyside 138kV	223
15	Fermeuse WG1	Eastern Avalon	1015	Goulds 66kV	457
16	Bay Bulls WG1	Eastern Avalon	1016	Goulds 66kV	457
17	Goulds WG1	Eastern Avalon	1017	Goulds 66kV	457
18	Kelligrews WG1	Eastern Avalon	1018	Kelligrews 66kV	348
19	Bay Roberts WG1	Eastern Avalon	1019	Bay Roberts 66kV	309
20	Heart's Content WG1	Eastern Avalon	1020	Heart's Content 66kV	501

For dynamic modeling, PSS®E Generic Wind model "Type 3" of a doubly fed induction generator was used. This model is comprised of four individual models as follows:

i) WT3G1 - Generator / converter model
ii) WT3E1 – Converter control model
iii) WT3T1 – Wind Turbine Torsional model (two mass)
iv) WT3P1 – Pitch Control model

The dynamic data for these models were obtained from two sources, i) Draft "WECC Wind Power Plant Dynamic Modeling Guide – August 2010" and ii) "Evaluation of the DFIG Wind Turbine Bulit-in Model in PSS/E" prepared by Mohammad Seyedi, University of Technology, Goteborg, Sweden, June 2009. Appendix C contains the data sheets used for this study.

Low Voltage Ride Through (LVRT) capability of DFIG has been modeled in stability using the "VTGDCA" user model which can be viewed in the dynamics data file. This LVRT function has been replicated using the Vestas V90 model, as shown in Figure 2. If voltage at the wind turbine plant's terminal bus goes below the curve for corresponding time interval, then that plant is disconnected from the electrical system model.

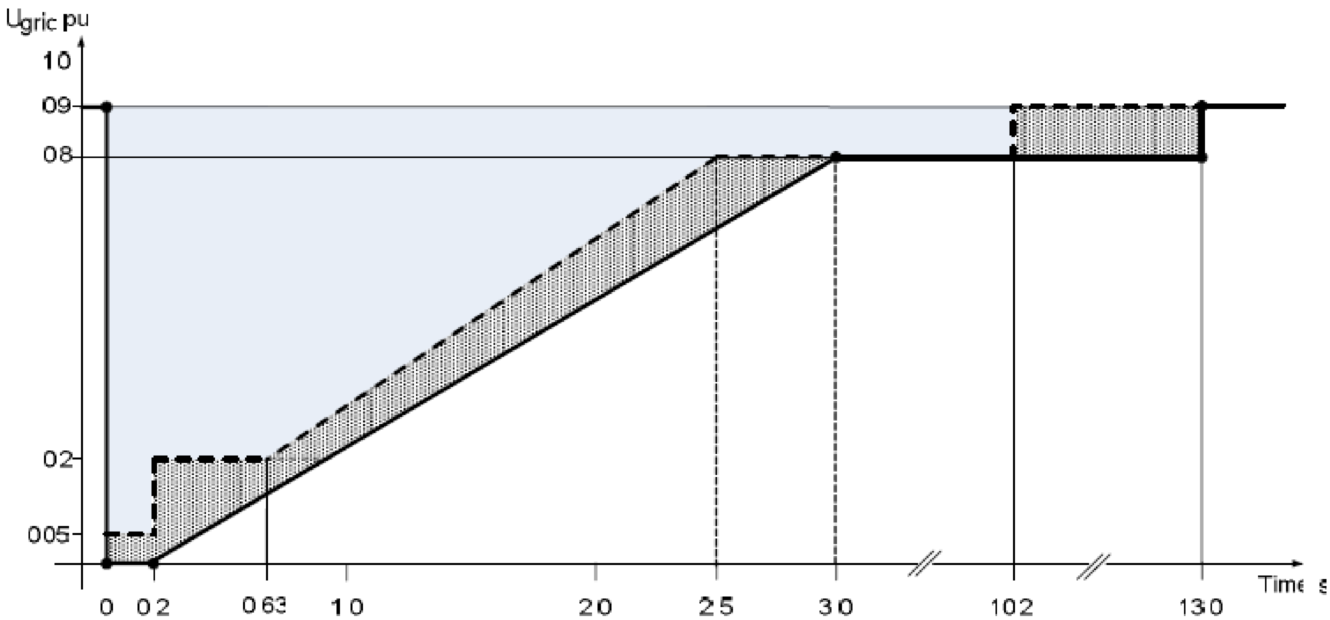


Figure 2

Low Voltage Ride Through Capability of Vestas V90[1]

Frequency protection has also been modeled in PSS®E using the "FRQDCA" user model as outlined in the dynamics data file. The protection settings used in this analysis are as follows:

Over Frequency Setting:	61.2 Hz for 0.2 seconds
Under Frequency Setting:	56.4 Hz for 0.2 seconds.

3.3.New Generation Sources / Model Additions

For the study years of 2020 and 2035, the following system additions have been added to NLH's existing PSS®E system isolated island model.

2020

1. New 230kV line from Bay d'Espoir to Western Avalon Terminal Station.
2. New 25MW wind farm added, assumed to be located at Bay Bulls with POI at Goulds 66kV bus, Fermeuse 25MW wind farm modeled as connected directly to Goulds 66kV bus as well.
3. Island Pond (36MW hydro – Kaplan unit) added, modeling data assumed similar to Granite Canal.

[1] Vestas – Documentation of VCRS PSS/E Model rev. 5.5 VCRS-Turbines, Dynamic Simulation for Advanced Grid Option (AGO2), 2006.

4. Round Pond (18MW hydro – Kaplan unit) added, modeling data assumed similar to Granite Canal.
5. Portland Creek (2 x 11.5MW hydro – Pelton unit) added, modeling data assumed similar to Cat Arm.
6. New 125MVA transformer added at Oxen Pond Terminal Station.
7. New 20 MVAR shunt reactor added at Bottom Brook 230kV bus.

2035

1. New 170MW CCCT at Holyrood. This is modeled as two units, a steam unit with maximum output of 59MW and a gas turbine with maximum output of 111MW. The steam unit will only have generator modeled in dynamics while the gas turbine will be modeled similar to the existing Hardwoods Gas Turbine.
2. The existing Hardwoods Gas Turbine is replaced with two (2) new 50MW gas turbines with modeling similar to existing Hardwoods Gas Turbine with exception of the electrical generators which will be modeled as Brush generators with maximum rating of 165.9MVA each. The gas generator will only be rated for 50MW, but the increased size of the generator will be for synchronous condenser operation.
3. The existing Stephenville Gas Turbine is replaced with a new 50MW gas turbine with modeling similar to existing Hardwoods Gas Turbine with exception of the electrical generator which will be modeled as a Brush generator with maximum rating of 165.9MVA. The gas generator will only be rated for 50MW, but the increased size of the generator will be for synchronous condenser operation.

3.4.Power System Planning and Operating Criteria

The following System Planning and Operating Criteria were used as the basis for this study:

3.4.1. Voltage Criteria

Under normal conditions the transmission system is operated such that the voltage is maintained between 95% and 105% of nominal. During contingency events the transmission system voltage is permitted to vary between 90% and 110% of nominal prior to operator intervention. Following an event, operators will take steps (ie. Re-dispatch generation, switch equipment in/out of service, curtail load/production) to return the transmission system voltage to the 95% to 105% normal operating range.

3.4.2. Stability Criteria

Control of frequency on the Island System is the responsibility of NLH's generating stations. Adding non-dispatchable generation to the Island may result in fewer of NLH's dispatchable generation resources being on line. As fewer generators are left to control system frequency, frequency excursions become magnified for the same change in load. A theoretical point can be reached where the slightest increase in load will cause the system to become unstable. NLH's criteria with regard to dynamic stability are as follows:

- NLH's generation must be able to return the system frequency to nominal following a sudden increase in load or a sudden decrease in load (load rejection);
- The transmission system must be able to withstand the rejection of 74.3MW of load (existing model used for Voisey Bay Nickel site).
- The system must be able to withstand the sudden step change in load of 15MW such that system frequency does not fall below 59.6 Hz. Given that the first stage of under frequency load shedding scheme incorporates relays settings at 59.5 Hz it is prudent not to encroach upon that level and risk the potential of false under frequency load trips and associated customer interruptions.
- The frequency must not remain above 61.2 Hz for more than 0.2 seconds based upon Vestas wind turbine protection settings.
- The system must be able to survive the loss of the largest on line generator with accompanying load shedding.
- The system must be able to withstand a three phase fault on 230kV transmission system for 6 cycles and subsequent tripping of faulted line. System shall not survive a 3 phase fault at Bay d'Espoir generating station and this contingency shall not be considered as it has also been ruled out as a survivable contingency in the Interconnected Island case with Muskrat Falls.
- The system shall survive an unsuccessful L-G fault on the 230kV system.
- Minimal accepted frequency of 58.0 Hz during system events. Frequencies at this value should trigger under frequency load shedding which shall return system frequency to acceptable levels.
- Minimal accepted frequency of 59.0 Hz for 15 seconds or less. Frequency values beyond this range shall cause load shedding to restore system frequency to acceptable levels.

3.5.Simulated Events

The following contingency events were simulated to observe steady state system performance against above criteria:

1. Loss of 230kV line TL233 (Bottom Brook to Buchans)
2. Loss of 230kV line TL211 (Bottom Brook to Massey Drive)
3. Loss of 230kV line TL228 (Massey Drive to Buchans)
4. Loss of 230kV line TL248 (Massey Drive to Deer Lake)
5. Loss of 230kV line TL232 (Buchans to Stony Brook)
6. Loss of 230kV line TL231 (Stony Brook to Bay d'Espoir)
7. Loss of 230kV line TL202 (Bay d'Espoir to Sunnyside)
8. Loss of 230kV line TL217 (Western Avalon to Holyrood)
9. Loss of Holyrood Unit No. 3 when in synchronous condenser mode

The following system events were simulated to obtain dynamic system responses for various load configurations and wind turbine penetration levels:

i) Load rejection of 74.3 MW from Voisey Bay Nickel processing facility (load buses 231, 239, 256, 257).
ii) Survive loss of the largest on line generator .

iii) Sudden load increase of 15MW at VBN (bus 231).
iv) Three phase fault for 6 cycles followed by subsequent tripping of 230kV transmission lines at the following locations:
   - Hardwoods Terminal Station (trip TL242)
   - Sunnyside Terminal Station (trip TL202)
   - Bottom Brook Terminal Station (trip TL233)
   - Stony Brook Terminal Station (trip TL231)
v) Line to ground fault followed by unsuccessful reclose and eventual trip of the following lines:
   - TL242 (fault at Holyrood end)
   - TL202 (fault at Sunnyside end)

3.6.Study Assumptions

The following assumptions were used in the analysis:

i) Extreme light loading corresponds to worst case scenario and is estimated to be 490MW in 2020 and 557MW in 2035. This corresponds to an estimated NLH Island Generation of 511MW and 581MW respectively. This loading level includes NLH supplied load only and not include customer supplied load such as Kruger or NP.
ii) Forecasted peak loading is estimated to be 1539MW in 2020 and 1798MW in 2035. This corresponds to an estimated NLH Island Generation of 1587MW and 1853MW respectively.
iii) Wind generators provide VAR support.
iv) Wind generation is assumed widely distributed as outlined in Table 1.
v) Wind dynamic model implementation assumes that the wind speed is constant during the typical dynamic simulation run (10 to 30 seconds) therefore, dynamics associated with changes in wind power are not considered.

4. Technical Analysis

The determination of maximum wind penetration levels to the Isolated Island system of Newfoundland & Labrador was made by analyzing both voltage regulation (steady state) and transient stability of various wind generation dispatch levels. Twenty (20) individual wind turbine plants were modeled, each with a maximum output of 25MW for a maximum total of 500MW, in a distributed fashion throughout the Island grid. Maximum wind generation of 500MW was chosen as it represented approximately 100% of the NLH generation for 2020 Extreme Light Load case. Wind generation dispatch levels were progressively increased by increments of 25MW each for four (4) base cases to determine voltage and stability limitations, these cases were as follows:

i. 2020 Extreme Light Load Case
ii. 2020 Peak Load Case
iii. 2035 Extreme Light Load Case
iv. 2035 Peak Load Case

4.1. Voltage Regulation Results

Load flows were completed for each base case listed above as well as nine (9) single element contingencies as outlined in Section 3.5 by varying the wind generation dispatch level. The following results are presented for each case and its associated maximum wind generation penetration level.

4.1.1. 2020 Extreme Light Load

Maximum wind penetration of 500MW was achieved in the steady state load flow case with the generation dispatch levels presented in Table 3 below.

Table 3
Generation Dispatch Levels
2020 Extreme Light Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation
NLH	19.2 [1]	3.1 %
Kruger	97.1	15.7 %
Wind	500	81.0 %
Total	616.3	100 %

Notes
1. BDE Unit 1 on for 19.2MW, BDE7 / CAT2 / HRD3 / HWD GT / SVL GT all in Sync. Cond. Mode

Appendix D graphically shows the results of both the overall system and the 20 wind turbine sites. There are no voltage concerns with distributed generation throughout the island as the wind generation sources are capable of contributing to voltage support. Table 4 below outlines the results of the nine single element contingency events.

Table 4
Single Element Contingency with 500MW Wind Generation
2020 Extreme Light Load Base Case

Contingency Event	Description	Results	Mitigation
1	TL233 Outage	Low voltage on west coast, greater than 0.90 pu	Wind turbine and SVL G.T. voltage setpoint adjustment solves low voltage concerns
2	TL211 Outage	Low voltage on west coast, greater than 0.90 pu	Wind turbine and SVL G.T. voltage setpoint adjustment solves low voltage concerns
3	TL228 Outage	Low voltage on west coast, greater than 0.90 pu	Wind turbine and SVL G.T. voltage setpoint adjustment solves low voltage concerns
4	TL248 Outage	Low voltage at BBK, MDR, SVL – High voltage at DLK > 1.10pu	Cat Arm units needed to operate in S.C. mode to avoid overvoltage at DLK. Wind turbine and SVL G.T. voltage setpoint adjustment solves low voltage concerns
5	TL232 Outage	No voltage or overload violations	None
6	TL231 Outage	No voltage or overload violations	None
7	TL202 Outage	No voltage or overload violations	None
8	TL217 Outage	No voltage or overload violations	None
9	HRD SC #3 Outage	Extreme low voltages on east coast	Capacitor banks at HWD and OPD to be in-service prior to loss of HRD SC#3

Theoretically, 500 MW of wind generation can be placed on the island isolated system from a steady state point of view with no voltage or overloading concerns for the 2020 Extreme Light Load Base case and associated contingencies.

With 500 MW of wind dispatched in the extreme light load case, existing Non Utility Generators (NUGs) have been turned off, this in reality is non dispatchable generation that Newfoundland & Labrador Hydro would utilize before non dispatchable wind generation. Presently, there is approximately 125 MW of NUGs available, excluding the existing 50 MW of wind generation. Therefore the practical steady state limit of non dispatchable wind generation under extreme light loading would be 375 MW.

4.1.2. 2020 Peak Load

Maximum wind penetration of 500MW was achieved in the steady state load flow case with the generation dispatch levels presented in Table 5 below.

Table 5
Generation Dispatch Levels
2020 Peak Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation
NLH [1]	1127.9	64.9 %
Kruger	109.1	6.3 %
Wind	500	28.8 %
Total	1737.0	100 %

Notes:
1. NLH generation is combination of NLH, Exploits and NUGs

Appendix E graphically shows the results of both the overall system and the 20 wind turbine sites. There are no voltage concerns with the distributed generation throughout the island as the wind generation sources are capable of contributing to voltage support. Table 6 below outlines the results of the nine single element contingency events.

Table 6
Single Element Contingency with 500MW Wind Generation
2020 Peak Load Base Case

Contingency Event	Description	Results	Mitigation
1	TL233 Outage	No voltage or overload violations	None
2	TL211 Outage	No voltage or overload violations	None
3	TL228 Outage	No voltage or overload violations	None
4	TL248 Outage (Current protection scheme has tripping of TL247 and loss of Cat Arm generation if total generation exceeds 75MW, thus U/F load shedding is likely)	Voltages low on 230kV buses West Coast, line overloads on the following lines: i) TL222 – 115% ii) TL223 – 125% iii) TL224 – 142% iv) TL225 – 169%	Reduction of Cat Arm hydro generation and re-dispatch to Bay d'Espoir alleviates overloading issues. Transformer tap setting and generator voltage setpoint changes eliminate voltage issues.
5	TL232 Outage	No voltage or overload violations	None
6	TL231 Outage	No voltage or overload violations	None
7	TL202 Outage	Low voltage at VBN, no overload violations	HRD output increased from 210 to 240 MW
8	TL217 Outage	No voltage or overload violations	None
9	HRD #3 Outage	Extreme low voltages on east coast, < 0.90pu	HRD G1 and G2 output increased to 100 MW each.

500 MW of wind generation can be placed on the island isolated system from a steady state point of view with no voltage or overloading concerns for the 2020 Peak Load Base case and associated

contingencies. Re-dispatch of hydro generation would be required for line outage contingency of TL248 (DLK-MDR).

4.1.3. 2035 Extreme Light Load

Maximum wind penetration of 500MW was achieved in the steady state load flow case with the generation dispatch levels presented in Table 7 below.

Table 7
Generation Dispatch Levels
2035 Extreme Light Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation
NLH	109.5 (Note 1)	15.5 %
Kruger	97.1	13.7 %
Wind	500	70.8 %
Total	706.6	100 %

Note 1: BDE Unit 1 on for 28.5MW, BDE7 on for 81MW, CAT2 / HRD3 / HWD GT / SVL GT all in Sync. Cond. Mode

Appendix F graphically shows the results of both the overall system and the 20 wind turbine sites. There are no voltage concerns with the distributed generation throughout the island as the wind generation sources are capable of contributing to voltage support. Table 8 below outlines the results of the nine single element contingency events.

Table 8
Single Element Contingency with 500MW Wind Generation
2035 Extreme Light Load Base Case

Contingency Event	Description	Results	Mitigation
1	TL233 Outage	No voltage or overload violations	None
2	TL211 Outage	Slightly high voltages at BBK and SVL, greater than 1.05 pu	SVL G.T. voltage setpoint adjustment solves high voltage concerns
3	TL228 Outage	No voltage or overload violations	None
4	TL248 Outage	No voltage or overload violations	None
5	TL232 Outage	No voltage or overload violations	None
6	TL231 Outage	No voltage or overload violations	None
7	TL202 Outage	No voltage or overload violations	None
8	TL217 Outage	No voltage or overload violations	None
9	HRD SC #3 Outage	No voltage or overload violations	None

500 MW of wind generation can be placed on the island isolated system from a steady state point of view with no voltage or overloading concerns for the 2035 Extreme Light Load Base case and associated contingencies.

With 500 MW of wind dispatched in the extreme light load case, existing Non Utility Generators (NUGs) have been turned off, this in reality is non dispatchable generation that Newfoundland & Labrador Hydro would utilize before non dispatchable wind generation. Presently, there is approximately 125 MW of NUGs available, excluding the existing 50 MW of wind generation. Therefore the practical steady state limit of non dispatchable wind generation under extreme light loading would be 375 MW.

4.1.4. 2035 Peak Load

Maximum wind penetration of 500MW was achieved in the steady state load flow case with the generation dispatch levels presented in Table 9 below.

Table 9
Generation Dispatch Levels
2035 Peak Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation
NLH	1402.5	69.7 %
Kruger	109.1	5.4 %
Wind	500	24.9 %
Total	2011.6	100 %

Appendix G graphically shows the results of both the overall system and the 20 wind turbine sites. There are no voltage concerns with the distributed generation throughout the island as the wind generation sources are capable of contributing to voltage support. Table 10 below outlines the results of the nine single element contingency events.

Table 10
Single Element Contingency with 500MW Wind Generation
2035 Peak Load Base Case

Contingency Event	Description	Results	Mitigation
1	TL233 Outage	No voltage or overload violations	None
2	TL211 Outage	No voltage or overload violations	None
3	TL228 Outage	No voltage or overload violations	None
4	TL248 Outage	Low voltage on 230kV bus at MDR, line overloads on the following lines: i) TL222 – 107% ii) TL223 – 118% iii) TL224 – 137% iv) TL225 – 169%	Reduction of Cat Arm hydro generation and re-dispatch to Bay d'Espoir alleviates overloading issues. Transformer tap setting and generator voltage setpoint changes eliminate voltage issues.
5	TL232 Outage	No voltage or overload violations	None
6	TL231 Outage	No voltage or overload violations	None
7	TL202 Outage	Low voltages at WAV / SSD / VBN, TL206 at 106% rating	HRD output increased from 340 to 400 MW to mitigate voltage and overload issues
8	TL217 Outage	Low voltages at WAV / SSD / VBN	HRD output increased from 340 to 400 MW to mitigate voltage issues
9	HRD #3 Outage	Extreme low voltages on east coast, < 0.90pu, generation deficit	HRD G1 and G2 output increased to 120 MW each to make up for deficit.

500 MW of wind generation can be placed on the island isolated system from a steady state point of view with no voltage or overloading concerns for the 2035 Peak Load Base case and associated contingencies. Re-dispatch of hydro generation would be required for line outage contingency of TL248 (DLK-MDR).

4.2. Transient Stability Results

Transient stability analysis was performed on each of the four base cases by incrementing the wind power generation dispatch to the island grid by 25 MW and determining the dispatch level that violated the stability criteria outlined previously. The following system events were simulated:

i) Load rejection of 74.3 MW from Voisey Bay Nickel processing facility;
ii) Survive loss of the largest on line generator;
iii) Sudden load increase of 15MW at VBN;
iv) Three phase fault for 6 cycles followed by subsequent tripping of 230kV transmission lines at the following locations:
   - Hardwoods Terminal Station (trip TL242);
   - Sunnyside Terminal Station (trip TL202);
   - Bottom Brook Terminal Station (trip TL233);
   - Stony Brook Terminal Station (trip TL231)
v) Line to ground fault followed by unsuccessful reclose and eventual trip of the following lines:
   - TL242 (fault at Holyrood end) – 30 cycle reclose time;
   - TL202 (fault at Sunnyside end) – 45 cycle reclose time

Results indicate that maximum wind generation dispatch for the extreme light load base cases was determined by the sudden load increase of 15MW, which brought system frequency close to 59.6 Hz. The following sections outline the stability results of each base case year's maximum wind generation dispatch level for the simulated system events.

4.2.1. 2020 Extreme Light Load

A maximum wind generation dispatch level of 225 MW was determined based on a sudden load increase of 15 MW causing system frequency to decline to 59.6 Hz. Table 11 outlines system generation production and inertia for the maximum wind generation dispatch level of 225 MW. Table 12 outlines the results of the stability analysis for each system event simulated. Appendix H graphically shows the results of each event studied for maximum wind generation.

Table 11
Generation Dispatch Levels
2020 Extreme Light Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation	Inertia (MW.s)
NLH	278.0	45.4 %	2685
Kruger	109.1	17.8 %	655 [1]
Wind	225	36.8 %	0
Total	612.1	100 %	3340

Note 1: Comprised of motor and generator inertia (168 and 487 respectively)

Table 12
Stability Results for 225 MW Wind Generation Dispatch Level
2020 Extreme Light Load Base Case

Case	Description	Stable	Max Freq (Hz)	Min Freq (Hz)	Load Shedding Amount (MW)	Wind Turbines Remain Connected	Comments
1	Loss of VBN Load of 74.3 MW	Yes	60.8	-	0	7 / 9	Over frequency settings modified to trip before 61.2Hz on several WT's
2	Loss of Largest Unit (BDE 90MW)	Yes	-	58.3	44.0	9 / 9	Frequency exceeds 59.0 Hz after 19 seconds
3	Load Increase of 15 MW	Yes	-	59.6	0	9 / 9	Frequency level reached criteria
4	3Ph Flt at HWD (Trip TL242)	Yes	60.3	-	0	9 / 9	No issues [1]
5	3Ph Flt at SSD (Trip TL202)	Yes	60.3	-	0	9 / 9	No issues [1]
6	3Ph Flt at STB (Trip TL231)	Yes	60.2	-	0	9 / 9	No issues [1]
7	3Ph Flt at BBK (Trip TL233)	Yes	60.1	-	0	9 / 9	No issues [1]
8	LG Flt Near HRD on TL242 – 30cyc	Yes	60.1	-	0	9 / 9	No issues [1]
9	LG Flt Near SSD on TL202 – 45cyc	Yes	60.1	-	0	9 / 9	No issues [1]

Note 1: LVRT Capability on wind turbines successful for this fault

4.2.2. 2020 Peak Load

A maximum wind generation dispatch level of 500 MW was observed to cause no issues from a transient stability point of view. Table 13 outlines system generation production and inertia for the maximum wind generation dispatch level of 500 MW. Table 14 outlines the results of the stability analysis for each system event simulated. Appendix I graphically shows the results of each event studied for maximum wind generation.

Table 13
Generation Dispatch Levels
2020 Peak Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation	Inertia (MW.s)
NLH	1146.2	65.3 %	6542
Kruger	109.1	6.2 %	655 [1]
Wind	500	28.5 %	0
Total	1755.3	100 %	7197

Note 1: Comprised of motor and generator inertia (168 and 487 respectively)

Table 14
Stability Results for 500 MW Wind Generation Dispatch Level
2020 Peak Load Base Case

Case	Description	Stable	Max Freq (Hz)	Min Freq (Hz)	Load Shedding Amount (MW)	Wind Turbines Remain Connected	Comments
1	Loss of VBN Load of 74.3 MW	Yes	60.4	-	0	9 / 9	No issues
2	Loss of Largest Unit (BDE 110MW)	Yes	-	58.8	34.6	9 / 9	Frequency exceeds 59.0 Hz after 8 seconds
3	Load Increase of 15 MW	Yes	-	59.9	0	9 / 9	No issues
4	3Ph Flt at HWD (Trip TL242)	Yes	60.3	-	0	9 / 9	Voltage at HRD Plant @ 0.25pu, no loss of unit as generation <80 MW per unit
5	3Ph Flt at SSD (Trip TL202)	Yes	60.4	-	0	9 / 9	Voltage at HRD Plant @ 0.45pu, no loss of unit as generation <80 MW per unit
6	3Ph Flt at STB (Trip TL231)	Yes	60.1	-	0	9 / 9	No issues [1]
7	3Ph Flt at BBK (Trip TL233)	Yes	60.1	-	0	9 / 9	No issues [1]
8	LG Flt Near HRD on TL242 – 30cyc	Yes	60.1	-	0	9 / 9	No issues [1]
9	LG Flt Near SSD on TL202 – 45cyc	Yes	60.1	-	0	9 / 9	No issues [1]

Note 1: LVRT Capability on wind turbines successful for this fault

4.2.3. 2035 Extreme Light Load

A maximum wind generation dispatch level of 300 MW was observed based on a sudden load increase of 15 MW causing system frequency to decline to 59.6 Hz. Table 15 outlines system generation production and inertia for the maximum wind generation dispatch level of 300 MW. Table 16 outlines the results of the stability analysis for each system event simulated. Appendix J graphically shows the results of each event studied for maximum wind generation.

Table 15
Generation Dispatch Levels
2035 Extreme Light Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation	Inertia (MW.s)
NLH	274.7	40.2 %	2685
Kruger	109.1	16.0 %	655 [1]
Wind	300	43.8 %	0
Total	683.8 [2]	100 %	3340

Note 1: Comprised of motor and generator inertia (168 and 487 respectively)
Note 2: Dispatch levels differ slightly from Load Flow case as 18MW of Exploits Generation was netted with load because of convergence problems on Bus 29 during stability simulations.

Table 16
Stability Results for 300 MW Wind Generation Dispatch Level
2035 Extreme Light Load Base Case

Case	Description	Stable	Max Freq (Hz)	Min Freq (Hz)	Load Shedding Amount (MW)	Wind Turbines Remain Connected	Comments
1	Loss of VBN Load of 74.3 MW	Yes	60.8	-	0	7 / 9	Over frequency settings modified to trip before 61.2Hz on several WT's
2	Loss of Largest Unit (BDE 81MW)	Yes	-	58.5	36.0	9 / 9	Frequency exceeds 59.0 Hz after 18 seconds
3	Load Increase of 15 MW	Yes	-	59.6	0	9 / 9	Frequency level reached criteria
4	3Ph Flt at HWD (Trip TL242)	Yes	60.4	-	0	9 / 9	No issues [1]
5	3Ph Flt at SSD (Trip TL202)	Yes	60.5	59.5	0	9 / 9	No issues [1]
6	3Ph Flt at STB (Trip TL231)	Yes	60.6	-	0	9 / 9	No issues [1]
7	3Ph Flt at BBK (Trip TL233)	Yes	60.6	-	0	9 / 9	No issues [1]
8	LG Flt Near HRD on TL242 – 30cyc	Yes	60.1	-	0	9 / 9	No issues [1]
9	LG Flt Near SSD on TL202 – 45cyc	Yes	60.1	-	0	9 / 9	No issues [1]

Note 1: LVRT Capability on wind turbines successful for this fault

4.2.4. 2035 Peak Load

A maximum wind generation dispatch level of 500 MW was observed to cause no issues from a transient stability point of view. Table 17 outlines system generation production and inertia for the maximum wind generation dispatch level of 500 MW. Table 18 outlines the results of the stability analysis for each system event simulated. Appendix K graphically shows the results of each event studied for maximum wind generation.

Table 17
Generation Dispatch Levels - 2035 Peak Load Base Case

Generation Source	Generation Dispatch Level (MW)	Percent of Total Generation	System Inertia (MW.s)
NLH	1404.4	69.8 %	6854
Kruger	109.1	5.4 %	655 [1]
Wind	500	24.8 %	0
Total	2013.5	100 %	7509

Note 1: Comprised of motor and generator inertia (168 and 487 respectively

Table 18
Stability Results for 500 MW Wind Generation Dispatch Level
2035 Peak Load Base Case

Case	Description	Stable	Max Freq (Hz)	Min Freq (Hz)	Load Shedding Amount (MW)	Wind Turbines Remain Connected	Comments
1	Loss of VBN Load of 74.3 MW	Yes	60.3	-	0	9 / 9	No issues
2	Loss of Largest Unit (BDE 142MW)	Yes	-	58.7	91.3	9 / 9	Frequency exceeds 59.0 Hz after 18 seconds
3	Load Increase of 15 MW	Yes	-	59.9	0	9 / 9	No issues
4	3Ph Flt at HWD (Trip TL242)	Yes	60.5	-	0	9 / 9	Voltage at HRD Plant not less than 0.5pu, no loss of unit as generation <80 MW per unit
5	3Ph Flt at SSD (Trip TL202)	Yes	60.5	-	0	9 / 9	Voltage at HRD Plant not less than 0.5pu, no loss of unit as generation <80 MW per unit
6	3Ph Flt at STB (Trip TL231)	Yes	60.2	-	0	9 / 9	No issues [1]
7	3Ph Flt at BBK (Trip TL233)	Yes	60.2	-	0	9 / 9	No issues [1]
8	LG Flt Near HRD on TL242 – 30cyc	Yes	60.1	-	0	9 / 9	No issues [1]
9	LG Flt Near SSD on TL202 – 45cyc	Yes	60.1	-	0	9 / 9	No issues [1]

Note 1: LVRT Capability on wind turbines successful for this fault

4.3 Multiple Loss of Wind Farms

Transient stability analysis was conducted on the sudden loss of multiple wind farms geographically close to one another as a result of high wind speed cut-out, which typically is set at 25m/sec. This analysis was conducted for the 2020 Extreme Light Load base case with 225MW of wind dispatched, as this is considered the most onerous case due to minimum system inertia and maximum wind penetration. Three cases were analyzed, these being; i) Loss of two 25MW farms simultaneously, ii) Loss of two 25MW farms simultaneously with additional system inertia, and iii) Loss of three 25MW farms simultaneously with additional system inertia. Appendix L graphically shows the system frequency results of each event studied.

4.3.1 Loss of Two 25MW Wind Farms

The loss of two 25MW wind farms simultaneously due to high wind speed during 2020 Extreme Light Load conditions is expected to cause approximately 9MW of load shedding as system frequency drops below the 58.8 Hz under frequency load shed setting.

4.3.2 Loss of Two 25MW Wind Farms – Additional System Inertia

With the addition of two 300MVA high inertia synchronous condensers at Sunnyside having an H constant of 7.84 each, the loss of two 25MW wind farms simultaneously due to high wind speed during 2020 Extreme Light Load conditions is not expected to cause any under frequency load shedding. Minimum frequency is approximately 58.86Hz, but recovers above 59Hz before the 15 second timer expired, thus avoiding any under frequency load shedding.

4.3.3 Loss of Three 25MW Wind Farms – Additional System Inertia

With the addition of two 300MVA high speed high inertia synchronous condensers at Sunnyside having an H constant of 7.84 each, the loss of three 25MW wind farms simultaneously due to high wind speed during 2020 Extreme Light Load conditions is expected to cause approximately 20MW of load shedding. Minimum frequency is approximately 58.64Hz and load shedding occurs as a result of both 58.8Hz and 59.0Hz / 15 second protection settings.

These results highlight the importance of geographically diversifying wind farms to avoid simultaneous loss of nearby wind farms due to high wind speeds and system load shedding as a result. While the addition of rotating mass in the form of high inertia synchronous condensers will eliminate 9MW of load shedding for loss of two wind farms, it will not avoid load shedding as a result of simultaneous loss of three wind farms. It is not clear whether or not the cost associated with the addition of inertia is justified as the probability of this event occurring during extreme light load conditions is unknown.

In the absence of detailed wind surveys, it is recommended that future wind farm developments be geographically dispersed to avoid the possibility of this event from occurring. As well, detailed study is recommended to investigate alternate solutions of avoiding under frequency load shedding due to loss of multiple wind farms. Possible solutions may include high speed flywheel energy storage systems and dispatch of fast response generation such as gas turbines during periods of predicted high wind speeds and high wind penetration.

5.0 Conclusions

Load flow analysis of the two base case years 2020 and 2035 indicate that there are no steady state restrictions up to and including 500 MW of wind power generation for the Isolated Island option. 500 MW was the maximum steady state wind generation dispatch analysed due to the fact that NLH generation at extreme light load conditions approaches this value. The practical steady state limit during extreme light load conditions would be limited to 375MW due to other NUG generation dispatch of approximately 125MW.

Transient stability analysis of the two base case years indicate a maximum wind dispatch level of 225 MW and 300 MW for the 2020 and 2035 Extreme Light Load cases respectively. This is based on a sudden load increase of 15 MW causing a frequency decline to 59.6 Hz which was the pre-defined criteria for frequency deviation. There was no restriction up to and including 500 MW of wind generation for peak loading periods of 2020 and 2035. System events on the 230kV system such as three phase and line to ground faults that were cleared within normal operating times did not adversely affect operation of the wind generation due to the advances of the Low Voltage Ride Through (LVRT) capability. Table 19 below summarizes the resulting restrictions as a result of the transient stability analysis.

Table 19
Maximum Wind Generation Dispatch
Stability Analysis Results

Year	Extreme Light Load			Peak Load		
	Wind Generation Level (MW)	Wind Penetration Level (%)	System Inertia (MW.s)	Wind Generation Level (MW)	Wind Penetration Level (%)	System Inertia (MW.s)
2020	225	36.8	3340	500	28.5	7197
2035	300	43.8	3340	500	24.8	7509

Based on the simulation studies conducted in this report, the transient stability constraint is found to be the limiting factor in determining the amount of wind penetration during the extreme light load conditions. Thus, it is recommended that no more than 225MW and 300MW of net wind generation is dispatched during the extreme light load conditions during the years 2020 and 2035, respectively. However, the extreme light loading conditions are likely to occur for very short durations of the year, particularly during night hours of the summer season, when wind generation profile is usually at its minimum. Thus, it is anticipated that the available wind generation under light load conditions is in close proximity to the wind penetration level limited by the transient stability constraint. It is recommended that historical wind data be obtained for potential wind sites around the island, which can then be used to determine time and duration of minimal wind generation profiles coinciding with minimum system loading.

Overall analysis indicates that the current wind generation technology of the Doubly Fed Induction Generator (DFIG) model, similar to the Vestas V90 used in St. Lawrence and Fermeuse, provides voltage support on the island when dispatch is widely distributed. As well, the control system of the DFIG model aids in frequency response control for the first 5-7 seconds during certain system events, such as loss of generation or sudden load increase. This is accomplished by converting the kinetic energy of the spinning turbine blades into excess power which in turn allows time for conventional generation governors to respond to system conditions.

The analysis presented in this report does not assume time varying wind patterns and further analysis is recommended to simulate its effect on overall system frequency control. It is believed that higher wind penetration levels on the island system could cause larger frequency deviations than currently experienced without additional fast acting counter measures. These could include high inertia synchronous condensers or high speed flywheel energy storage / regulation plants to minimize frequency deviations as a result of time varying wind patterns.

These results highlight the importance of geographically diversifying wind farms to avoid simultaneous loss of nearby wind farms due to high wind speeds and system load shedding as a result. In the absence of detailed wind surveys, it is recommended that future wind farm developments be geographically dispersed to avoid the possibility of this event from occurring. As well, detailed study is recommended to investigate alternate solutions of avoiding under frequency load shedding due to loss of multiple wind farms. Possible solutions may include high speed flywheel energy storage systems and dispatch of fast response generation such as gas turbines during periods of predicted high wind and high wind penetration.

APPENDIX A - LOAD FORECAST (2018 – 2067)

NP Energy Purchases (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	688	631	623	505	432	353	329	327	340	429	519	653
2019	698	640	633	513	439	358	334	332	345	435	527	663
2020	705	646	638	518	443	362	337	335	349	439	532	669
2021	717	657	649	527	451	368	343	341	355	447	541	680
2022	729	668	660	536	459	375	349	346	361	455	550	692
2023	740	678	670	544	466	381	355	352	367	462	559	703
2024	750	687	680	552	473	386	360	357	372	468	567	712
2025	760	696	689	560	479	391	364	361	377	475	574	722
2026	769	705	697	566	485	396	369	366	381	480	581	730
2027	779	714	707	575	492	402	374	371	387	487	589	741
2028	790	724	716	583	499	408	379	376	392	494	597	750
2029	799	732	724	589	505	412	384	380	396	500	604	759
2030	808	741	733	597	512	418	389	385	401	506	612	768
2031	817	749	741	604	517	422	393	389	406	512	618	777
2032	826	757	750	610	523	427	398	394	410	517	625	785
2033	835	765	758	617	529	432	402	398	415	523	632	794
2034	844	774	766	624	535	437	406	402	420	529	639	802
2035	853	781	774	631	541	441	411	406	424	534	646	811
2036	861	789	781	637	546	446	415	410	428	539	652	818
2037	868	796	788	643	551	450	419	414	432	545	658	826
2038	876	803	796	649	557	454	422	418	436	550	664	833
2039	884	810	803	655	562	459	426	422	440	555	670	841
2040	892	817	810	661	567	463	430	425	444	560	676	848
2041	899	824	816	666	571	466	434	429	447	564	681	855
2042	906	830	823	671	576	470	437	432	451	569	687	862
2043	913	837	829	677	581	474	441	435	454	573	692	868
2044	920	843	835	682	585	478	444	439	458	577	697	875
2045	927	849	842	687	590	481	447	442	462	582	703	882
2046	933	855	848	692	594	485	451	445	465	586	708	888
2047	940	861	854	697	598	488	454	448	468	590	713	894
2048	946	867	859	702	603	492	457	452	471	594	718	900
2049	953	873	865	707	607	495	460	455	475	599	723	906
2050	959	878	871	711	611	499	463	458	478	602	727	912
2051	964	884	876	716	615	502	466	460	481	606	732	918
2052	970	889	881	720	618	505	469	463	483	610	736	923
2053	975	894	886	724	622	508	472	466	486	613	740	928
2054	981	899	891	728	626	511	474	468	489	617	745	934
2055	987	904	896	733	629	514	477	471	492	620	749	939
2056	992	909	902	737	633	517	480	474	495	624	753	944
2057	998	914	907	741	637	520	483	477	498	627	757	950
2058	1003	919	912	746	641	523	485	479	500	631	762	955
2059	1009	924	917	750	644	526	488	482	503	635	766	960
2060	1015	930	922	754	648	529	491	485	506	638	770	966
2061	1020	935	927	758	652	532	494	487	509	642	775	971
2062	1026	940	932	763	655	535	497	490	512	645	779	976
2063	1031	945	937	767	659	538	499	493	515	649	783	982
2064	1037	950	942	771	663	541	502	495	517	653	788	987
2065	1042	955	948	775	666	544	505	498	520	656	792	992
2066	1048	960	953	780	670	547	508	501	523	660	796	998
2067	1054	965	958	784	674	550	510	504	526	663	800	1003

NP Peak Demand Purchases (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	1302	1294	1115	972	851	716	624	596	655	855	997	1294
2019	1313	1305	1132	987	863	727	633	604	665	867	1012	1305
2020	1329	1322	1142	996	872	734	639	610	671	875	1022	1322
2021	1343	1335	1162	1014	887	746	650	620	682	890	1040	1335
2022	1362	1354	1182	1031	902	759	660	631	693	905	1057	1354
2023	1385	1377	1200	1047	916	770	671	640	704	918	1074	1377
2024	1404	1396	1217	1062	929	781	680	649	713	931	1089	1396
2025	1422	1414	1233	1076	941	791	689	657	722	943	1104	1414
2026	1439	1430	1248	1090	952	801	697	665	731	954	1117	1430
2027	1455	1446	1266	1105	966	812	707	675	741	967	1133	1446
2028	1472	1464	1283	1120	979	823	716	684	751	980	1149	1464
2029	1489	1481	1298	1133	990	832	724	691	759	991	1162	1481
2030	1504	1495	1314	1148	1002	842	733	700	769	1003	1177	1495
2031	1519	1510	1329	1161	1014	852	741	708	777	1014	1190	1510
2032	1534	1525	1343	1174	1025	861	749	715	786	1025	1203	1525
2033	1549	1540	1358	1187	1036	870	757	723	794	1036	1217	1540
2034	1564	1555	1373	1200	1047	880	765	731	802	1047	1230	1555
2035	1578	1569	1387	1212	1058	889	773	738	810	1057	1243	1569
2036	1592	1582	1400	1224	1068	897	780	745	818	1067	1254	1582
2037	1605	1596	1413	1235	1078	905	787	752	825	1077	1266	1596
2038	1618	1609	1427	1247	1088	914	794	759	833	1087	1278	1609
2039	1632	1622	1440	1258	1098	922	802	766	841	1096	1290	1622
2040	1644	1635	1452	1269	1108	930	808	772	848	1106	1301	1635
2041	1656	1647	1464	1280	1116	937	815	778	854	1114	1312	1647
2042	1668	1658	1475	1290	1125	945	821	784	861	1123	1322	1658
2043	1680	1670	1487	1300	1134	952	827	790	867	1132	1333	1670
2044	1692	1682	1498	1310	1143	959	834	796	874	1140	1343	1682
2045	1703	1693	1510	1320	1152	967	840	802	881	1149	1353	1693
2046	1714	1704	1521	1330	1160	973	846	808	887	1157	1363	1704
2047	1725	1715	1531	1339	1168	980	852	814	893	1165	1373	1715
2048	1736	1726	1542	1349	1176	987	858	819	899	1173	1382	1726
2049	1747	1737	1553	1358	1184	994	863	825	905	1181	1392	1737
2050	1757	1747	1563	1367	1192	1000	869	830	911	1188	1401	1747
2051	1766	1756	1572	1375	1199	1006	874	835	916	1195	1409	1756
2052	1776	1765	1581	1383	1206	1012	879	840	921	1202	1418	1765
2053	1785	1775	1590	1391	1213	1018	884	845	927	1209	1426	1775
2054	1795	1784	1600	1399	1220	1024	889	849	932	1215	1434	1784
2055	1804	1794	1609	1408	1227	1029	894	854	937	1222	1443	1794
2056	1813	1803	1618	1416	1234	1035	899	859	942	1229	1451	1803
2057	1823	1812	1627	1424	1241	1041	904	864	948	1236	1459	1812
2058	1832	1822	1637	1432	1248	1047	909	869	953	1243	1468	1822
2059	1842	1831	1646	1440	1255	1053	914	874	958	1250	1476	1831
2060	1851	1840	1655	1448	1262	1059	919	878	964	1257	1484	1840
2061	1860	1850	1664	1456	1269	1065	925	883	969	1264	1493	1850
2062	1870	1859	1674	1465	1276	1070	930	888	974	1270	1501	1859
2063	1879	1868	1683	1473	1283	1076	935	893	979	1277	1509	1868
2064	1889	1878	1692	1481	1291	1082	940	898	985	1284	1518	1878
2065	1898	1887	1701	1489	1298	1088	945	903	990	1291	1526	1887
2066	1907	1896	1711	1497	1305	1094	950	907	995	1298	1534	1896
2067	1917	1906	1720	1505	1312	1100	955	912	1001	1305	1543	1906

Hydro Rural Energy Purchases (Bulk Deliveries) (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	46.9	40.1	41.8	35.4	34.1	31.1	29.8	28.6	28.1	31.1	34.9	44.3
2019	46.4	39.6	41.3	35.0	33.7	30.8	29.5	28.3	27.8	30.8	34.6	43.9
2020	46.1	39.4	41.1	34.8	33.5	30.6	29.3	28.1	27.7	30.6	34.4	43.6
2021	46.4	39.6	41.3	35.0	33.7	30.8	29.5	28.2	27.8	30.8	34.6	43.8
2022	46.8	40.0	41.7	35.3	34.0	31.0	29.8	28.5	28.1	31.0	34.9	44.2
2023	47.1	40.3	42.0	35.6	34.3	31.3	30.0	28.7	28.3	31.3	35.1	44.6
2024	47.4	40.5	42.3	35.8	34.5	31.5	30.2	28.9	28.5	31.5	35.4	44.8
2025	47.7	40.7	42.5	36.0	34.7	31.6	30.3	29.0	28.6	31.6	35.5	45.1
2026	48.0	41.0	42.7	36.2	34.9	31.8	30.5	29.2	28.8	31.8	35.8	45.3
2027	48.3	41.3	43.1	36.5	35.2	32.1	30.8	29.4	29.0	32.1	36.0	45.7
2028	48.7	41.6	43.4	36.7	35.4	32.3	31.0	29.7	29.2	32.3	36.3	46.0
2029	49.0	41.9	43.7	37.0	35.7	32.5	31.2	29.9	29.4	32.5	36.5	46.3
2030	49.4	42.2	44.0	37.2	35.9	32.8	31.4	30.1	29.6	32.8	36.8	46.7
2031	49.6	42.4	44.2	37.4	36.1	32.9	31.6	30.2	29.8	32.9	37.0	46.9
2032	49.9	42.6	44.4	37.6	36.3	33.1	31.7	30.4	29.9	33.1	37.2	47.2
2033	50.1	42.9	44.7	37.8	36.5	33.3	31.9	30.5	30.1	33.3	37.4	47.4
2034	50.4	43.1	44.9	38.0	36.7	33.5	32.1	30.7	30.2	33.5	37.6	47.7
2035	50.7	43.3	45.1	38.2	36.9	33.6	32.2	30.9	30.4	33.6	37.8	47.9
2036	50.9	43.5	45.4	38.4	37.0	33.8	32.4	31.0	30.6	33.8	38.0	48.2
2037	51.2	43.8	45.6	38.6	37.2	34.0	32.6	31.2	30.7	34.0	38.2	48.4
2038	51.5	44.0	45.8	38.8	37.4	34.2	32.7	31.3	30.9	34.2	38.4	48.7
2039	51.7	44.2	46.1	39.0	37.6	34.3	32.9	31.5	31.0	34.3	38.6	48.9
2040	52.0	44.4	46.3	39.2	37.8	34.5	33.1	31.7	31.2	34.5	38.8	49.2
2041	52.2	44.6	46.5	39.4	38.0	34.7	33.2	31.8	31.3	34.7	38.9	49.4
2042	52.5	44.9	46.8	39.6	38.2	34.8	33.4	32.0	31.5	34.8	39.1	49.6
2043	52.8	45.1	47.0	39.8	38.4	35.0	33.6	32.1	31.7	35.0	39.3	49.9
2044	53.0	45.3	47.3	40.0	38.6	35.2	33.8	32.3	31.8	35.2	39.5	50.1
2045	53.3	45.5	47.5	40.2	38.8	35.4	33.9	32.5	32.0	35.4	39.7	50.4
2046	53.6	45.8	47.7	40.4	39.0	35.5	34.1	32.6	32.1	35.5	39.9	50.6
2047	53.8	46.0	48.0	40.6	39.1	35.7	34.3	32.8	32.3	35.7	40.1	50.9
2048	54.1	46.2	48.2	40.8	39.3	35.9	34.4	32.9	32.5	35.9	40.3	51.1
2049	54.4	46.4	48.4	41.0	39.5	36.1	34.6	33.1	32.6	36.1	40.5	51.4
2050	54.6	46.7	48.7	41.2	39.7	36.2	34.8	33.3	32.8	36.2	40.7	51.6
2051	54.9	46.9	48.9	41.4	39.9	36.4	34.9	33.4	32.9	36.4	40.9	51.9
2052	55.1	47.1	49.1	41.6	40.1	36.6	35.1	33.6	33.1	36.6	41.1	52.1
2053	55.4	47.3	49.4	41.8	40.3	36.8	35.3	33.7	33.2	36.8	41.3	52.4
2054	55.7	47.6	49.6	42.0	40.5	36.9	35.4	33.9	33.4	36.9	41.5	52.6
2055	55.9	47.8	49.8	42.2	40.7	37.1	35.6	34.1	33.6	37.1	41.7	52.9
2056	56.2	48.0	50.1	42.4	40.9	37.3	35.8	34.2	33.7	37.3	41.9	53.1
2057	56.5	48.2	50.3	42.6	41.1	37.5	35.9	34.4	33.9	37.5	42.1	53.4
2058	56.7	48.5	50.5	42.8	41.2	37.6	36.1	34.5	34.0	37.6	42.3	53.6
2059	57.0	48.7	50.8	43.0	41.4	37.8	36.3	34.7	34.2	37.8	42.5	53.9
2060	57.2	48.9	51.0	43.2	41.6	38.0	36.4	34.9	34.3	38.0	42.7	54.1
2061	57.5	49.1	51.2	43.4	41.8	38.2	36.6	35.0	34.5	38.2	42.9	54.4
2062	57.8	49.4	51.5	43.6	42.0	38.3	36.8	35.2	34.7	38.3	43.1	54.6
2063	58.0	49.6	51.7	43.8	42.2	38.5	36.9	35.3	34.8	38.5	43.3	54.9
2064	58.3	49.8	51.9	44.0	42.4	38.7	37.1	35.5	35.0	38.7	43.5	55.1
2065	58.6	50.0	52.2	44.2	42.6	38.9	37.3	35.7	35.1	38.9	43.7	55.4
2066	58.8	50.3	52.4	44.4	42.8	39.0	37.4	35.8	35.3	39.0	43.8	55.6
2067	59.1	50.5	52.6	44.6	43.0	39.2	37.6	36.0	35.4	39.2	44.0	55.9

Hydro Rural Demand Purchases (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	90.5	86.9	80.1	72.9	68.6	63.8	59.3	56.1	59.3	63.4	72.4	90.5
2019	89.6	86.0	79.3	72.1	67.9	63.1	58.7	55.5	58.7	62.7	71.6	89.6
2020	89.0	85.5	78.8	71.7	67.5	62.8	58.3	55.2	58.3	62.3	71.2	89.0
2021	89.5	85.9	79.2	72.0	67.8	63.1	58.6	55.5	58.6	62.6	71.6	89.5
2022	90.3	86.7	79.9	72.7	68.4	63.7	59.1	56.0	59.1	63.2	72.2	90.3
2023	91.0	87.3	80.5	73.2	69.0	64.1	59.6	56.4	59.6	63.7	72.8	91.0
2024	91.6	87.9	81.0	73.7	69.4	64.5	60.0	56.8	60.0	64.1	73.2	91.6
2025	92.1	88.4	81.5	74.1	69.8	64.9	60.3	57.1	60.3	64.4	73.6	92.1
2026	92.6	88.9	81.9	74.5	70.2	65.3	60.6	57.4	60.6	64.8	74.1	92.6
2027	93.3	89.6	82.6	75.1	70.7	65.8	61.1	57.9	61.1	65.3	74.7	93.3
2028	94.0	90.2	83.2	75.7	71.2	66.3	61.6	58.3	61.6	65.8	75.2	94.0
2029	94.6	90.9	83.8	76.2	71.7	66.7	62.0	58.7	62.0	66.2	75.7	94.6
2030	95.3	91.5	84.3	76.7	72.2	67.2	62.4	59.1	62.4	66.7	76.2	95.3
2031	96.3	92.4	85.2	77.5	73.0	67.9	63.0	59.7	63.0	67.4	77.0	96.3
2032	96.8	92.9	85.6	77.9	73.3	68.2	63.4	60.0	63.4	67.7	77.4	96.8
2033	97.3	93.4	86.1	78.3	73.7	68.6	63.7	60.3	63.7	68.1	77.8	97.3
2034	97.8	93.9	86.5	78.7	74.1	68.9	64.0	60.6	64.0	68.4	78.2	97.8
2035	98.3	94.4	87.0	79.1	74.5	69.3	64.4	60.9	64.4	68.8	78.6	98.3
2036	98.8	94.9	87.4	79.5	74.9	69.7	64.7	61.3	64.7	69.2	79.0	98.8
2037	99.3	95.3	87.9	79.9	75.3	70.0	65.0	61.6	65.0	69.5	79.5	99.3
2038	99.8	95.8	88.3	80.4	75.7	70.4	65.4	61.9	65.4	69.9	79.9	99.8
2039	100.3	96.3	88.8	80.8	76.1	70.7	65.7	62.2	65.7	70.2	80.3	100.3
2040	100.8	96.8	89.2	81.2	76.4	71.1	66.1	62.5	66.1	70.6	80.7	100.8
2041	101.4	97.3	89.7	81.6	76.8	71.5	66.4	62.8	66.4	70.9	81.1	101.4
2042	101.9	97.8	90.1	82.0	77.2	71.8	66.7	63.2	66.7	71.3	81.5	101.9
2043	102.4	98.3	90.6	82.4	77.6	72.2	67.1	63.5	67.1	71.7	81.9	102.4
2044	102.9	98.8	91.0	82.8	78.0	72.5	67.4	63.8	67.4	72.0	82.3	102.9
2045	103.4	99.3	91.5	83.2	78.4	72.9	67.7	64.1	67.7	72.4	82.7	103.4
2046	103.9	99.7	92.0	83.6	78.8	73.2	68.1	64.4	68.1	72.7	83.1	103.9
2047	104.4	100.2	92.4	84.0	79.1	73.6	68.4	64.7	68.4	73.1	83.5	104.4
2048	104.9	100.7	92.9	84.5	79.5	74.0	68.7	65.0	68.7	73.4	83.9	104.9
2049	105.4	101.2	93.3	84.9	79.9	74.3	69.1	65.4	69.1	73.8	84.3	105.4
2050	105.9	101.7	93.8	85.3	80.3	74.7	69.4	65.7	69.4	74.2	84.8	105.9
2051	106.4	102.2	94.2	85.7	80.7	75.0	69.7	66.0	69.7	74.5	85.2	106.4
2052	107.0	102.7	94.7	86.1	81.1	75.4	70.1	66.3	70.1	74.9	85.6	107.0
2053	107.5	103.2	95.1	86.5	81.5	75.8	70.4	66.6	70.4	75.2	86.0	107.5
2054	108.0	103.7	95.6	86.9	81.8	76.1	70.7	66.9	70.7	75.6	86.4	108.0
2055	108.5	104.1	96.0	87.3	82.2	76.5	71.1	67.3	71.1	75.9	86.8	108.5
2056	109.0	104.6	96.5	87.7	82.6	76.8	71.4	67.6	71.4	76.3	87.2	109.0
2057	109.5	105.1	96.9	88.2	83.0	77.2	71.7	67.9	71.7	76.7	87.6	109.5
2058	110.0	105.6	97.4	88.6	83.4	77.6	72.1	68.2	72.1	77.0	88.0	110.0
2059	110.5	106.1	97.8	89.0	83.8	77.9	72.4	68.5	72.4	77.4	88.4	110.5
2060	111.0	106.6	98.3	89.4	84.2	78.3	72.7	68.8	72.7	77.7	88.8	111.0
2061	111.5	107.1	98.7	89.8	84.6	78.6	73.1	69.2	73.1	78.1	89.2	111.5
2062	112.1	107.6	99.2	90.2	84.9	79.0	73.4	69.5	73.4	78.4	89.6	112.1
2063	112.6	108.1	99.6	90.6	85.3	79.4	73.7	69.8	73.7	78.8	90.1	112.6
2064	113.1	108.6	100.1	91.0	85.7	79.7	74.1	70.1	74.1	79.2	90.5	113.1
2065	113.6	109.0	100.5	91.4	86.1	80.1	74.4	70.4	74.4	79.5	90.9	113.6
2066	114.1	109.5	101.0	91.8	86.5	80.4	74.7	70.7	74.7	79.9	91.3	114.1
2067	114.6	110.0	101.4	92.3	86.9	80.8	75.1	71.1	75.1	80.2	91.7	114.6

CBPP Energy Purchases (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2019	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2020	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2021	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2022	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2023	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2024	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2025	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2026	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2027	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2028	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2029	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2030	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2031	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2032	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2033	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2034	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2035	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2036	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2037	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2038	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2039	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2040	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2041	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2042	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2043	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2044	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2045	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2046	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2047	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2048	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2049	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2050	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2051	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2052	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2053	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2054	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2055	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2056	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2057	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2058	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2059	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2060	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2061	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2062	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2063	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2064	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2065	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2066	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2
2067	8.2	7.4	8.2	7.9	8.2	7.9	8.2	8.2	7.9	8.2	7.9	8.2

CBPP Peak Demand Purchases (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2019	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2020	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2021	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2022	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2023	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2024	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2025	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2026	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2027	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2028	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2029	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2030	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2031	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2032	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2033	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2034	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2035	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2036	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2037	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2038	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2039	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2040	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2041	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2042	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2043	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2044	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2045	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2046	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2047	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2048	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2049	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2050	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2051	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2052	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2053	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2054	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2055	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2056	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2057	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2058	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2059	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2060	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2061	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2062	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2063	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2064	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2065	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2066	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0
2067	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0	23.0

NARL Energy Purchases (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2019	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2020	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2021	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2022	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2023	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2024	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2025	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2026	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2027	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2028	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2029	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2030	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2031	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2032	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2033	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2034	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2035	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2036	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2037	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2038	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2039	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2040	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2041	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2042	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2043	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2044	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2045	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2046	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2047	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2048	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2049	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2050	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2051	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2052	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2053	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2054	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2055	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2056	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2057	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2058	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2059	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2060	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2061	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2062	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2063	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2064	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2065	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2066	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2
2067	25.6	23.5	24.7	22.4	19.7	22.8	25.7	26.0	24.4	22.7	22.8	22.2

NARL Peak Demand Purchases (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2019	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2020	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2021	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2022	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2023	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2024	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2025	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2026	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2027	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2028	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2029	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2030	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2031	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2032	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2033	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2034	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2035	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2036	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2037	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2038	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2039	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2040	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2041	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2042	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2043	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2044	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2045	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2046	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2047	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2048	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2049	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2050	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2051	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2052	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2053	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2054	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2055	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2056	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2057	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2058	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2059	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2060	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2061	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2062	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2063	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2064	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2065	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2066	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5
2067	37.0	37.0	36.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	35.5	36.5

VI Energy Purchases (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2019	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2020	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2021	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2022	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2023	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2024	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2025	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2026	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2027	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2028	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2029	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2030	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2031	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2032	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2033	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2034	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2035	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2036	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2037	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2038	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2039	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2040	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2041	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2042	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2043	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2044	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2045	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2046	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2047	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2048	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2049	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2050	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2051	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2052	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2053	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2054	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2055	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2056	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2057	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2058	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2059	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2060	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2061	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2062	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2063	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2064	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2065	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2066	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6
2067	58.6	52.8	58.6	56.7	58.5	56.6	58.4	58.4	56.6	58.5	56.7	58.6

VI Peak Demand Purchases (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2019	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2020	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2021	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2022	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2023	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2024	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2025	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2026	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2027	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2028	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2029	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2030	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2031	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2032	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2033	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2034	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2035	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2036	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2037	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2038	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2039	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2040	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2041	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2042	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2043	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2044	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2045	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2046	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2047	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2048	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2049	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2050	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2051	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2052	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2053	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2054	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2055	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2056	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2057	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2058	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2059	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2060	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2061	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2062	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2063	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2064	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2065	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2066	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6
2067	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6	94.6

Transmission Losses (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	23.2	21.1	21.2	17.6	16.0	17.4	17.1	17.0	16.0	17.0	19.2	22.8
2019	23.4	21.4	21.4	17.8	16.2	17.6	17.3	17.2	16.2	17.2	19.5	23.1
2020	23.6	21.5	21.6	17.9	16.3	17.8	17.4	17.3	16.3	17.3	19.6	23.2
2021	24.0	21.8	21.9	18.2	16.6	18.0	17.7	17.5	16.5	17.6	19.9	23.6
2022	24.3	22.2	22.2	18.4	16.8	18.2	17.9	17.8	16.7	17.8	20.2	23.9
2023	24.6	22.5	22.5	18.7	17.0	18.5	18.1	18.0	16.9	18.1	20.4	24.2
2024	24.9	22.7	22.8	18.9	17.2	18.7	18.3	18.2	17.1	18.3	20.7	24.5
2025	25.2	23.0	23.0	19.1	17.4	18.9	18.5	18.4	17.3	18.5	20.9	24.8
2026	25.5	23.2	23.3	19.3	17.6	19.1	18.7	18.5	17.5	18.7	21.1	25.1
2027	25.8	23.5	23.6	19.6	17.8	19.3	18.9	18.7	17.7	18.9	21.4	25.4
2028	26.1	23.8	23.8	19.8	18.0	19.5	19.1	18.9	17.9	19.1	21.6	25.7
2029	26.3	24.0	24.1	20.0	18.2	19.7	19.3	19.1	18.0	19.3	21.8	25.9
2030	26.6	24.3	24.3	20.2	18.4	19.9	19.5	19.3	18.2	19.5	22.1	26.2
2031	26.9	24.5	24.6	20.4	18.6	20.1	19.6	19.5	18.4	19.7	22.3	26.5
2032	27.1	24.7	24.8	20.6	18.7	20.3	19.8	19.6	18.5	19.8	22.5	26.7
2033	27.4	25.0	25.0	20.8	18.9	20.4	20.0	19.8	18.7	20.0	22.7	27.0
2034	27.6	25.2	25.3	21.0	19.1	20.6	20.2	20.0	18.9	20.2	22.9	27.2
2035	27.9	25.4	25.5	21.2	19.3	20.8	20.3	20.1	19.0	20.4	23.1	27.5
2036	28.1	25.6	25.7	21.3	19.4	21.0	20.5	20.3	19.2	20.5	23.3	27.7
2037	28.3	25.9	25.9	21.5	19.6	21.1	20.6	20.4	19.3	20.7	23.5	27.9
2038	28.6	26.1	26.1	21.7	19.7	21.3	20.8	20.6	19.5	20.9	23.7	28.2
2039	28.8	26.3	26.3	21.9	19.9	21.5	21.0	20.7	19.6	21.0	23.9	28.4
2040	29.0	26.5	26.5	22.0	20.0	21.6	21.1	20.9	19.7	21.2	24.1	28.6
2041	29.2	26.7	26.7	22.2	20.2	21.8	21.2	21.0	19.9	21.3	24.2	28.8
2042	29.4	26.8	26.9	22.3	20.3	21.9	21.4	21.2	20.0	21.5	24.4	29.0
2043	29.6	27.0	27.1	22.5	20.5	22.1	21.5	21.3	20.1	21.6	24.6	29.2
2044	29.8	27.2	27.3	22.6	20.6	22.2	21.7	21.4	20.3	21.8	24.7	29.4
2045	30.0	27.4	27.5	22.8	20.7	22.4	21.8	21.6	20.4	21.9	24.9	29.6
2046	30.2	27.6	27.6	22.9	20.9	22.5	21.9	21.7	20.5	22.0	25.1	29.8
2047	30.4	27.7	27.8	23.1	21.0	22.6	22.1	21.8	20.6	22.2	25.2	30.0
2048	30.6	27.9	28.0	23.2	21.1	22.8	22.2	21.9	20.7	22.3	25.4	30.2
2049	30.8	28.1	28.1	23.4	21.3	22.9	22.3	22.1	20.9	22.4	25.5	30.4
2050	31.0	28.2	28.3	23.5	21.4	23.0	22.4	22.2	21.0	22.6	25.7	30.5
2051	31.1	28.4	28.5	23.6	21.5	23.1	22.5	22.3	21.1	22.7	25.8	30.7
2052	31.3	28.5	28.6	23.8	21.6	23.3	22.7	22.4	21.2	22.8	25.9	30.9
2053	31.4	28.7	28.8	23.9	21.7	23.4	22.8	22.5	21.3	22.9	26.1	31.0
2054	31.6	28.8	28.9	24.0	21.8	23.5	22.9	22.6	21.4	23.0	26.2	31.2
2055	31.8	29.0	29.1	24.1	21.9	23.6	23.0	22.7	21.5	23.2	26.3	31.3
2056	31.9	29.1	29.2	24.3	22.1	23.7	23.1	22.8	21.6	23.3	26.5	31.5
2057	32.1	29.3	29.4	24.4	22.2	23.8	23.2	22.9	21.7	23.4	26.6	31.7
2058	32.3	29.4	29.5	24.5	22.3	24.0	23.3	23.0	21.8	23.5	26.7	31.8
2059	32.4	29.6	29.7	24.6	22.4	24.1	23.4	23.2	21.9	23.6	26.9	32.0
2060	32.6	29.7	29.8	24.8	22.5	24.2	23.6	23.3	22.0	23.7	27.0	32.2
2061	32.8	29.9	30.0	24.9	22.6	24.3	23.7	23.4	22.1	23.9	27.1	32.3
2062	32.9	30.0	30.1	25.0	22.7	24.4	23.8	23.5	22.2	24.0	27.3	32.5
2063	33.1	30.2	30.3	25.1	22.8	24.5	23.9	23.6	22.3	24.1	27.4	32.6
2064	33.3	30.3	30.4	25.3	23.0	24.7	24.0	23.7	22.4	24.2	27.6	32.8
2065	33.4	30.5	30.6	25.4	23.1	24.8	24.1	23.8	22.6	24.3	27.7	33.0
2066	33.6	30.6	30.7	25.5	23.2	24.9	24.2	23.9	22.7	24.4	27.8	33.1
2067	33.7	30.8	30.9	25.6	23.3	25.0	24.3	24.0	22.8	24.6	28.0	33.3
2013-14	3.2%	3.2%	3.2%	3.2%	3.9%	4.5%	4.5%	4.5%	4.5%	3.3%	3.3%	3.3%
2015-67	2.8%	2.8%	2.8%	2.8%	2.9%	3.7%	3.8%	3.8%	3.5%	3.1%	3.0%	2.9%

Transmission Losses (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	46.9	46.6	40.8	36.2	39.1	39.1	35.0	33.6	36.3	33.1	37.8	46.7
2019	47.2	46.9	41.3	36.6	39.6	39.6	35.3	34.0	36.7	33.4	38.3	47.0
2020	47.7	47.4	41.6	36.9	39.9	39.8	35.6	34.2	36.9	33.7	38.6	47.5
2021	48.1	47.8	42.2	37.4	40.4	40.4	36.0	34.6	37.4	34.2	39.2	47.9
2022	48.8	48.4	42.9	38.0	41.0	40.9	36.5	35.1	37.9	34.6	39.7	48.5
2023	49.5	49.1	43.5	38.5	41.6	41.5	37.0	35.5	38.4	35.1	40.3	49.2
2024	50.1	49.7	44.0	39.0	42.1	42.0	37.4	35.9	38.8	35.5	40.8	49.8
2025	50.7	50.3	44.5	39.4	42.5	42.4	37.8	36.3	39.3	35.9	41.2	50.4
2026	51.2	50.8	45.0	39.8	43.0	42.8	38.2	36.7	39.6	36.2	41.7	50.9
2027	51.7	51.3	45.6	40.3	43.5	43.3	38.6	37.1	40.1	36.7	42.2	51.4
2028	52.3	51.9	46.1	40.8	44.0	43.8	39.0	37.5	40.5	37.1	42.7	52.0
2029	52.8	52.4	46.6	41.2	44.4	44.2	39.4	37.8	40.9	37.5	43.2	52.5
2030	53.3	52.9	47.1	41.7	44.9	44.7	39.8	38.2	41.3	37.9	43.6	53.0
2031	53.8	53.4	47.6	42.1	45.4	45.1	40.2	38.6	41.7	38.2	44.1	53.5
2032	54.3	53.9	48.0	42.5	45.8	45.6	40.5	38.9	42.1	38.6	44.5	54.0
2033	54.7	54.3	48.5	43.0	46.2	46.0	40.9	39.3	42.5	38.9	44.9	54.4
2034	55.2	54.8	49.0	43.4	46.7	46.4	41.3	39.6	42.9	39.3	45.4	54.9
2035	55.7	55.3	49.4	43.8	47.1	46.8	41.6	40.0	43.2	39.6	45.8	55.4
2036	56.1	55.7	49.8	44.1	47.5	47.2	41.9	40.3	43.6	40.0	46.2	55.8
2037	56.5	56.1	50.3	44.5	47.9	47.6	42.2	40.6	43.9	40.3	46.6	56.2
2038	57.0	56.6	50.7	44.9	48.2	47.9	42.6	40.9	44.2	40.6	47.0	56.7
2039	57.4	57.0	51.1	45.2	48.6	48.3	42.9	41.2	44.6	40.9	47.4	57.1
2040	57.8	57.4	51.5	45.6	49.0	48.7	43.2	41.5	44.9	41.2	47.7	57.5
2041	58.2	57.8	51.9	45.9	49.3	49.0	43.5	41.8	45.2	41.5	48.1	57.9
2042	58.6	58.1	52.2	46.2	49.7	49.3	43.8	42.0	45.5	41.8	48.4	58.2
2043	58.9	58.5	52.6	46.6	50.0	49.7	44.1	42.3	45.8	42.1	48.7	58.6
2044	59.3	58.9	53.0	46.9	50.4	50.0	44.4	42.6	46.1	42.4	49.1	59.0
2045	59.7	59.3	53.4	47.2	50.7	50.3	44.6	42.9	46.4	42.6	49.4	59.4
2046	60.0	59.6	53.7	47.5	51.0	50.6	44.9	43.1	46.7	42.9	49.7	59.7
2047	60.4	60.0	54.0	47.8	51.4	50.9	45.2	43.4	46.9	43.2	50.1	60.1
2048	60.7	60.3	54.4	48.1	51.7	51.2	45.4	43.6	47.2	43.4	50.4	60.4
2049	61.1	60.7	54.7	48.4	52.0	51.5	45.7	43.9	47.5	43.7	50.7	60.8
2050	61.4	61.0	55.0	48.7	52.3	51.8	46.0	44.1	47.8	43.9	51.0	61.1
2051	61.7	61.3	55.3	49.0	52.6	52.1	46.2	44.3	48.0	44.2	51.3	61.4
2052	62.0	61.6	55.6	49.2	52.8	52.4	46.4	44.6	48.2	44.4	51.6	61.7
2053	62.3	61.9	55.9	49.5	53.1	52.6	46.6	44.8	48.5	44.6	51.8	62.0
2054	62.6	62.2	56.2	49.8	53.4	52.9	46.9	45.0	48.7	44.9	52.1	62.3
2055	63.0	62.5	56.5	50.0	53.7	53.2	47.1	45.2	49.0	45.1	52.4	62.6
2056	63.3	62.8	56.8	50.3	54.0	53.4	47.3	45.5	49.2	45.3	52.7	62.9
2057	63.6	63.1	57.1	50.6	54.2	53.7	47.6	45.7	49.5	45.5	52.9	63.2
2058	63.9	63.4	57.4	50.8	54.5	54.0	47.8	45.9	49.7	45.8	53.2	63.5
2059	64.2	63.7	57.7	51.1	54.8	54.2	48.0	46.1	49.9	46.0	53.5	63.8
2060	64.5	64.0	58.0	51.4	55.1	54.5	48.3	46.3	50.2	46.2	53.8	64.1
2061	64.8	64.3	58.3	51.6	55.3	54.8	48.5	46.6	50.4	46.5	54.0	64.4
2062	65.1	64.6	58.6	51.9	55.6	55.0	48.7	46.8	50.7	46.7	54.3	64.7
2063	65.4	64.9	58.9	52.2	55.9	55.3	49.0	47.0	50.9	46.9	54.6	65.0
2064	65.7	65.2	59.2	52.4	56.2	55.6	49.2	47.2	51.1	47.1	54.9	65.4
2065	66.0	65.5	59.5	52.7	56.5	55.9	49.4	47.4	51.4	47.4	55.1	65.7
2066	66.3	65.8	59.8	52.9	56.7	56.1	49.7	47.7	51.6	47.6	55.4	66.0
2067	66.6	66.1	60.1	53.2	57.0	56.4	49.9	47.9	51.9	47.8	55.7	66.3
2013-14	3.1%	3.1%	3.1%	3.1%	3.8%	4.3%	4.3%	4.3%	4.3%	3.2%	3.2%	3.1%
2015-67	3.1%	3.1%	3.1%	3.1%	3.8%	4.3%	4.3%	4.3%	4.3%	3.2%	3.2%	3.1%

NLH Energy Requirements (GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	851	776	778	645	569	489	468	465	473	566	661	809
2019	861	785	787	653	575	494	473	470	478	573	668	819
2020	867	791	793	658	579	498	476	473	482	577	673	825
2021	879	802	804	667	588	504	483	479	488	585	683	837
2022	892	814	816	677	596	511	489	485	495	593	693	849
2023	904	825	826	686	604	518	495	491	501	601	702	860
2024	915	834	836	694	611	524	500	496	506	608	710	871
2025	925	844	846	702	618	529	506	501	511	614	718	880
2026	934	852	854	709	624	534	510	506	516	620	725	890
2027	946	863	865	718	632	541	516	512	522	628	734	901
2028	957	873	875	726	639	547	522	517	528	635	743	911
2029	966	882	884	733	645	552	527	522	533	641	750	920
2030	977	891	893	741	652	558	532	527	538	648	758	930
2031	986	900	902	748	659	563	537	532	543	654	765	939
2032	996	908	910	756	665	568	541	536	548	660	772	948
2033	1005	917	919	763	671	573	546	541	553	666	780	957
2034	1015	926	928	770	677	578	551	546	558	672	787	966
2035	1024	934	936	777	683	583	555	550	562	678	794	975
2036	1032	942	944	783	689	588	560	554	567	683	800	983
2037	1040	949	951	790	695	592	564	558	571	689	807	991
2038	1049	957	959	796	700	597	568	562	575	694	814	999
2039	1057	965	967	803	706	602	573	567	580	700	820	1007
2040	1065	972	974	809	711	606	577	571	584	705	826	1015
2041	1073	979	981	814	716	610	580	574	588	709	832	1022
2042	1080	986	988	820	721	614	584	578	591	714	838	1029
2043	1088	992	995	826	726	618	588	582	595	719	843	1036
2044	1095	999	1001	832	731	622	592	585	599	724	849	1044
2045	1103	1006	1008	837	736	626	595	589	603	729	855	1051
2046	1109	1012	1014	842	740	630	599	592	606	733	860	1057
2047	1116	1019	1021	848	745	634	602	596	610	738	866	1064
2048	1123	1025	1027	853	750	638	606	599	614	742	871	1071
2049	1130	1031	1033	858	754	642	609	603	617	746	876	1077
2050	1137	1037	1039	863	759	645	613	606	620	751	881	1083
2051	1143	1043	1045	868	763	648	616	609	624	755	886	1089
2052	1149	1048	1050	872	767	652	619	612	627	758	890	1095
2053	1155	1054	1056	877	771	655	622	615	630	762	895	1101
2054	1161	1059	1061	881	775	658	625	618	633	766	900	1106
2055	1167	1065	1067	886	779	662	628	621	636	770	904	1112
2056	1173	1070	1072	891	783	665	631	624	639	774	909	1118
2057	1179	1075	1078	895	787	668	634	627	642	778	914	1124
2058	1185	1081	1083	900	791	672	637	630	645	782	918	1129
2059	1191	1086	1089	904	795	675	640	632	648	786	923	1135
2060	1197	1092	1094	909	799	678	643	635	651	789	927	1141
2061	1203	1097	1100	914	803	681	646	638	655	793	932	1147
2062	1209	1103	1105	918	807	685	649	641	658	797	937	1152
2063	1215	1108	1111	923	811	688	652	644	661	801	941	1158
2064	1221	1114	1116	927	815	691	655	647	664	805	946	1164
2065	1227	1119	1122	932	819	695	659	650	667	809	951	1170
2066	1233	1125	1127	936	823	698	662	653	670	813	955	1175
2067	1239	1130	1133	941	827	701	665	656	673	817	960	1181

NLH Peak Demand (MW)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	1560	1549	1357	1203	1081	942	842	809	874	1074	1229	1552
2019	1570	1559	1374	1217	1093	953	851	818	884	1086	1244	1562
2020	1587	1575	1384	1227	1101	959	857	823	890	1094	1253	1579
2021	1601	1589	1405	1245	1117	973	868	834	901	1109	1272	1592
2022	1622	1610	1426	1263	1133	986	880	846	914	1125	1291	1614
2023	1646	1634	1445	1280	1148	999	891	856	925	1139	1308	1637
2024	1666	1654	1463	1296	1162	1010	901	866	936	1153	1324	1657
2025	1685	1673	1480	1311	1175	1021	910	875	945	1165	1340	1676
2026	1703	1691	1496	1325	1187	1031	919	883	955	1177	1354	1694
2027	1720	1708	1515	1342	1202	1044	930	893	966	1191	1371	1711
2028	1739	1726	1533	1358	1216	1056	940	903	976	1205	1388	1729
2029	1757	1744	1549	1371	1228	1066	948	911	985	1216	1402	1748
2030	1773	1760	1566	1387	1241	1077	958	921	995	1229	1417	1763
2031	1789	1776	1582	1401	1253	1087	967	929	1005	1241	1432	1779
2032	1805	1792	1598	1415	1265	1097	976	938	1014	1253	1446	1795
2033	1821	1807	1613	1428	1277	1107	985	946	1023	1265	1460	1811
2034	1837	1823	1629	1442	1290	1117	993	954	1032	1276	1474	1827
2035	1852	1838	1644	1455	1301	1127	1002	962	1041	1287	1487	1842
2036	1866	1853	1658	1468	1312	1136	1010	970	1049	1298	1500	1856
2037	1880	1867	1672	1480	1322	1145	1017	977	1057	1308	1513	1870
2038	1895	1881	1686	1492	1333	1154	1025	985	1065	1319	1525	1884
2039	1909	1895	1700	1505	1344	1163	1033	992	1073	1329	1538	1899
2040	1922	1909	1713	1516	1354	1172	1040	999	1081	1339	1550	1912
2041	1935	1921	1725	1527	1364	1180	1047	1006	1088	1348	1561	1925
2042	1948	1934	1738	1538	1373	1188	1054	1012	1096	1357	1572	1937
2043	1960	1946	1750	1549	1383	1196	1061	1019	1103	1367	1583	1950
2044	1973	1959	1762	1560	1392	1204	1068	1026	1110	1376	1594	1962
2045	1985	1971	1774	1571	1402	1212	1075	1032	1117	1385	1605	1975
2046	1997	1983	1786	1581	1410	1219	1081	1038	1124	1393	1616	1986
2047	2009	1994	1797	1591	1419	1227	1088	1045	1131	1402	1626	1998
2048	2020	2006	1809	1601	1428	1234	1094	1051	1137	1410	1636	2010
2049	2032	2017	1820	1611	1437	1241	1101	1057	1144	1419	1647	2021
2050	2043	2028	1831	1620	1445	1248	1107	1062	1150	1427	1656	2032
2051	2053	2038	1841	1629	1453	1255	1112	1068	1156	1434	1665	2042
2052	2063	2048	1851	1638	1460	1261	1118	1073	1162	1442	1674	2052
2053	2073	2058	1861	1647	1468	1268	1123	1079	1168	1449	1683	2062
2054	2084	2069	1871	1656	1476	1274	1129	1084	1173	1457	1692	2072
2055	2094	2079	1881	1664	1483	1280	1135	1089	1179	1464	1701	2083
2056	2104	2089	1890	1673	1491	1287	1140	1095	1185	1471	1710	2093
2057	2114	2099	1900	1682	1499	1293	1146	1100	1191	1479	1719	2103
2058	2124	2109	1910	1691	1506	1300	1151	1105	1197	1486	1728	2113
2059	2134	2119	1920	1699	1514	1306	1157	1111	1203	1494	1737	2123
2060	2144	2129	1930	1708	1522	1313	1163	1116	1208	1501	1746	2133
2061	2155	2139	1940	1717	1529	1319	1168	1121	1214	1509	1755	2143
2062	2165	2149	1950	1726	1537	1326	1174	1127	1220	1516	1764	2153
2063	2175	2159	1960	1734	1545	1332	1179	1132	1226	1523	1773	2163
2064	2185	2169	1970	1743	1552	1339	1185	1137	1232	1531	1782	2173
2065	2195	2180	1980	1752	1560	1345	1190	1143	1238	1538	1791	2184
2066	2205	2190	1990	1761	1568	1351	1196	1148	1243	1546	1800	2194
2067	2216	2200	2000	1770	1575	1358	1202	1153	1249	1553	1809	2204

APPENDIX B - ESTIMATED SYSTEM LOADS FOR STUDY YEARS

2014

Case	Load Period	Peak Load Factor	Forecast Loading (MW)						Estimated Losses (MW)	System Generation (MW)	Avalon Load (MW)	No. of HRD Units On (2 Lines from BDE)	HRD Unit 3 as Sync. Cond.
			NP	RURAL	NARL	VALE	CBP&P	DUCK					
1	Peak Day (Mid January)	1	1269.6	93.2	24.6	58.2	18.1	5.5	45.5	1514.7	838.2	3	No
2	Peak Night (Mid January)	0.7	888.7	65.2	24.6	58.2	18.1	5.5	32.9	1093.2	611.6	2	No
3	Peak Day (Early May)	0.63	799.8	58.7	24.6	58.2	18.1	5.5	29.9	994.8	558.7	1	Yes
4	Peak Night (Early May)	0.38	482.4	35.4	24.6	58.2	18.1	5.5	19.4	643.6	369.9	0	Yes
5	Peak Day (Late July)	0.47	596.7	43.8	24.6	58.2	18.1	5.5	32.1	779.0	437.9	0	Yes
6	Peak Night (Late July)	0.26	330.1	24.2	24.6	58.2	18.1	5.5	19.8	480.5	279.2	0	Yes
7	Peak Day (Mid November)	0.75	952.2	69.9	24.6	58.2	18.1	5.5	35.0	1163.4	649.4	2	No
8	Peak Night (Mid November)	0.48	609.4	44.7	24.6	58.2	18.1	5.5	23.6	784.1	445.4	0	Yes

2020

Case	Load Period	Peak Load Factor	Forecast Loading (MW)						Estimated Losses (MW)	System Generation (MW)	Avalon Load (MW)	No. of HRD Units On (3rd Ckt from BDE)	HRD Unit 3 as Sync. Cond.
			NP	RURAL	NARL	VALE	CBP&P	DUCK					
1	Peak Day (Mid January)	1	1329.0	89.0	29.0	74.3	18.1	0.0	47.7	1587.1	894.1	3	No
2	Peak Night (Mid January)	0.7	930.3	62.3	29.0	74.3	18.1	0.0	34.5	1148.5	656.8	2	No
3	Peak Day (Early May)	0.63	837.3	56.1	29.0	74.3	18.1	0.0	31.5	1046.2	601.5	1	Yes
4	Peak Night (Early May)	0.38	505.0	33.8	29.0	74.3	18.1	0.0	20.5	680.7	403.8	0	Yes
5	Peak Day (Late July)	0.47	624.6	41.8	29.0	74.3	18.1	0.0	33.9	821.7	475.0	0	Yes
6	Peak Night (Late July)	0.26	345.5	23.1	29.0	74.3	18.1	0.0	21.1	511.1	308.9	0	Yes
7	Peak Day (Mid November)	0.75	996.8	66.8	29.0	74.3	18.1	0.0	36.7	1221.6	696.4	3	No
8	Peak Night (Mid November)	0.48	637.9	42.7	29.0	74.3	18.1	0.0	24.9	826.9	482.9	0	Yes

2030

Case	Load Period	Peak Load Factor	Forecast Loading (MW)						Estimated Losses (MW)	System Generation (MW)	Avalon Load (MW)	No. of HRD Units On (3rd Ckt from BDE)	HRD Unit 3 as Sync. Cond.	
			NP	RURAL	NARL	VALE	CBP&P	DUCK						
1	Peak Day (Mid January)	1	1504.0	95.3	29.0	74.3	18.1	0.0	53.3	1774.0	998.2	3	No	
2	Peak Night (Mid January)	0.7	1052.8	66.7	29.0	74.3	18.1	0.0	38.5	1279.3	729.7	3	No	
3	Peak Day (Early May)	0.63	947.5	60.0	29.0	74.3	18.1	0.0	35.0	1163.9	667.1	2	Yes	Note 3
4	Peak Night (Early May)	0.38	571.5	36.2	29.0	74.3	18.1	0.0	22.6	751.7	443.4	0	Yes	
5	Peak Day (Late July)	0.47	706.9	44.8	29.0	74.3	18.1	0.0	37.5	910.6	523.9	0	Yes	
6	Peak Night (Late July)	0.26	391.0	24.8	29.0	74.3	18.1	0.0	23.1	560.3	336.0	0	Yes	
7	Peak Day (Mid November)	0.75	1128.0	71.5	29.0	74.3	18.1	0.0	40.9	1361.8	774.5	3	No	
8	Peak Night (Mid November)	0.48	721.9	45.7	29.0	74.3	18.1	0.0	27.6	916.6	532.8	0	Yes	

2035

Case	Load Period	Peak Load Factor	Forecast Loading (MW)						Estimated Losses (MW)	System Generation (MW)	Avalon Load (MW)	No. of HRD Units On (3rd Ckt from BDE)	HRD Unit 3 as Sync. Cond.	
			NP	RURAL	NARL	VALE	CBP&P	DUCK						
1	Peak Day (Mid January)	1	1578.0	98.3	29.0	74.3	18.1	0.0	55.7	1853.4	1042.2	3	No	
2	Peak Night (Mid January)	0.7	1104.6	68.8	29.0	74.3	18.1	0.0	40.1	1334.9	760.5	3	No	
3	Peak Day (Early May)	0.63	994.1	61.9	29.0	74.3	18.1	0.0	36.5	1213.9	694.8	3	No	Note 3
4	Peak Night (Early May)	0.38	599.6	37.4	29.0	74.3	18.1	0.0	23.5	781.9	460.1	0	Yes	
5	Peak Day (Late July)	0.47	741.7	46.2	29.0	74.3	18.1	0.0	39.1	948.3	544.6	1	Yes	
6	Peak Night (Late July)	0.26	410.3	25.6	29.0	74.3	18.1	0.0	24.0	581.2	347.4	0	Yes	
7	Peak Day (Mid November)	0.75	1183.5	73.7	29.0	74.3	18.1	0.0	42.7	1421.3	807.5	3	No	
8	Peak Night (Mid November)	0.48	757.4	47.2	29.0	74.3	18.1	0.0	28.7	954.7	554.0	1	Yes	

Notes:
1. Forecast provided by P. Stratton "NLH Island Demand & Energy Requirements 2018 to 2067" dated 02-25-2011, same as provided to J. Barnard
2. Avalon Load assumed at 59.5% of Total NP Load
3. New CCT available as backup

APPENDIX C - DYNAMIC MODEL SHEETS FOR WIND TURBINES MODELED

17.4 WT3G1

Doubly-Fed Induction Generator (Type 3)

1001

This model is located at system bus #_______ IBUS,
Machine identifier #_______ ID,
This model uses CONs starting with #_______ J,
and STATEs starting with #_______ K,
and VARs starting with #_______ L,
and ICON #_______ M.

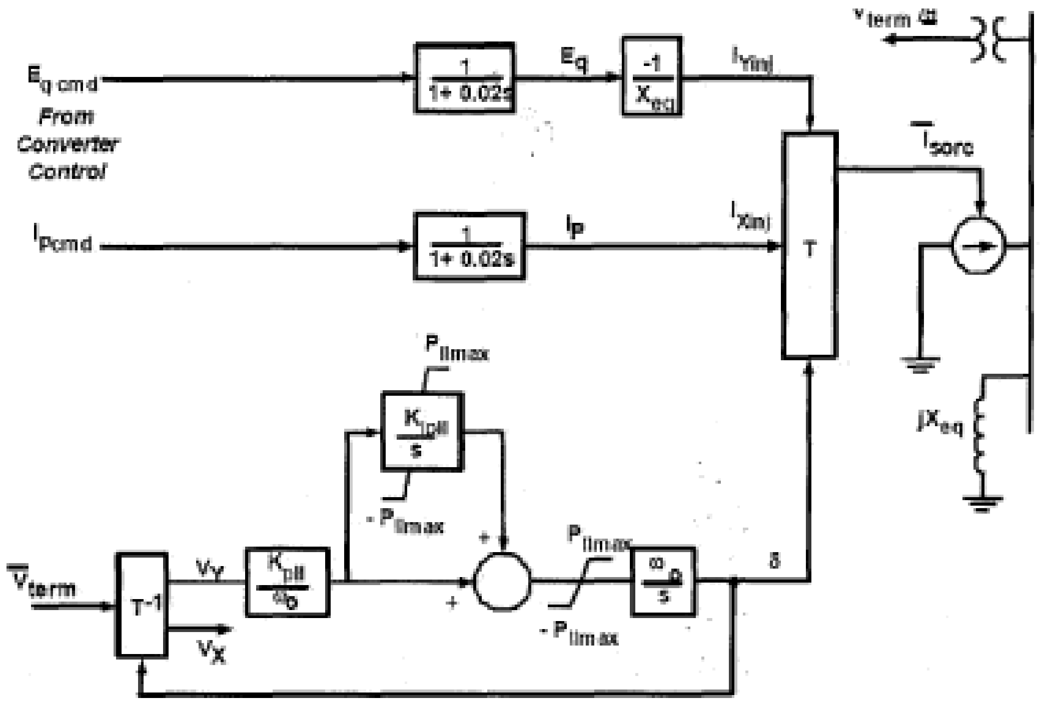
CONs	#	Value	Description
J		0.8	X_{eq}, Equivalent reactance for current injection (pu)
J+1		30	K_{pll}, PLL first integrator gain
J+2		0	K_{ipll}, PLL second integrator gain
J+3		0.1	P_{llmax}, PLL maximum limit
J+4		3.0	Prated, Turbine MW rating

STATEs	#	Description
K		Converter lag for Ipcmd
K+1		Converter lag for Eqcmd
K+2		PLL first integrator
K+3		PLL second integrator

VARs	#	Description
L		V_X, Real component of Vterm in generator ref. frame
L+1		V_Y, Imaginary component of Vterm in generator ref. frame
L+2		I_{xinj}, Active component of the injected current
L+3		I_{yinj}, Reactive component of the injected current

ICON	#	Description
M	9	Number of lumped wind turbines

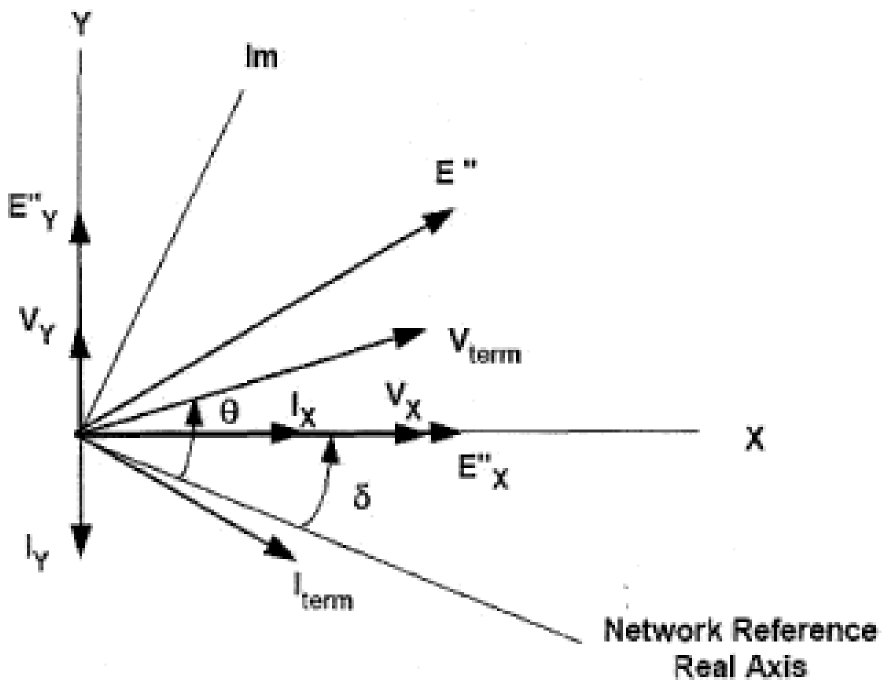
IBUS, 'WT3G1', ID, ICON(M), CON(J) to CON(J+4) /



Notes: 1. $\overline{V}_{term}$ and $\overline{I}_{sorc}$ are complex values on network reference frame.

2. In steady-state, $V_Y = 0$, $V_X = V_{term}$, and $\delta = \theta$.

3. X_{eq} = Imaginary (ZSORCE)



18.3 WT3E1

Electrical Control for Type 3 Wind Generator (for WT3G1 and WT3G2)

This model is located at system bus #_______ IBUS
Machine identifier #_______ ID
This model uses CONs starting with #_______ J
and STATEs starting with #_______ K
and VARs starting with #_______ L
and ICONs starting with #_______ M

CONs	#	Value	Description
J		0.15	T_{fv}, Filter time constant in voltage regulator (sec)
J+1		18	K_{pv}, Proportional gain in voltage regulator (pu)
J+2		5	K_{IV}, Integrator gain in voltage regulator (pu)
J+3		0	X_c, Line drop compensation reactance (pu)
J+4		0.05	T_{FP}, Filter time constant in torque regulator
J+5		3.0	K_{pp}, Proportional gain in torque regulator (pu)
J+6		0.6	K_{IP}, Integrator gain in torque regulator (pu)
J+7		1.12	P_{MX}, Max limit in torque regulator (pu)
J+8		0.1	P_{MN}, Min limit in torque regulator (pu)
J+9		0.296	Q_{MX}, Max limit in voltage regulator (pu)
J+10		-0.436	Q_{MN}, Min limit in voltage regulator (pu)
J+11		1.10	IP_{MAX}, Max active current limit
J+12		0.05	T_{RV}, Voltage sensor time constant

CONs	#	Value	Description
J+13		0.45	RP_{MX}, Max power order derivative
J+14		-0.45	RP_{MN}, Min power order derivative
J+15		5.0	$T_{\_Power}$, Power filter time constant
J+16		0.05	K_{qi}, MVAR/Voltage gain
J+17		0.9	V_{MINCL}, Min voltage limit
J+18		1.2	V_{MAXCL}, Max voltage limit
J+19		40.0	K_{qv}, Voltage/MVAR gain
J+20		-0.5	XIQ_{min}
J+21		0.4	XIQmax
J+22		0.05	T_v, Lag time constant in WindVar controller
J+23		0.05	T_p, P_{elec} filter in fast PF controller
J+24		1.0	Fn, A portion of online wind turbines
J+25		0.69	ωP_{min}, Shaft speed at P_{min} (pu)
J+26		0.78	ωP_{20}, Shaft speed at 20% rated power (pu)
J+27		0.98	ωP_{40}, Shaft speed at 40% rated power (pu)
J+28		1.12	ωP_{60}, Shaft speed at 60% rated power (pu)
J+29		0.74	P_{min}, Minimum power for operating at ωP_{100} speed (pu)
J+30		1.2	ωP_{100}, Shaft speed at 100% rated power (pu)

STATEs	#	Description
K		Filter in voltage regulator
K+1		Integrator in voltage regulator
K+2		Filter in torque regulator
K+3		Integrator in torque regulator
K+4		Voltage sensor
K+5		Power filter
K+6		MVAR/Vref integrator
K+7		Verror/internal machine voltage integrator
K+8		Lag of the WindVar controller
K+9		Input filter of P_{elec} for PF fast controller

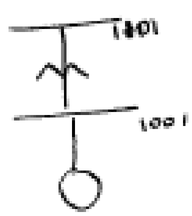
VARs	#	Description
L		Remote bus ref voltage

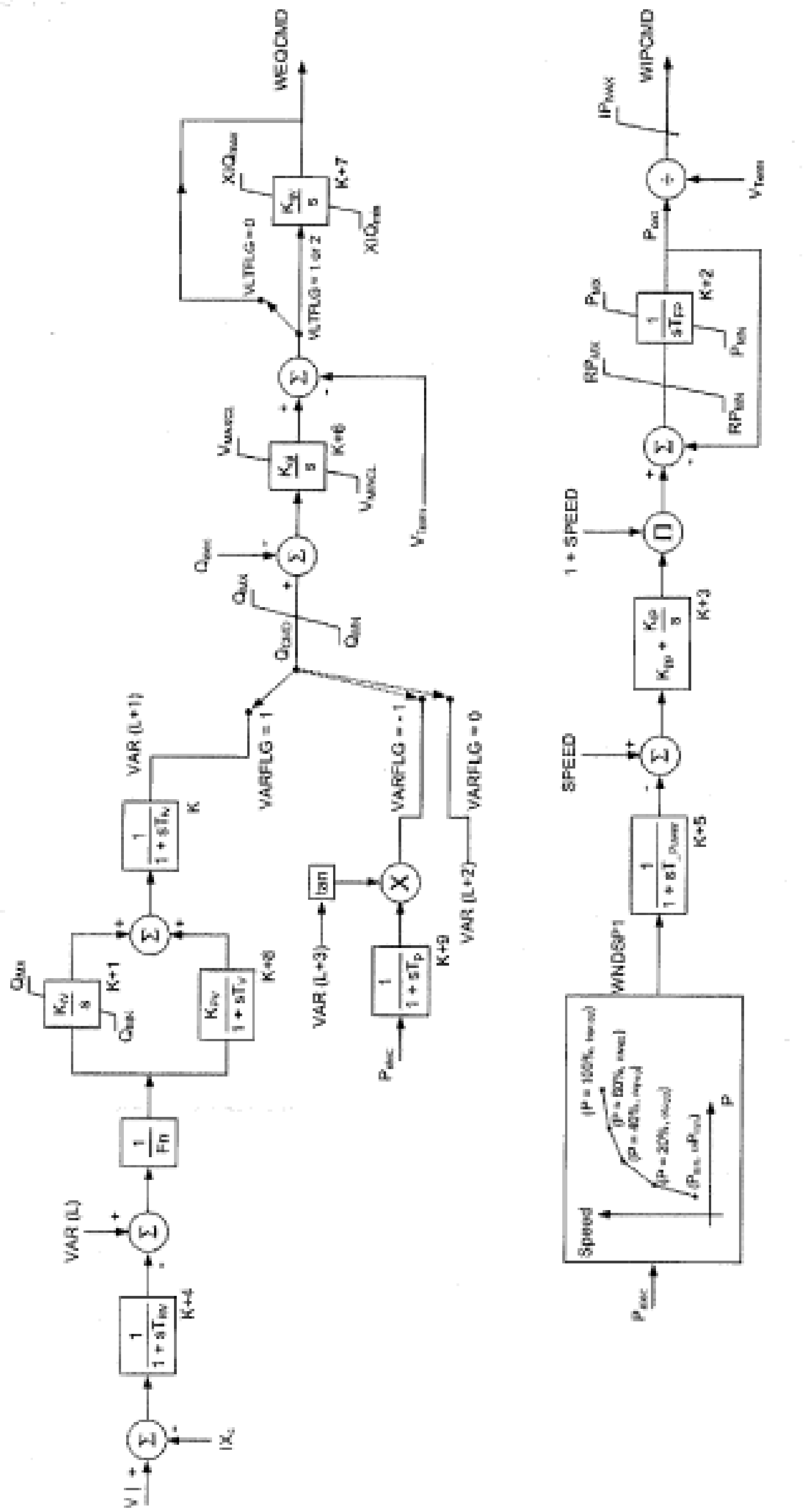
VARs	#	Description
L+1		MVAR order from MVAR emulator
L+2		Q reference if PFAFLG=0 & VARFLG=0
L+3		PF angle reference if PFAFLG=1
L+4		Storage of MW for computation of compensated voltage
L+5		Storage of MVAR for computation of compensated voltage
L+6		Storage of MVA for computation of compensated voltage

ICONs	#	Description
M	0	Remote bus # for voltage control; 0 for local voltage control
M+1	1	VARFLG: 0 Constant Q control 1 Use Wind Plant reactive power control -1 Constant power factor control
M+2[1]	1	VLTFLG: 0 Bypass terminal voltage control 1 Eqcmd limits are calculated as VTerm + XIQmin and VTerm + XIQmax, i.e., limits are functions of terminal voltage 2 Eqcmd limits are equal to XIQmin and XIQ max
M+3	1001	From bus of the interconnection transformer
M+4	1101	To bus of the interconnection transformer
M+5	1	Interconnection transformer ID

1 WT3E1 model can be used with WT3G1 as well as WT3G2 models. When used with WT3G1 model, it is recommended that ICON(M+2) be set to 1; and when used with WT3G2 model, the ICON(M+2) be set to 2.

IBUS, 'WT3E1', ID, ICON(M) to ICON(M+5), CON(J) to CON(J+30) /




WEQCMD
WIPCMD
VARFLG = 1
VARFLG = -1
VARFLG = 0
VAR (L+1)
VAR (L+2)
VAR (L+3)
VAR (L)
SPEED
1 + SPEED
WNDSP1
K+7
K+6
K+4
K+1
K+8
K+9
K+3
K+5
K+2
K

19.3 WT3T1

Mechanical System Model for Type 3 Wind Generator (for WT3G1 and WT3G2)

This model is located at system bus	#_______	IBUS,
Machine identifier	#_______	ID,
This model uses CONs starting with	#_______	J,
and STATEs starting with	#_______	K,
and VARs starting with	#_______	L.

In blkmdl, this model requires one reserved ICON.

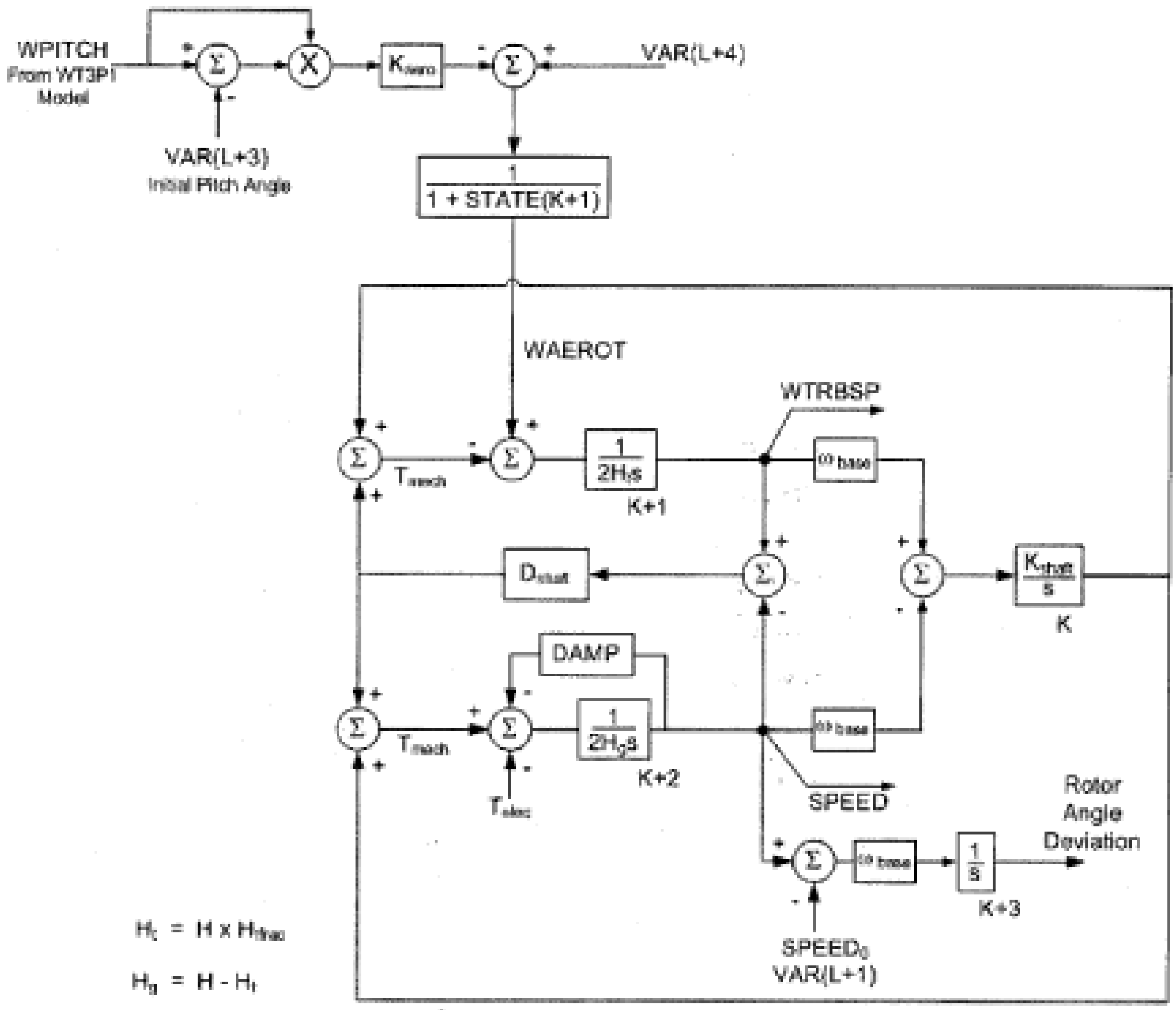
CONs	#	Value	Description
J		0.44	VW, Initial wind, pu of rated wind speed
J+1		4.95	H, Total inertia constant, sec
J+2		0	DAMP, Machine damping factor, pu P/pu speed
J+3		0.007	K_{aero}, Aerodynamic gain factor
J+4		21.98	Theta2, Blade pitch at twice rated wind speed, deg.
J+5		0.875	H_{tfrac}, Turbine inertia fraction (Hturb/H)[1]
J+6		1.8	Freq1, First shaft torsional resonant frequency, Hz
J+7		1.5	D_{shaft}, Shaft damping factor (pu)

[1] To simulate one-mass mechanical system, set $H_{tfrac} = 0$.
To simulate two-mass mechanical system, set H_{tfrac} as $0 < H_{tfrac} < 1$.

STATEs	#	Description
K		Shaft twist angle, rad.
K+1		Turbine rotor speed deviation, pu
K+2		Generator speed deviation, pu
K+3		Generator rotor angle deviation, pu

VARs	#	Description
L		P_{aero} on the rotor blade side, pu
L+1		Initial rotor slip
L+2		Initial internal angle
L+3		Initial pitch angle
L+4		P_{aero} initial

IBUS, 'WT3T1', ID, CON(J) to CON (J+7) /



$H_t = H \times H_{frac}$

$H_g = H - H_t$

$$K_{shaft} = \frac{2H_t \times H_g \times (2\pi \times Freq1)^2}{H \times \omega_0}$$

20.2 WT3P1

Pitch Control Model for Type 3 Wind Generator (for WT3G1 and WT3G2)

This model is located at system bus	#_______	IBUS,
Machine identifier	#_______	ID,
This model uses CONs starting with	#_______	J,
and STATEs starting with	#_______	K.

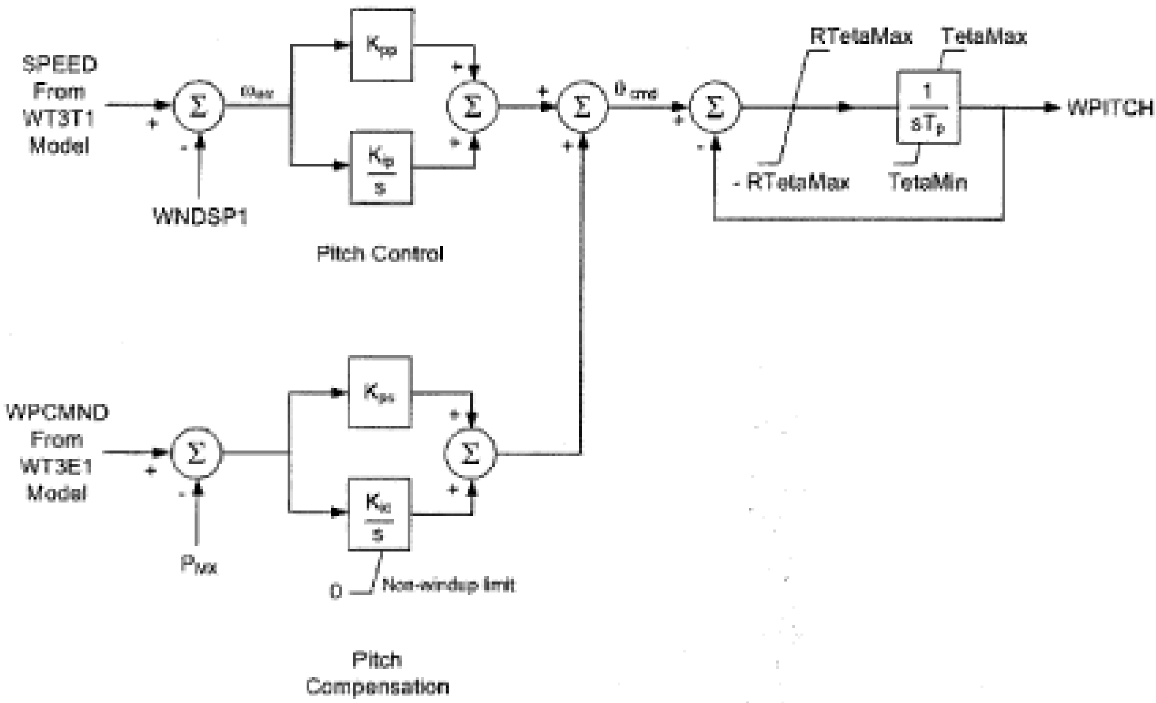
In blkmdl, this model requires one reserved ICON.

CONs	#	Value	Description
J		0.3	T_p, Blade response time constant
J+1		150	K_{pp}, Proportional gain of PI regulator (pu)
J+2		25	K_{ip}, Integrator gain of PI regulator (pu)
J+3		3	K_{pc}, Proportional gain of the compensator (pu)
J+4		30	K_{ic}, Integrator gain of the compensator (pu)
J+5		0	TetaMin, Lower pitch angle limit (degrees)
J+6		27	TetaMax, Upper pitch angle limit (degrees)
J+7		10	RTetaMax, Upper pitch angle rate limit (degrees/sec)
J+8		1	P_{MX}, Power reference, pu on MBASE

Note: When a WT operates with a partial output, the DSTATE(K+2) may show INITIAL CONDITION SUSPECT. In this case no actions are needed.

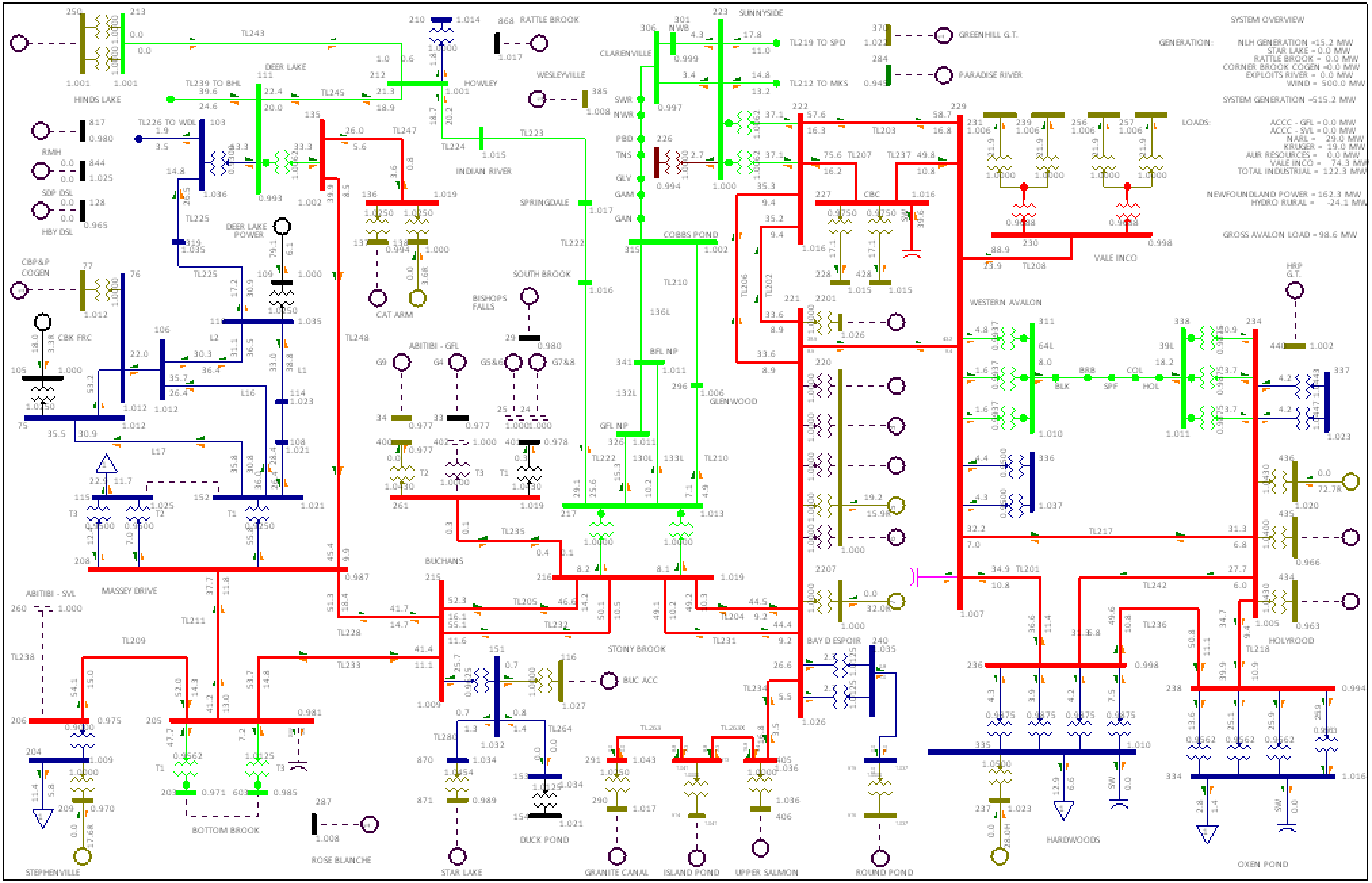
STATEs	#	Description
K		Output lag
K+1		Pitch control
K+2		Pitch compensation

IBUS, 'WT3P1', ID, CON(J) to CON (J+8) /


SPEED From WT3T1 Model
WNDSP1
K_{pp}
K_{ip} / s
Pitch Control
θ_{cmd}
RTetaMax
TetaMax
1 / sT_p
WPITCH
- RTetaMax
TetaMin
WPCMND From WT3E1 Model
P_{MX}
K_{pc}
K_{ic} / s
0
Non-windup limit
Pitch Compensation

APPENDIX D - GRAPHICAL LOAD FLOW RESULTS 2020 EXTREME LIGHT LOAD

500 MW WIND GENERATION

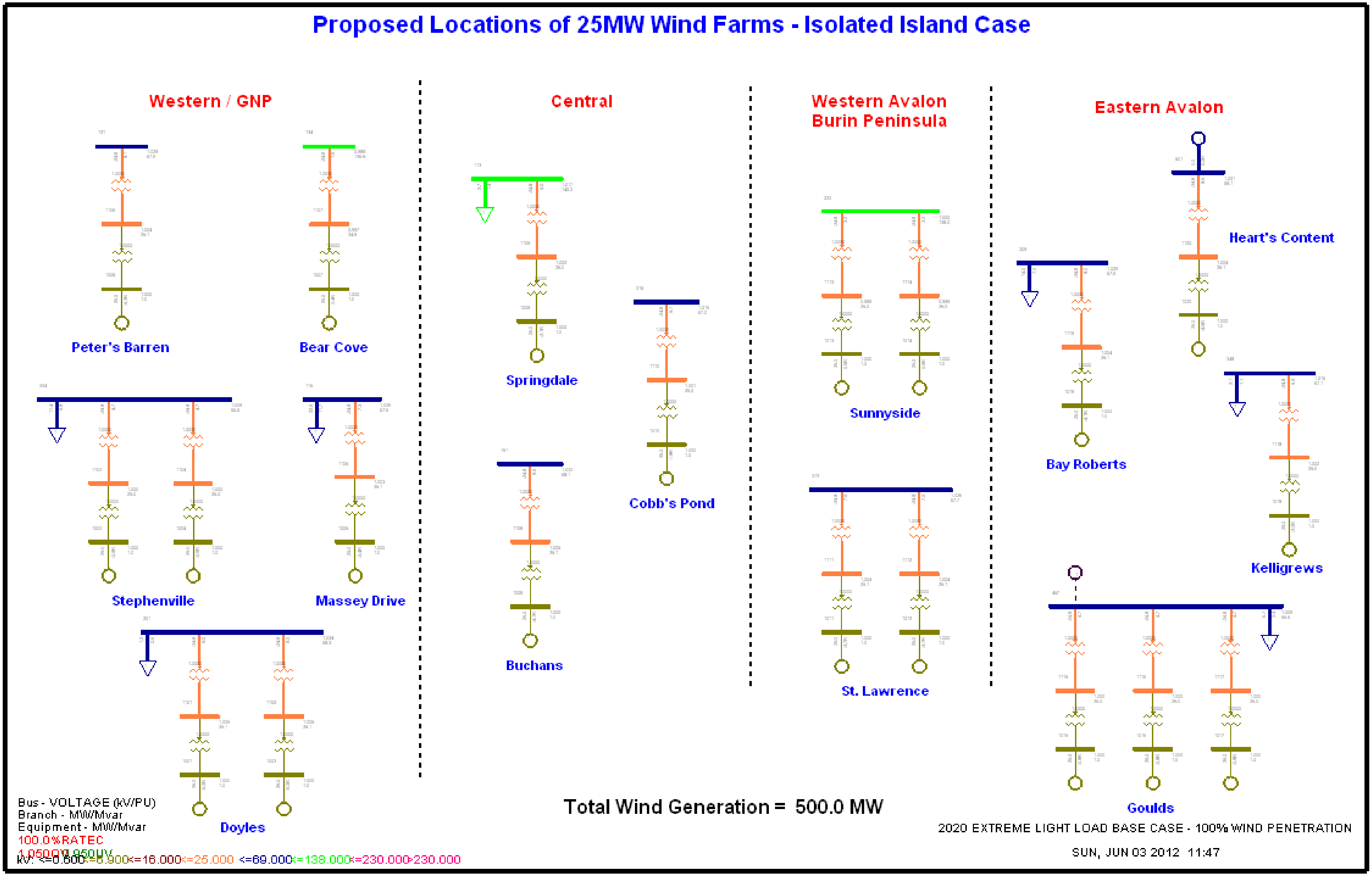


2020 EXTREME LIGHT LOAD BASE CASE - 100% WIND PENETRATION

SUN, JUN 03 2012 11:38

Bus - VOLTAGE (PU)
Branch - MVA/% OF RATE C
Equipment - MW/Mvar

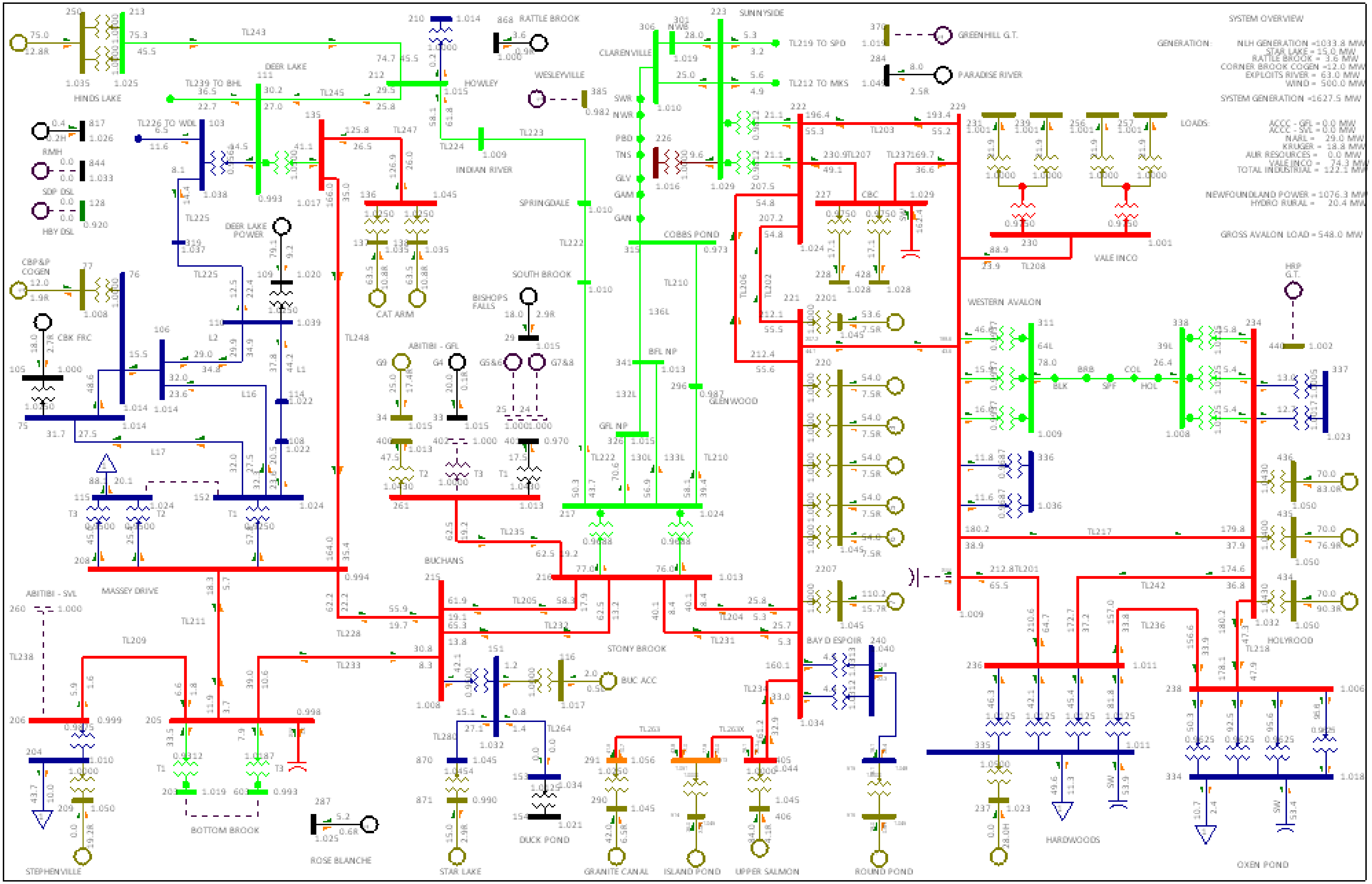
2020 Extreme Light Load Base Case 500MW wind integration (81% Wind Penetration)



2020 Extreme Light Load Base Case 500MW wind integration (81% Wind Penetration)

APPENDIX E - GRAPHICAL LOAD FLOW RESULTS 2020 PEAK LOAD

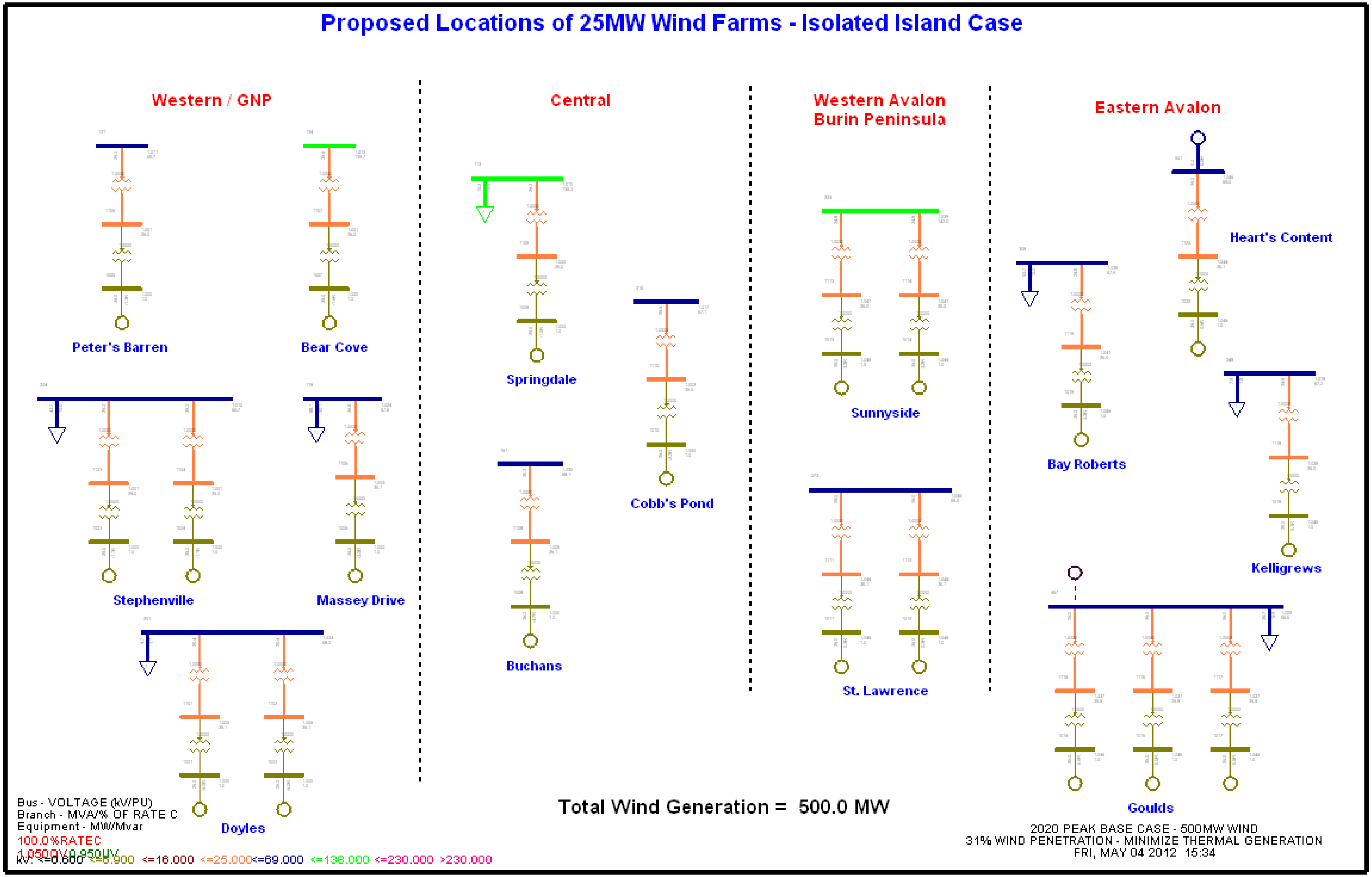
500 MW WIND GENERATION



2020 PEAK BASE CASE - 500MW WIND
31% WIND PENETRATION - MINIMIZE THERMAL GENERATION
FRI, MAY 04 2012 15:32

Bus - VOLTAGE (PU)
Branch - MVA/% OF RATE C
Equipment - MW/Mvar

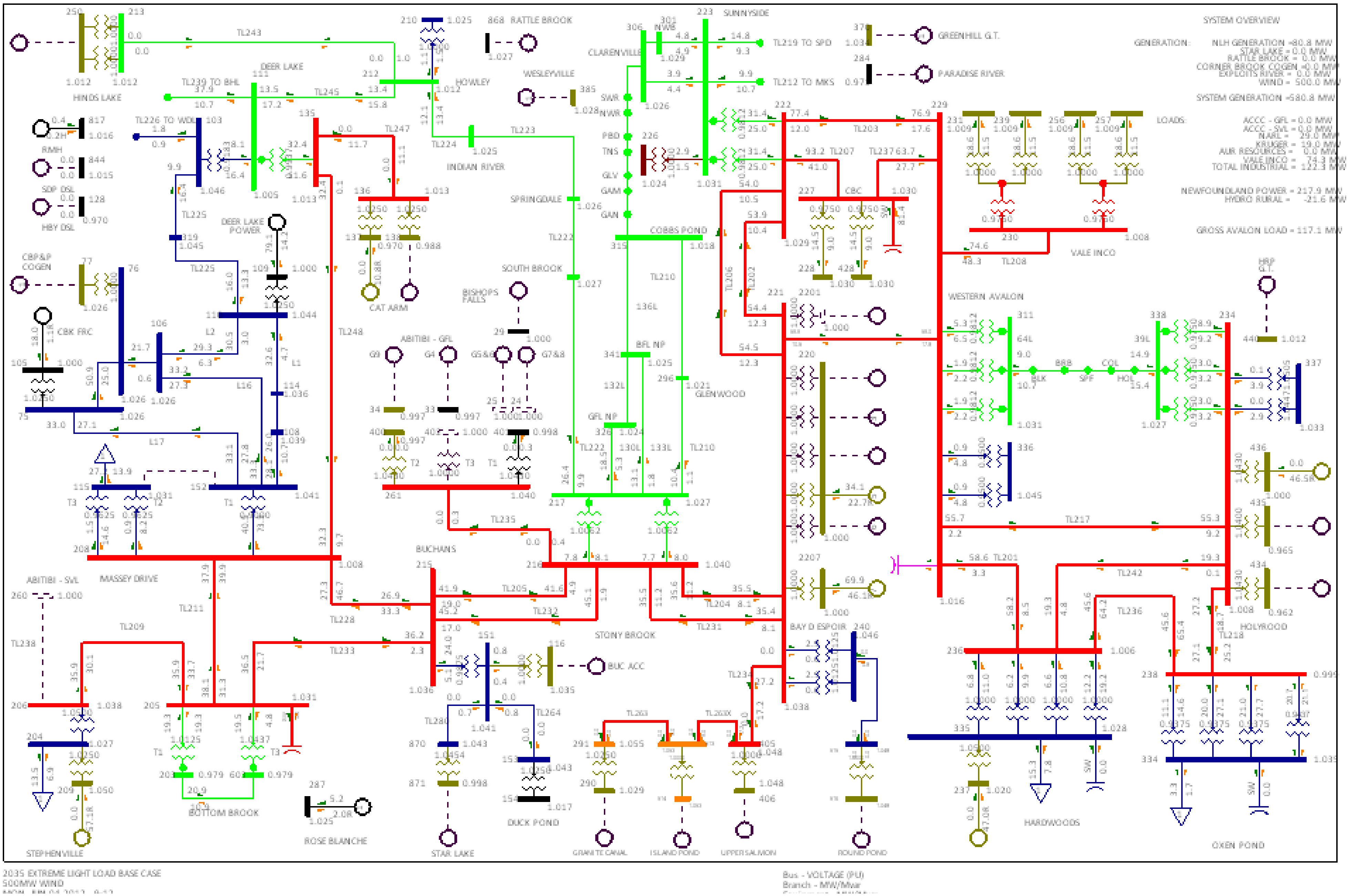
2020 Peak Load Base Case 500MW wind integration (27% Wind Penetration)



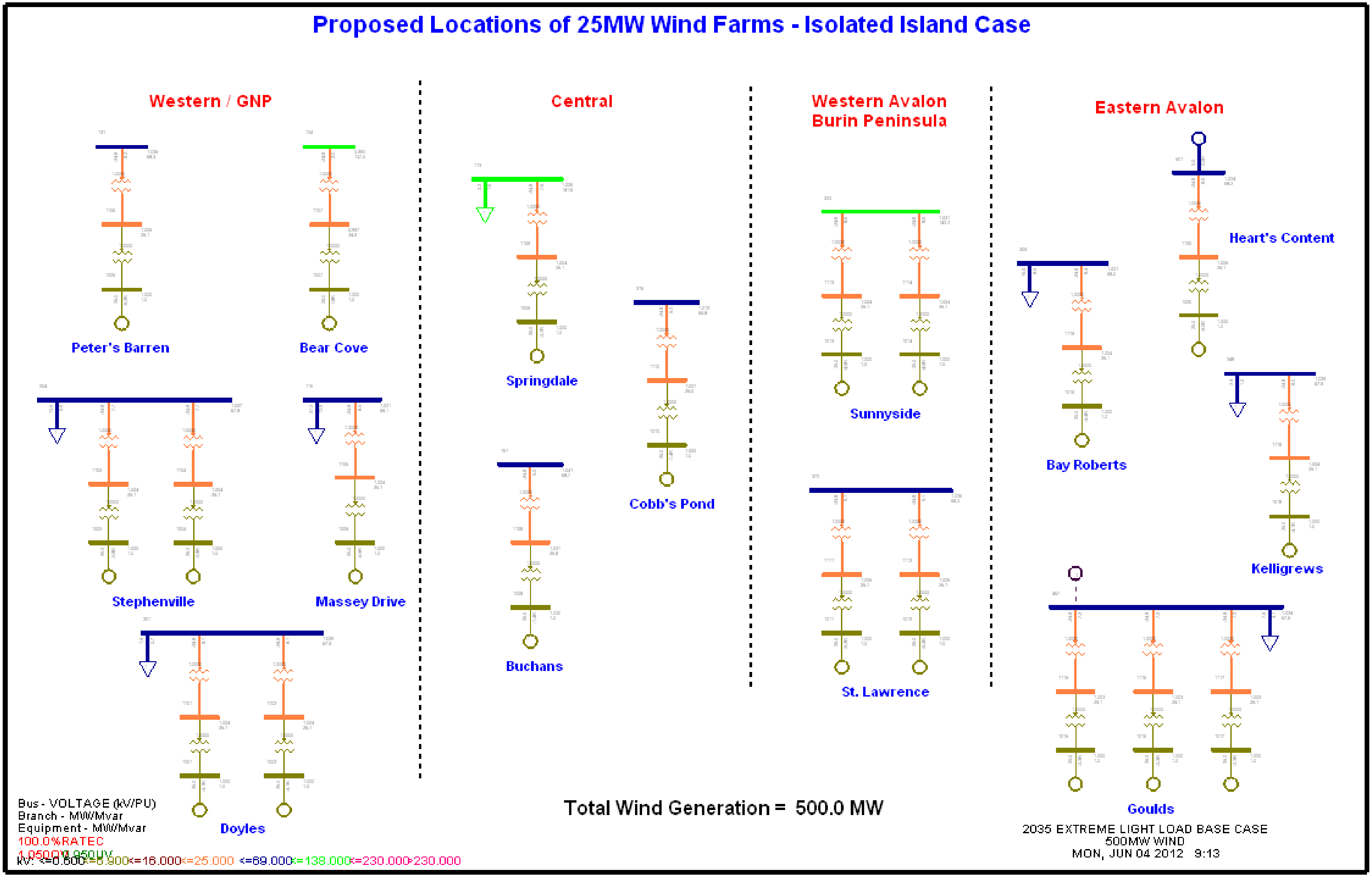
2020 Peak Load Base Case 500MW wind integration (27% Wind Penetration)

APPENDIX F - GRAPHICAL LOAD FLOW RESULTS 2035 EXTREME LIGHT LOAD

500 MW WIND GENERATION



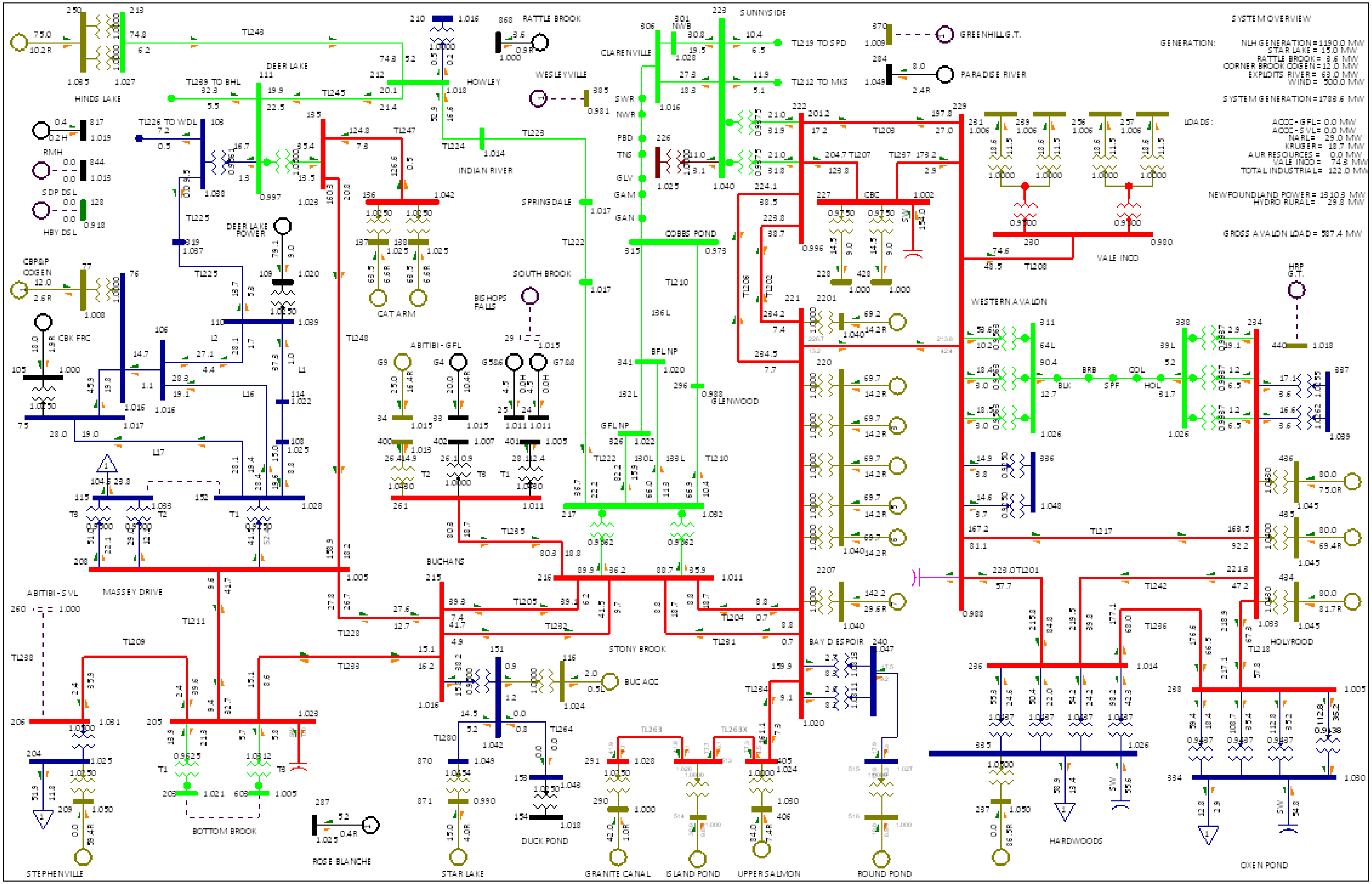
2035 Extreme Light Load 500MW Wind (71% Wind Penetration)



2035 Extreme Light Load 500MW Wind (71% Wind Penetration)

APPENDIX G - GRAPHICAL LOAD FLOW RESULTS 2035 PEAK LOAD

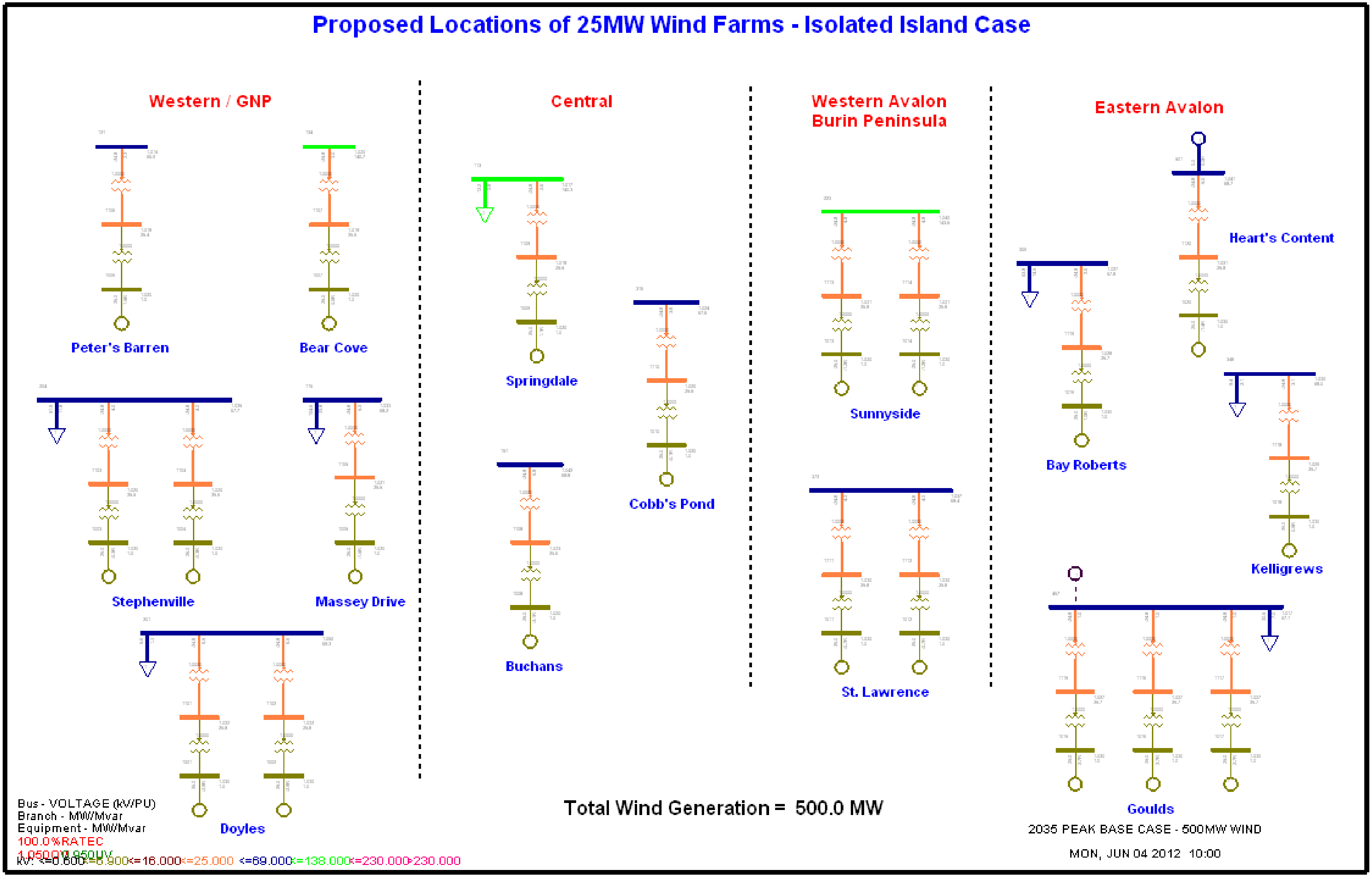
500 MW WIND GENERATION



2035 PEAK BASE CASE - 500MW WIND

Bus - VOLTAGE (PU)
Branch - MW/Mvar

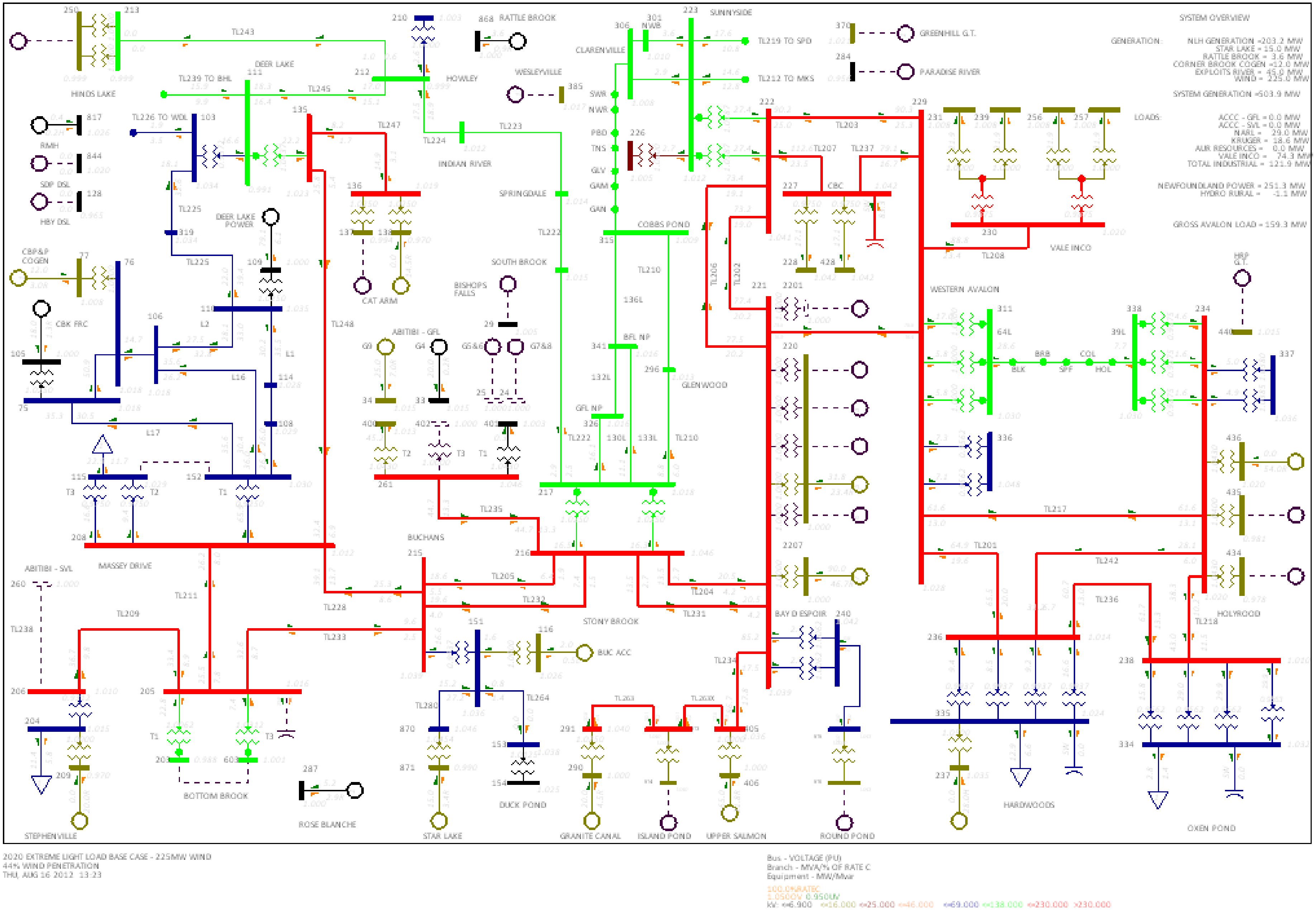
2035 Peak Load 500MW Wind (25% Wind Penetration)



2035 Peak Load 500MW Wind (25% Wind Penetration)

APPENDIX H - STABILITY RESULTS 2020 EXTREME LIGHT LOAD

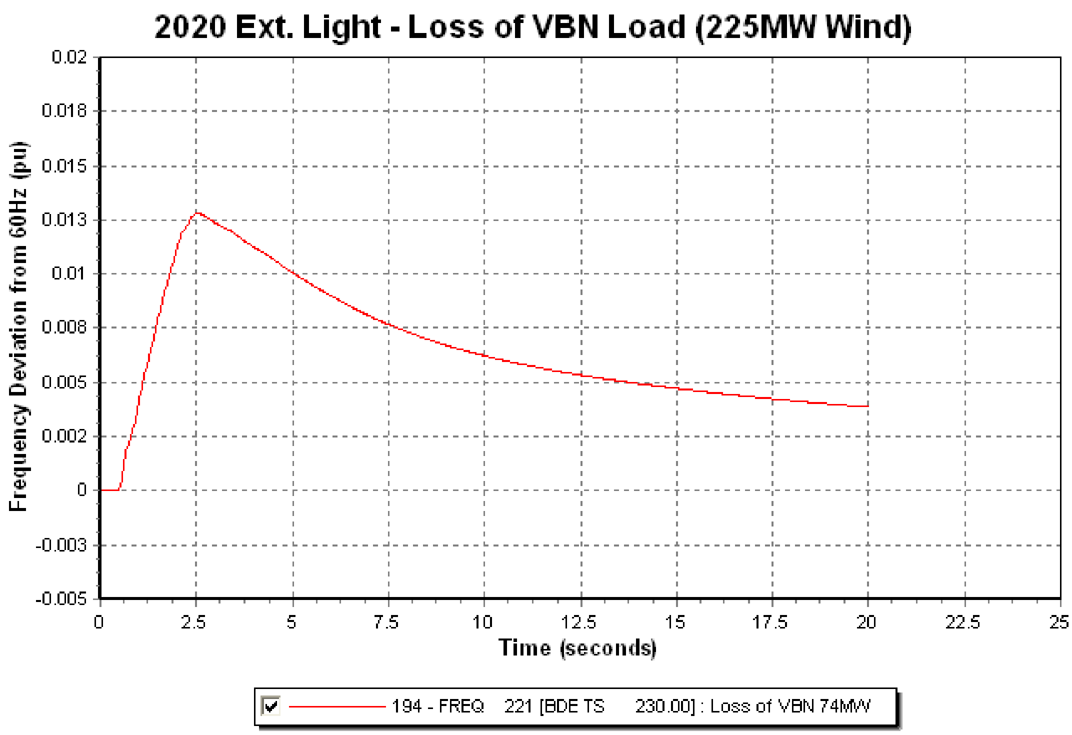
225 MW WIND GENERATION

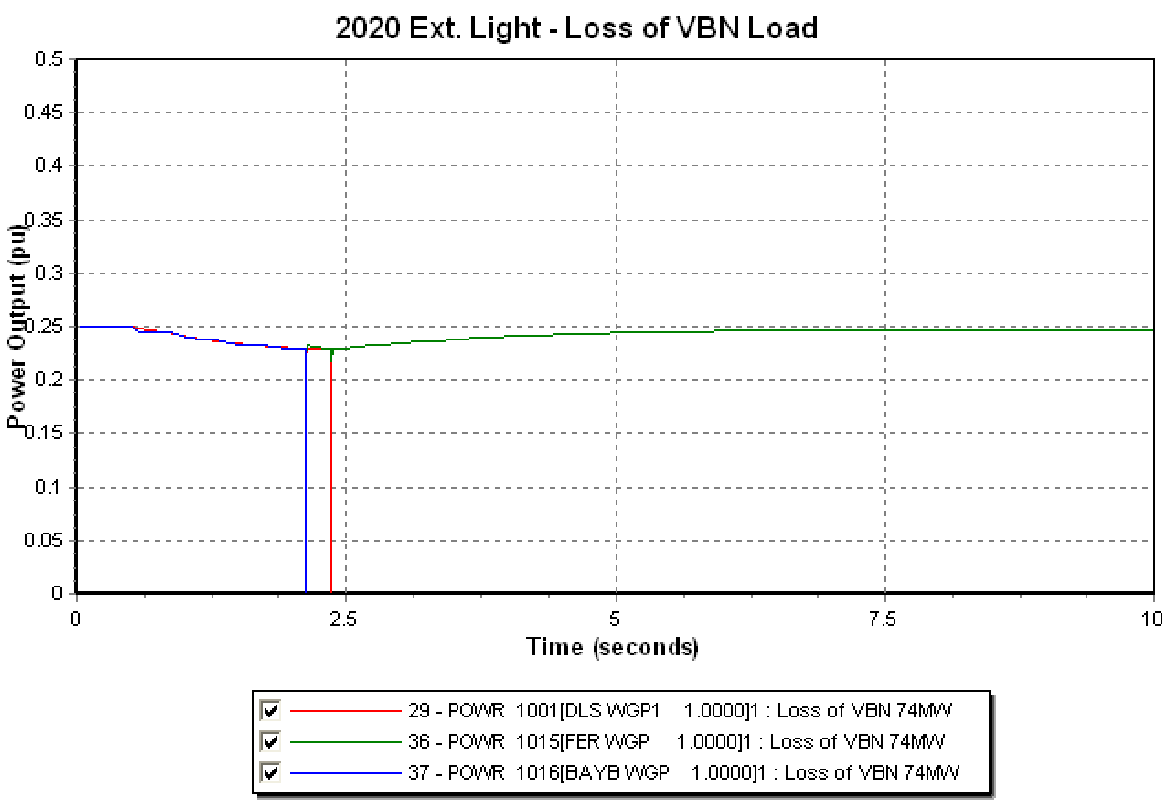


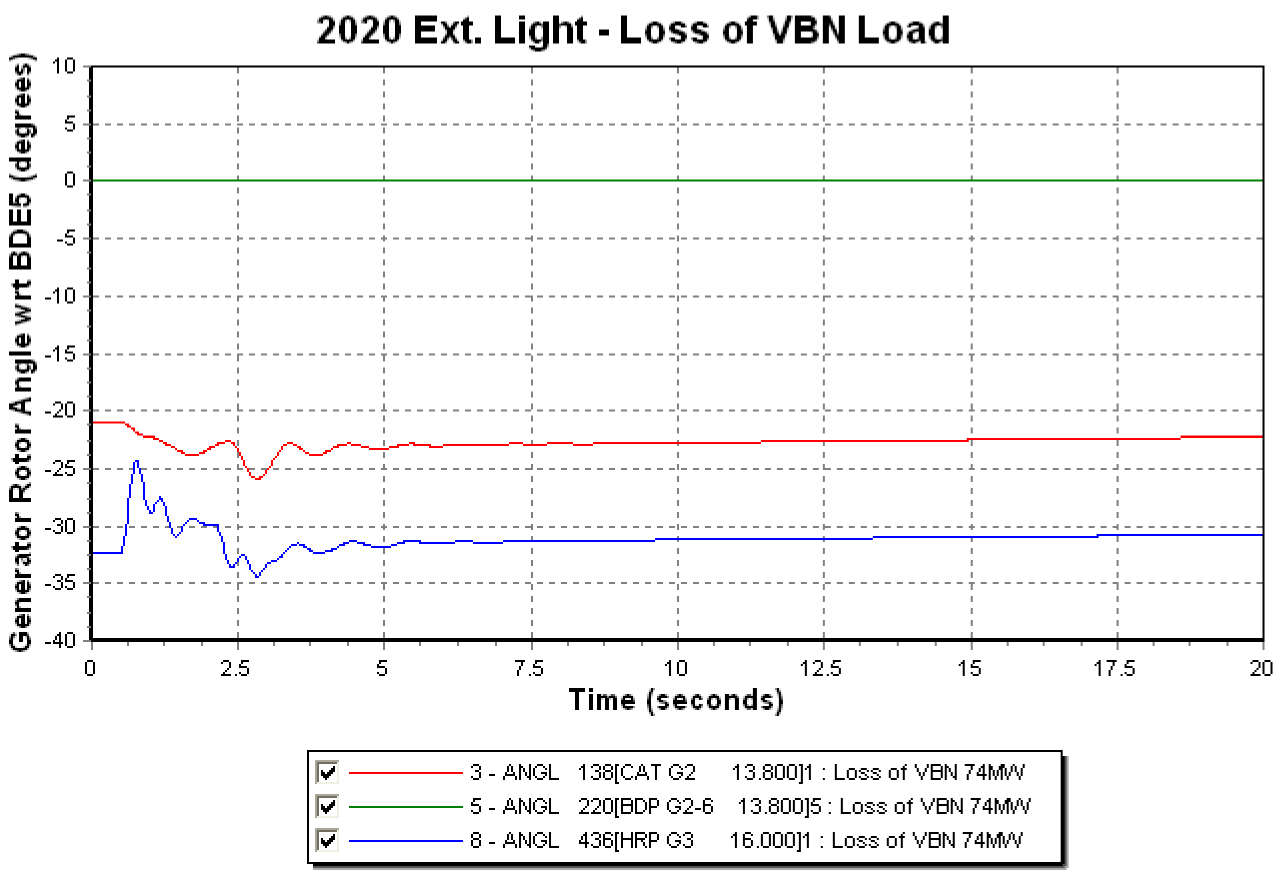
2020 Extreme Light Load – 225MW Wind – Generation Dispatch Prior to Dynamic Simulations

Case 1 – Loss of 74.3MW load at VBN

This causes an over frequency condition above 61.2 Hz. All wind turbines over frequency protection is engaged at 61.2Hz with time delay of 0.2seconds, thus causing loss of 225MW of generation from the island. This is considered unacceptable, thus there was a reduction in over frequency settings for several wind turbines to prevent mass tripping of all units at the same time. The following plots show system frequency response and power output from 3 wind turbine plants (two of which trip at 60.6 and 60.75 Hz respectively).

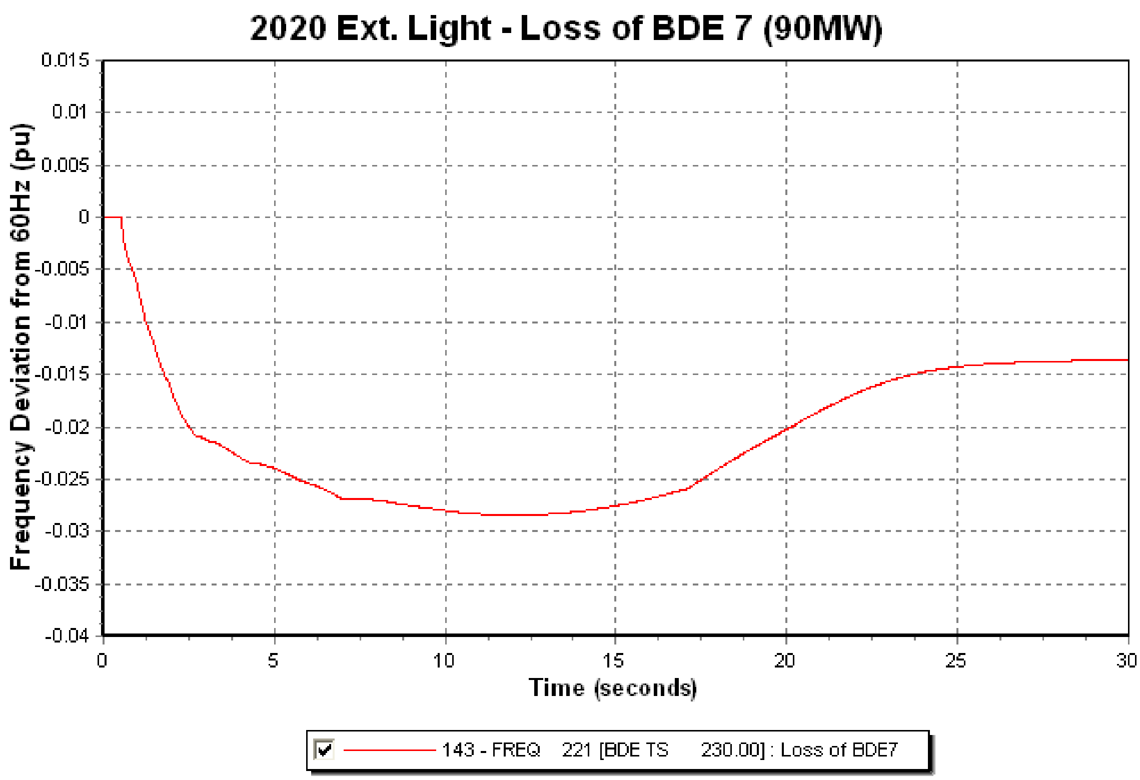


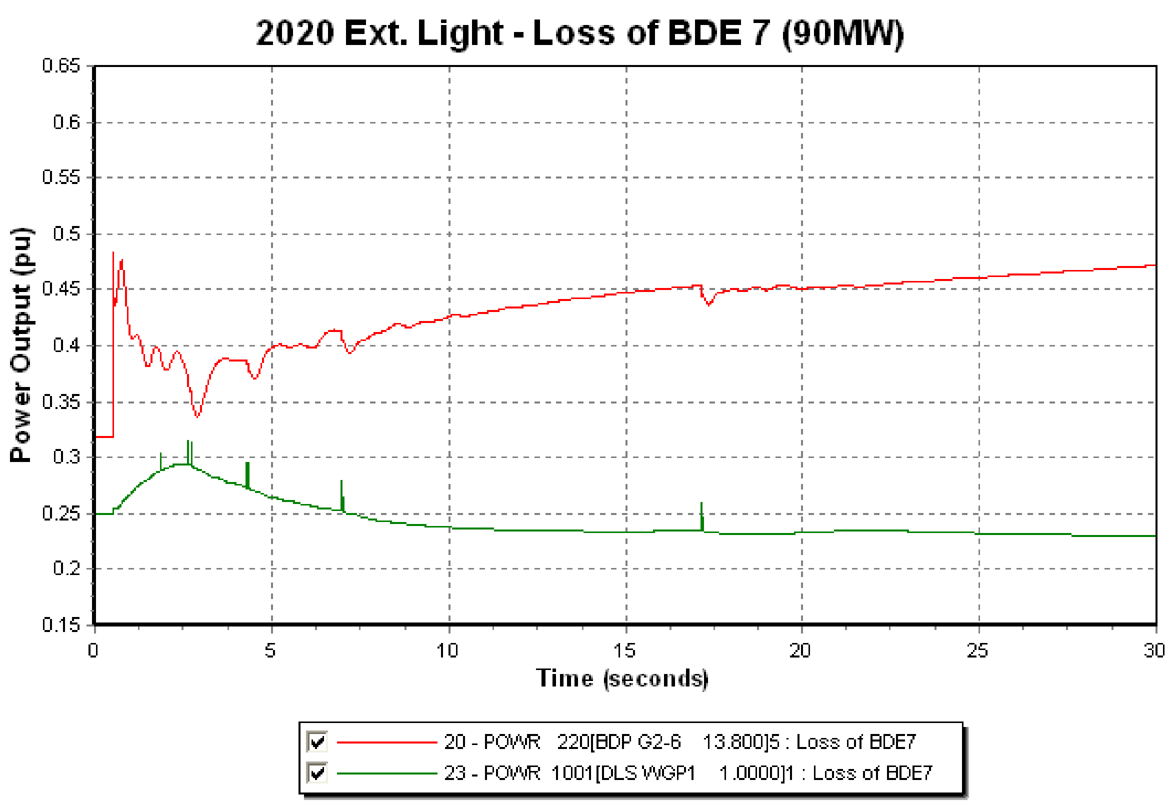


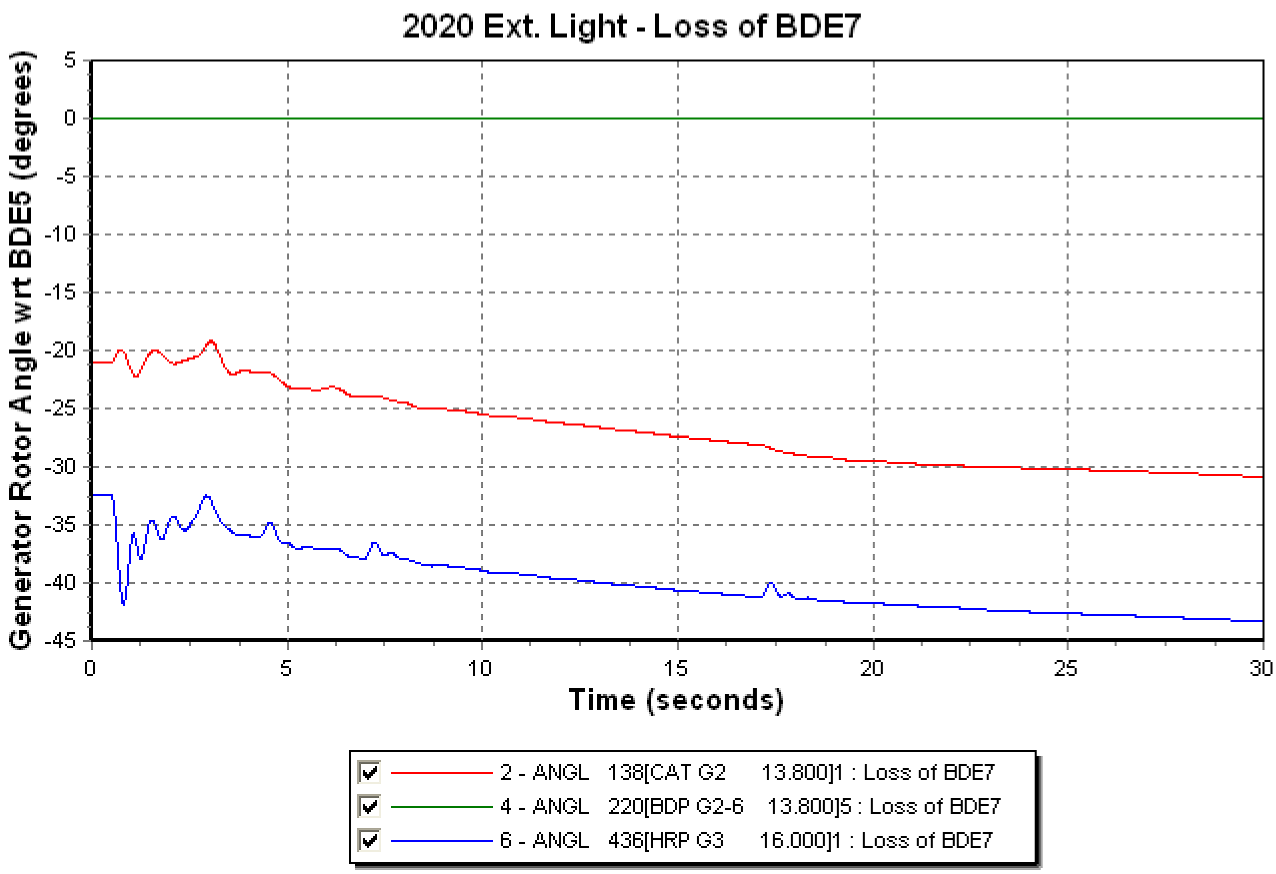

2020 Ext. Light - Loss of VBN Load
Generator Rotor Angle wrt BDE5 (degrees)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2.5
5
7.5
10
12.5
15
17.5
20
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : Loss of VBN 74MW
5 - ANGL 220[BDP G2-6 13.800]5 : Loss of VBN 74MW
8 - ANGL 436[HRP G3 16.000]1 : Loss of VBN 74MW

Case 2 – Loss of Largest Unit (BDE 7 at 90 MW)

For this contingency, the system is stable and all wind turbines remain connected to the grid. Frequency decline reaches 58.3 Hz and is arrested by operation of 44MW of load shedding. The plots below outline the system frequency and wind turbine / Bay d'Espoir Unit 5 power output responses.

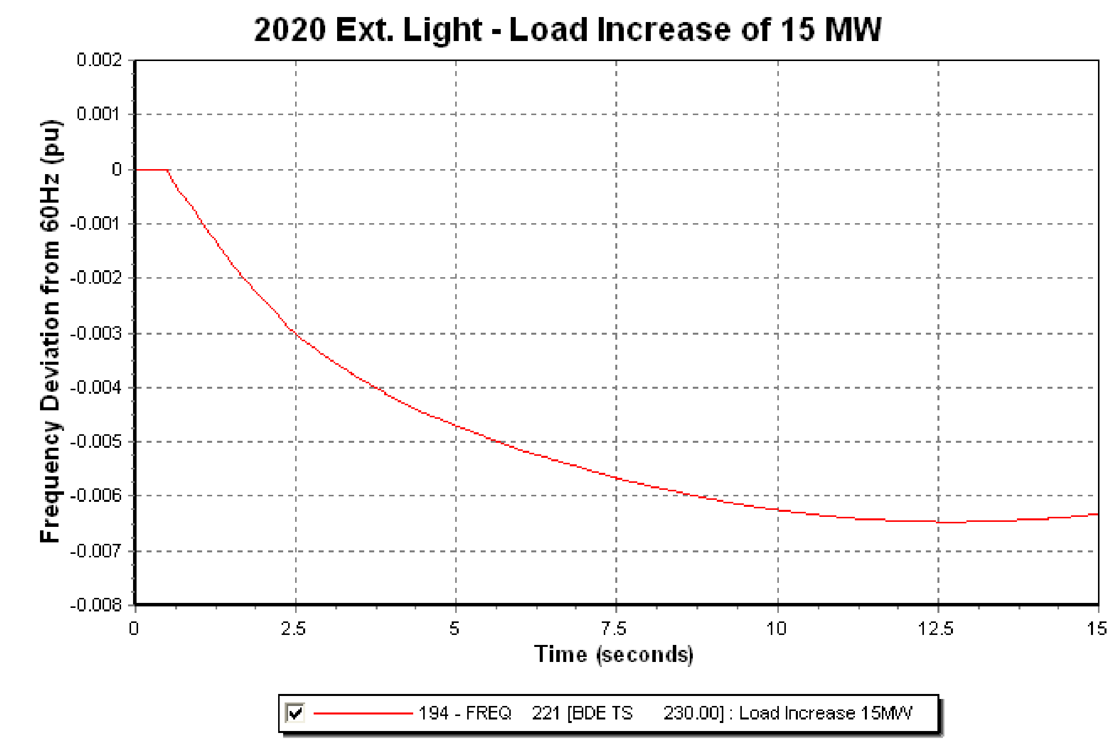


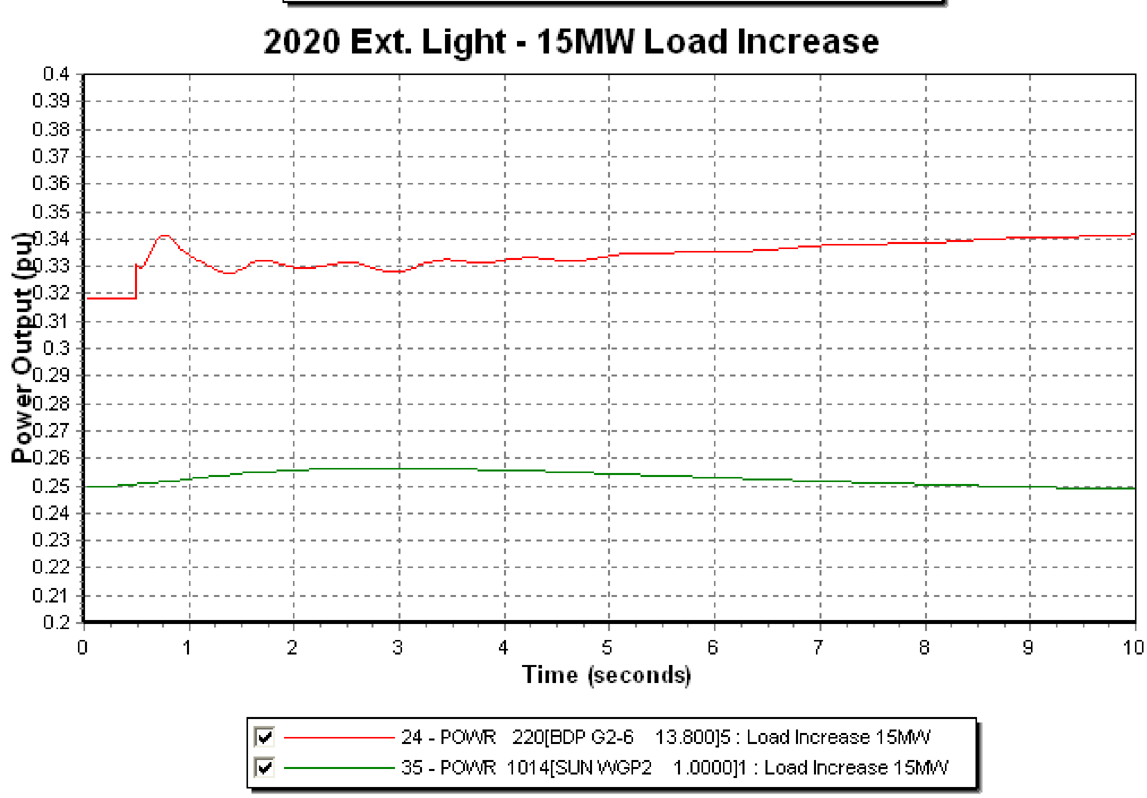


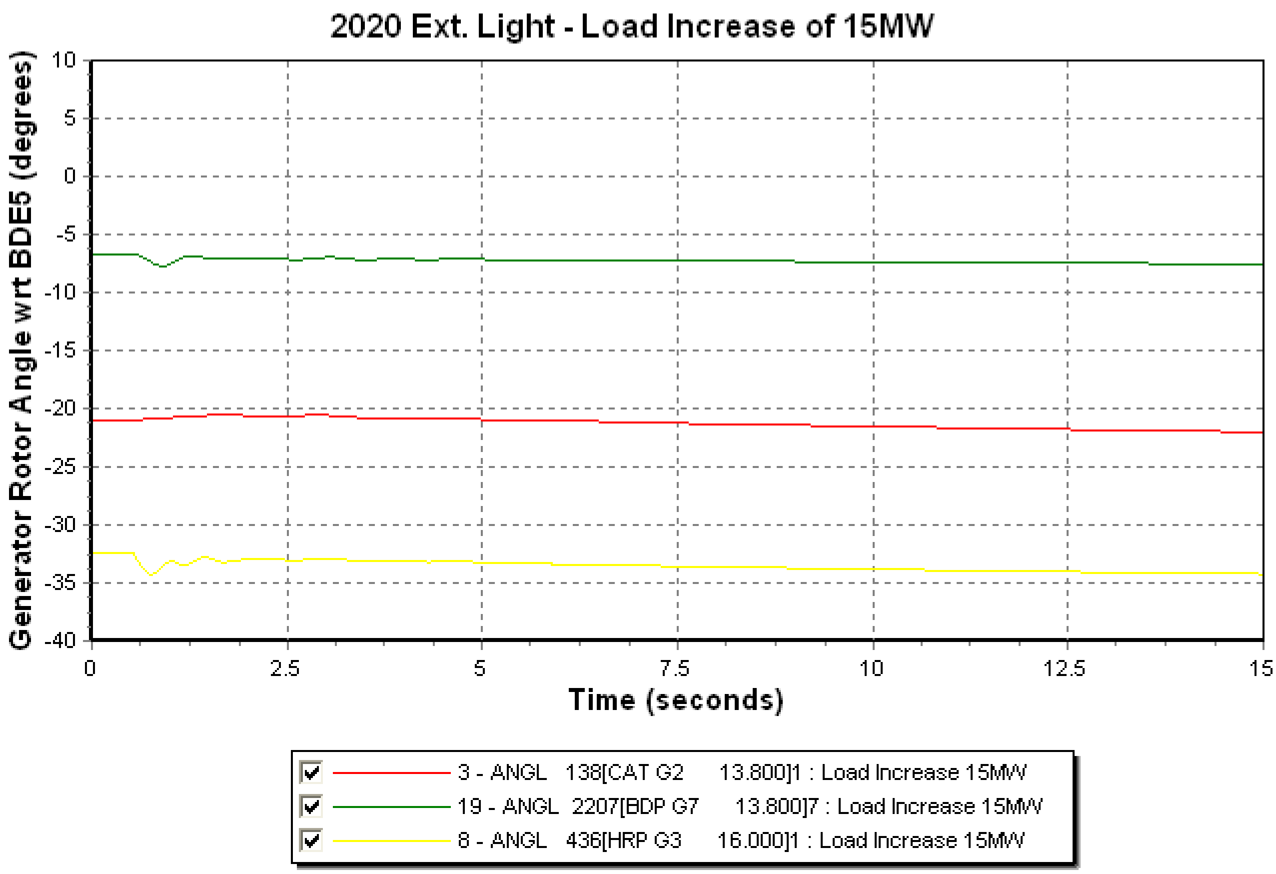

2020 Ext. Light - Loss of BDE7
Generator Rotor Angle wrt BDE5 (degrees)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
5
10
15
20
25
30
Time (seconds)
2 - ANGL 138[CAT G2 13.800]1 : Loss of BDE7
4 - ANGL 220[BDP G2-6 13.800]5 : Loss of BDE7
6 - ANGL 436[HRP G3 16.000]1 : Loss of BDE7

Case 3 – Sudden Load Increase of 15 MW

For this event, system frequency reaches a minimum level 59.6 Hz, which is slightly above the first stage under frequency load shedding stage of 59.5 Hz. This is the pre-defined limit of frequency decline for this type of event. The plots below outline the system frequency and a wind turbine / Bay d'Espoir Unit 7 power output responses.

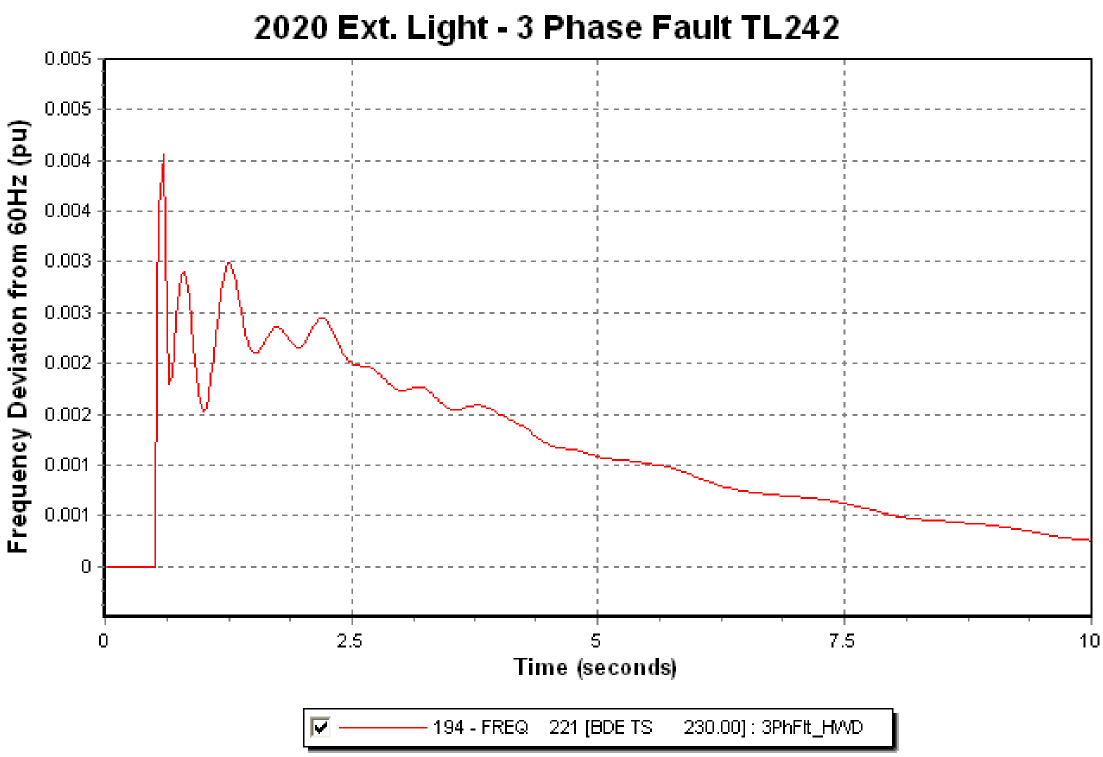


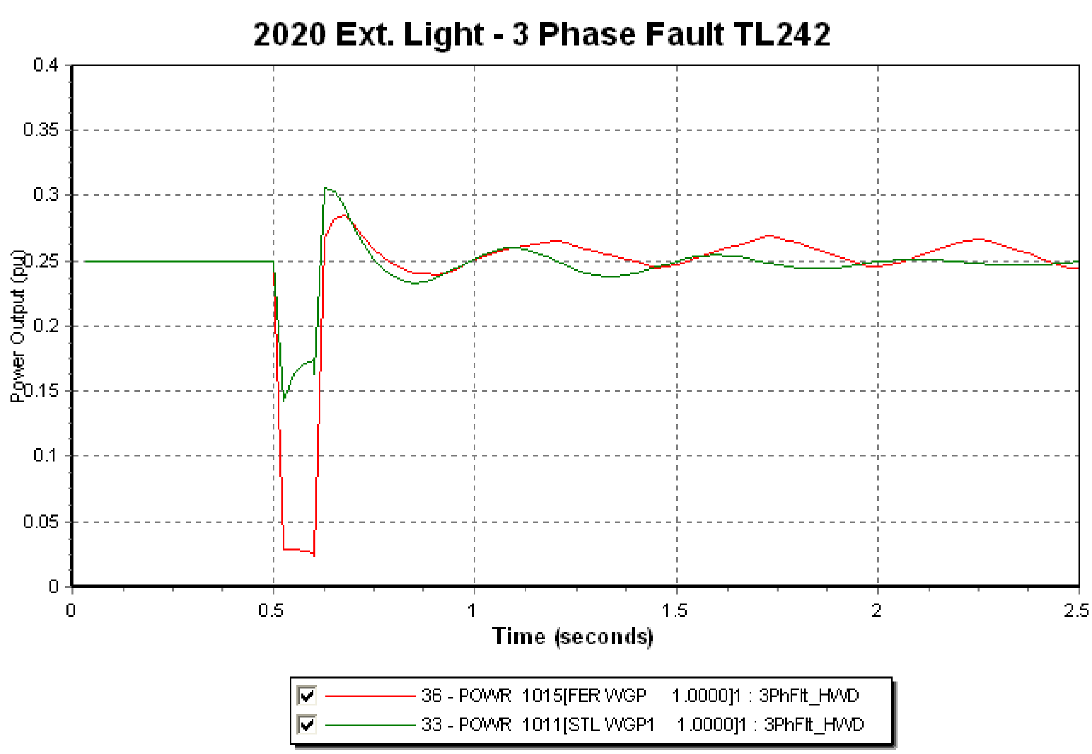


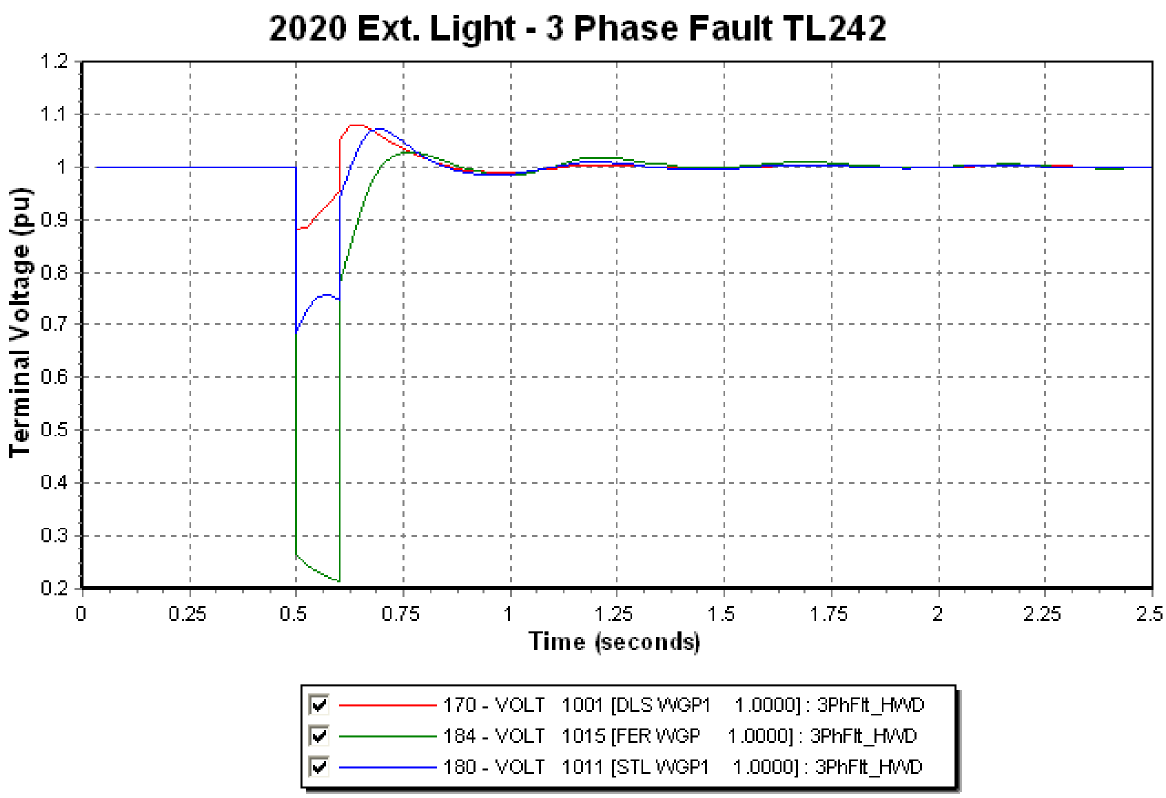

2020 Ext. Light - Load Increase of 15MW
Generator Rotor Angle wrt BDE5 (degrees)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : Load Increase 15MW
19 - ANGL 2207[BDP G7 13.800]7 : Load Increase 15MW
8 - ANGL 436[HRP G3 16.000]1 : Load Increase 15MW

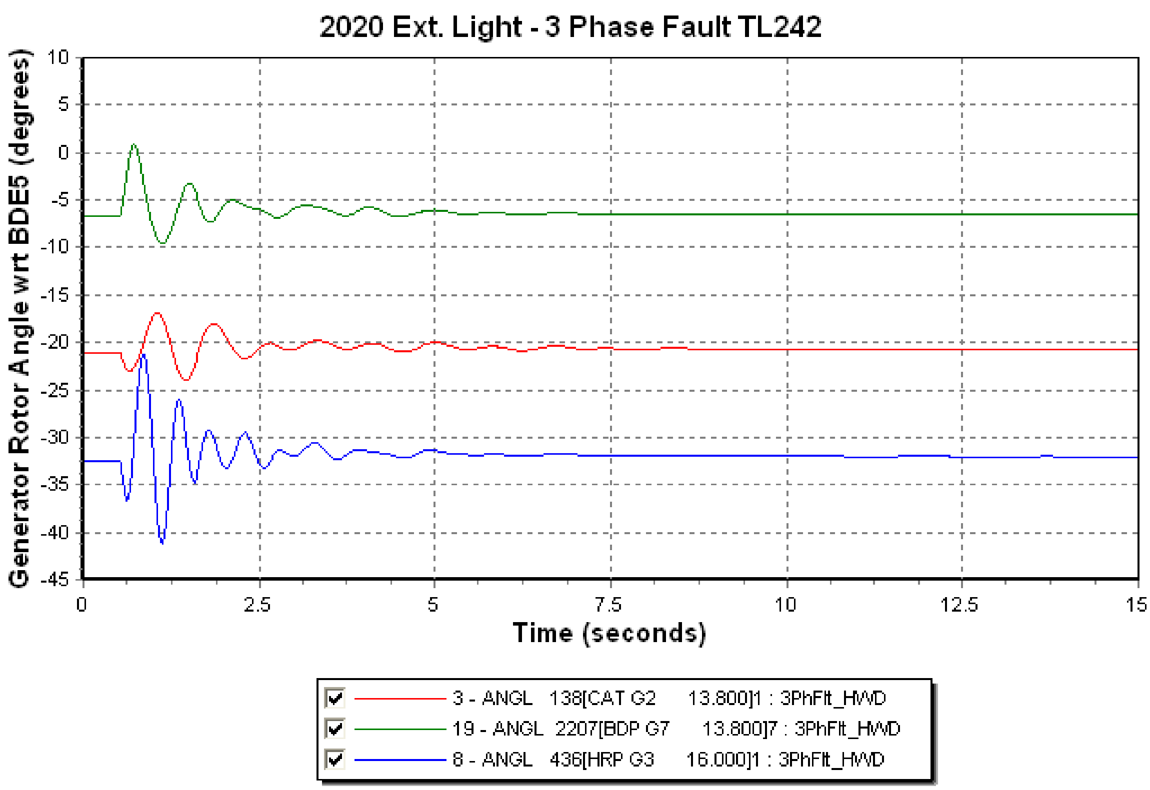
Case 4 – 3 Phase Fault at HWD (6 cycles – Trip TL242)

For this contingency a three phase fault has been applied on TL242 near Hardwoods terminal station for 6 cycles, followed by the tripping of TL242 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



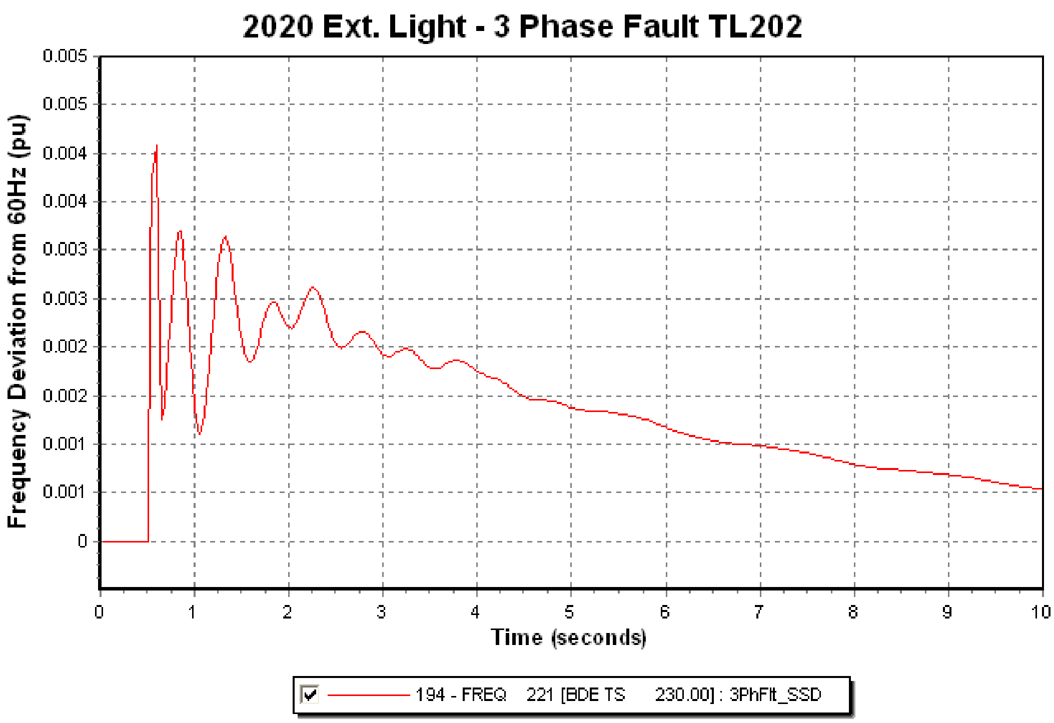


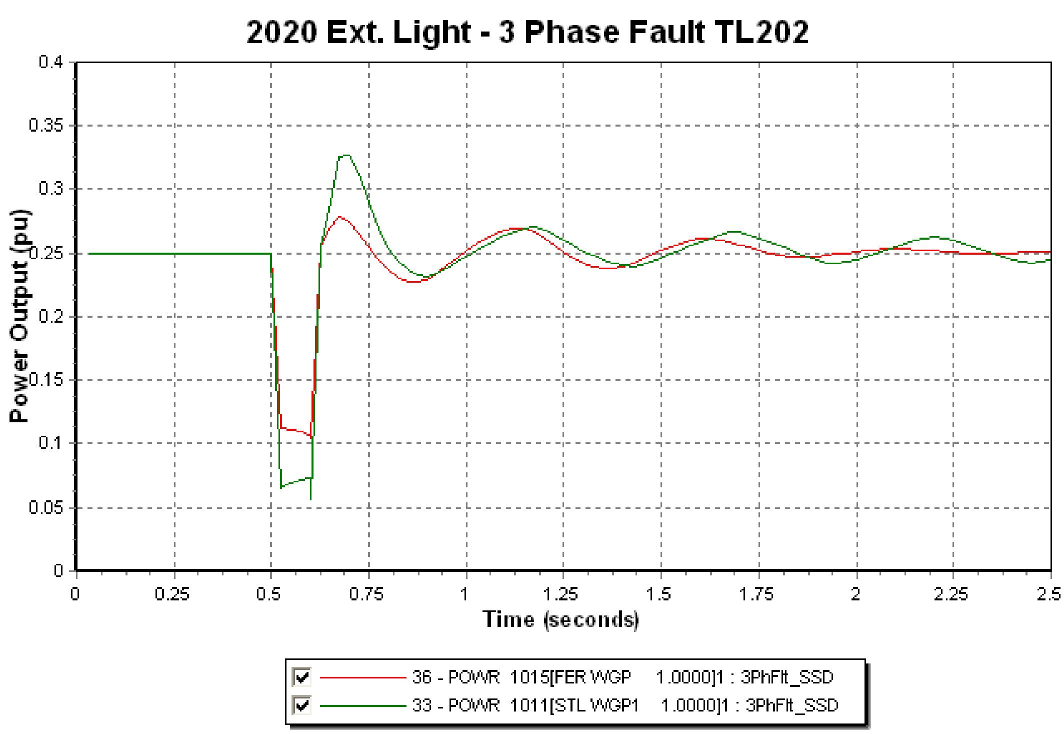

2020 Ext. Light - 3 Phase Fault TL242
Terminal Voltage (pu)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
170 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_HWD
184 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_HWD
180 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_HWD

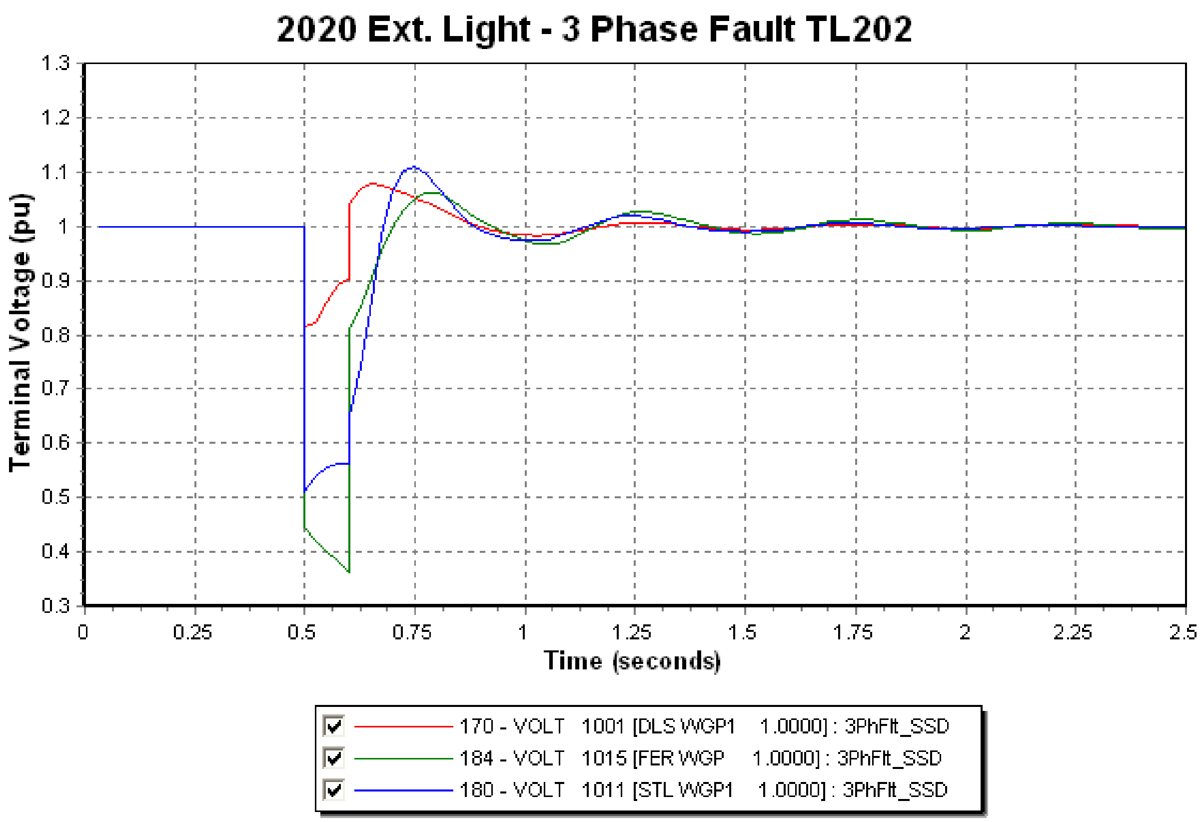

2020 Ext. Light - 3 Phase Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : 3PhFlt_HWD
19 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_HWD
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_HWD

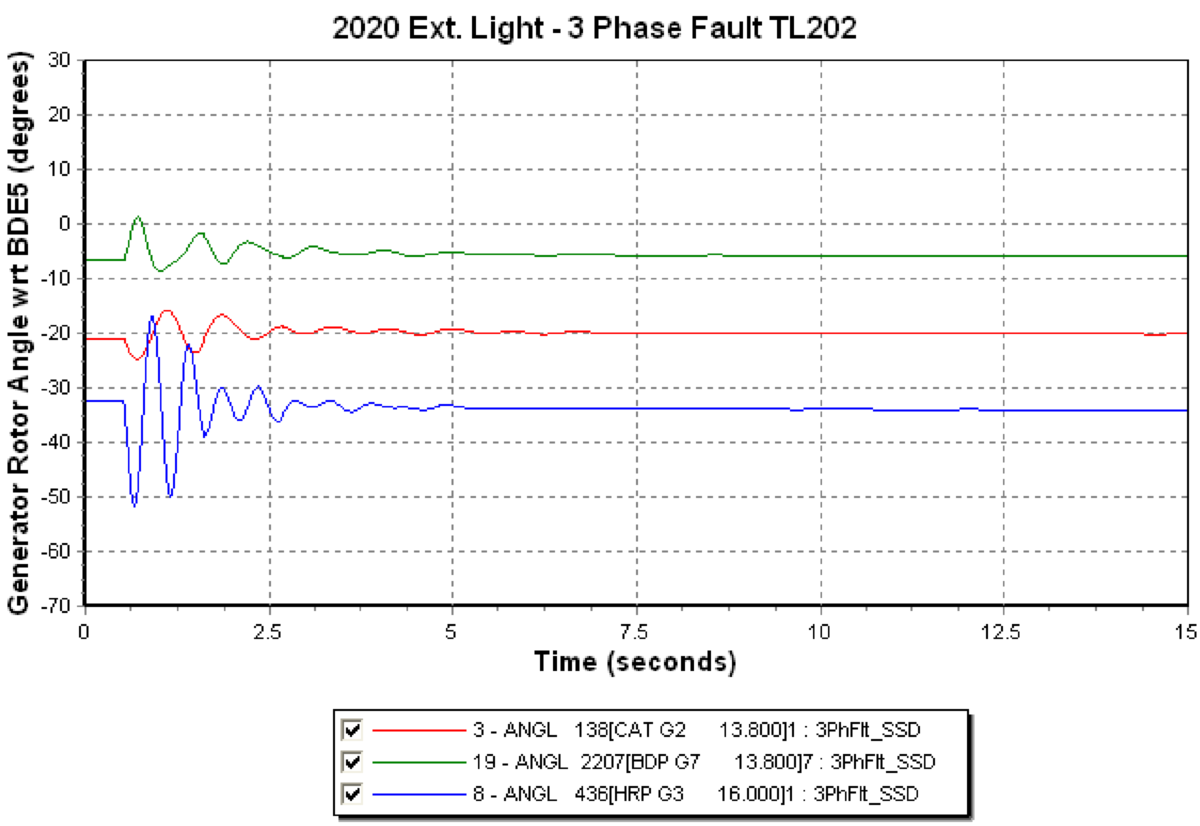
Case 5 – 3 Phase Fault at SSD (6 cycles – Trip TL202)

For this contingency a three phase fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the tripping of TL202 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



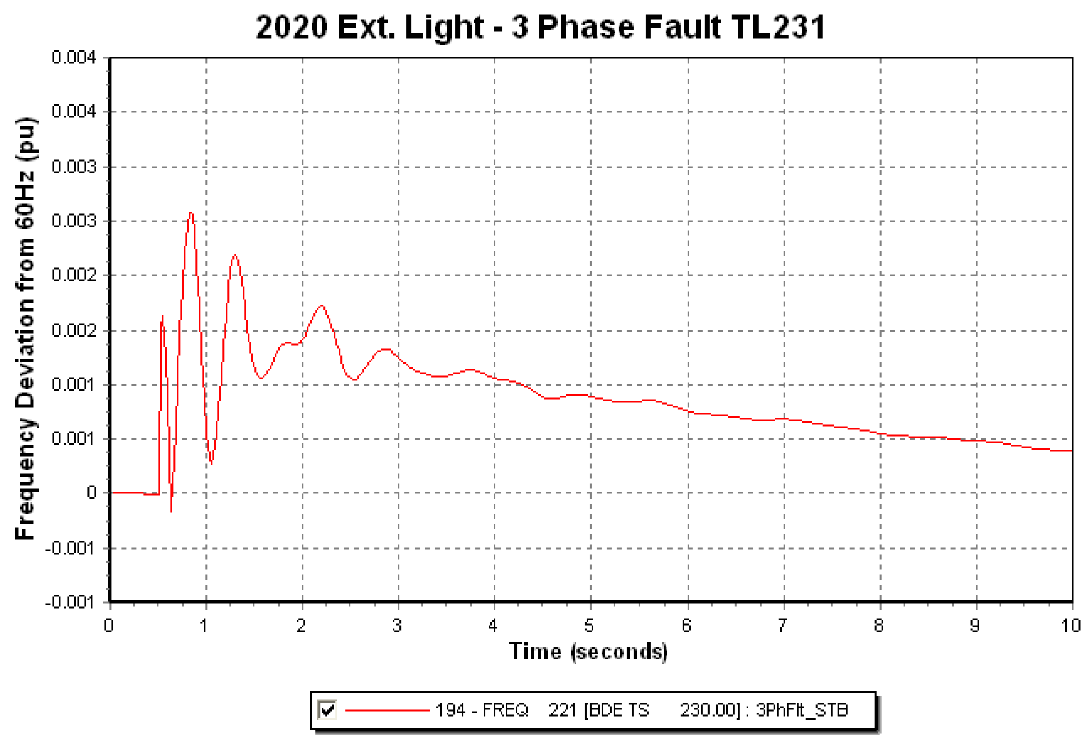


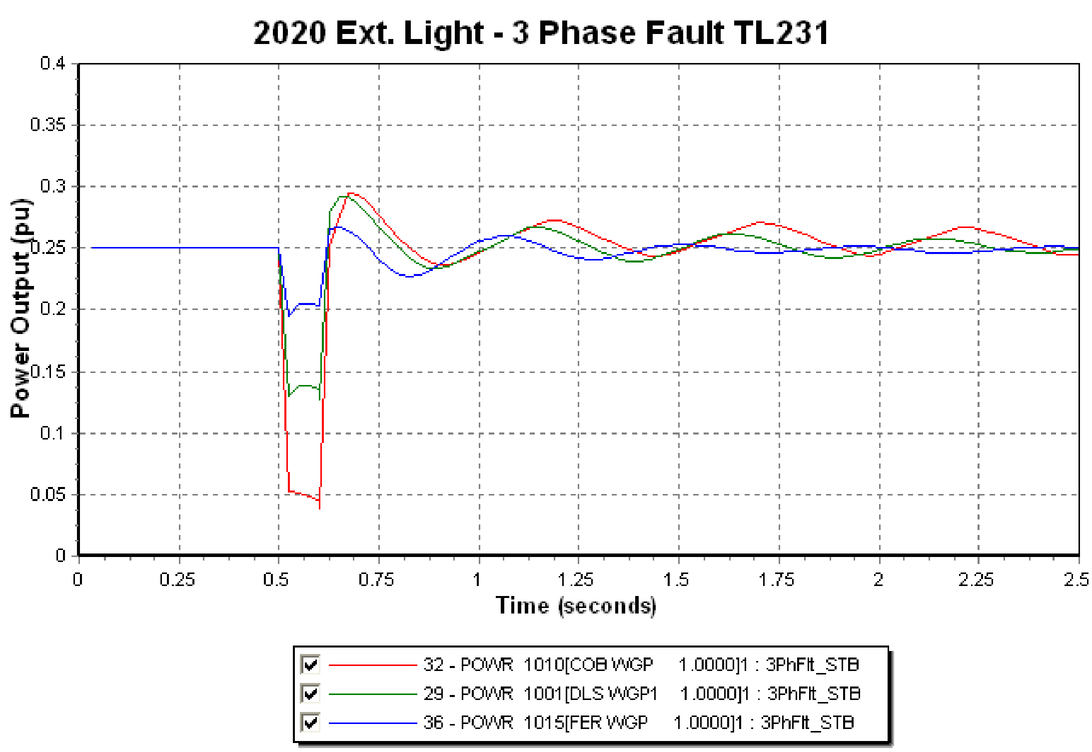

2020 Ext. Light - 3 Phase Fault TL202
Terminal Voltage (pu)
Time (seconds)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
170 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_SSD
184 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_SSD
180 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_SSD

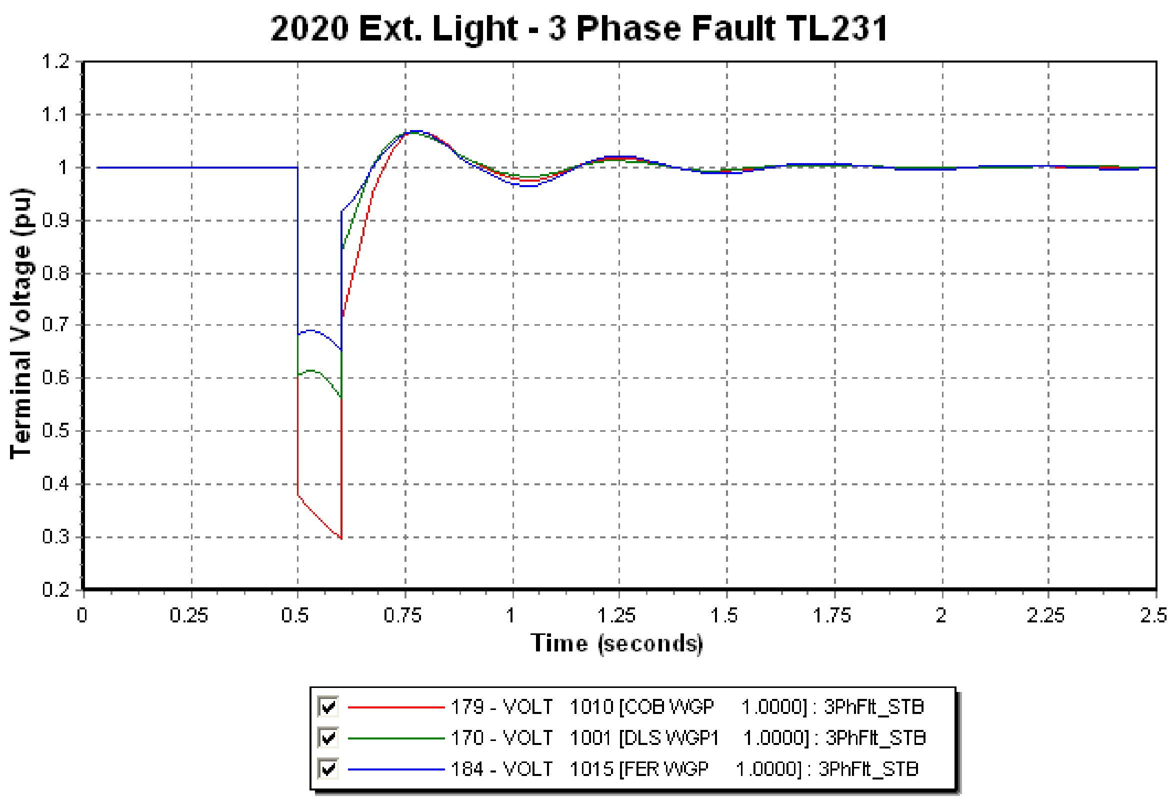

2020 Ext. Light - 3 Phase Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
2.5
5
7.5
10
12.5
15
3 - ANGL 138[CAT G2 13.800]1 : 3PhFlt_SSD
19 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_SSD
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_SSD

Case 6 – 3 Phase Fault at STB (6 cycles – Trip TL231)

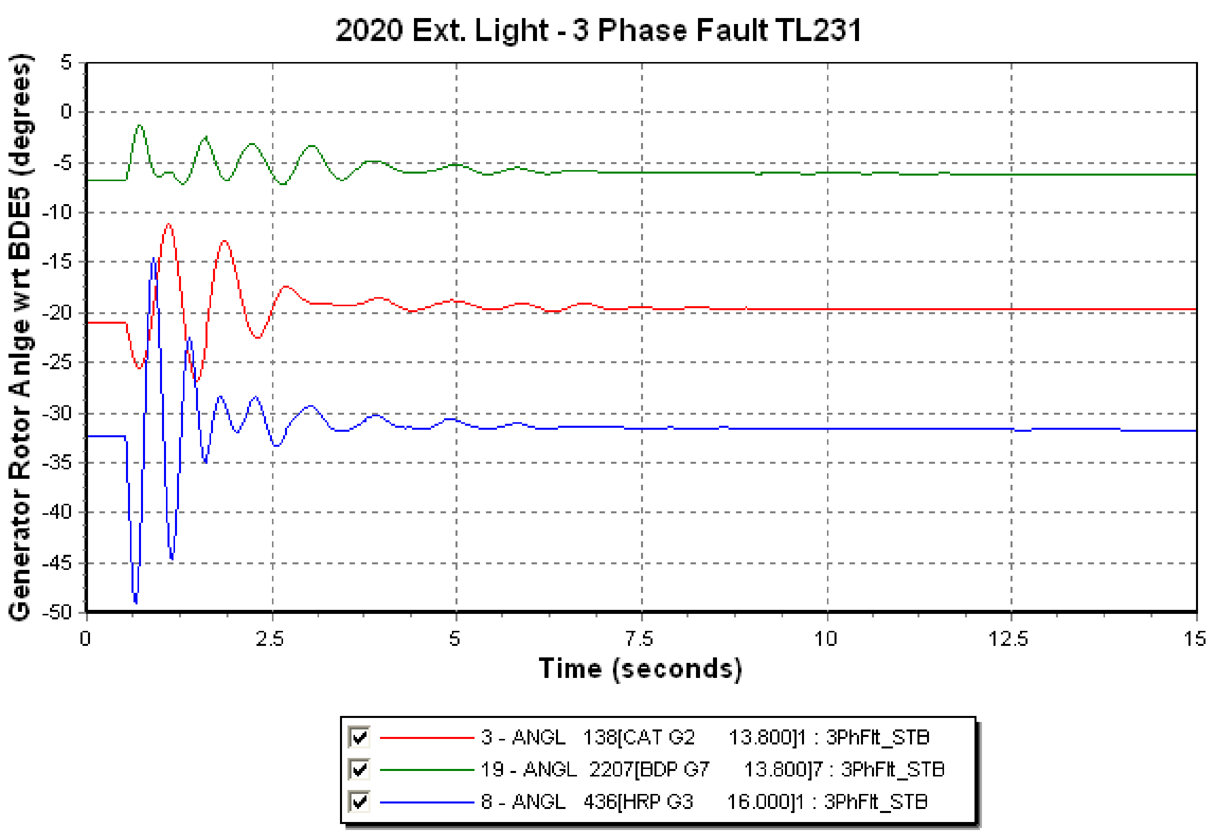
For this contingency a three phase fault has been applied on TL231 near Stony Brook terminal station for 6 cycles, followed by the tripping of TL231 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.







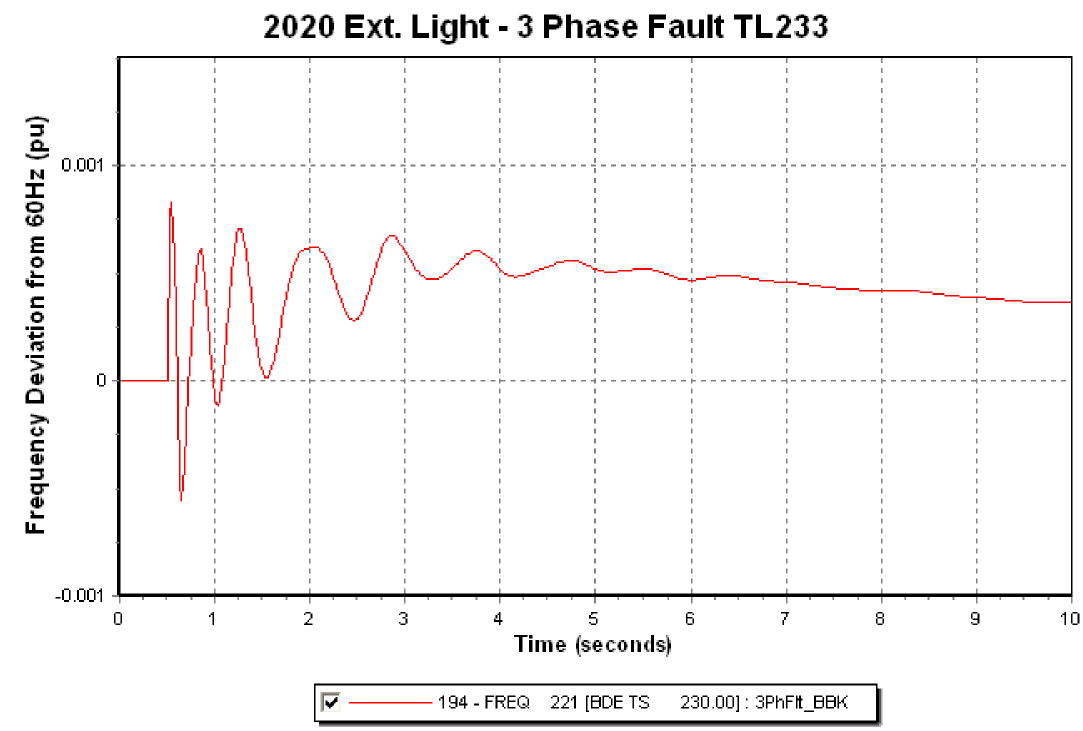
2020 Ext. Light - 3 Phase Fault TL231
Terminal Voltage (pu)
Time (seconds)
179 - VOLT 1010 [COB WGP 1.0000] : 3PhFlt_STB
170 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_STB
184 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_STB

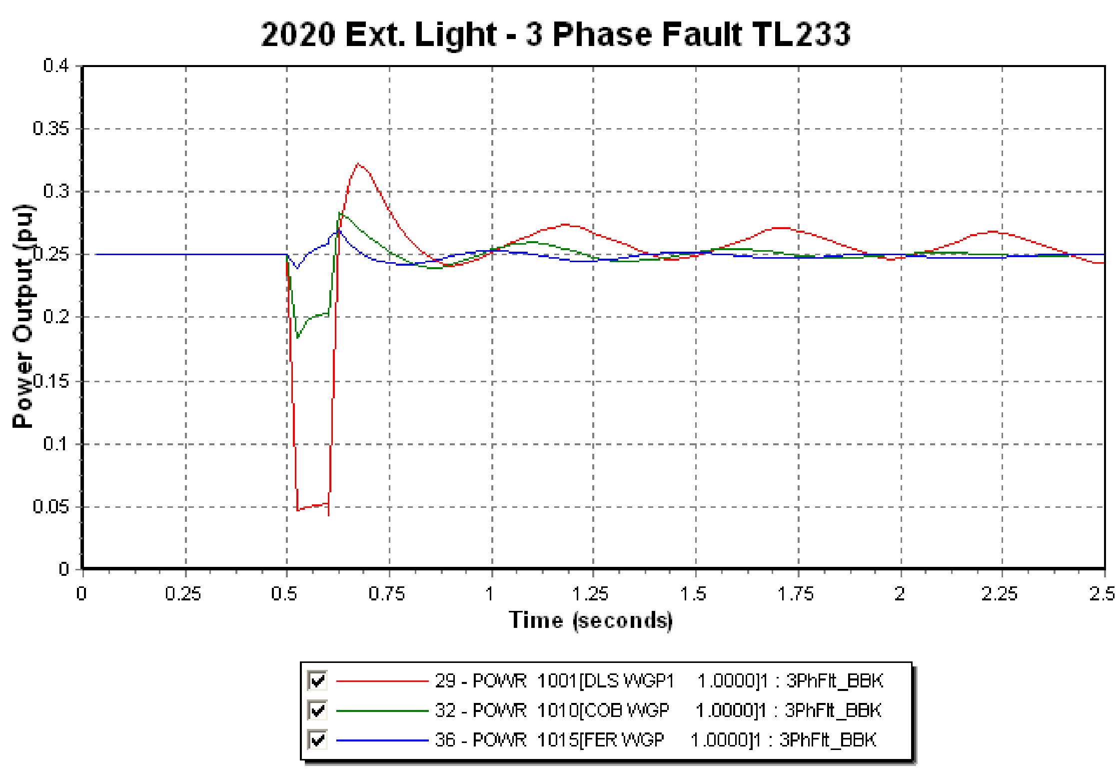


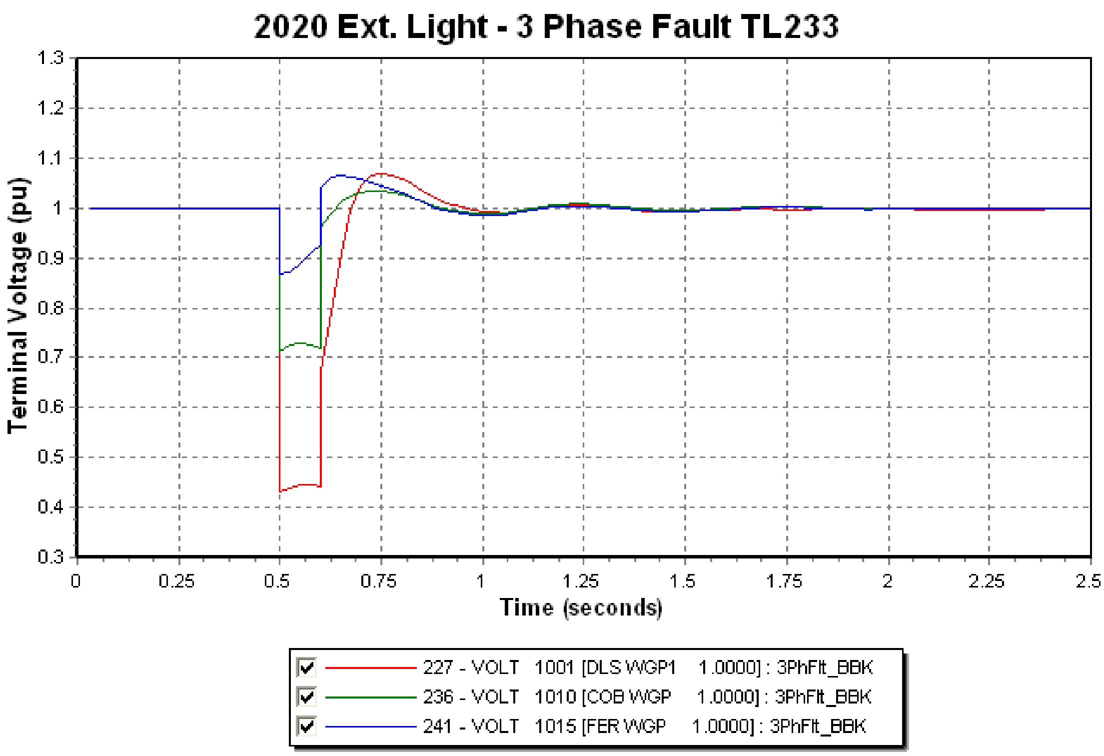
2020 Ext. Light - 3 Phase Fault TL231
Generator Rotor Anlge wrt BDE5 (degrees)
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : 3PhFlt_STB
19 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_STB
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_STB

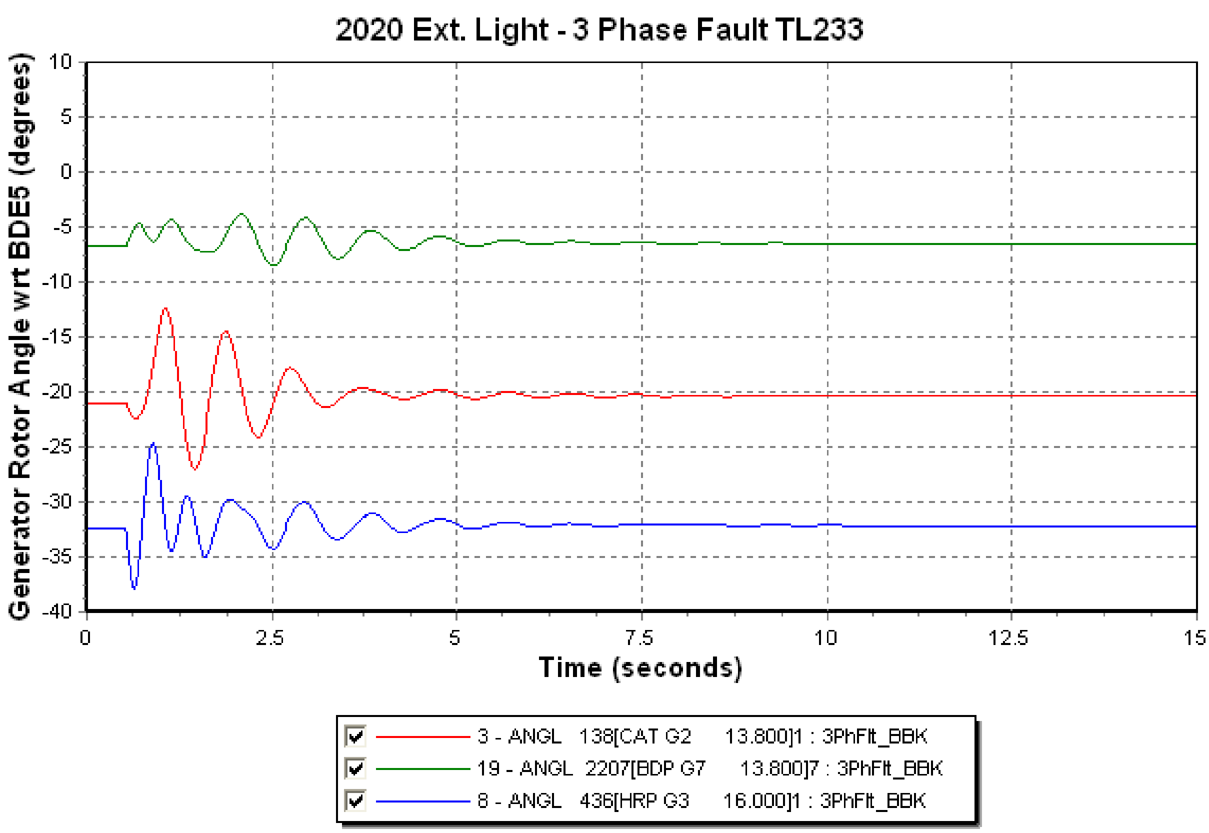
Case 7 – 3 Phase Fault at BBK (6 cycles – Trip TL233)

For this contingency a three phase fault has been applied on TL233 near Bottom Brook terminal station for 6 cycles, followed by the tripping of TL233 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



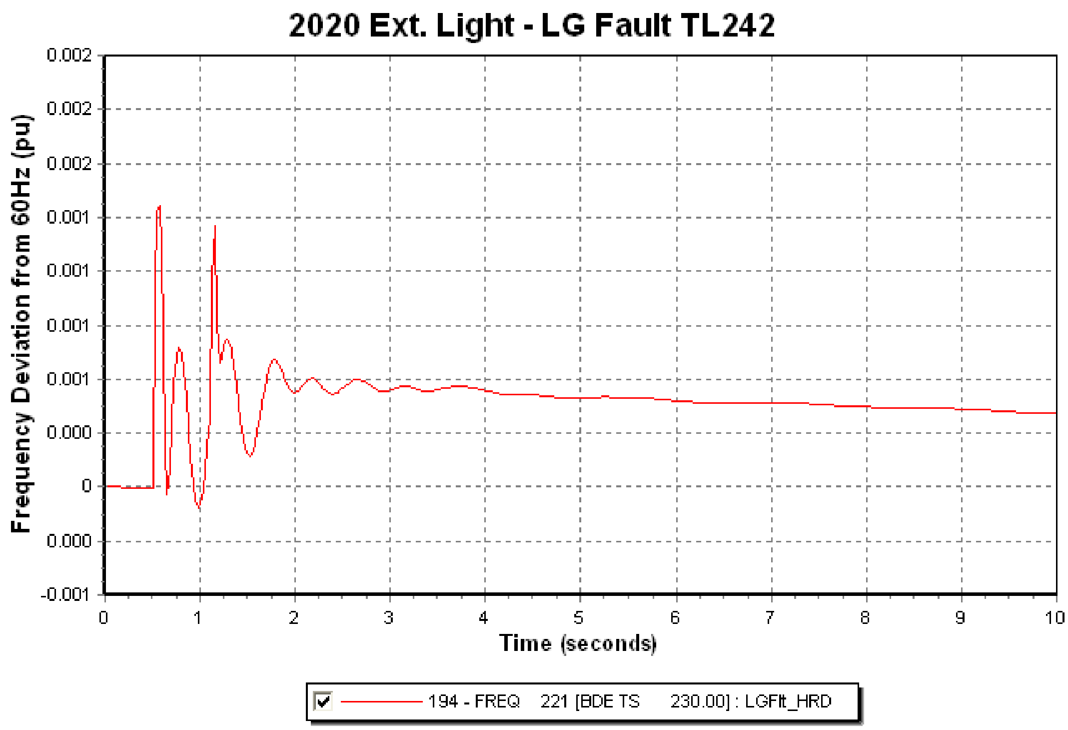


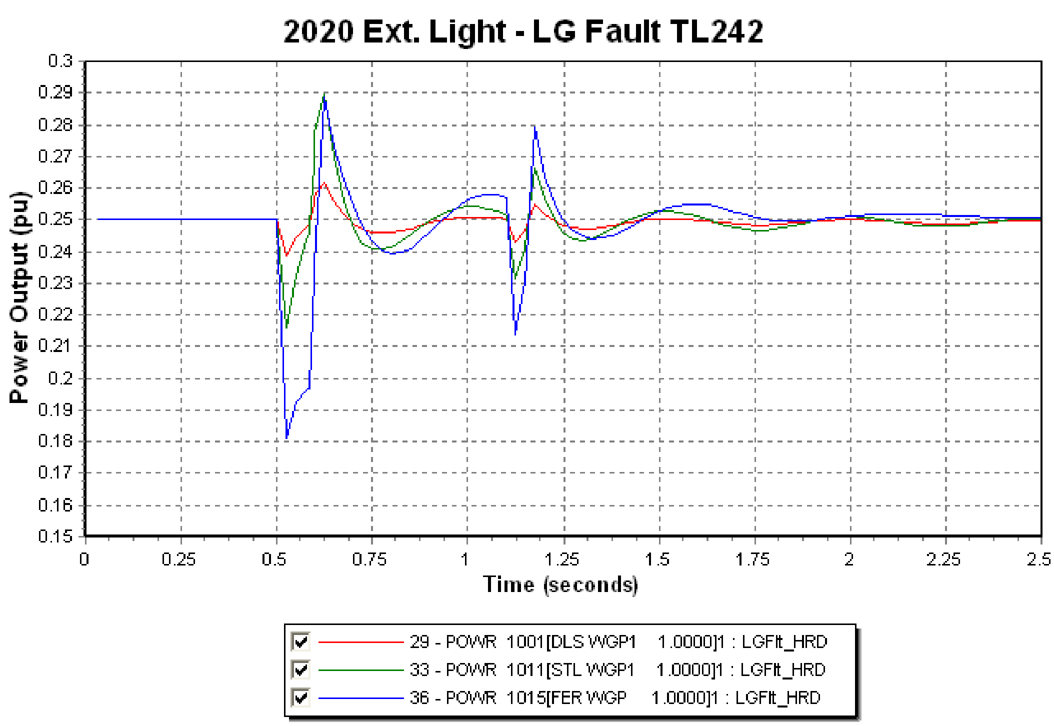

2020 Ext. Light - 3 Phase Fault TL233
Terminal Voltage (pu)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
227 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_BBK
236 - VOLT 1010 [COB WGP 1.0000] : 3PhFlt_BBK
241 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_BBK

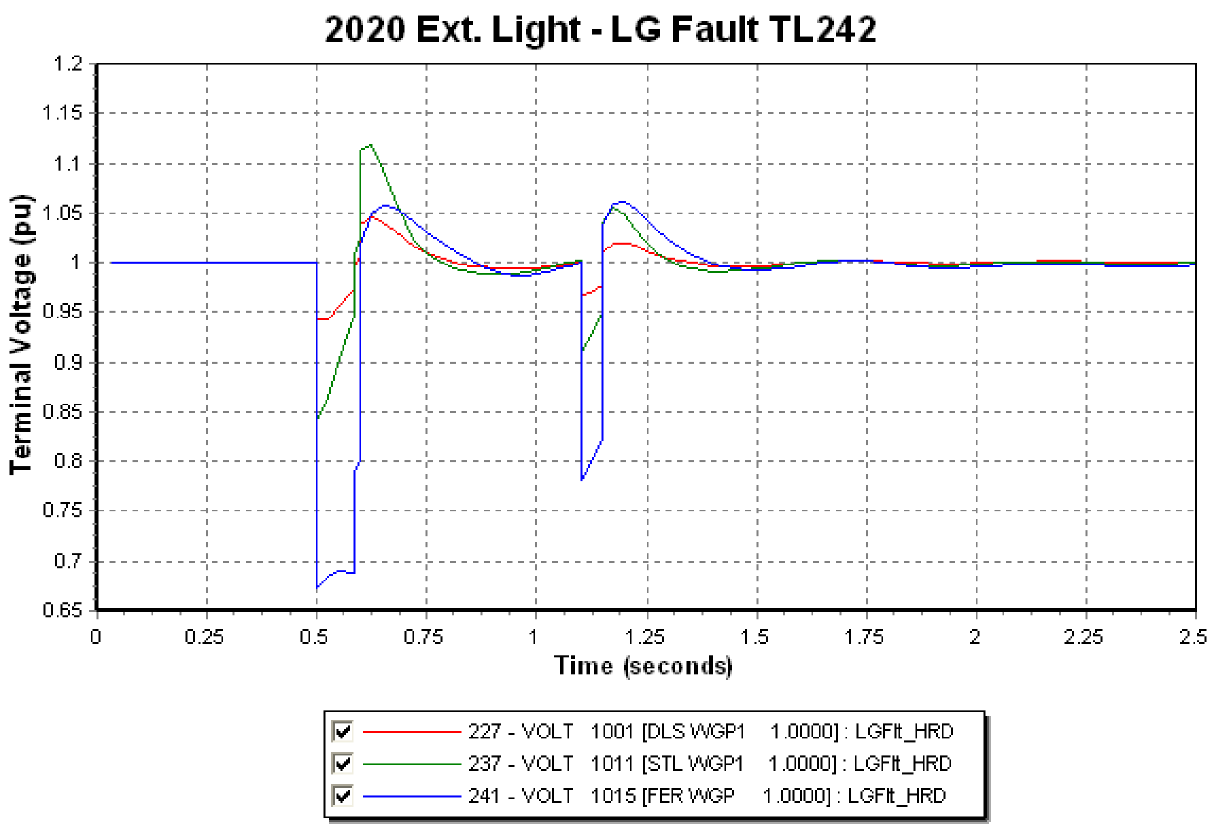

2020 Ext. Light - 3 Phase Fault TL233
Generator Rotor Angle wrt BDE5 (degrees)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : 3PhFlt_BBK
19 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_BBK
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_BBK

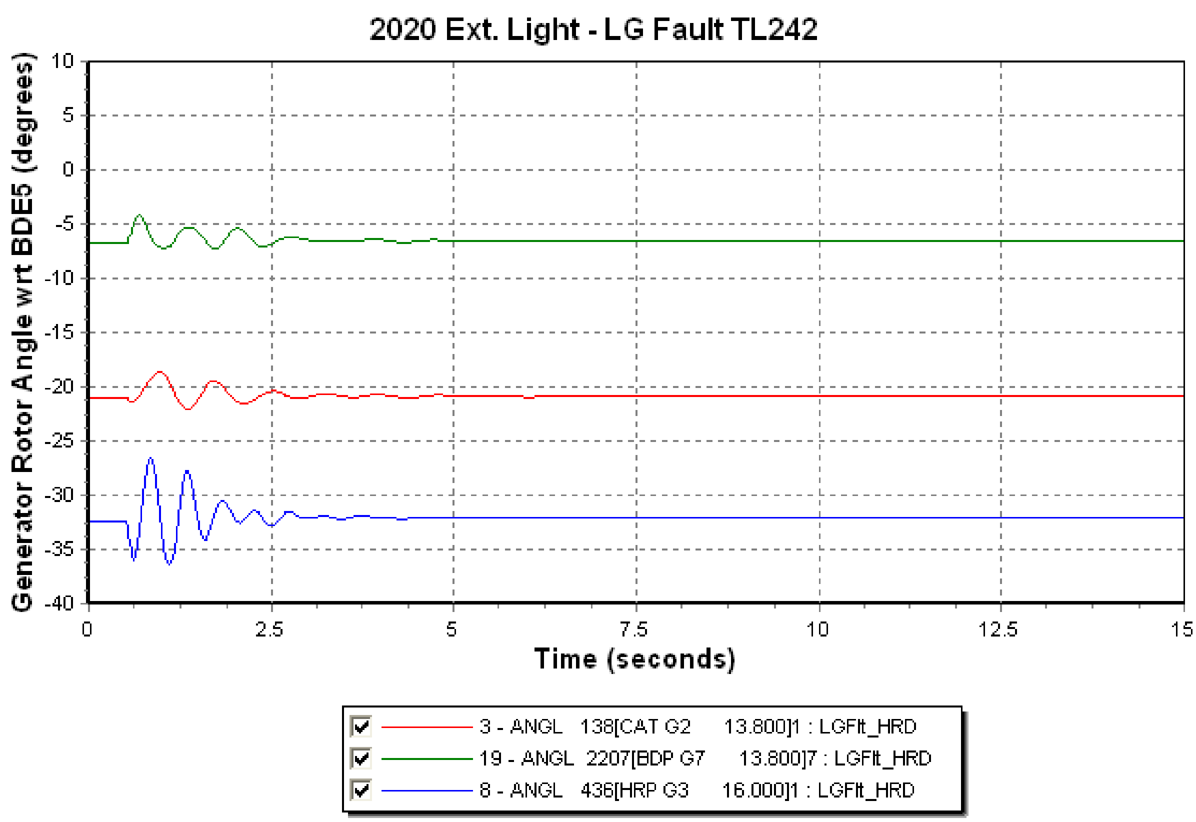
Case 8 – LG Fault at TL242 Near HRD

For this contingency a line to ground fault has been applied on TL242 near Holyrood Generating station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL242 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



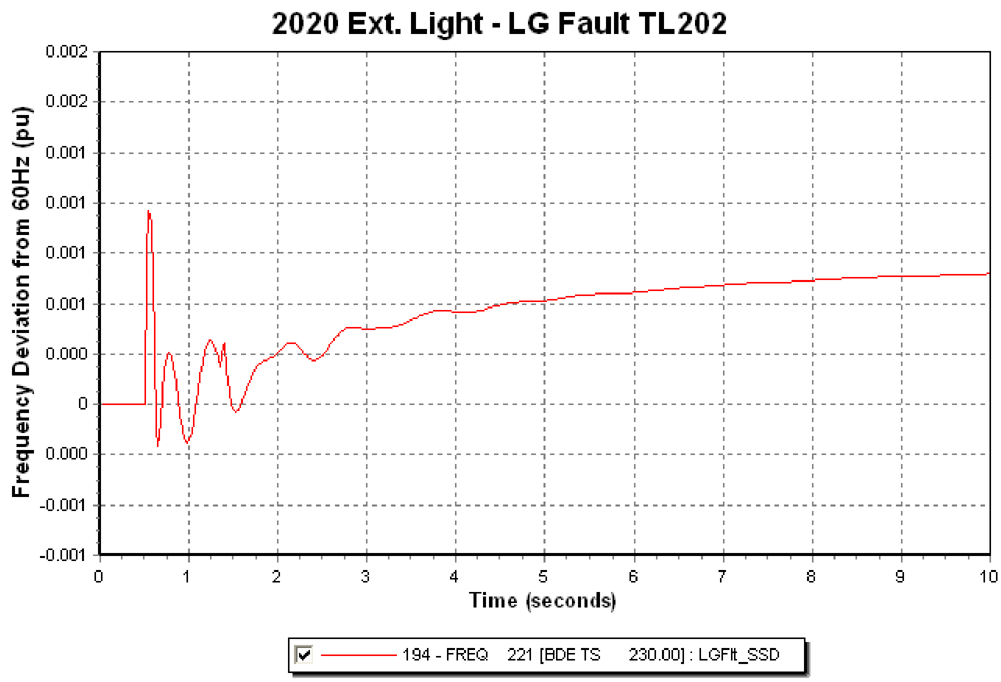


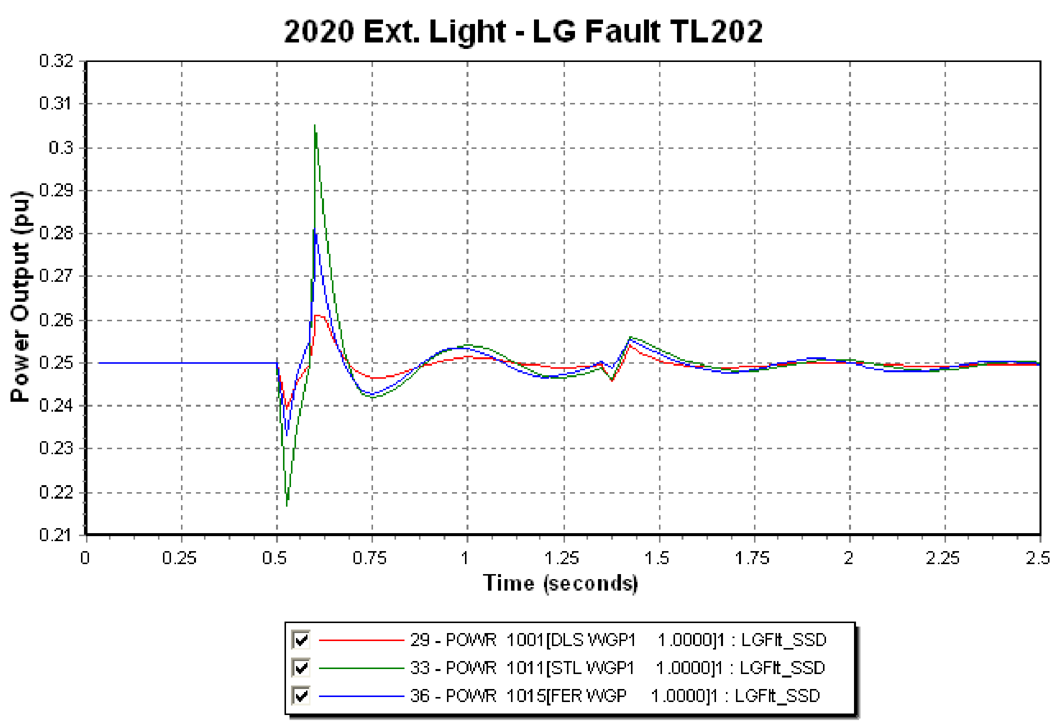

2020 Ext. Light - LG Fault TL242
Terminal Voltage (pu)
Time (seconds)
227 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_HRD
237 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_HRD
241 - VOLT 1015 [FER WGP 1.0000] : LGFlt_HRD

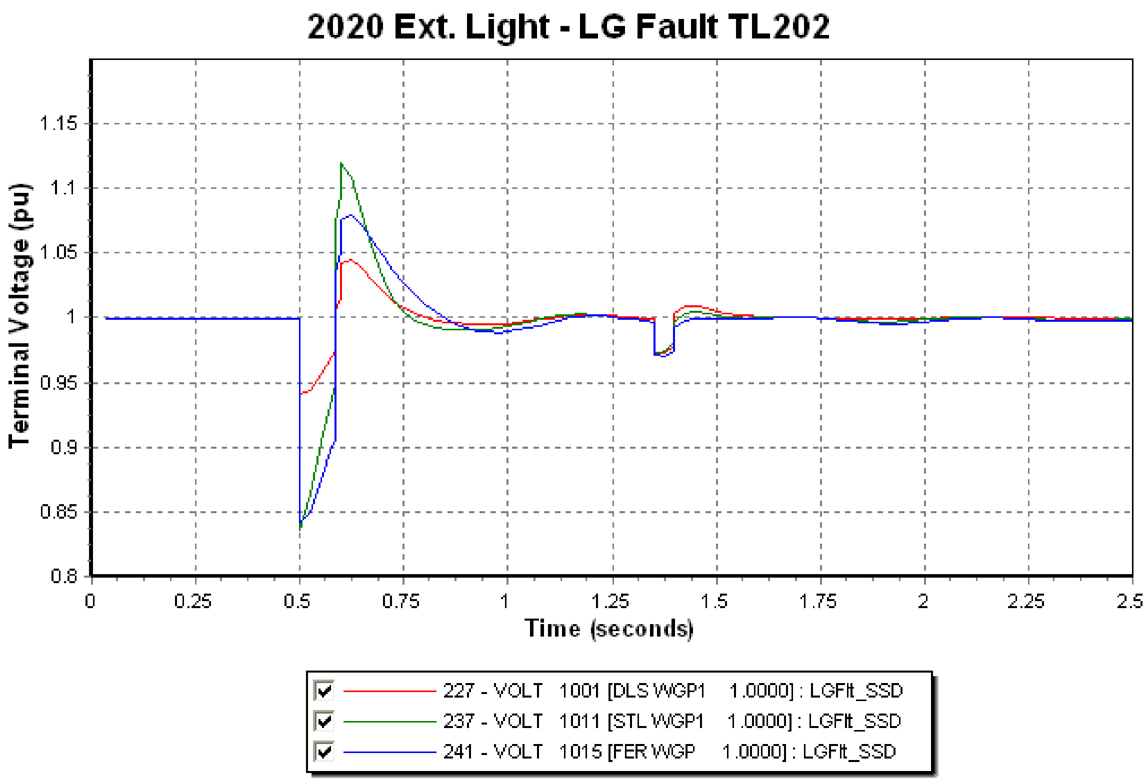

2020 Ext. Light - LG Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : LGFlt_HRD
19 - ANGL 2207[BDP G7 13.800]7 : LGFlt_HRD
8 - ANGL 436[HRP G3 16.000]1 : LGFlt_HRD

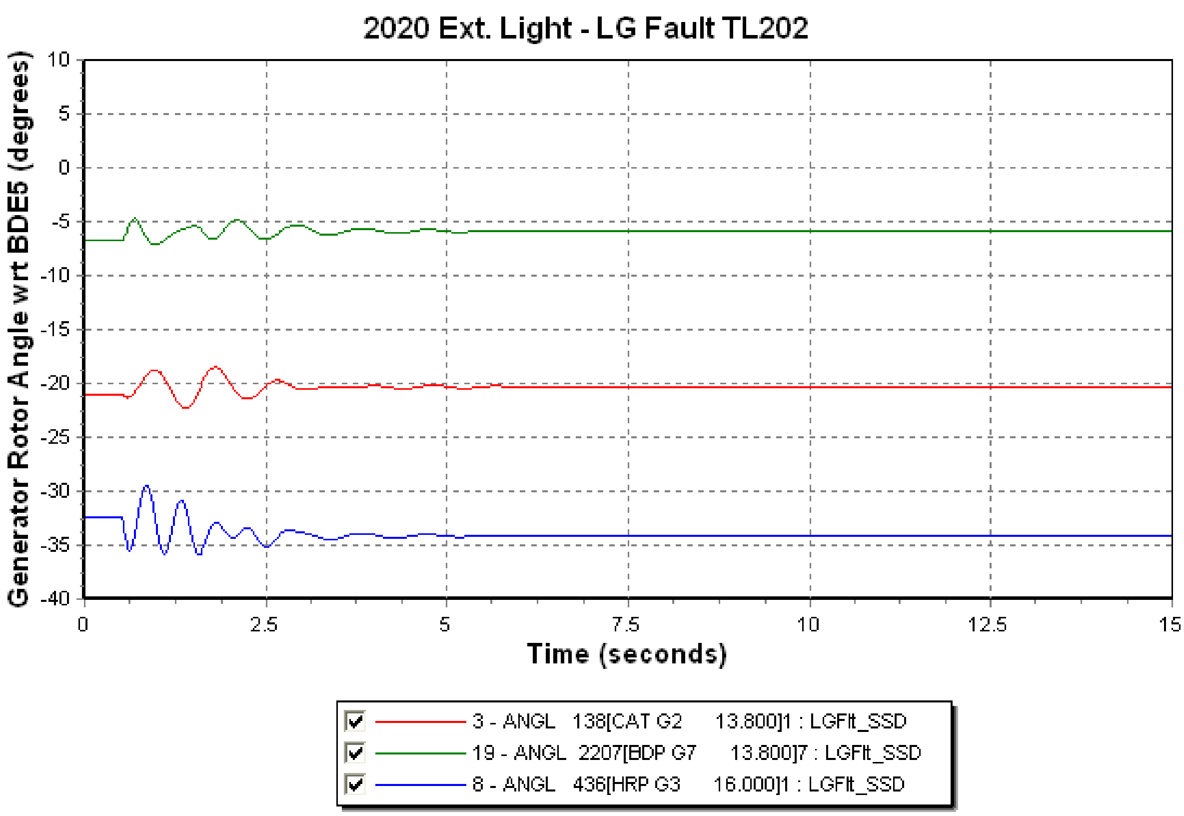
Case 9 – LG Fault at TL202 Near SSD

For this contingency a line to ground fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by th single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL202 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



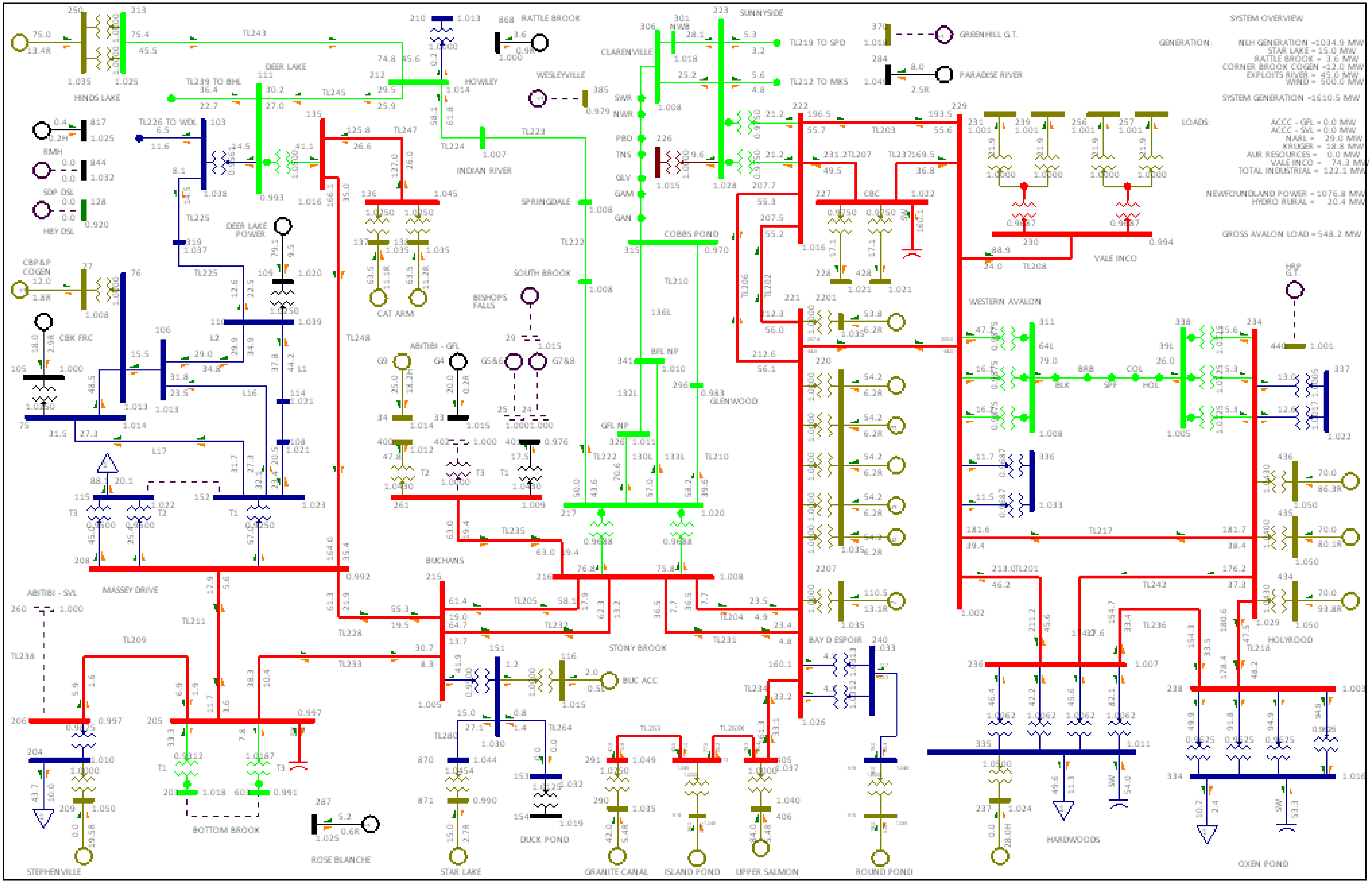



2020 Ext. Light - LG Fault TL202
Terminal Voltage (pu)
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
227 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_SSD
237 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_SSD
241 - VOLT 1015 [FER WGP 1.0000] : LGFlt_SSD


2020 Ext. Light - LG Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 138[CAT G2 13.800]1 : LGFlt_SSD
19 - ANGL 2207[BDP G7 13.800]7 : LGFlt_SSD
8 - ANGL 436[HRP G3 16.000]1 : LGFlt_SSD

APPENDIX I - STABILITY RESULTS 2020 PEAK LOAD

500 MW WIND GENERATION



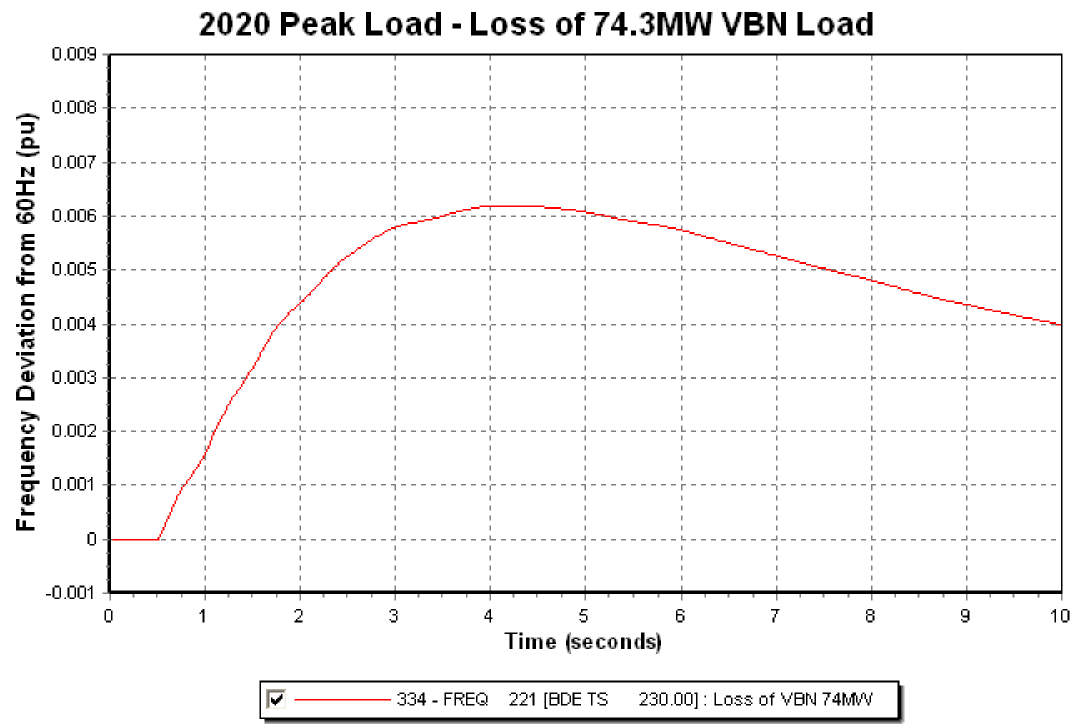
2020 PEAK BASE CASE - 500MW WIND
31% WIND PENETRATION - MINIMIZE THERMAL GENERATION
THU, AUG 16 2012 13:47

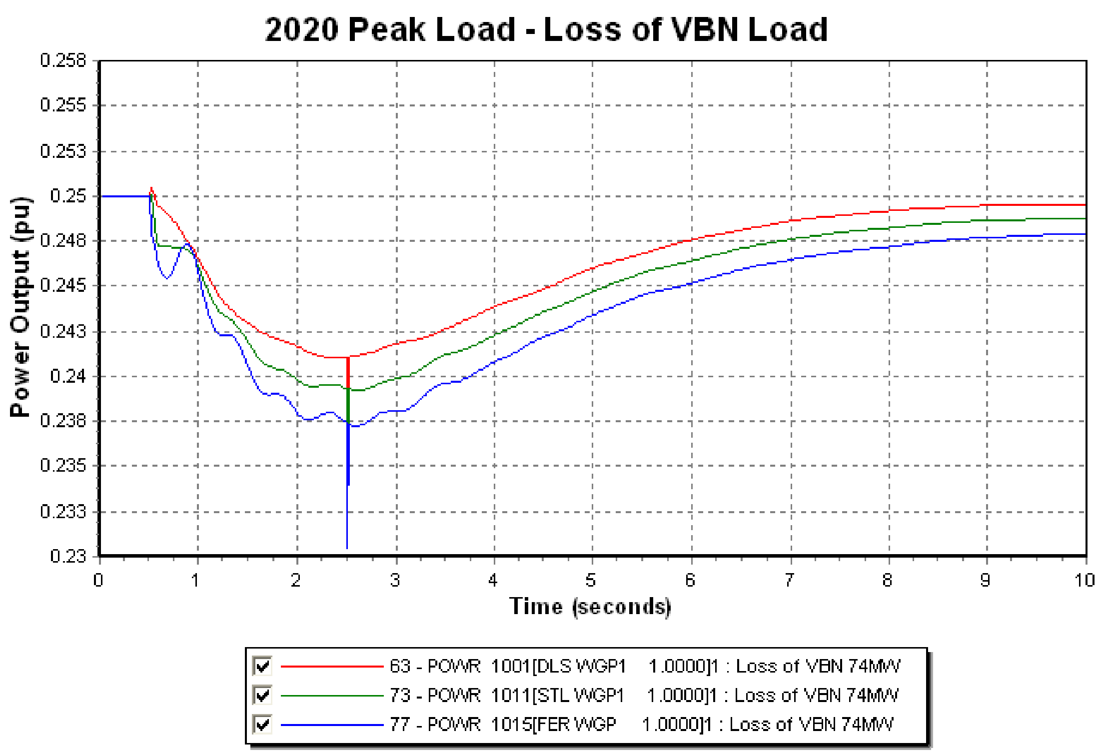
Bus - VOLTAGE (PU)
Branch - MVA/% OF RATE C
Equipment - MW/Mvar

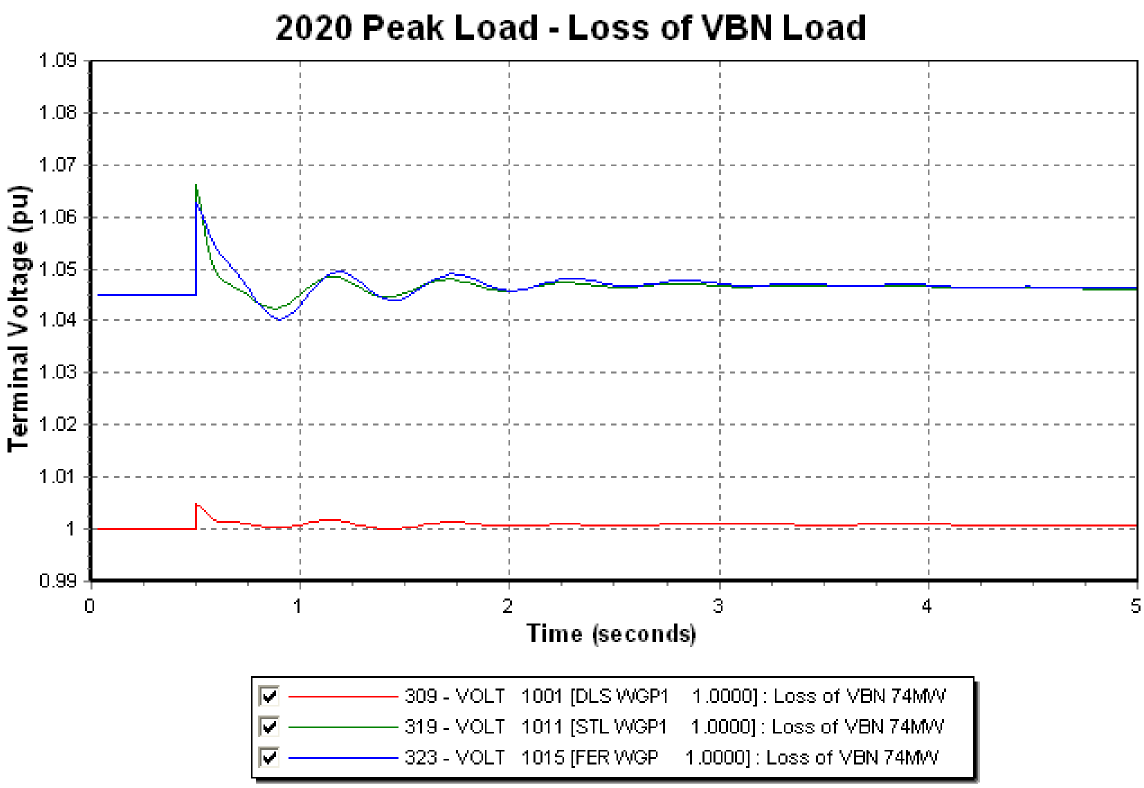
2020 Peak Load – 500MW Wind – Generation Dispatch Prior to Dynamic Simulations

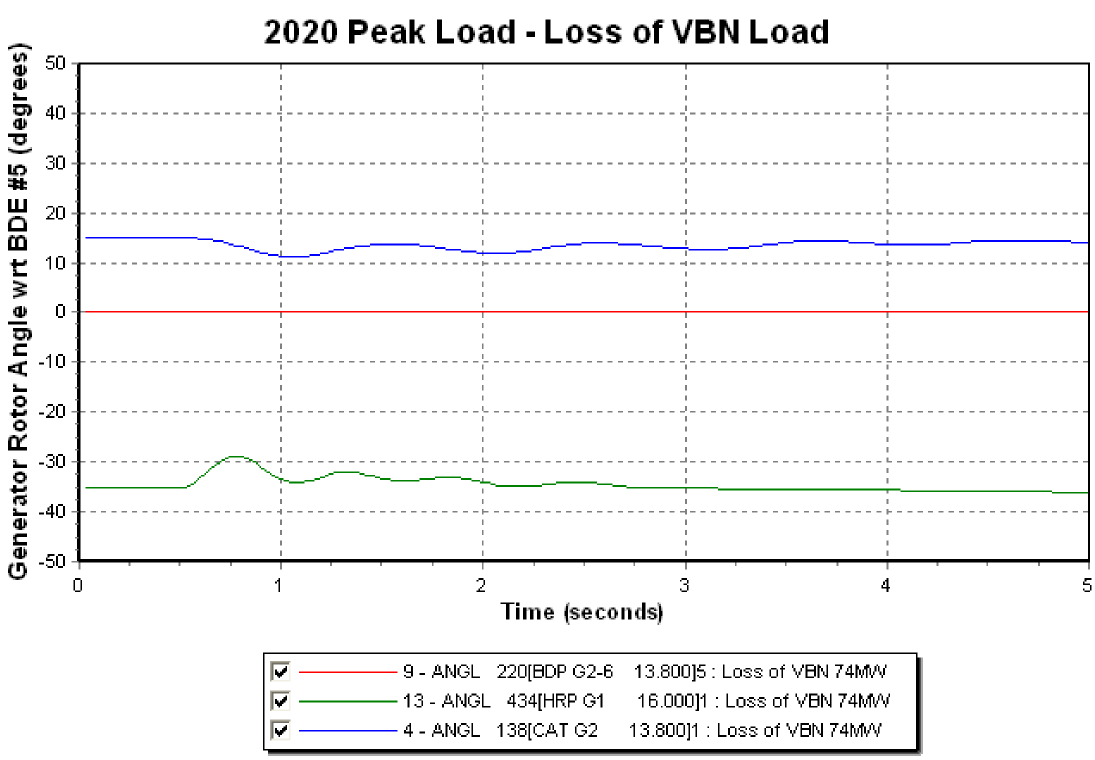
Case 1 – Loss of 74.3MW load at VBN

This causes an over frequency condition that reaches a maximum of 60.4Hz. All wind turbines remain on line as frequency doesn't reach 60.6Hz which is first wind turbine trip setpoint. The following plots show system frequency response, power output and terminal voltage from 3 wind turbine plants, and generator rotor angle with respect to Bay d'Espoir Unit 5.



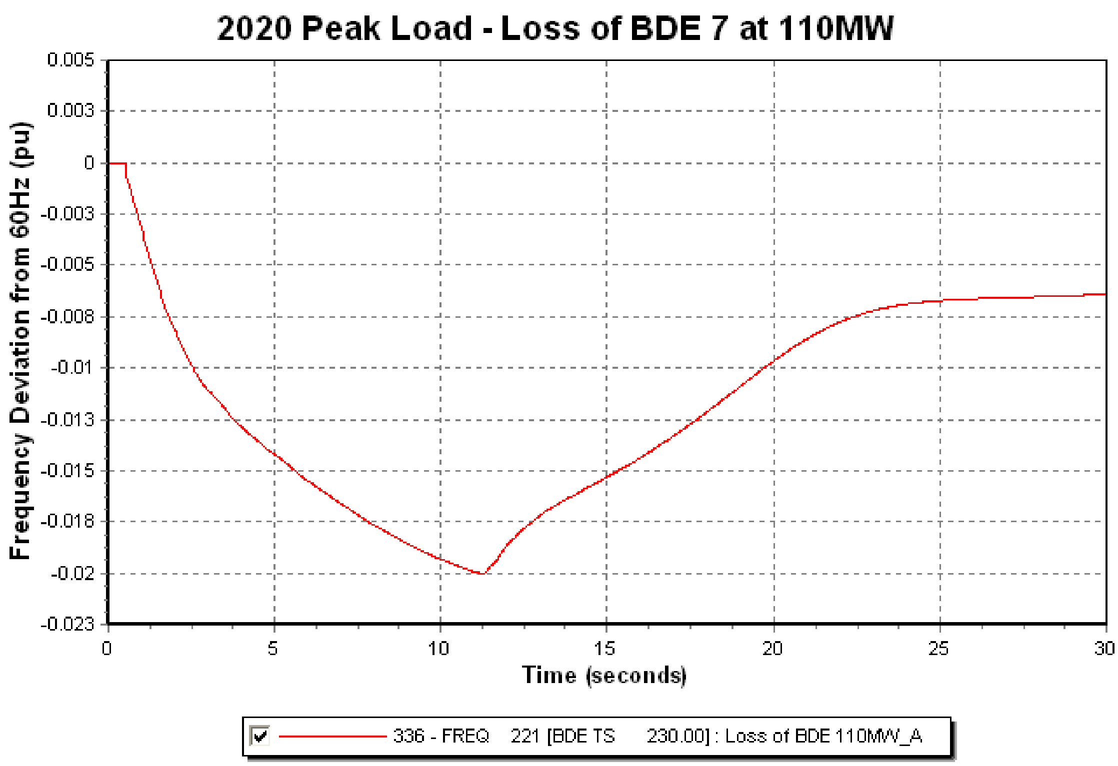


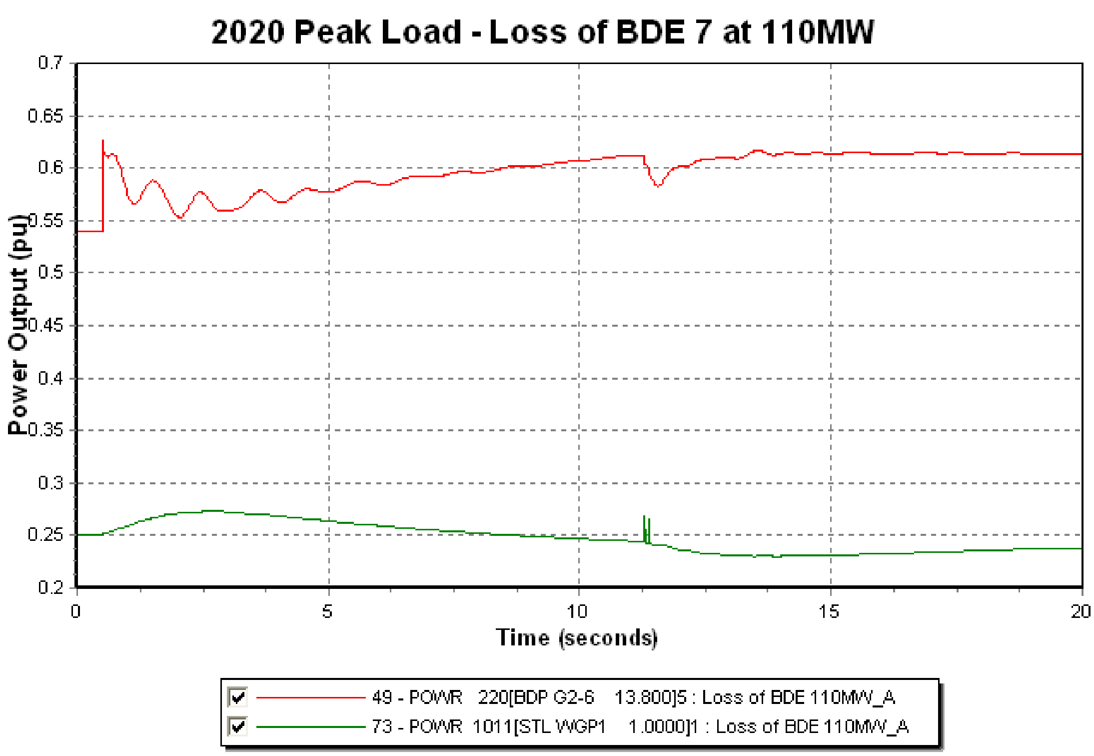

2020 Peak Load - Loss of VBN Load
Terminal Voltage (pu)
1.09
1.08
1.07
1.06
1.05
1.04
1.03
1.02
1.01
1
0.99
0
1
2
3
4
5
Time (seconds)
309 - VOLT 1001 [DLS WGP1 1.0000] : Loss of VBN 74MW
319 - VOLT 1011 [STL WGP1 1.0000] : Loss of VBN 74MW
323 - VOLT 1015 [FER WGP 1.0000] : Loss of VBN 74MW

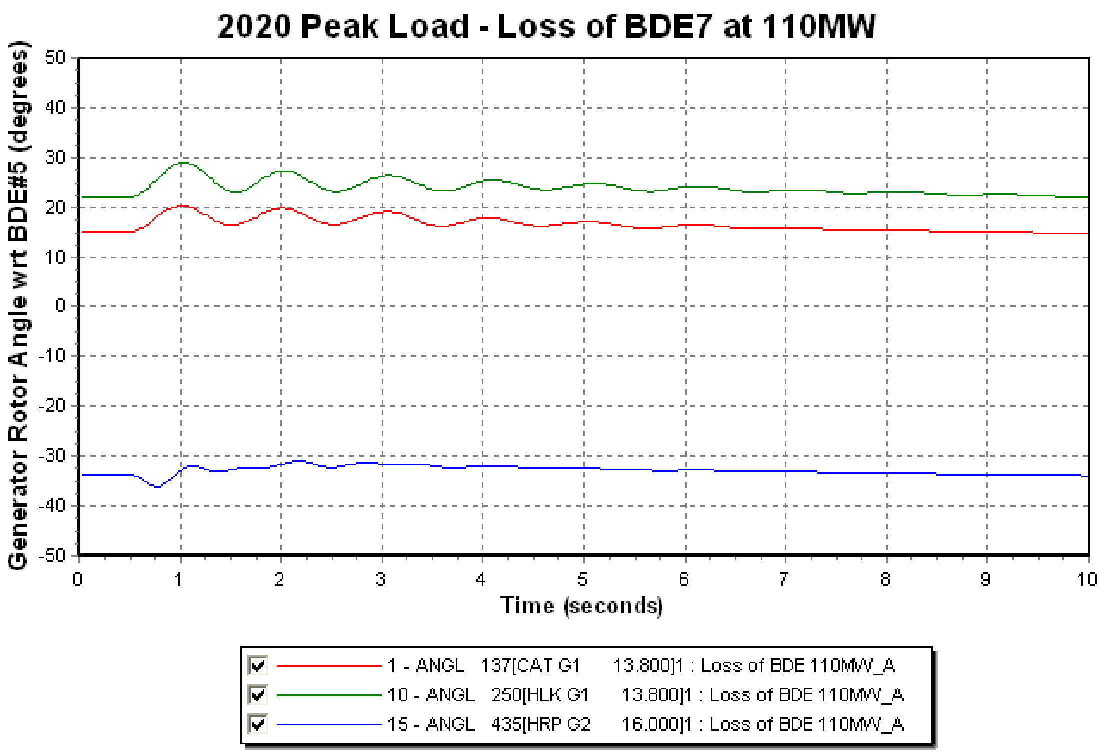

2020 Peak Load - Loss of VBN Load
Generator Rotor Angle wrt BDE #5 (degrees)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
1
2
3
4
5
Time (seconds)
9 - ANGL 220[BDP G2-6 13.800]5 : Loss of VBN 74MW
13 - ANGL 434[HRP G1 16.000]1 : Loss of VBN 74MW
4 - ANGL 138[CAT G2 13.800]1 : Loss of VBN 74MW

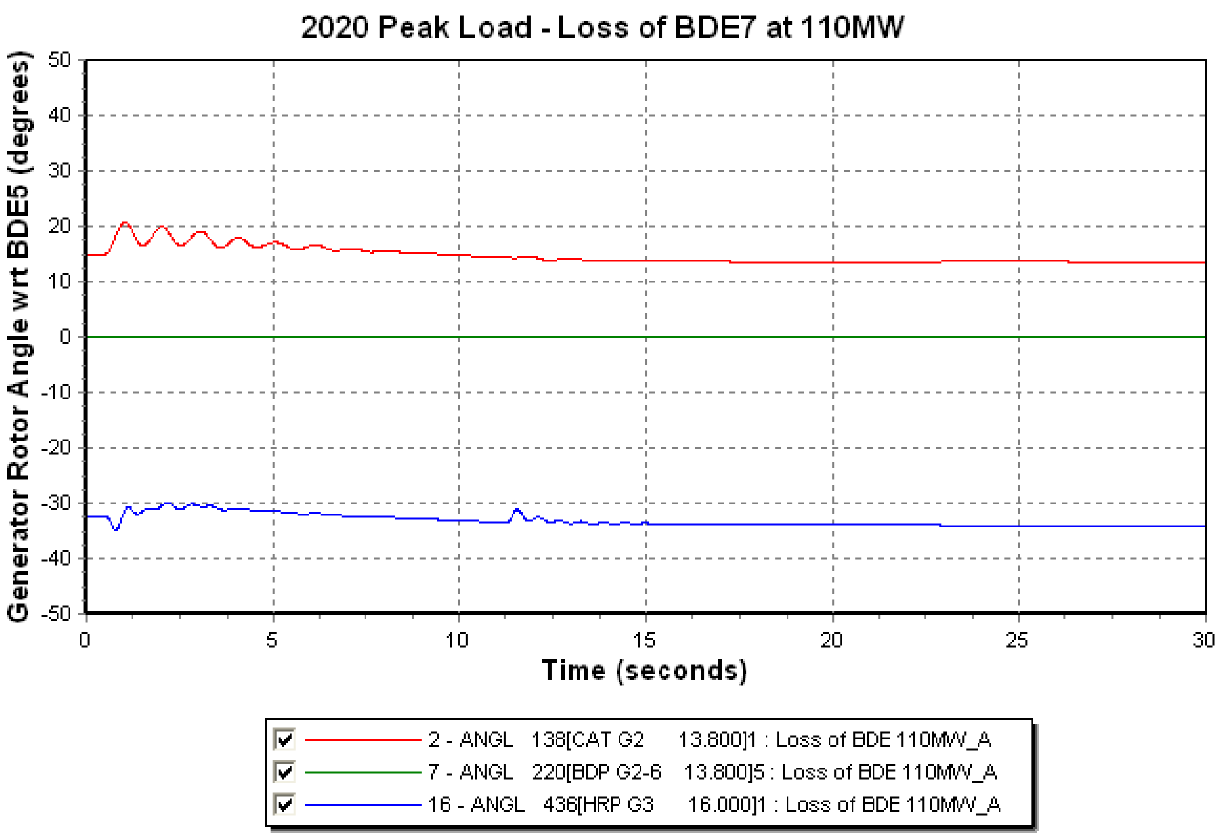
Case 2 – Loss of Largest Unit (BDE 7 at 110 MW)

For this contingency, the system is stable and all wind turbines remain connected to the grid. Frequency decline reaches 58.8 Hz and is arrested by operation of 35MW of load shedding. The plots below outline the system frequency, wind turbine / Bay d'Espoir Unit 5 power output and some key generator rotor angle with respect to Bay d'Espoir Unit 5.



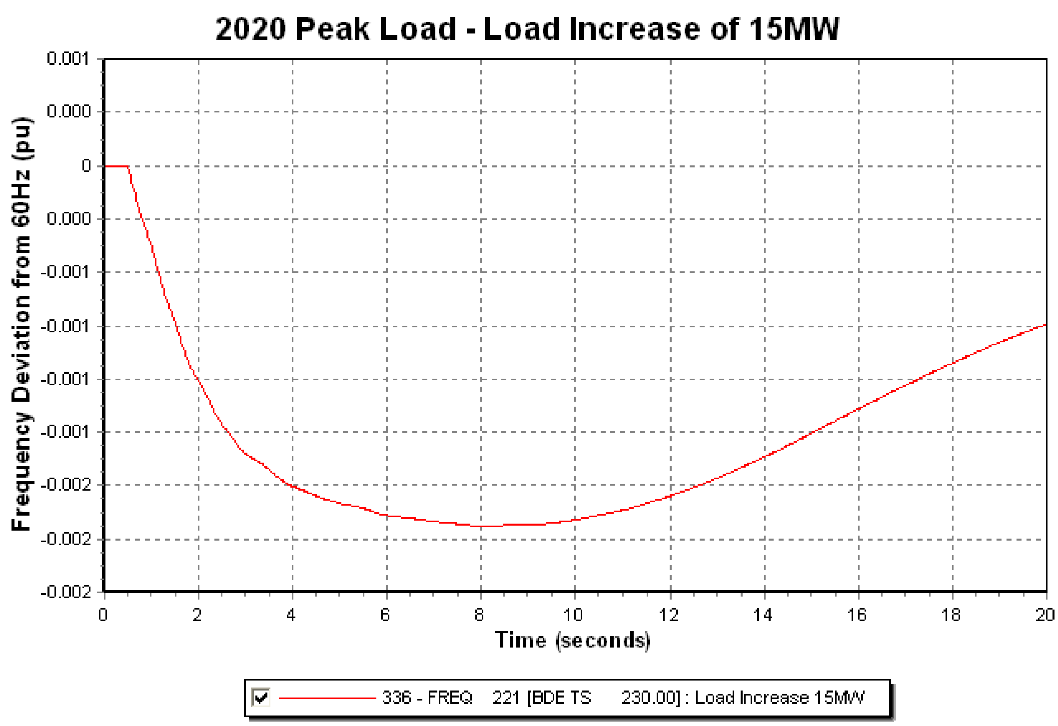


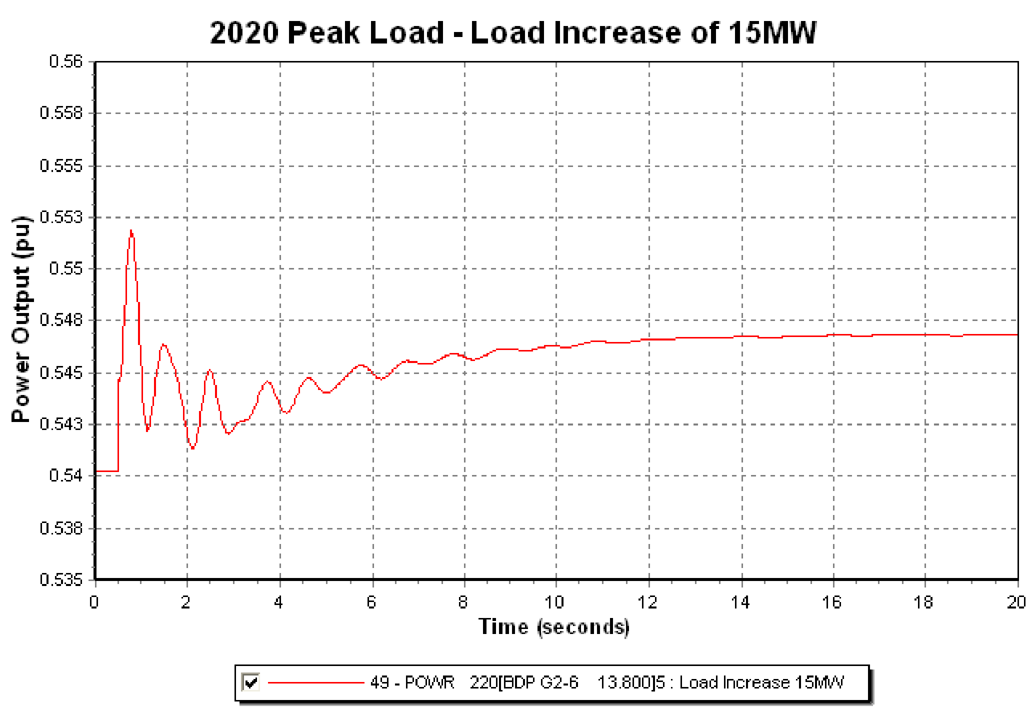

2020 Peak Load - Loss of BDE7 at 110MW
Generator Rotor Angle wrt BDE#5 (degrees)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : Loss of BDE 110MW_A
10 - ANGL 250[HLK G1 13.800]1 : Loss of BDE 110MW_A
15 - ANGL 435[HRP G2 16.000]1 : Loss of BDE 110MW_A

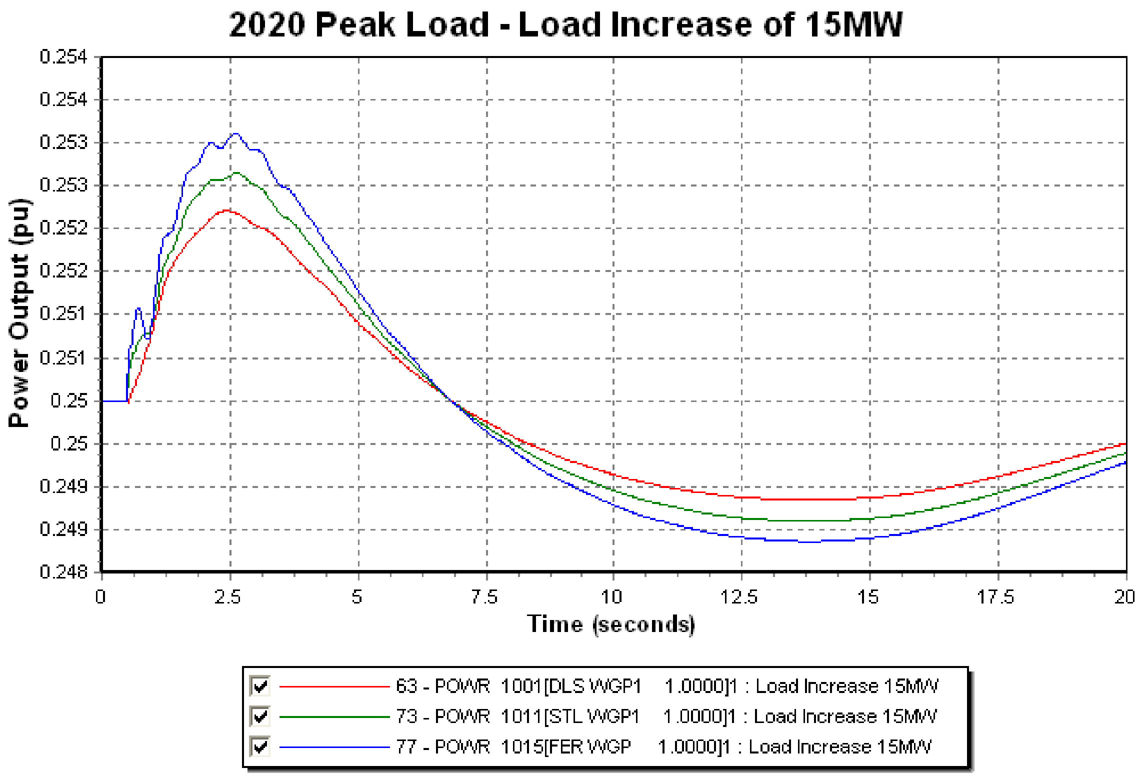

2020 Peak Load - Loss of BDE7 at 110MW
Generator Rotor Angle wrt BDE5 (degrees)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
5
10
15
20
25
30
Time (seconds)
2 - ANGL 138[CAT G2 13.800]1 : Loss of BDE 110MW_A
7 - ANGL 220[BDP G2-6 13.800]5 : Loss of BDE 110MW_A
16 - ANGL 436[HRP G3 16.000]1 : Loss of BDE 110MW_A

Case 3 – Sudden Load Increase of 15 MW

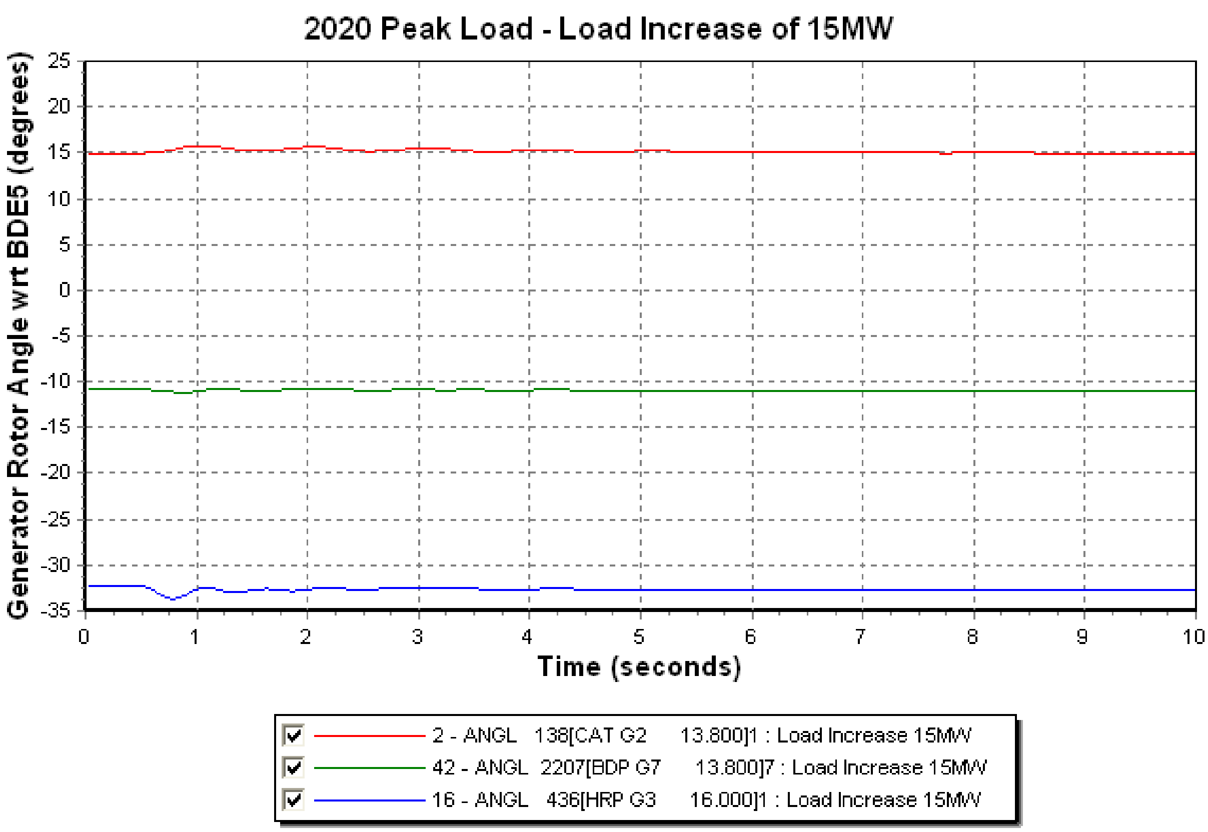
For this event, system frequency reaches a minimum level 59.9 Hz, which is slightly above the first stage under frequency load shedding stage of 59.5 Hz. This is the pre-defined limit of frequency decline for this type of event. The plots below outline the system frequency, Bay d'Espoir Unit 5 and some wind turbine power output responses.







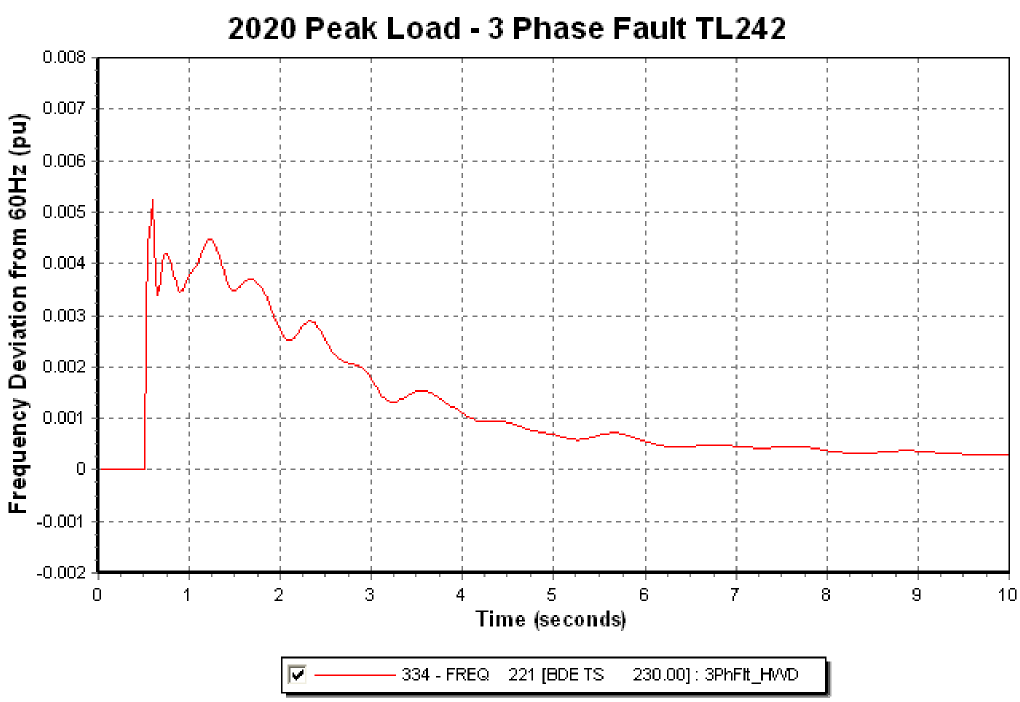
2020 Peak Load - Load Increase of 15MW
Power Output (pu)
0.254
0.254
0.253
0.253
0.252
0.252
0.251
0.251
0.25
0.25
0.249
0.249
0.248
0
2.5
5
7.5
10
12.5
15
17.5
20
Time (seconds)
63 - POWR 1001[DLS WGP1 1.0000]1 : Load Increase 15MW
73 - POWR 1011[STL WGP1 1.0000]1 : Load Increase 15MW
77 - POWR 1015[FER WGP 1.0000]1 : Load Increase 15MW

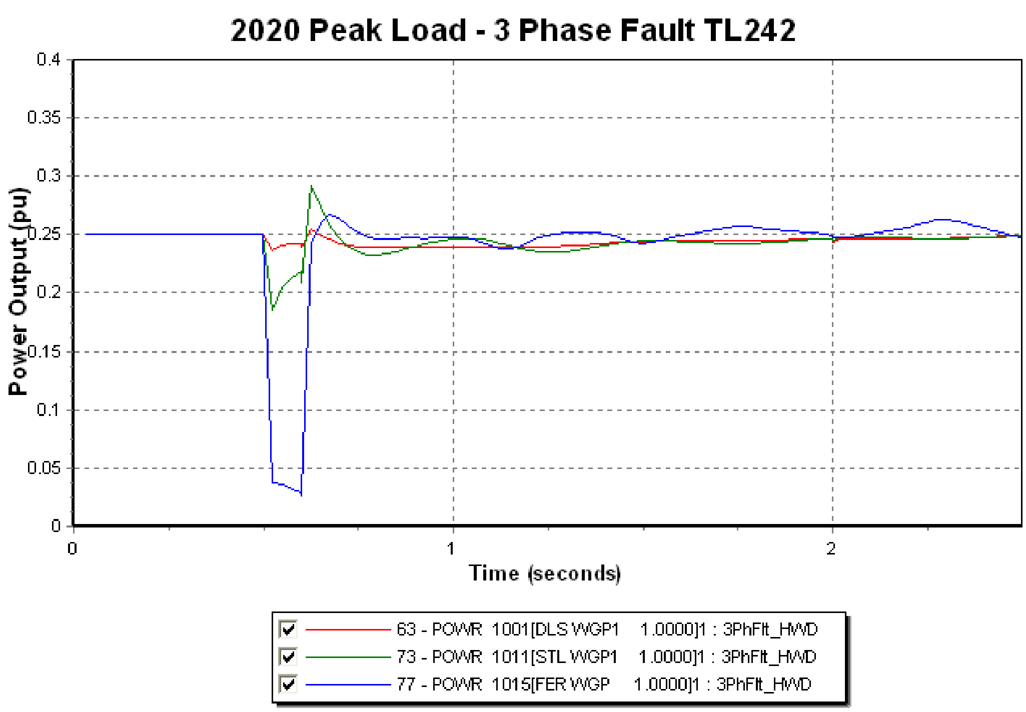


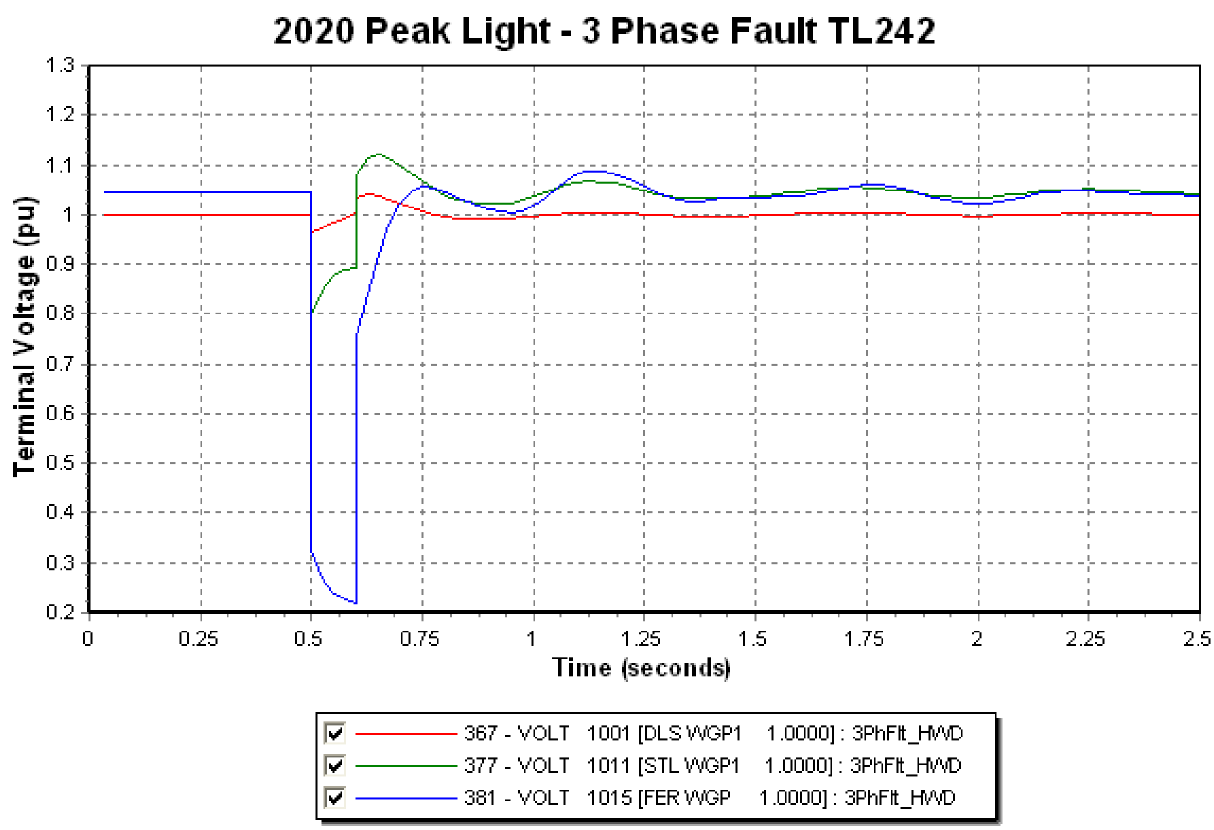
2020 Peak Load - Load Increase of 15MW
Generator Rotor Angle wrt BDE5 (degrees)
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
2 - ANGL 138[CAT G2 13.800]1 : Load Increase 15MW
42 - ANGL 2207[BDP G7 13.800]7 : Load Increase 15MW
16 - ANGL 436[HRP G3 16.000]1 : Load Increase 15MW

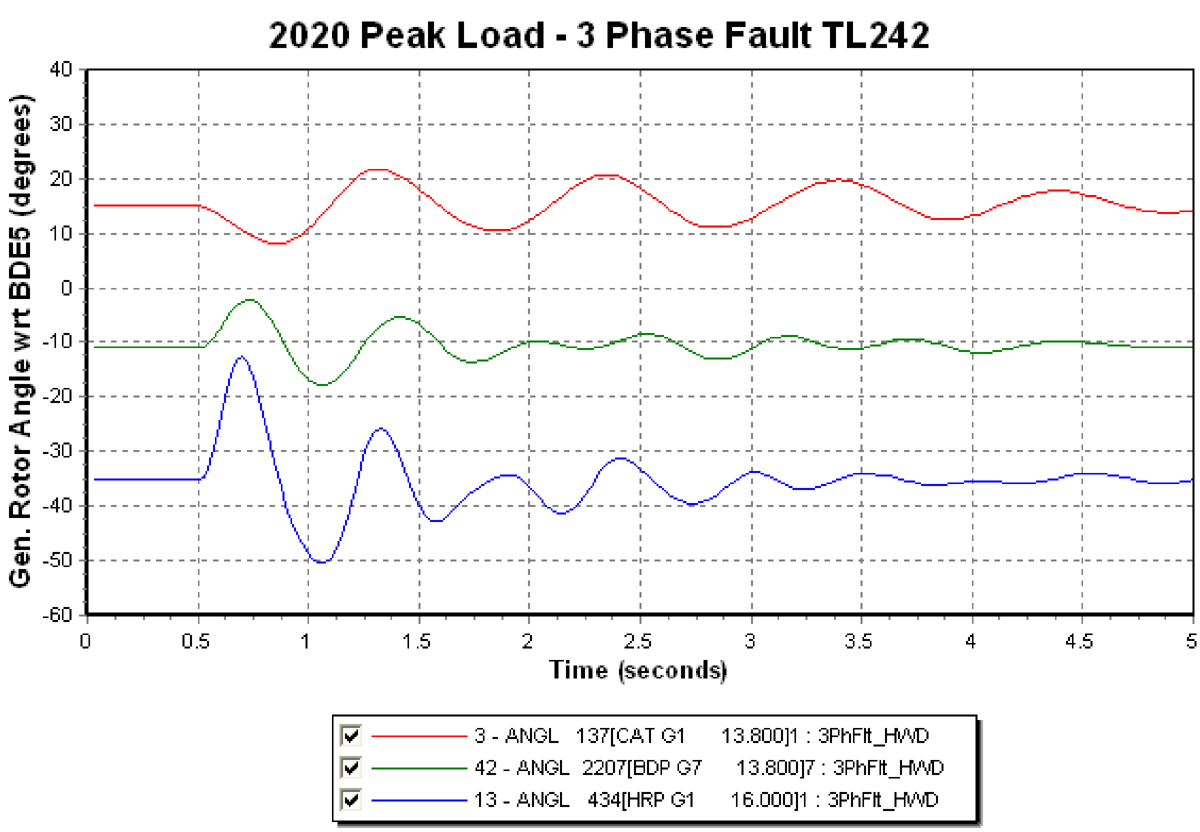
Case 4 – 3 Phase Fault at HWD (6 cycles – Trip TL242)

For this contingency a three phase fault has been applied on TL242 near Hardwoods terminal station for 6 cycles, followed by the tripping of TL242 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of the machines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



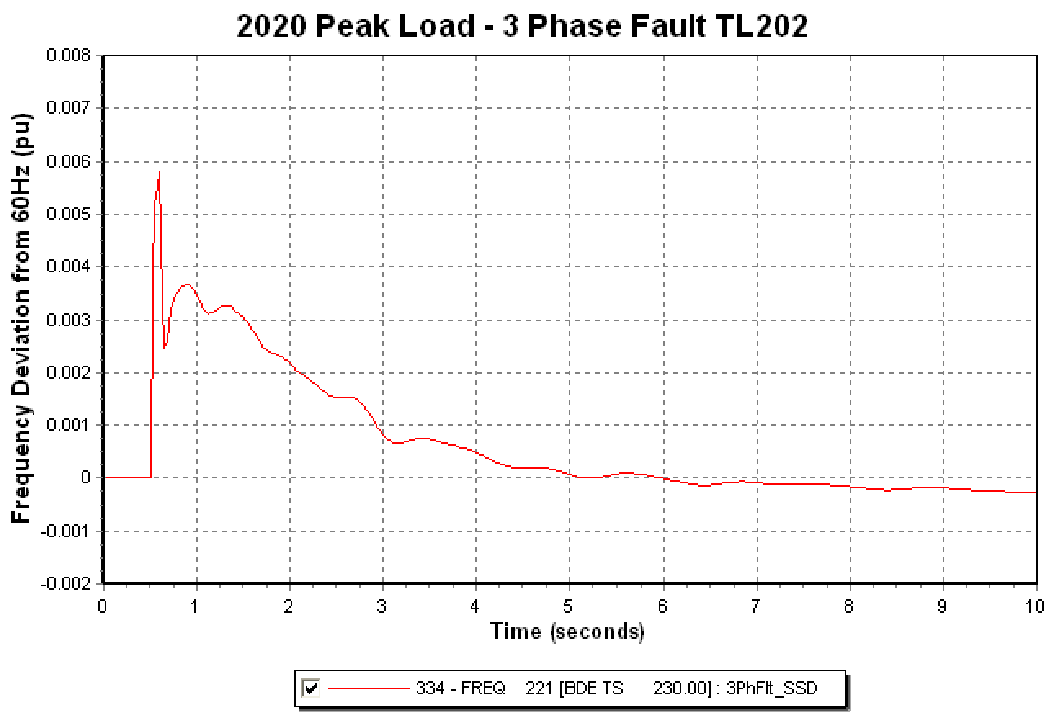


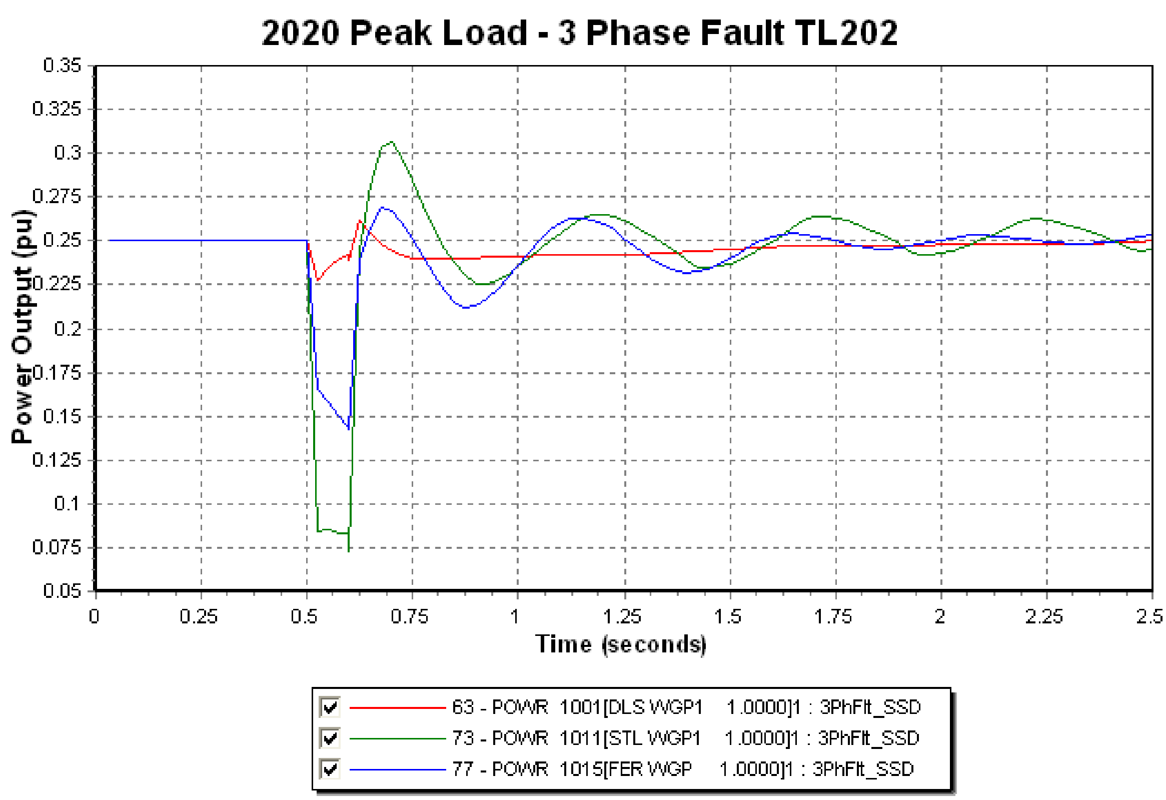

2020 Peak Light - 3 Phase Fault TL242
Terminal Voltage (pu)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
367 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_HWD
377 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_HWD
381 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_HWD

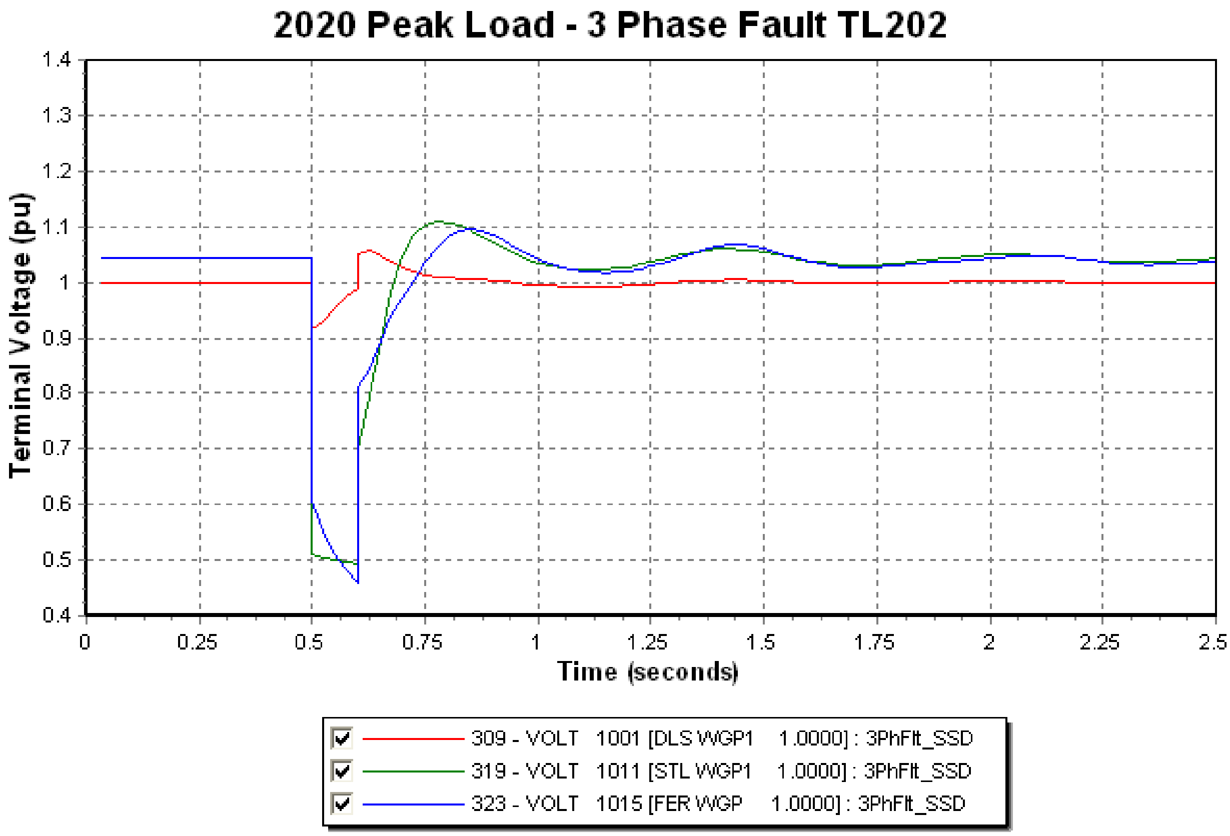

2020 Peak Load - 3 Phase Fault TL242
Gen. Rotor Angle wrt BDE5 (degrees)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_HWD
42 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_HWD
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_HWD

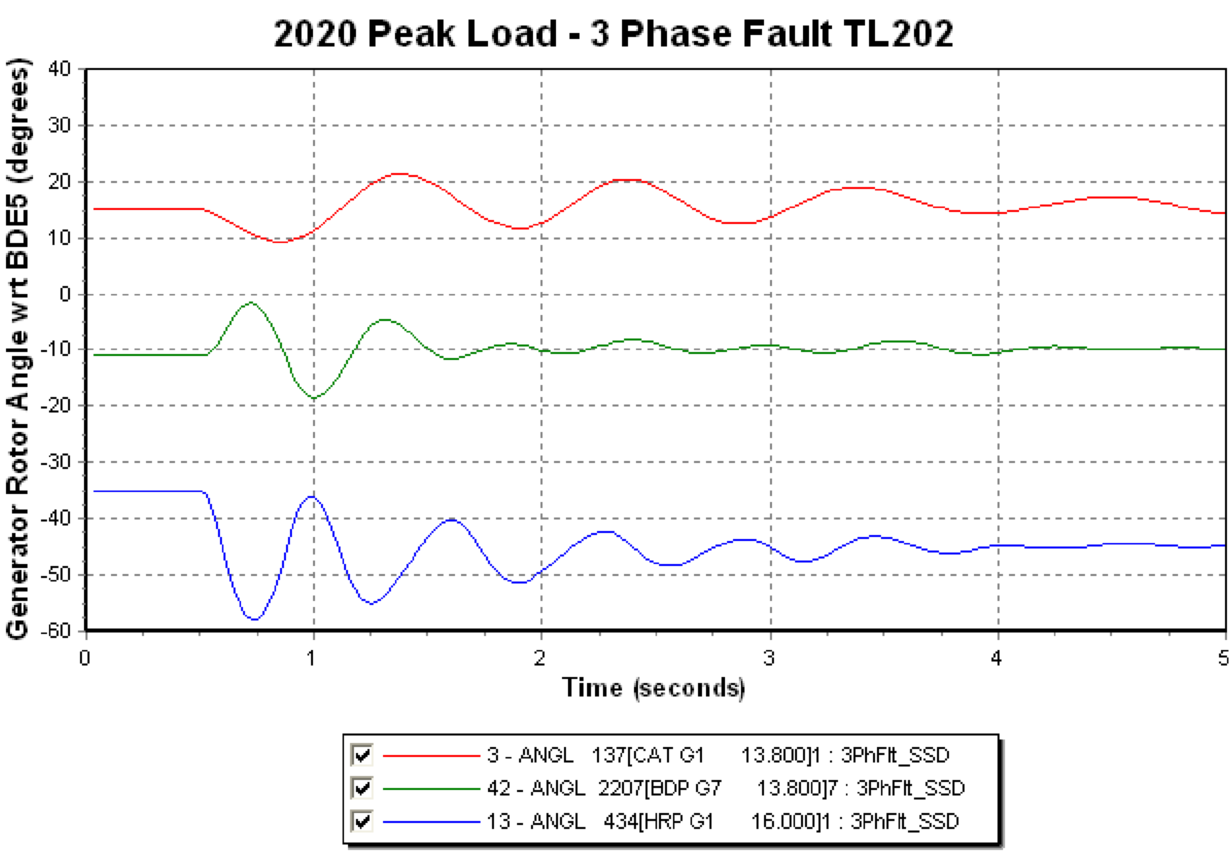
Case 5 – 3 Phase Fault at SSD (6 cycles – Trip TL202)

For this contingency a three phase fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the tripping of TL202 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of the machines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



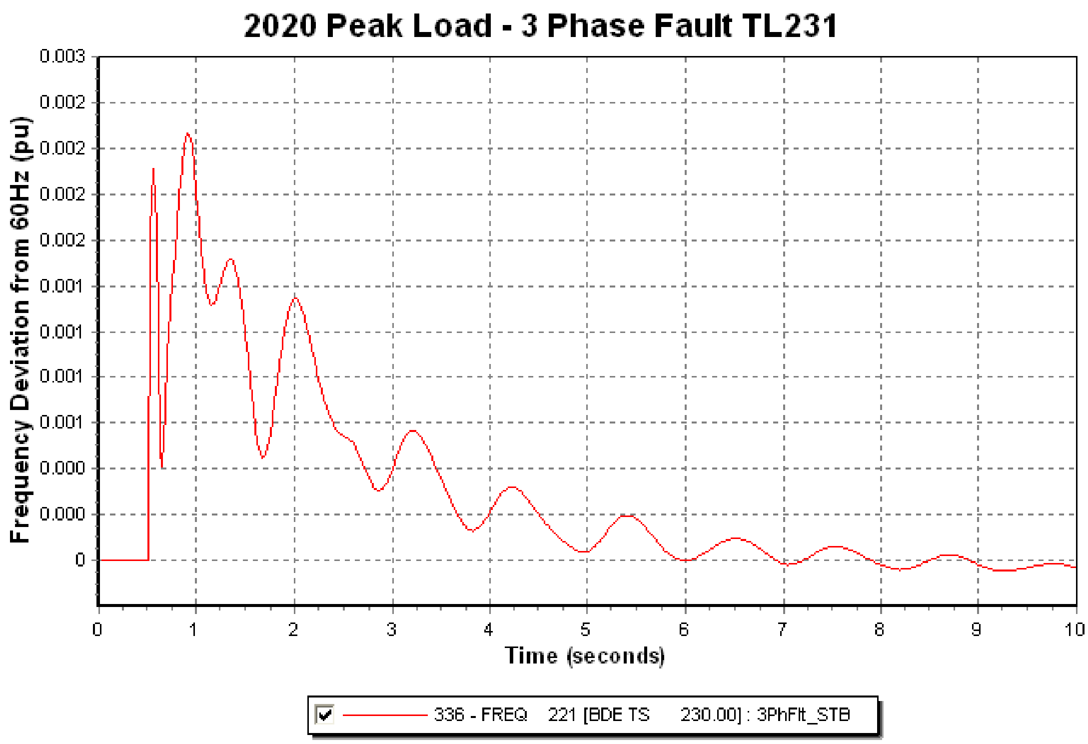


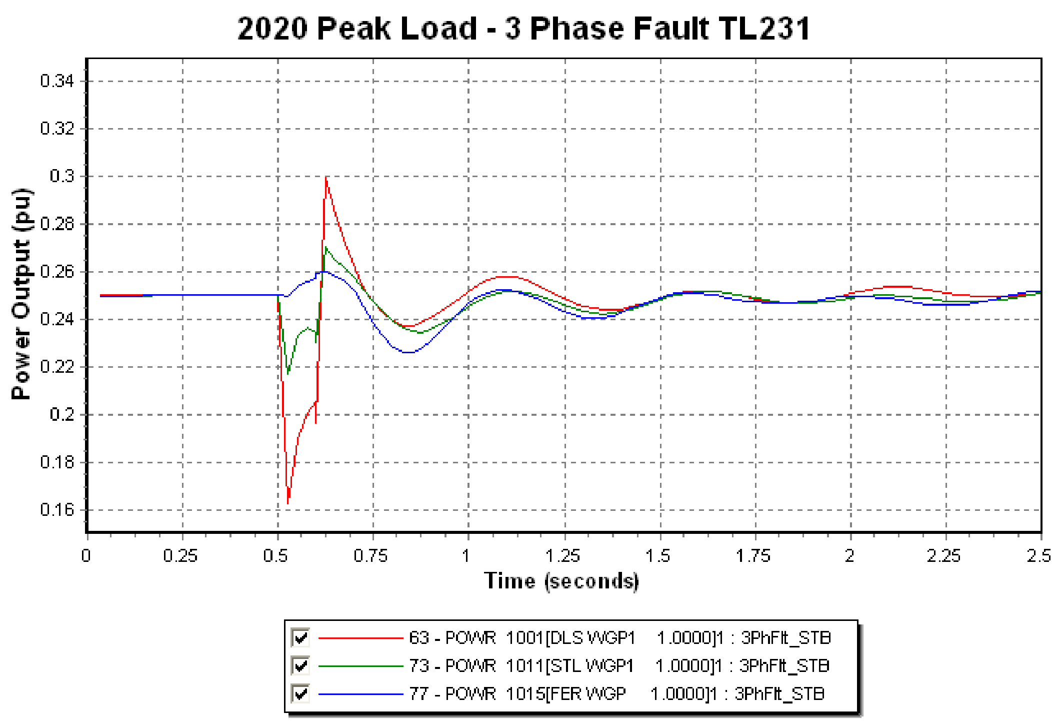

2020 Peak Load - 3 Phase Fault TL202
Terminal Voltage (pu)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
309 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_SSD
319 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_SSD
323 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_SSD

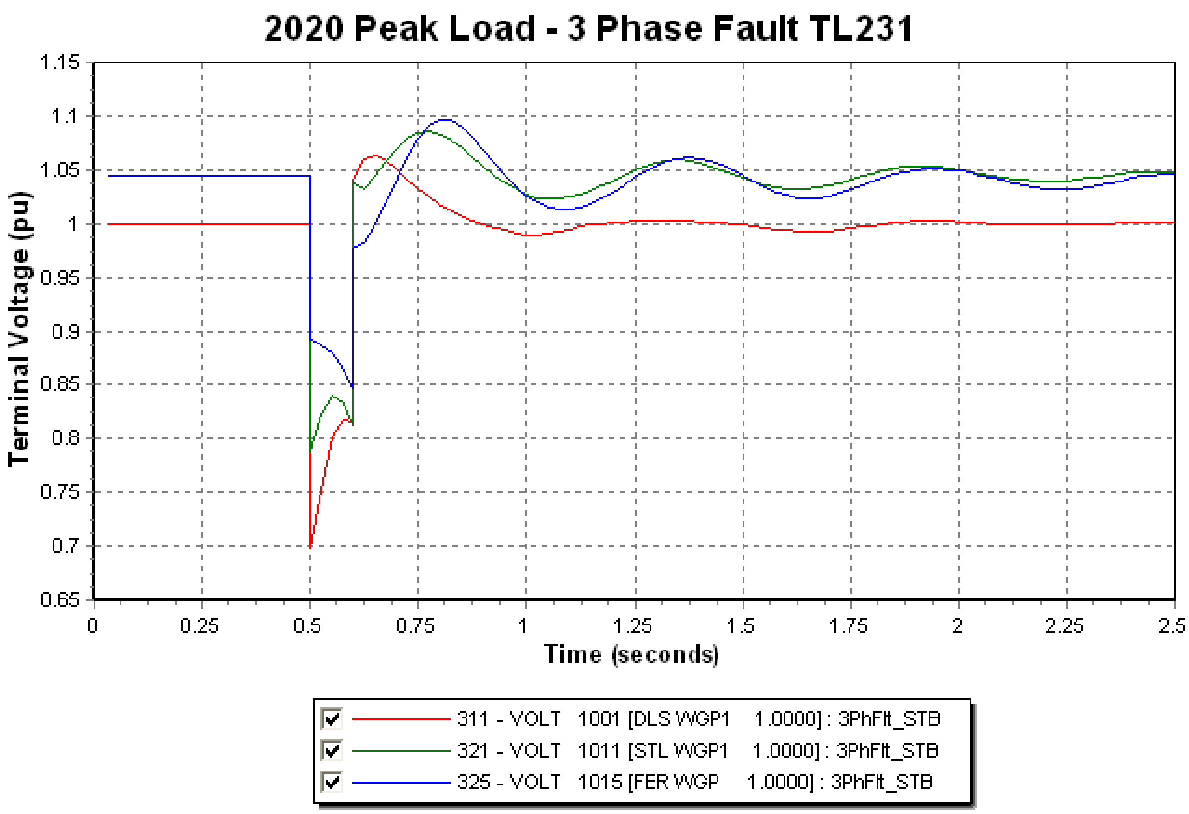

2020 Peak Load - 3 Phase Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_SSD
42 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_SSD
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_SSD

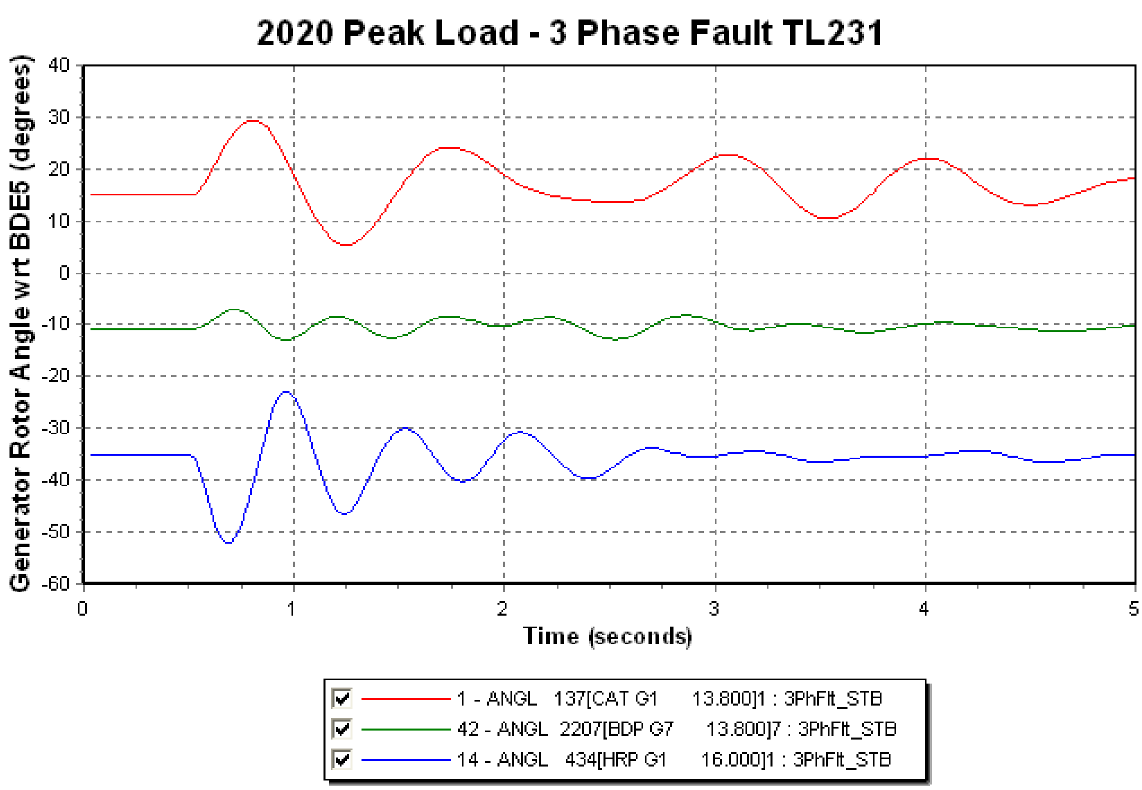
Case 6 – 3 Phase Fault at STB (6 cycles – Trip TL231)

For this contingency a three phase fault has been applied on TL231 near Stony Brook terminal station for 6 cycles, followed by the tripping of TL231 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of the machines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



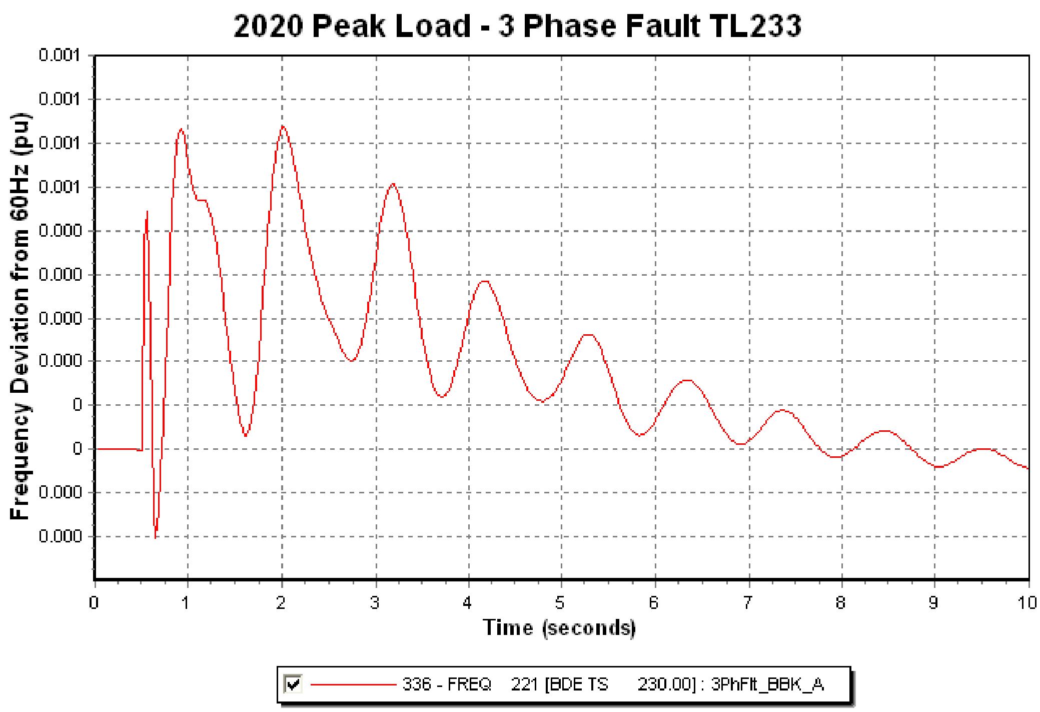


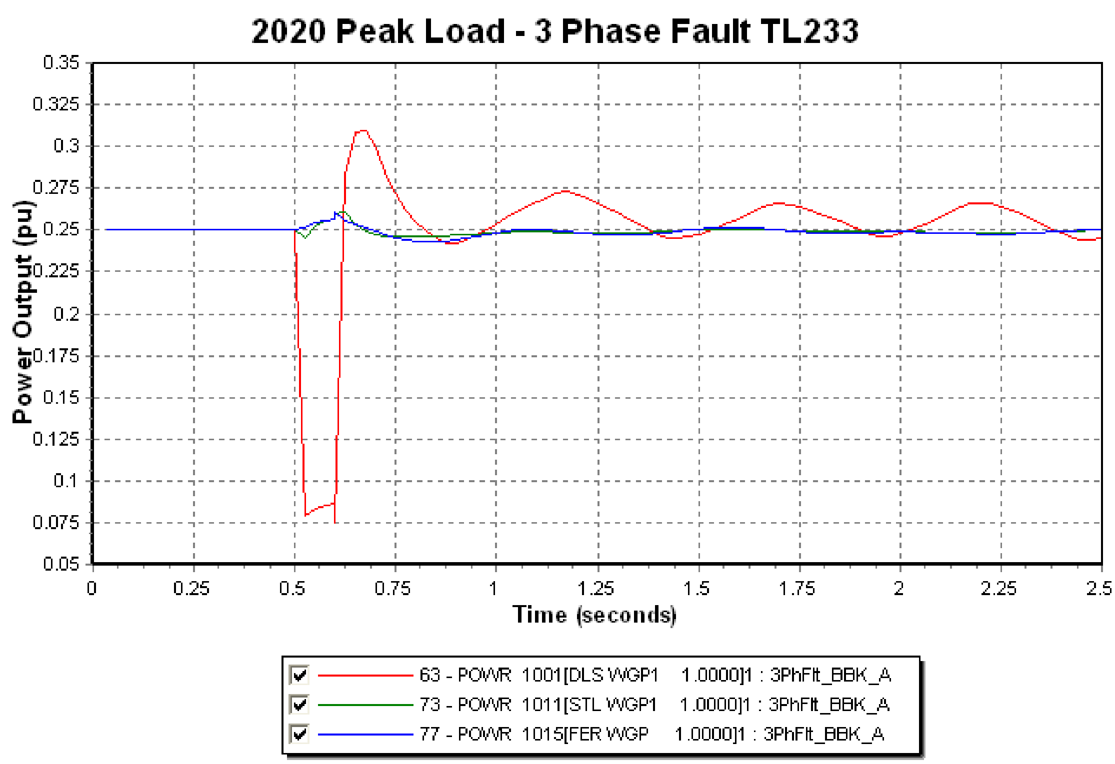

2020 Peak Load - 3 Phase Fault TL231
Terminal Voltage (pu)
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
311 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_STB
321 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_STB
325 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_STB

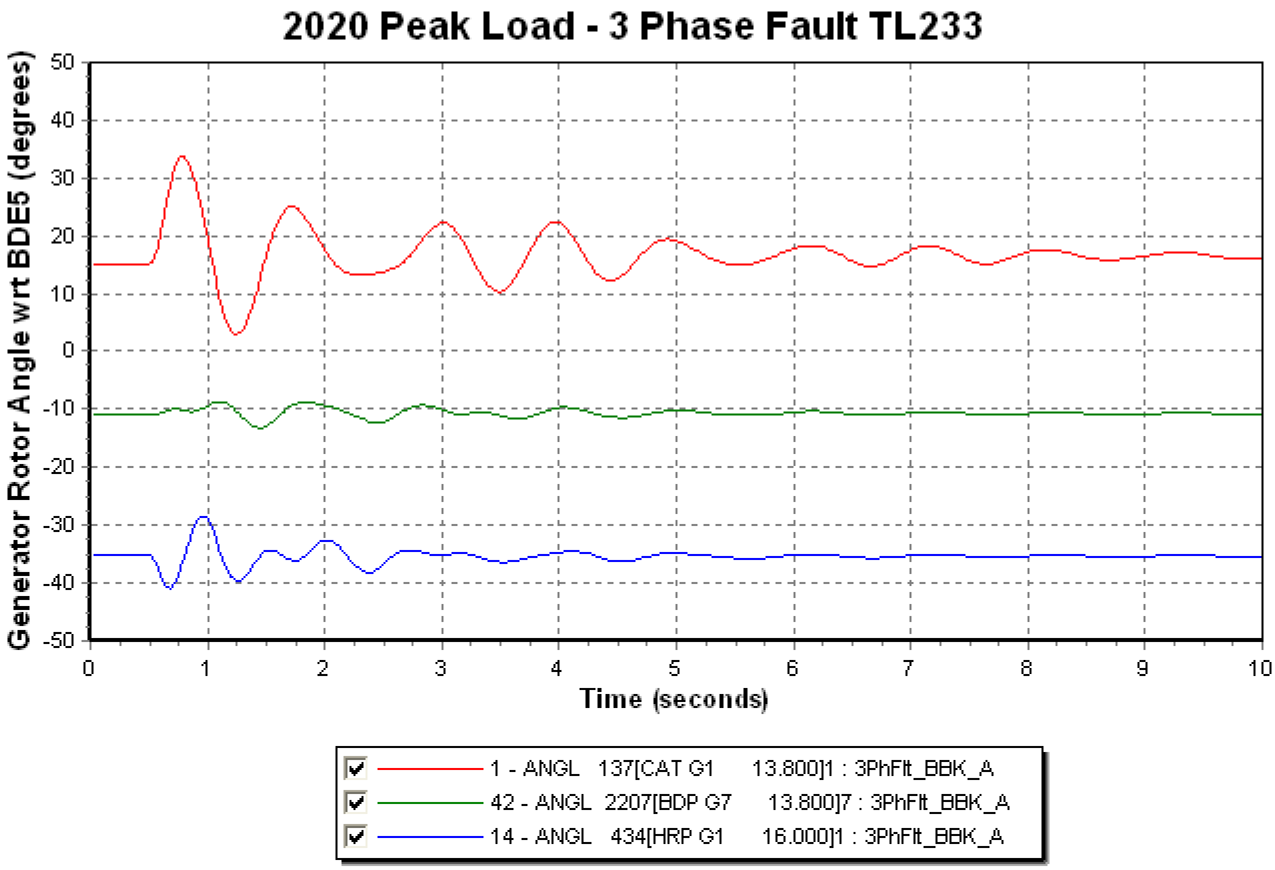

2020 Peak Load - 3 Phase Fault TL231
Generator Rotor Angle wrt BDE5 (degrees)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_STB
42 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_STB
14 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_STB

Case 7 – 3 Phase Fault at BBK (6 cycles – Trip TL233)

For this contingency a three phase fault has been applied on TL233 near Bottom Brook terminal station for 6 cycles, followed by the tripping of TL233 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.

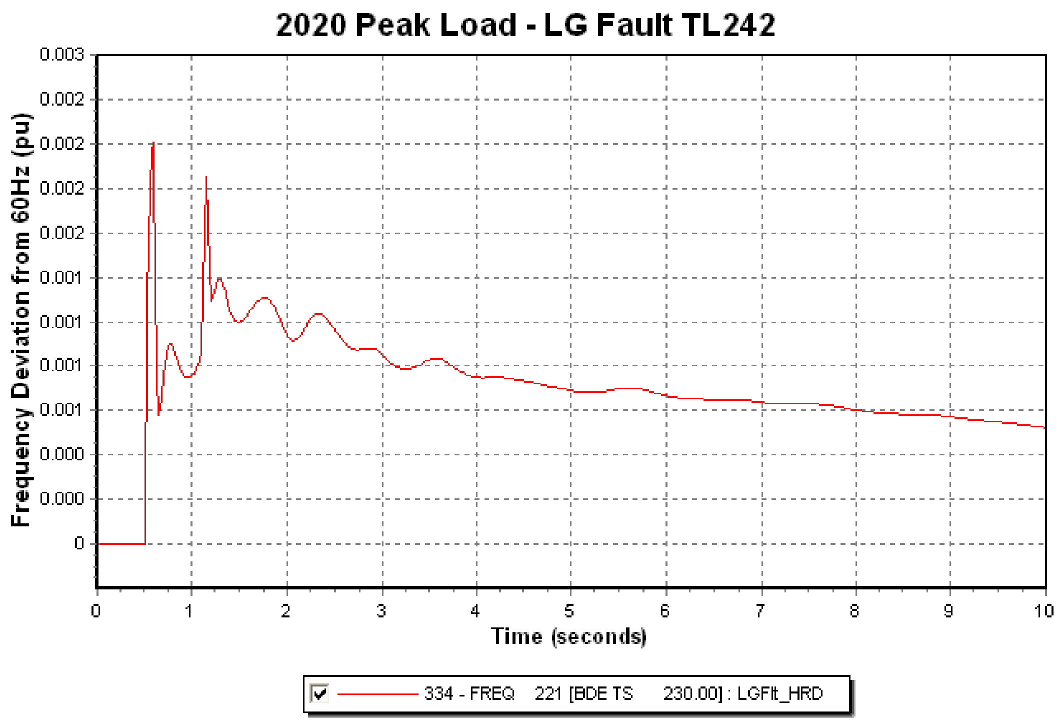


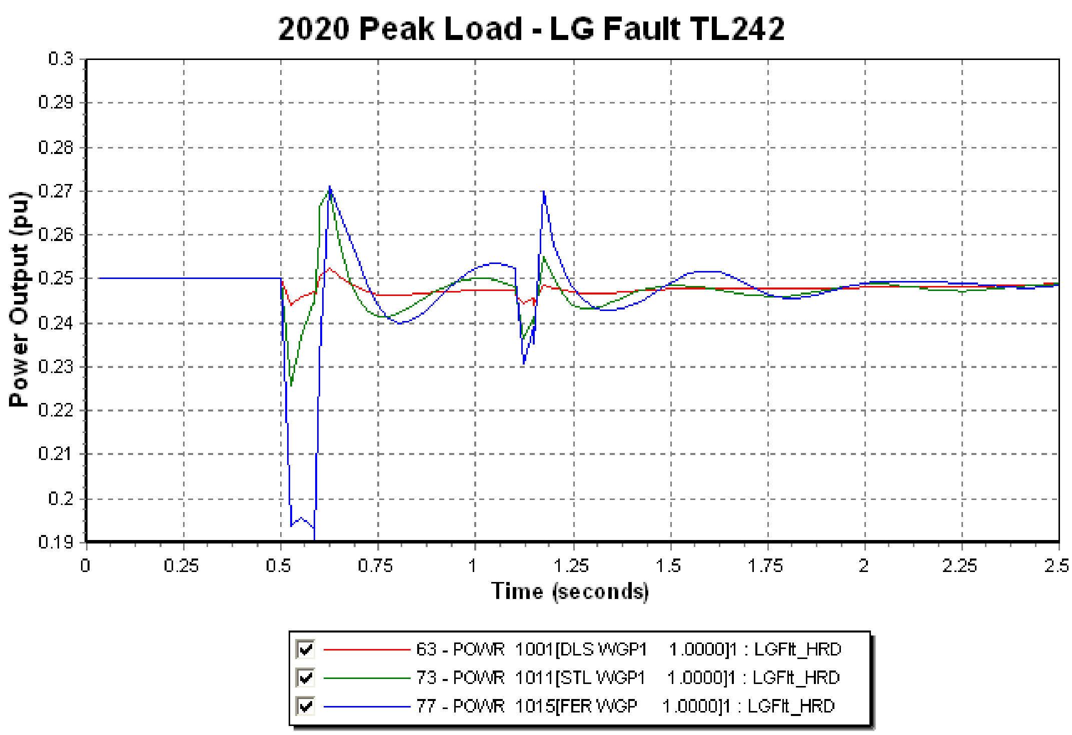


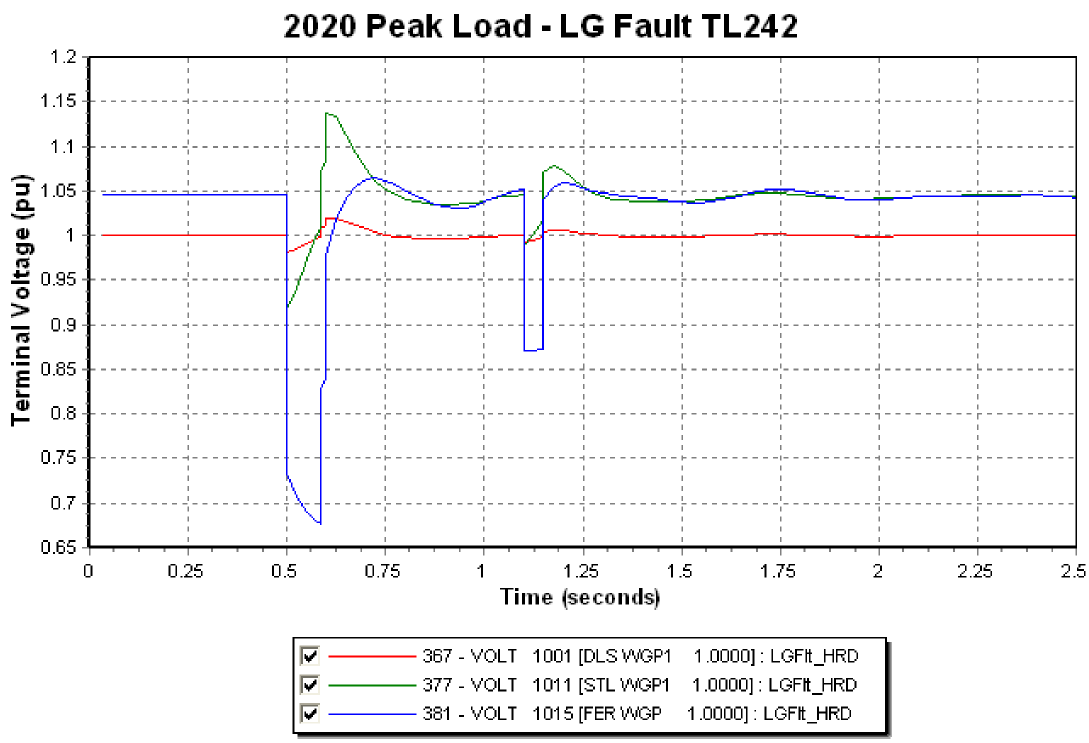

2020 Peak Load - 3 Phase Fault TL233
Generator Rotor Angle wrt BDE5 (degrees)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_BBK_A
42 - ANGL 2207[BDP G7 13.800]7 : 3PhFlt_BBK_A
14 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_BBK_A

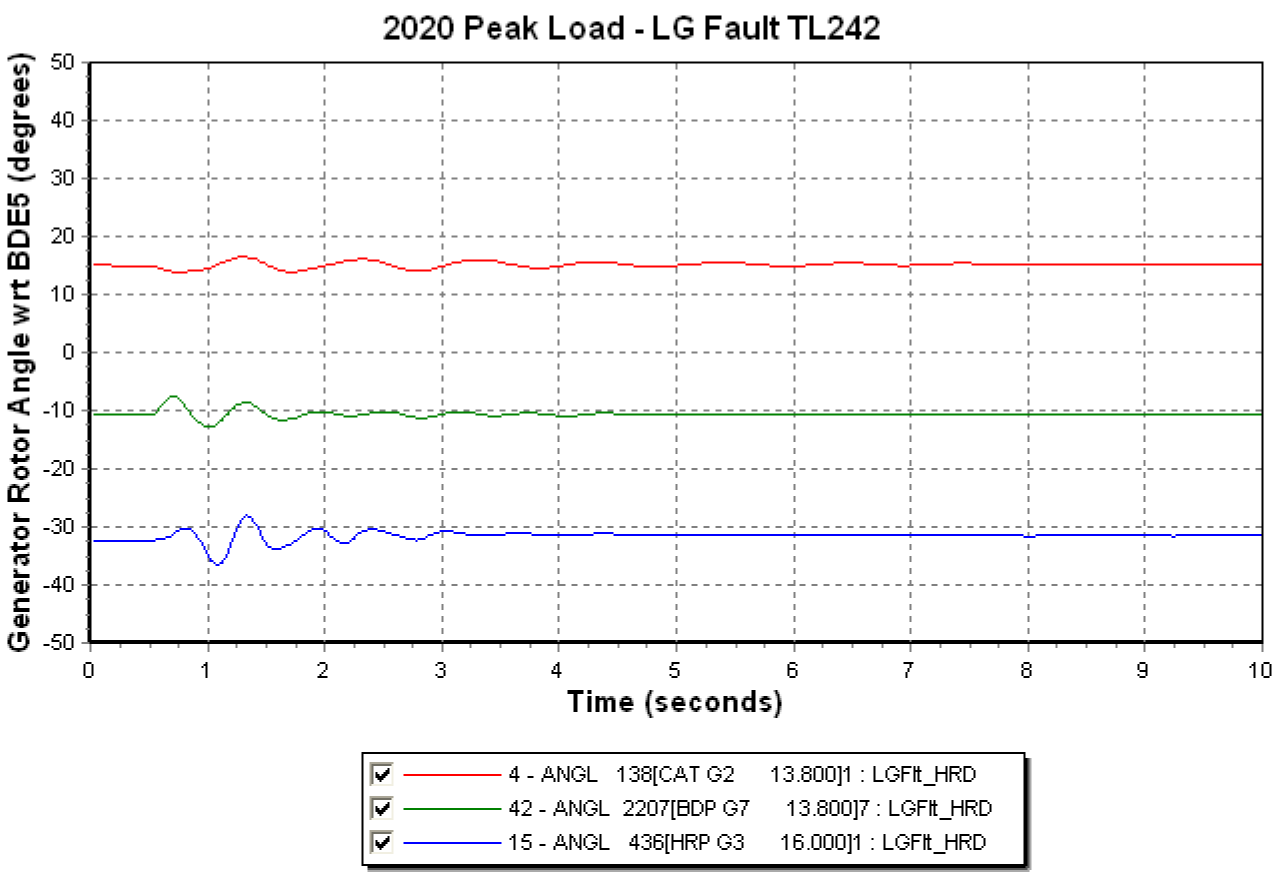
Case 8 – LG Fault at TL242 Near HRD

For this contingency a line to ground fault has been applied on TL242 near Holyrood Generating station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL242 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



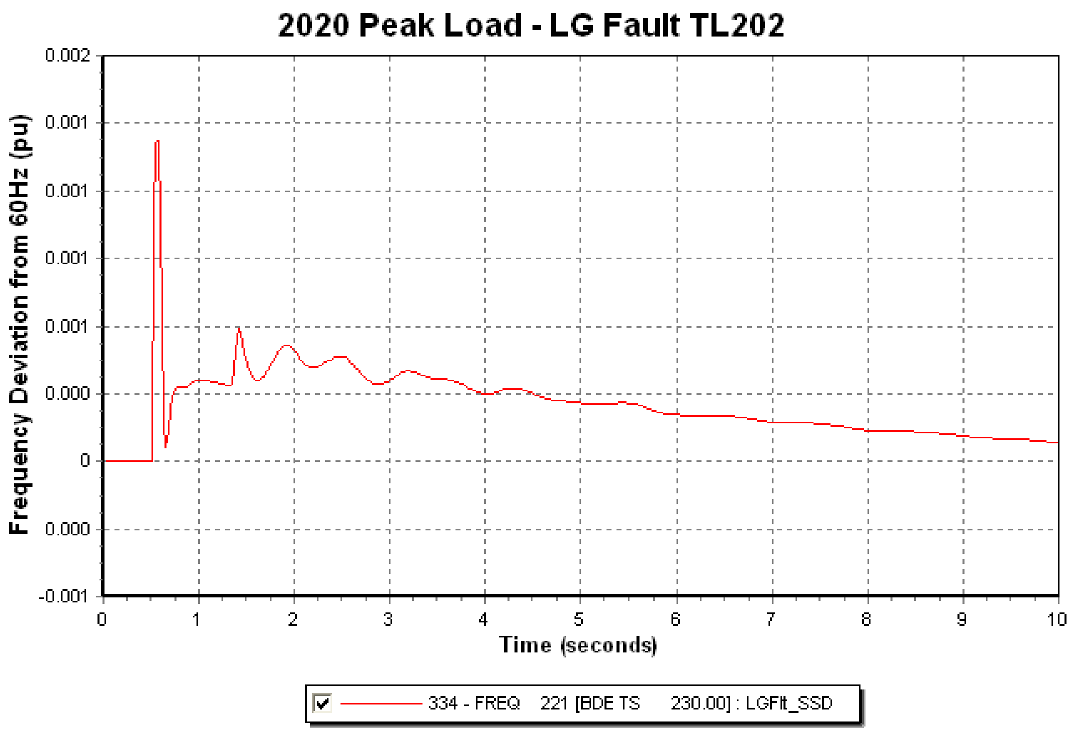


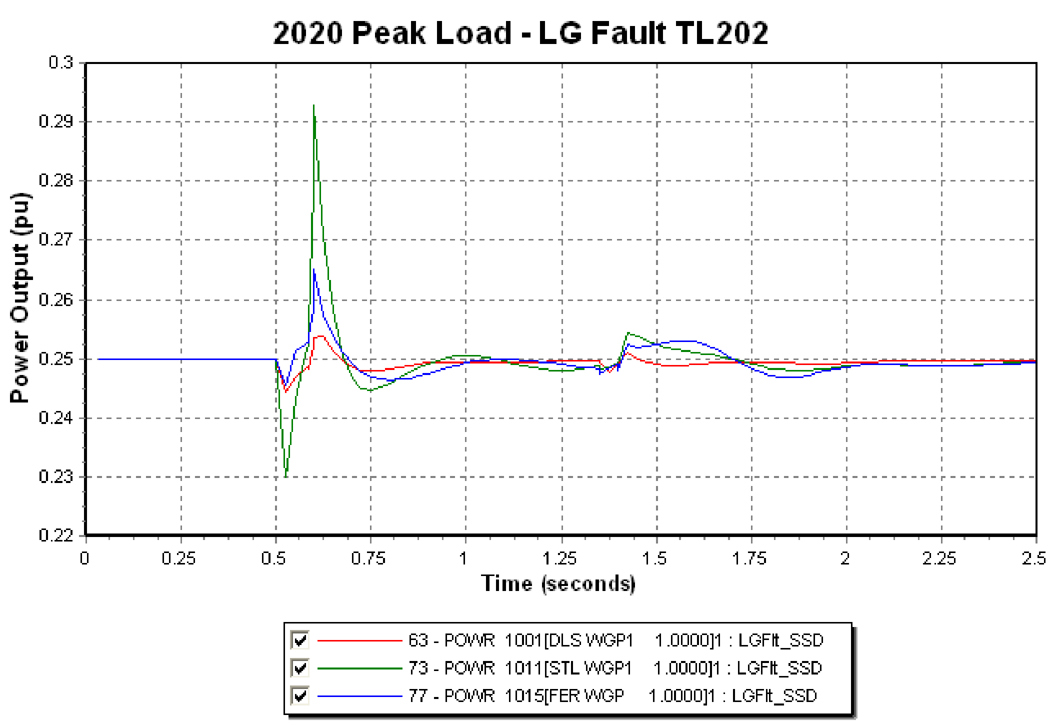

2020 Peak Load - LG Fault TL242
Terminal Voltage (pu)
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
367 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_HRD
377 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_HRD
381 - VOLT 1015 [FER WGP 1.0000] : LGFlt_HRD

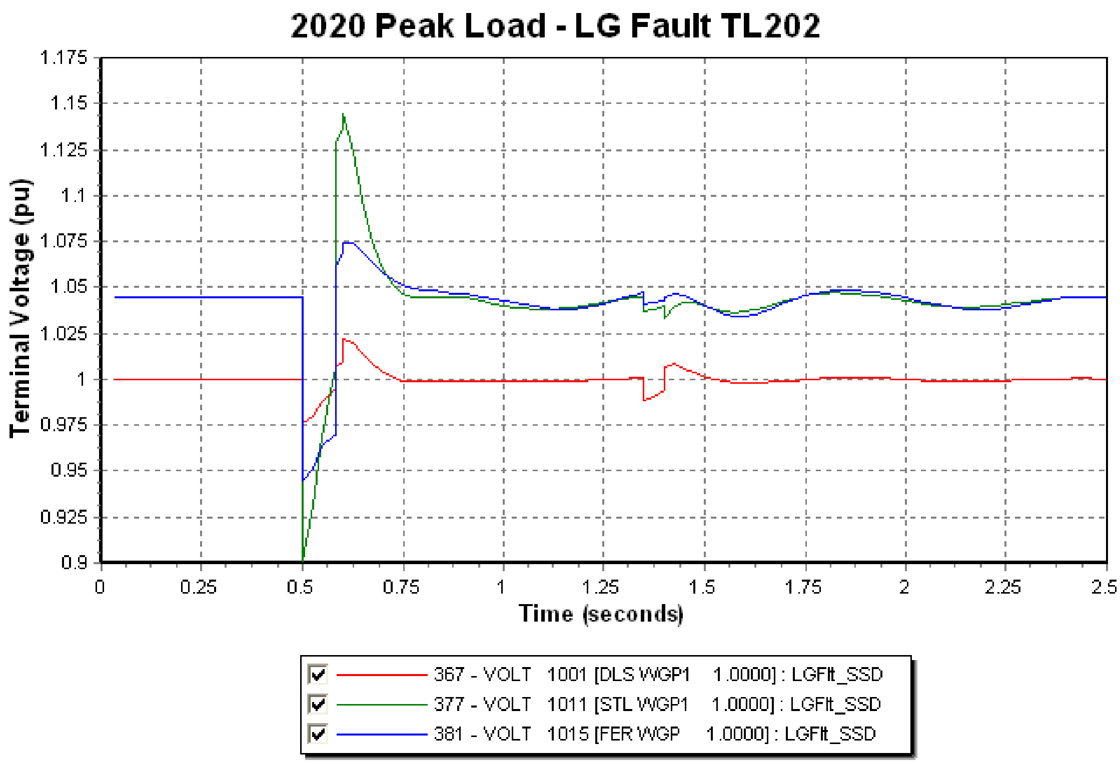

2020 Peak Load - LG Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
50
40
30
20
10
0
-10
-20
-30
-40
-50
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
4 - ANGL 138[CAT G2 13.800]1 : LGFlt_HRD
42 - ANGL 2207[BDP G7 13.800]7 : LGFlt_HRD
15 - ANGL 436[HRP G3 16.000]1 : LGFlt_HRD

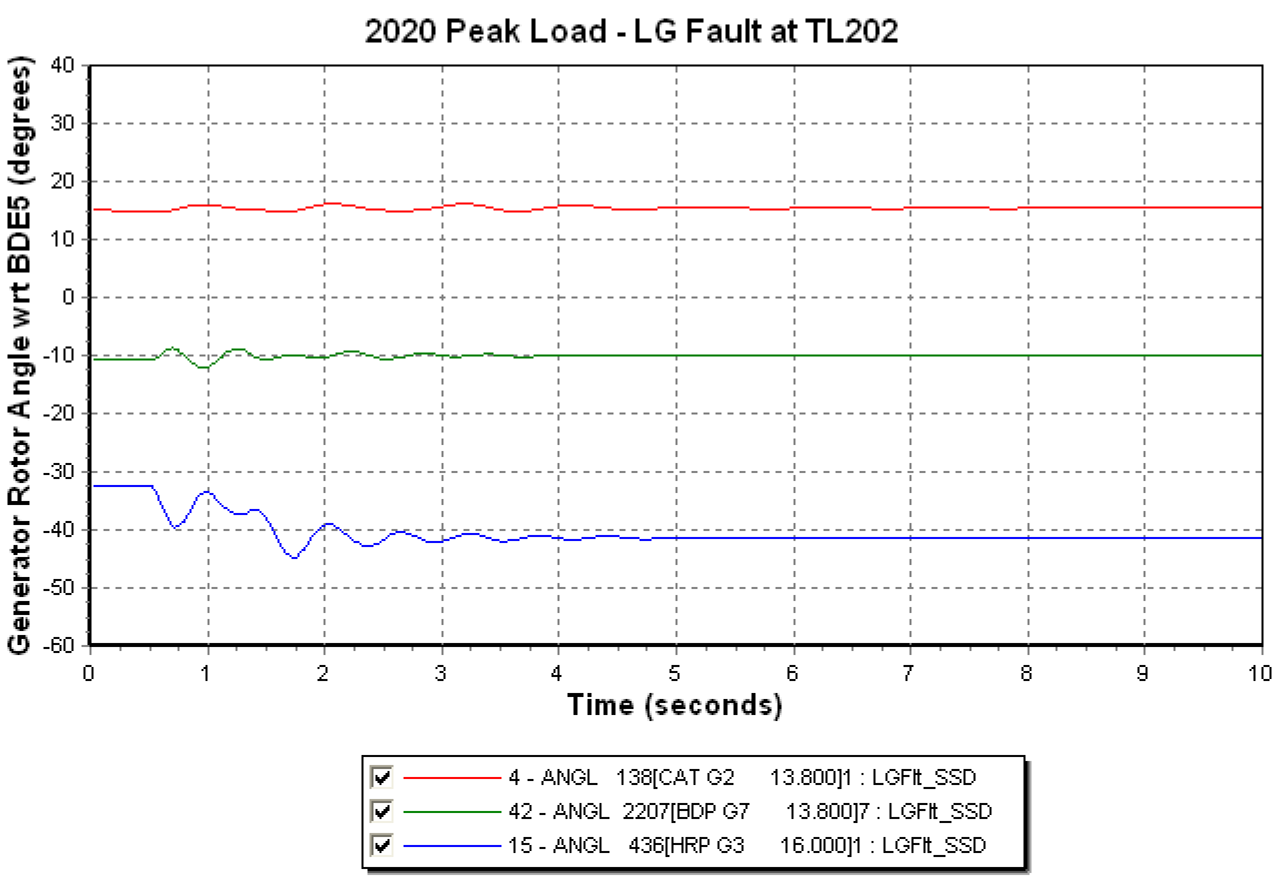
Case 9 – LG Fault at TL202 Near SSD

For this contingency a line to ground fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL202 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



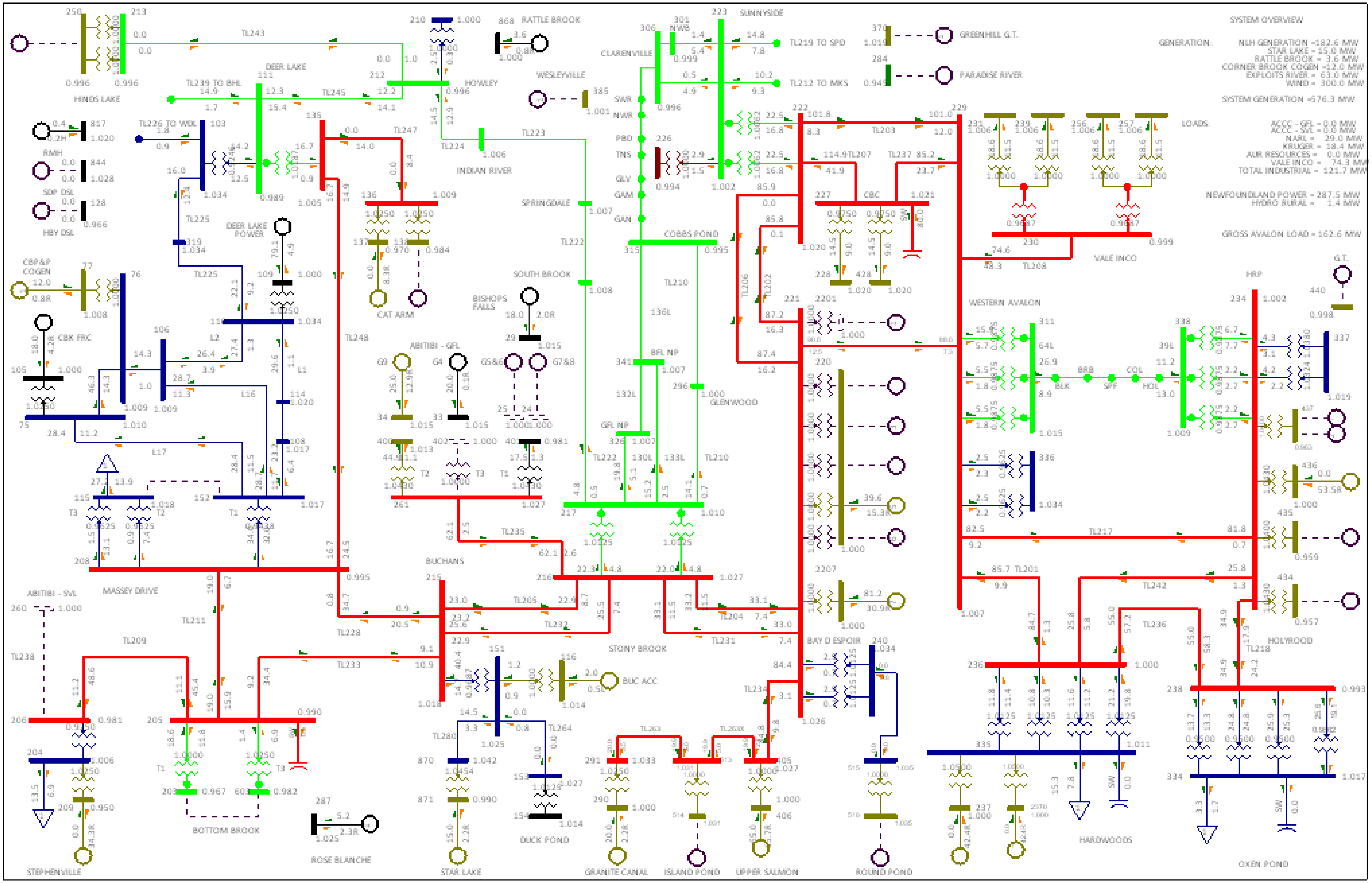



2020 Peak Load - LG Fault TL202
Terminal Voltage (pu)
1.175
1.15
1.125
1.1
1.075
1.05
1.025
1
0.975
0.95
0.925
0.9
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
367 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_SSD
377 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_SSD
381 - VOLT 1015 [FER WGP 1.0000] : LGFlt_SSD


2020 Peak Load - LG Fault at TL202
Generator Rotor Angle wrt BDE5 (degrees)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
4 - ANGL 138[CAT G2 13.800]1 : LGFlt_SSD
42 - ANGL 2207[BDP G7 13.800]7 : LGFlt_SSD
15 - ANGL 436[HRP G3 16.000]1 : LGFlt_SSD

APPENDIX J - STABILITY RESULTS 2035 EXTREME LIGHT LOAD

300 MW WIND GENERATION



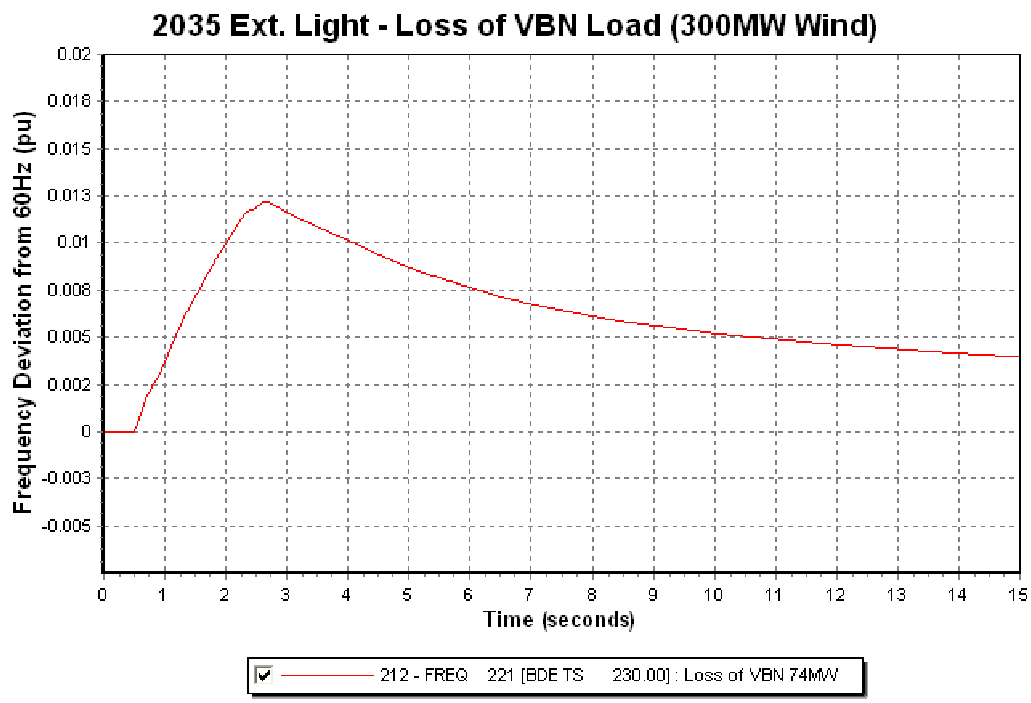
2035 EXTREME LIGHT LOAD BASE CASE
300MW WIND
THU, AUG 16 2012 13:55

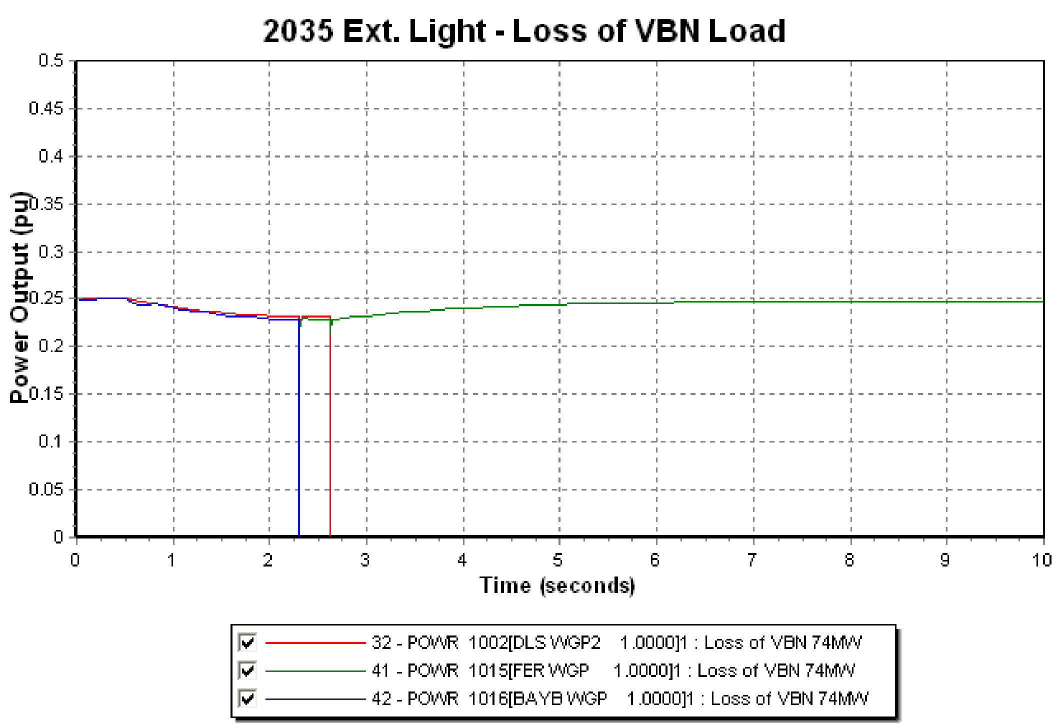
Bus - VOLTAGE (PU)
Branch - MW/Mvar
Equipment - MW/Mvar

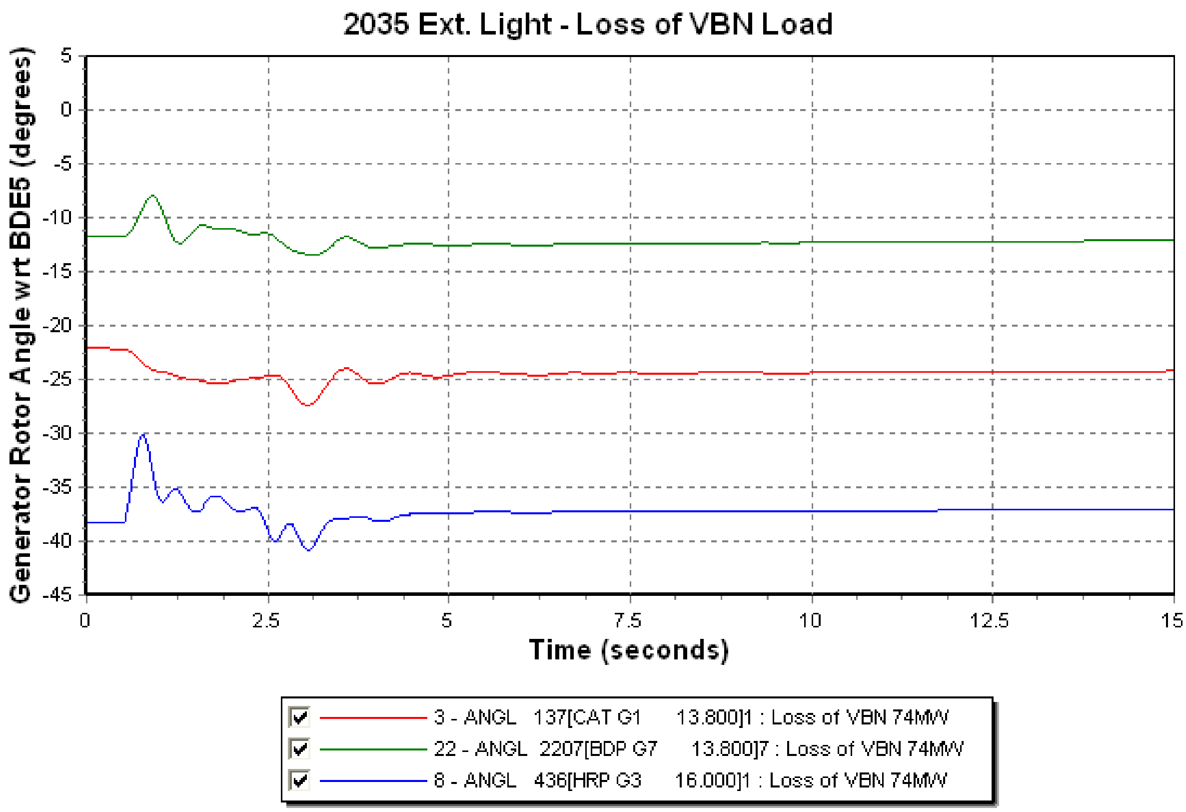
2035 Extreme Light Load – 300MW Wind – Generation Dispatch Prior to Dynamic Simulations

Case 1 – Loss of 74.3MW load at VBN

This causes an over frequency condition above 61.2 Hz. All wind turbines over frequency protection are engaged at 61.2Hz with time delay of 0.2seconds, thus causing loss of 300MW of generation from the island. This is considered unacceptable, thus there was a reduction in over frequency settings for several wind turbines to prevent mass tripping of all units at the same time. The following plots show system frequency response and power output from 3 wind turbine plants (two of which trip at 60.6 and 60.75 Hz respectively).

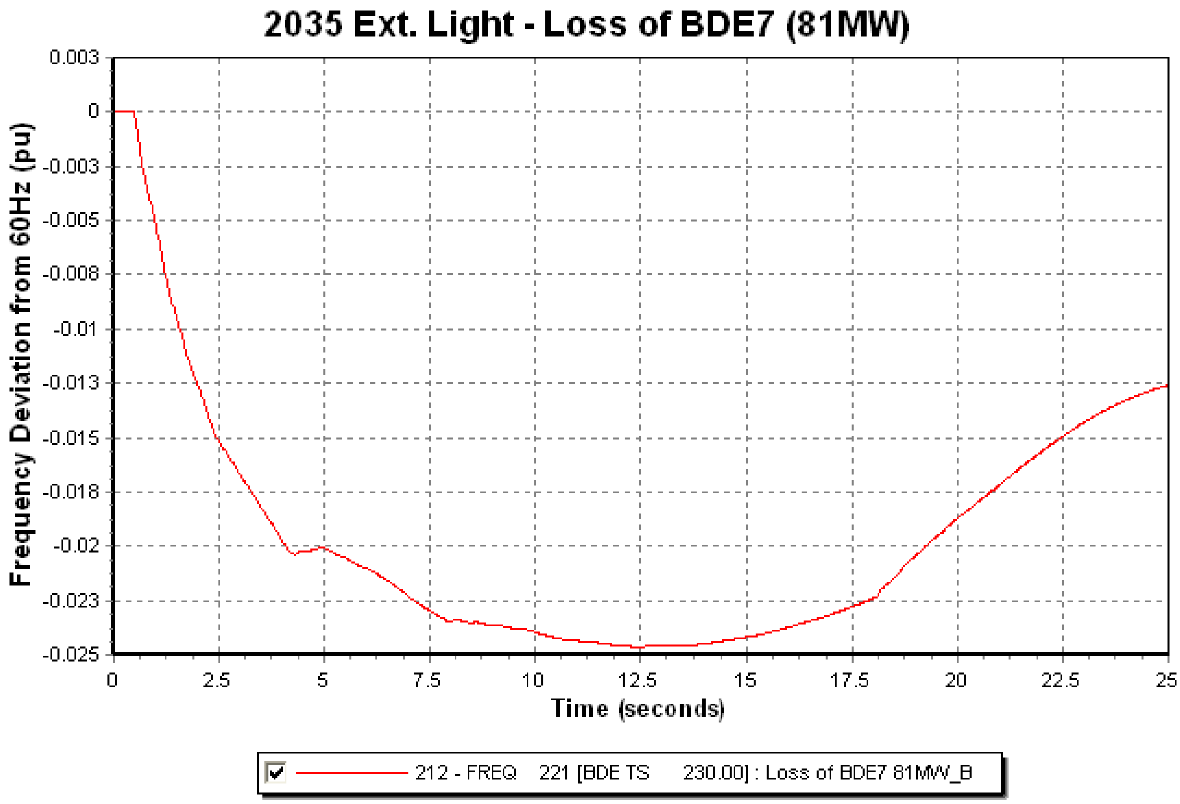


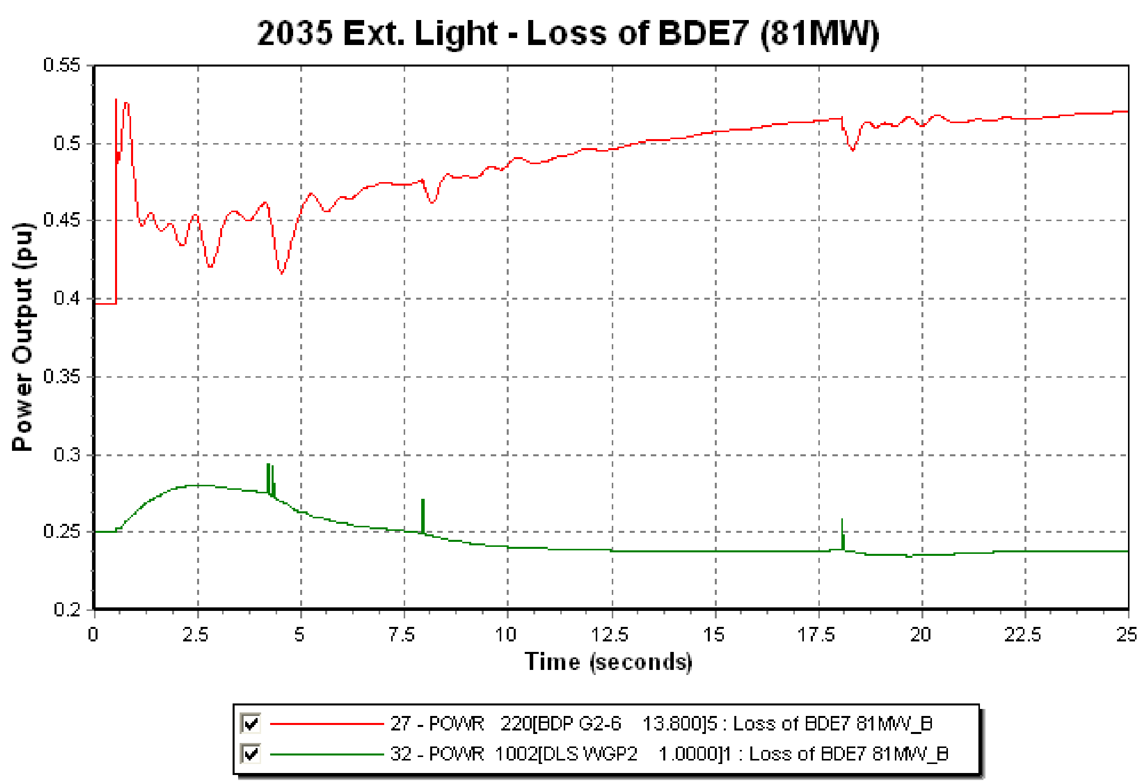


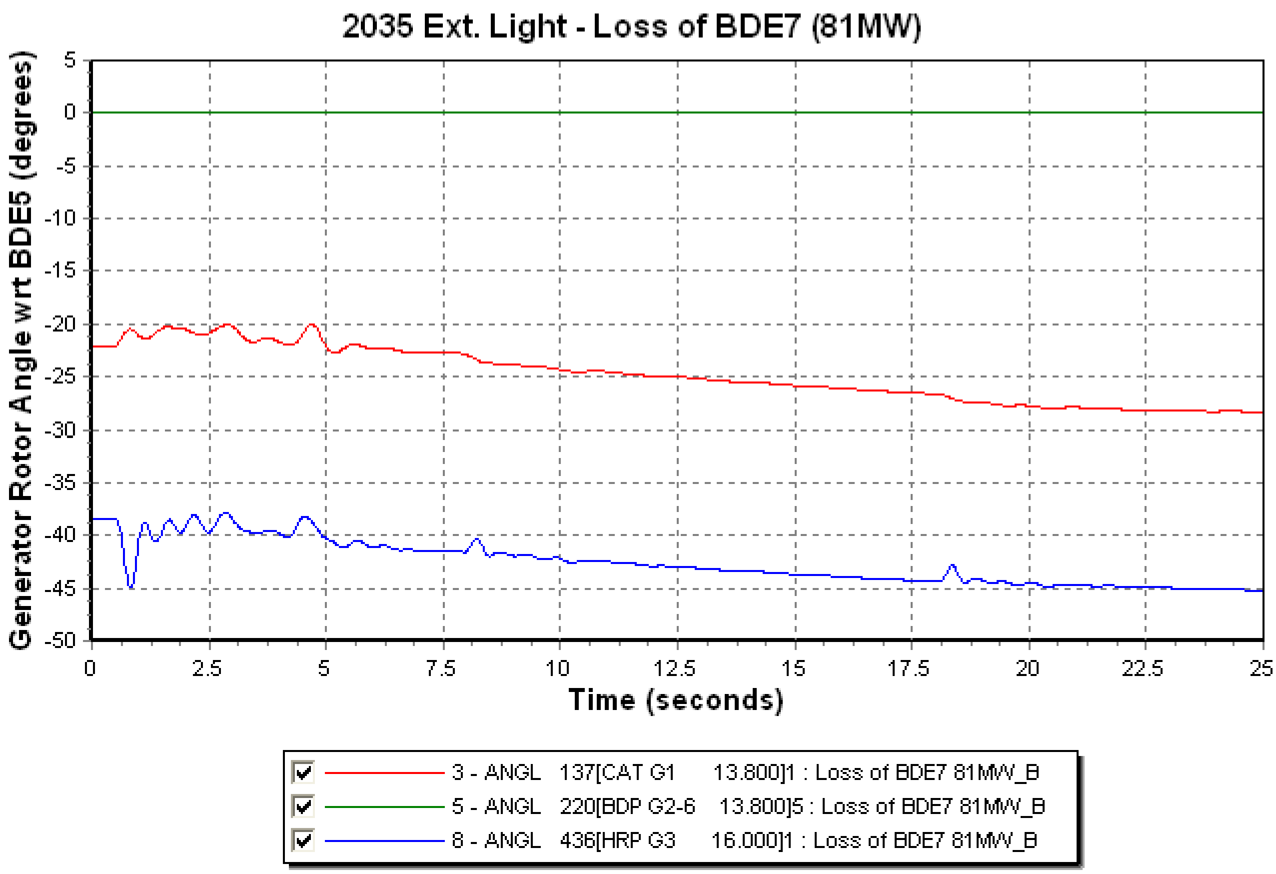

2035 Ext. Light - Loss of VBN Load
Generator Rotor Angle wrt BDE5 (degrees)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : Loss of VBN 74MW
22 - ANGL 2207[BDP G7 13.800]7 : Loss of VBN 74MW
8 - ANGL 436[HRP G3 16.000]1 : Loss of VBN 74MW

Case 2 – Loss of Largest Unit (BDE 7 at 81 MW)

For this contingency, the system is stable and all wind turbines remain connected to the grid. Frequency decline reaches 58.5 Hz and is arrested by operation of 36MW of load shedding. The plots below outline the system frequency and wind turbine / Bay d'Espoir Unit 5 power output responses.

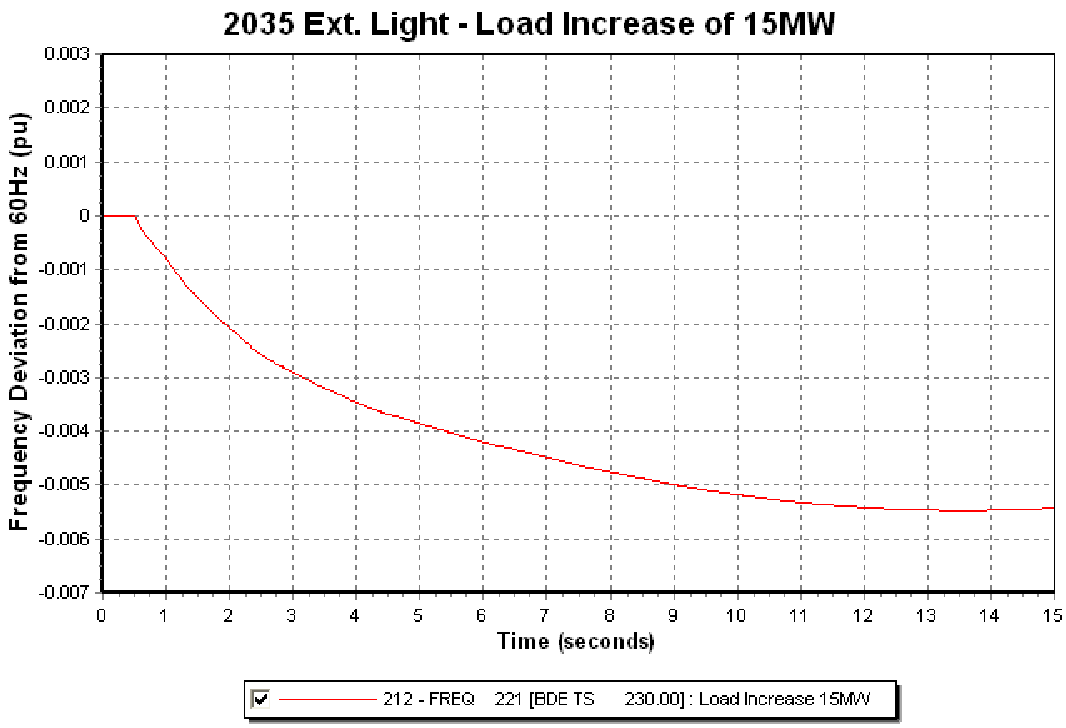


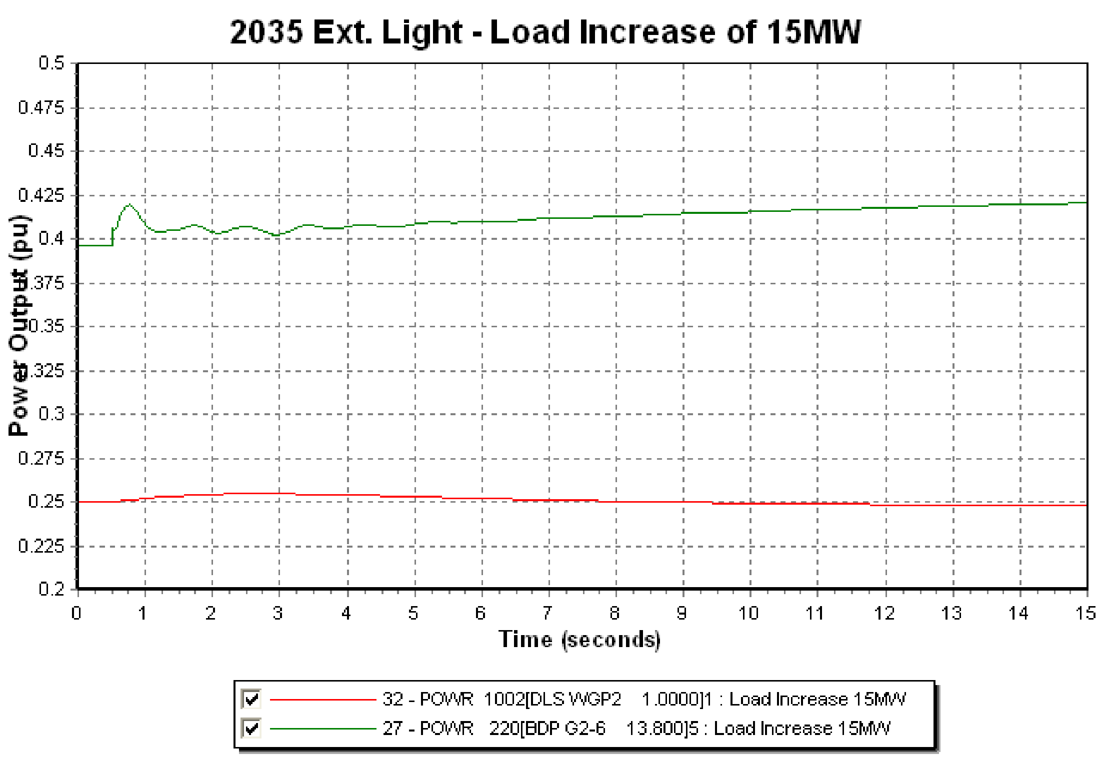


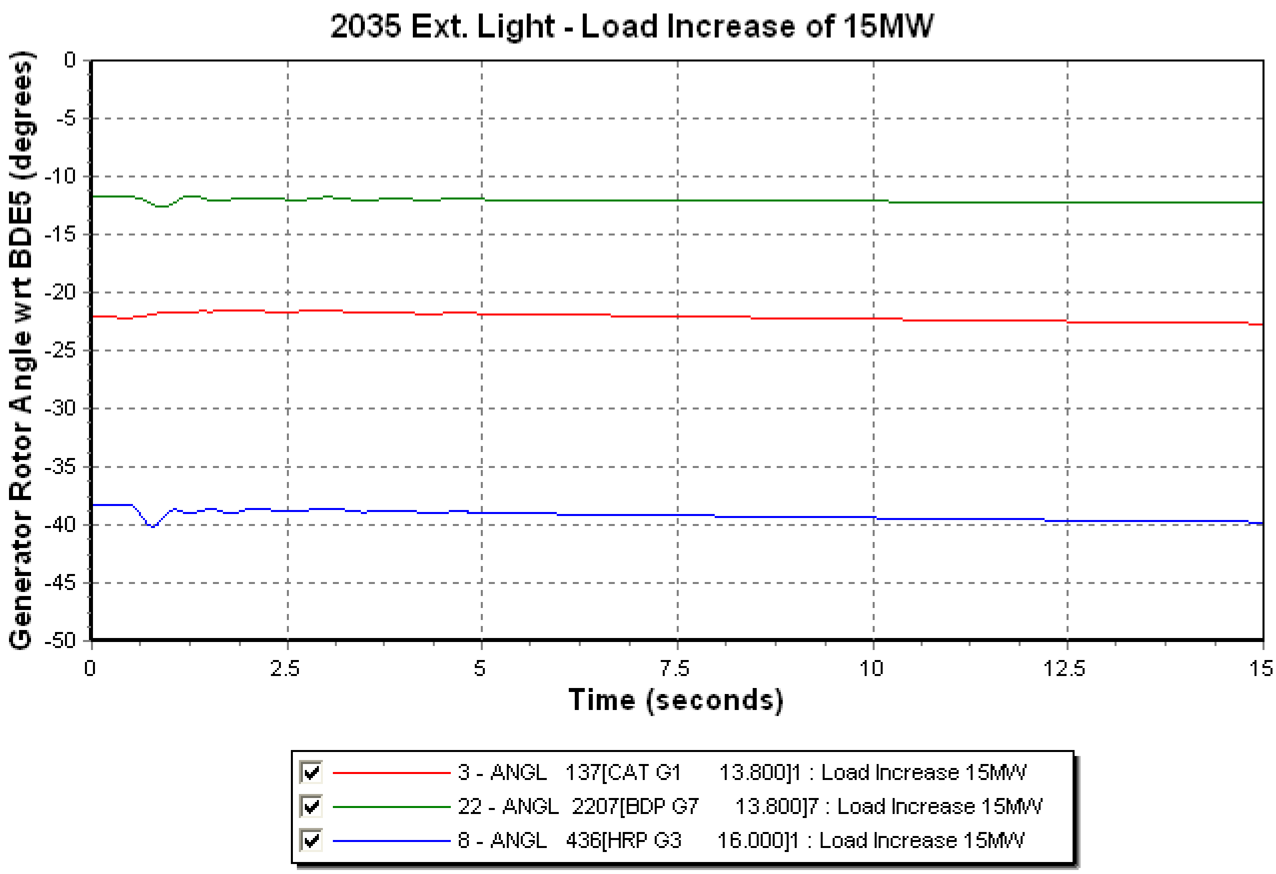

2035 Ext. Light - Loss of BDE7 (81MW)
Generator Rotor Angle wrt BDE5 (degrees)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : Loss of BDE7 81MW_B
5 - ANGL 220[BDP G2-6 13.800]5 : Loss of BDE7 81MW_B
8 - ANGL 436[HRP G3 16.000]1 : Loss of BDE7 81MW_B

Case 3 – Sudden Load Increase of 15 MW

For this event, system frequency reaches a minimum level 59.6 Hz, which is slightly above the first stage under frequency load shedding stage of 59.5 Hz. This is the pre-defined limit of frequency decline for this type of event. The plots below outline the system frequency and a wind turbine / Bay d'Espoir Unit 5 power output responses.

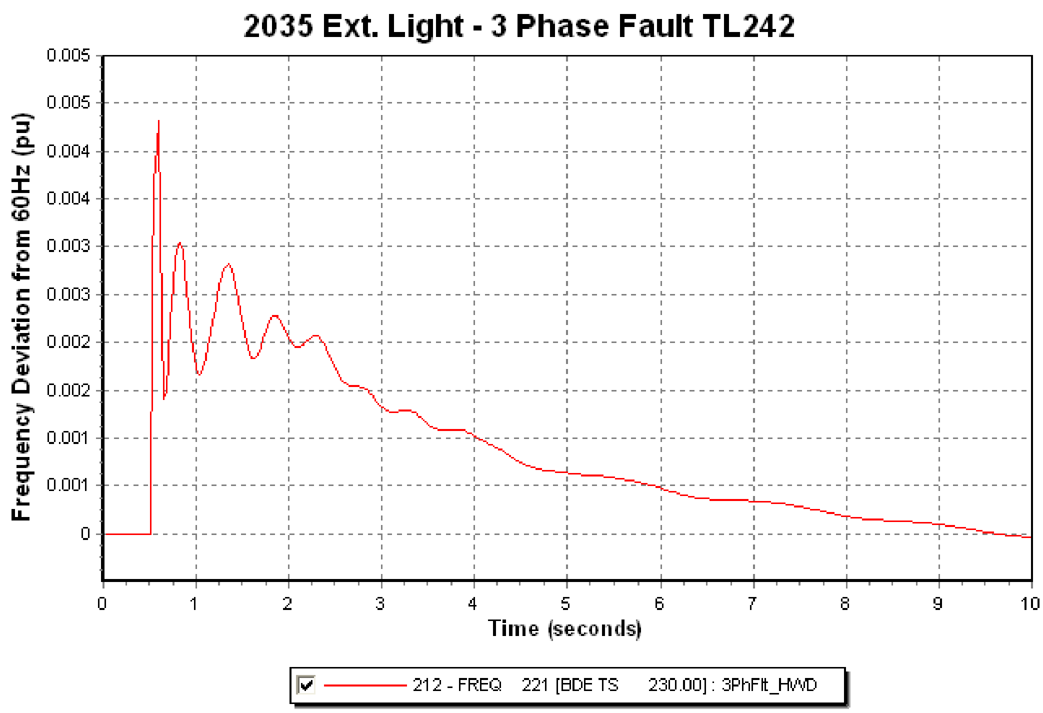


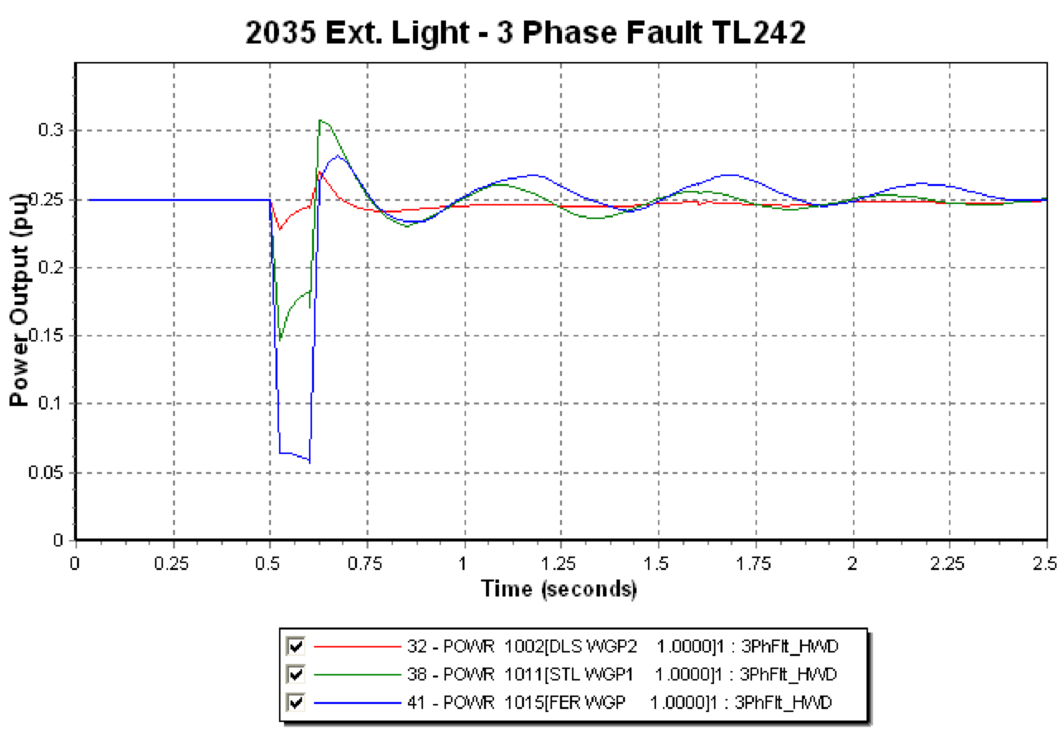


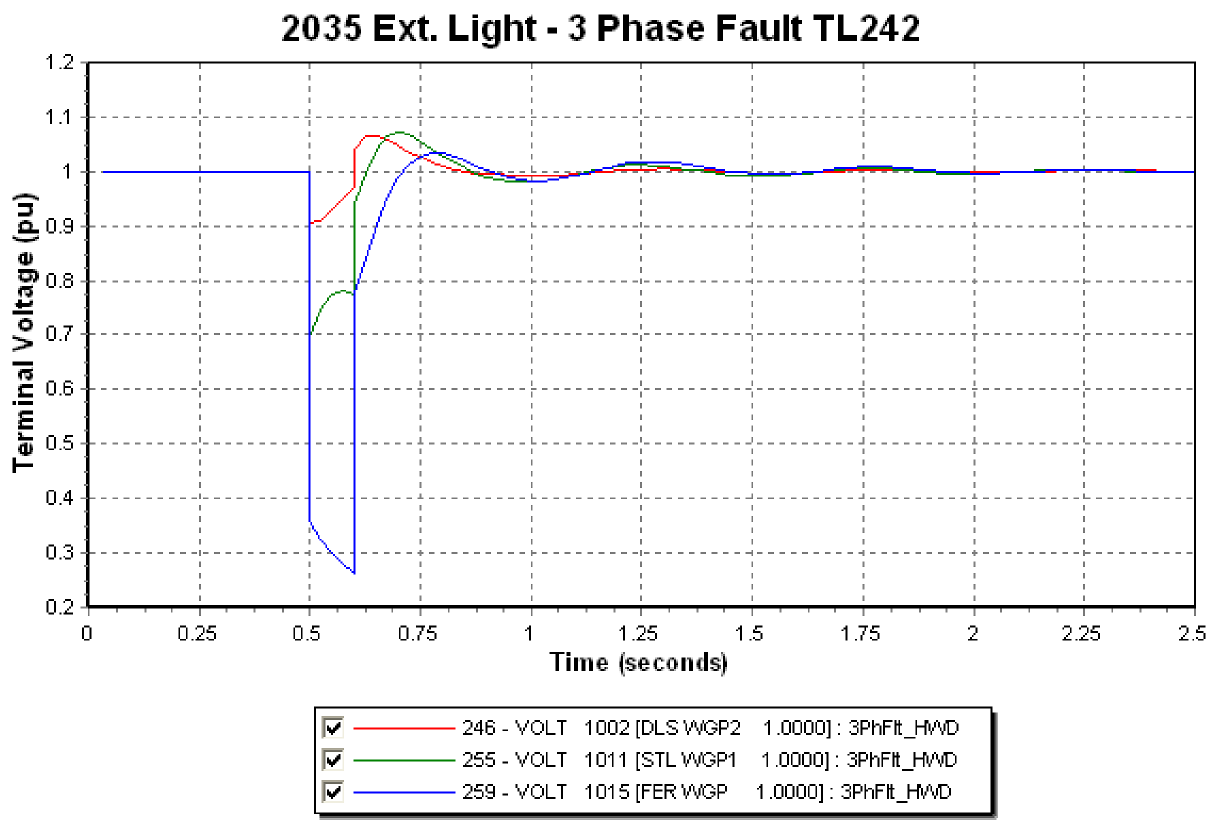

2035 Ext. Light - Load Increase of 15MW
Generator Rotor Angle wrt BDE5 (degrees)
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
2.5
5
7.5
10
12.5
15
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : Load Increase 15MW
22 - ANGL 2207[BDP G7 13.800]7 : Load Increase 15MW
8 - ANGL 436[HRP G3 16.000]1 : Load Increase 15MW

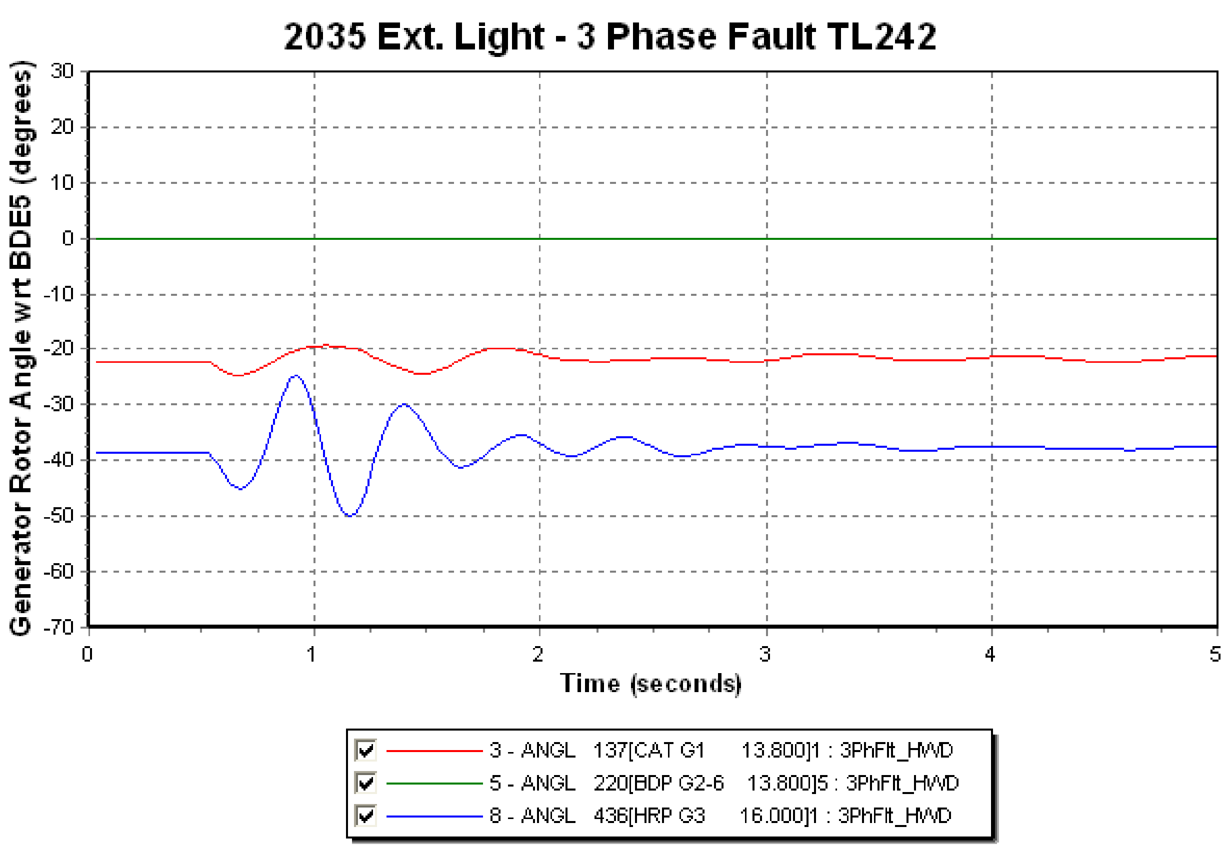
Case 4 – 3 Phase Fault at HWD (6 cycles – Trip TL242)

For this contingency a three phase fault has been applied on TL242 near Hardwoods terminal station for 6 cycles, followed by the tripping of TL242 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



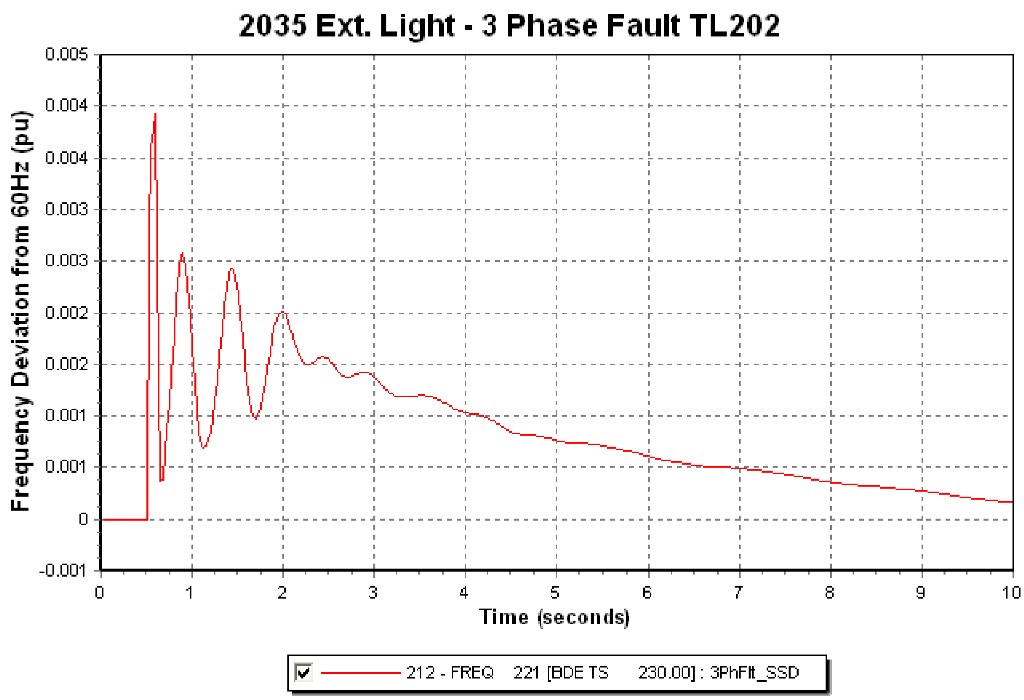


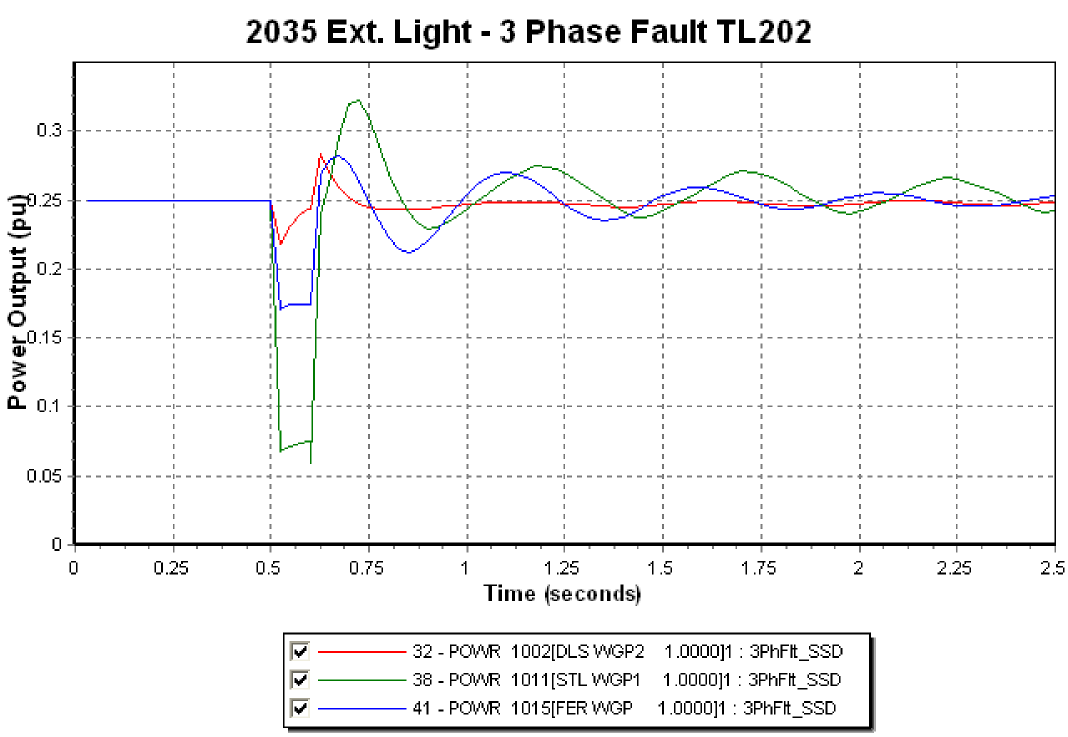

2035 Ext. Light - 3 Phase Fault TL242
Terminal Voltage (pu)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : 3PhFlt_HWD
255 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_HWD
259 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_HWD

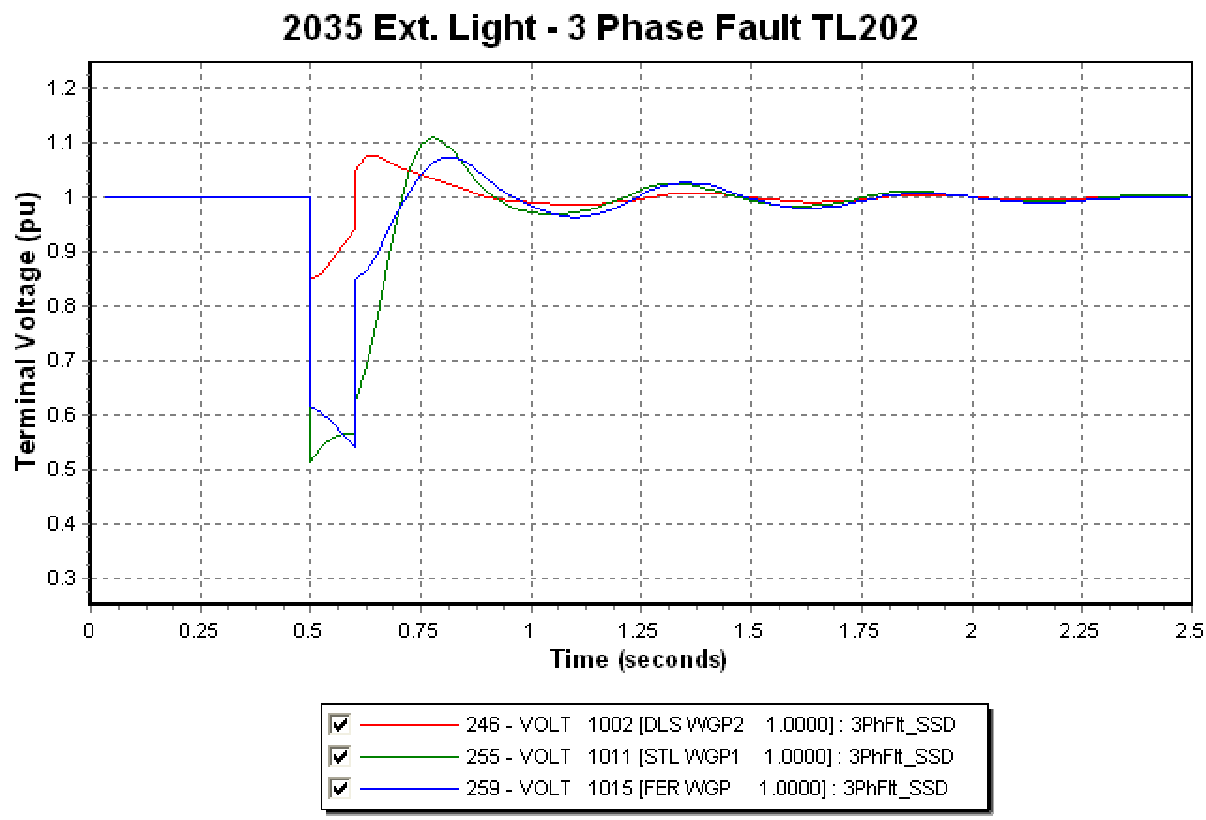

2035 Ext. Light - 3 Phase Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_HWD
5 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_HWD
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_HWD

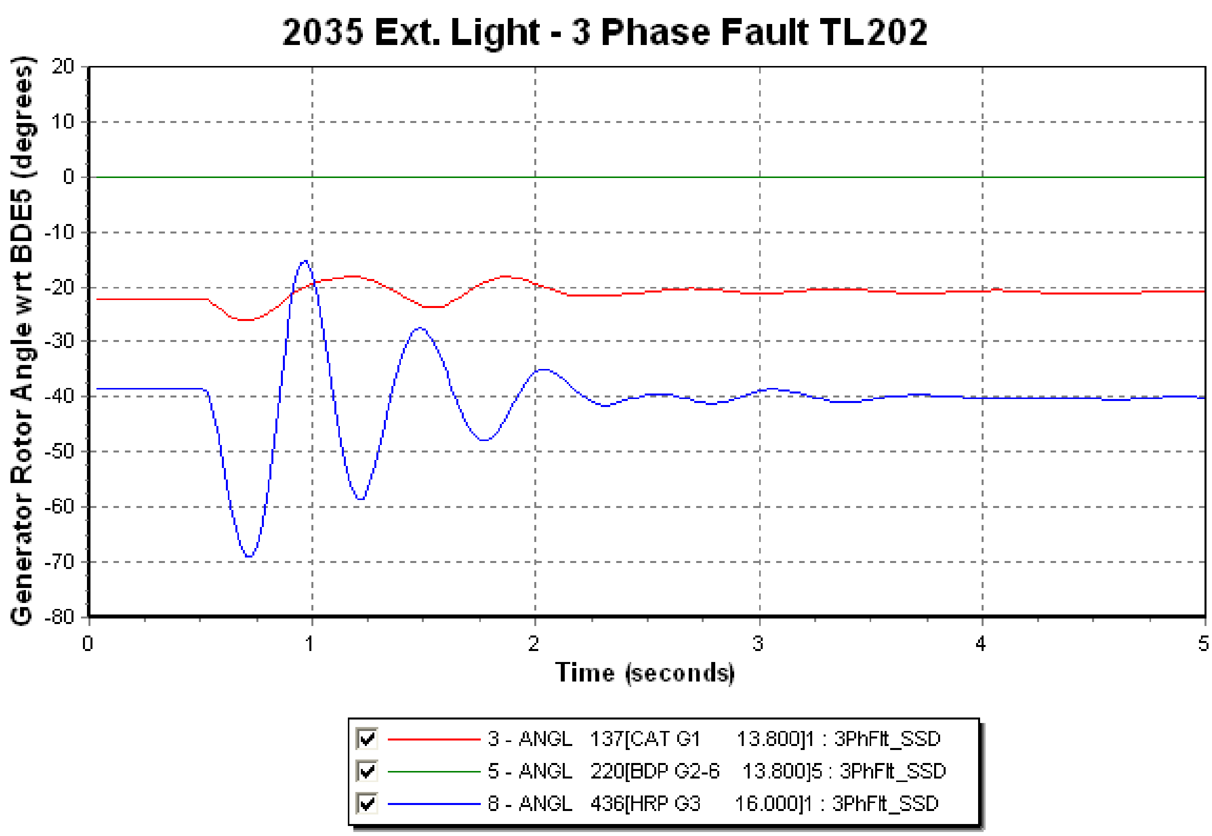
Case 5 – 3 Phase Fault at SSD (6 cycles – Trip TL202)

For this contingency a three phase fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the tripping of TL202 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



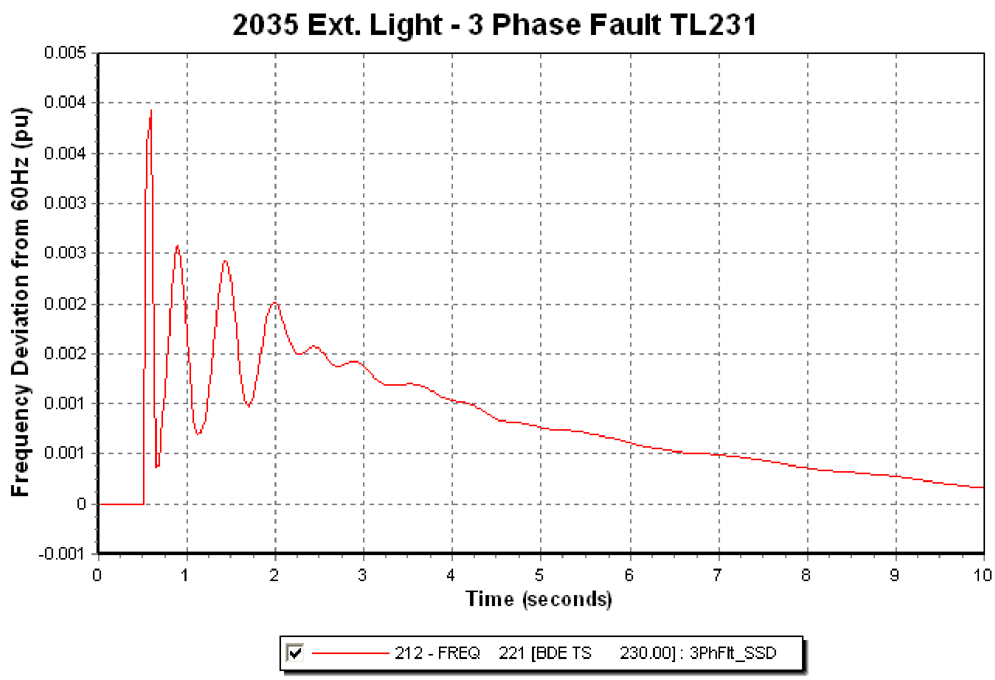


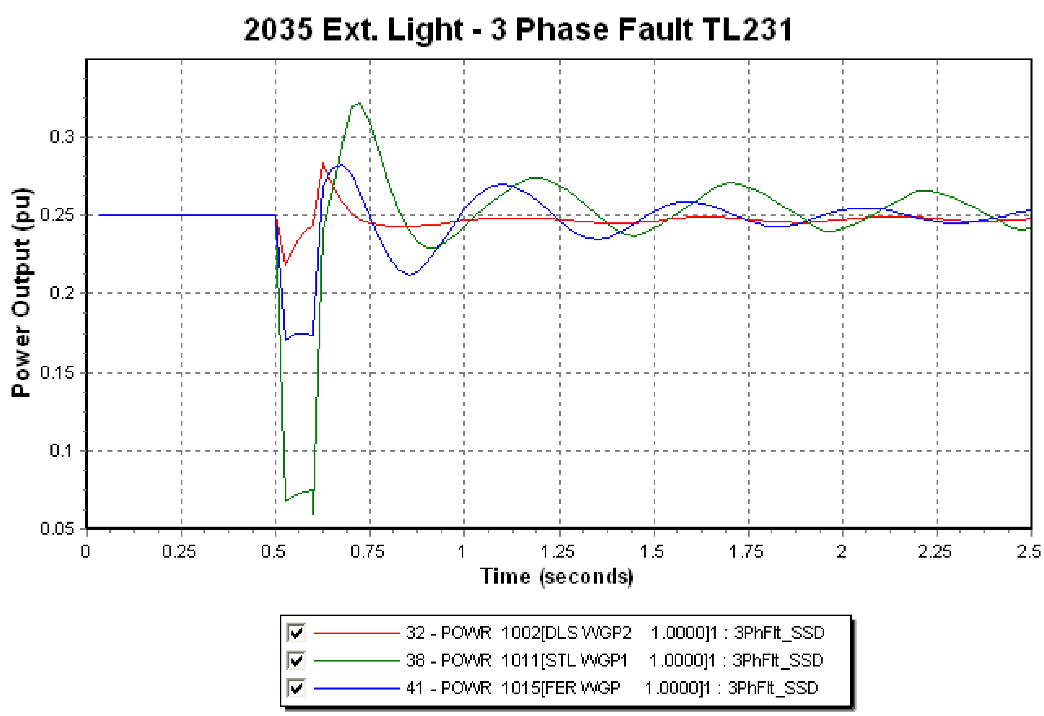

2035 Ext. Light - 3 Phase Fault TL202
Terminal Voltage (pu)
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : 3PhFlt_SSD
255 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_SSD
259 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_SSD

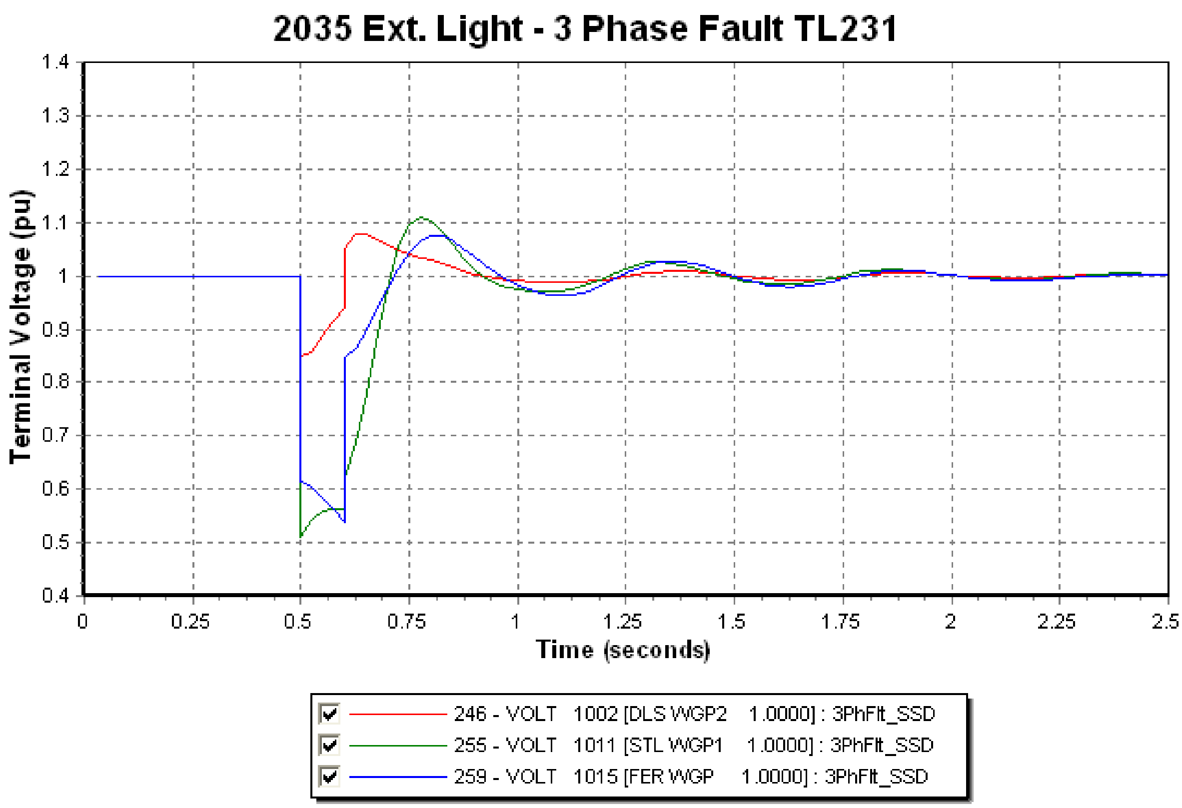

2035 Ext. Light - 3 Phase Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_SSD
5 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_SSD
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_SSD

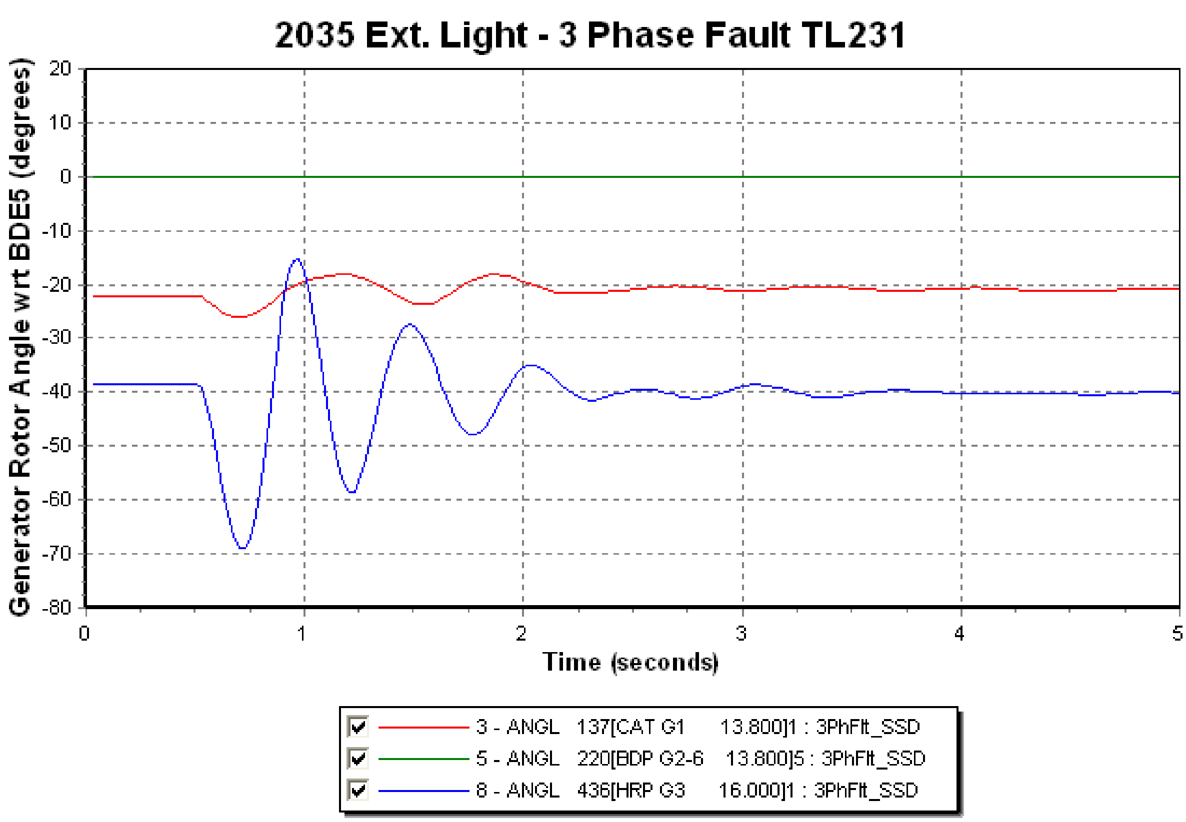
Case 6 – 3 Phase Fault at STB (6 cycles – Trip TL231)

For this contingency a three phase fault has been applied on TL231 near Stony Brook terminal station for 6 cycles, followed by the tripping of TL231 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



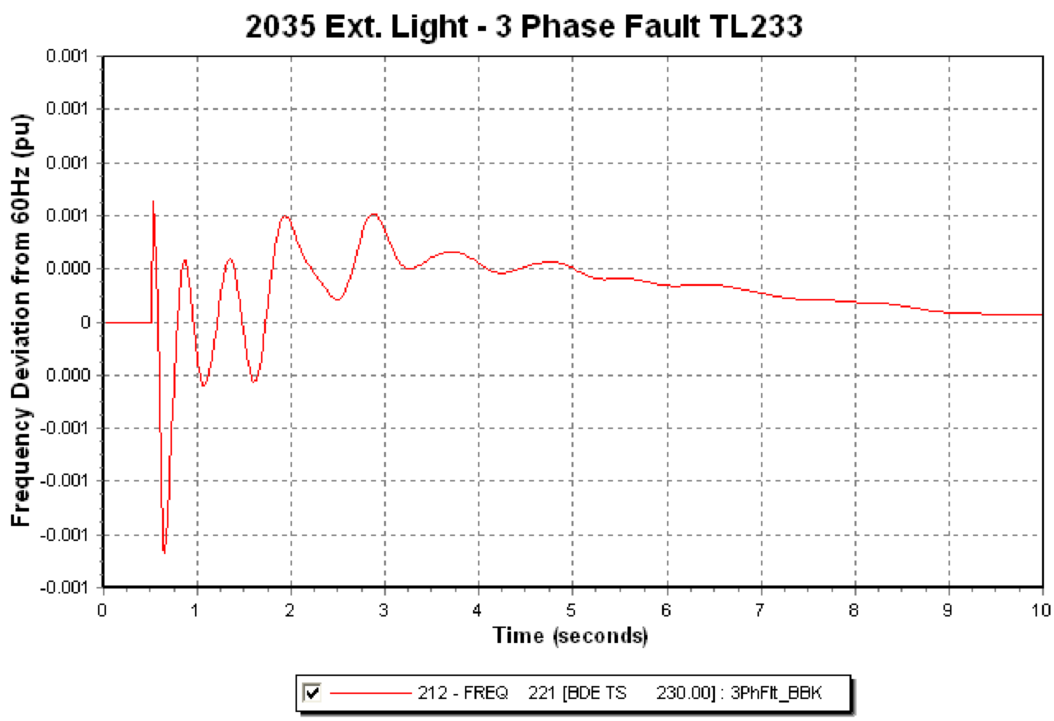


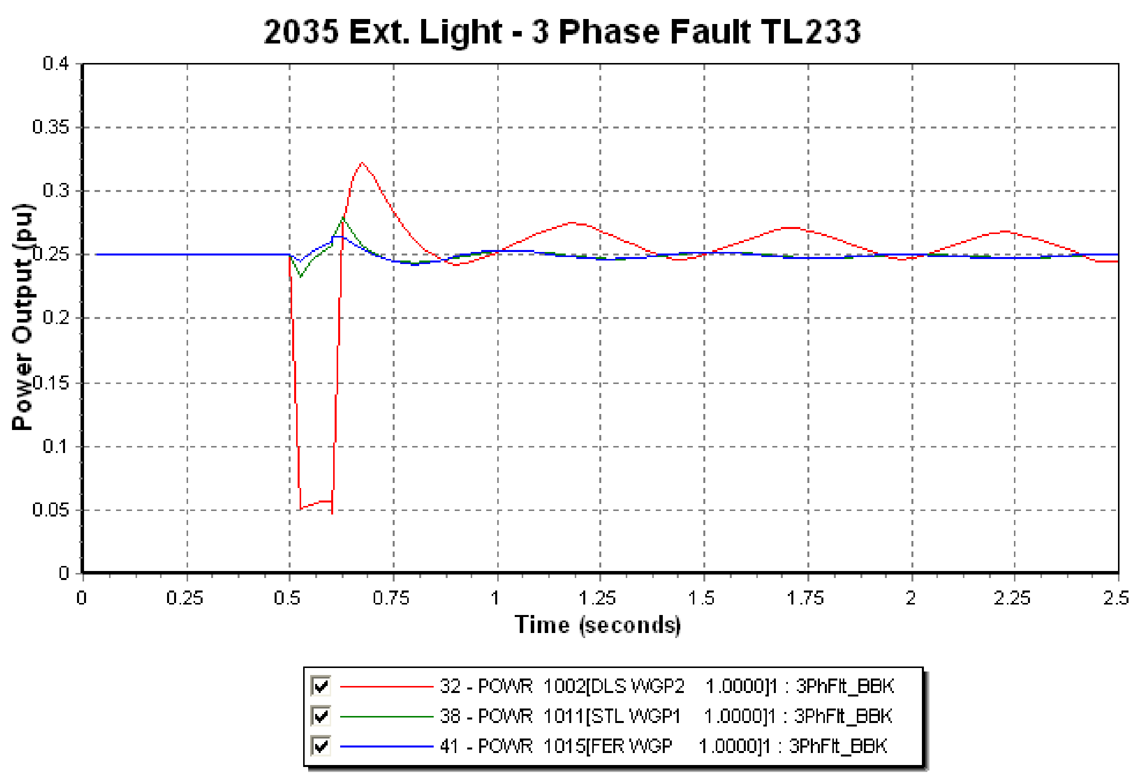

2035 Ext. Light - 3 Phase Fault TL231
Terminal Voltage (pu)
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : 3PhFlt_SSD
255 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_SSD
259 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_SSD

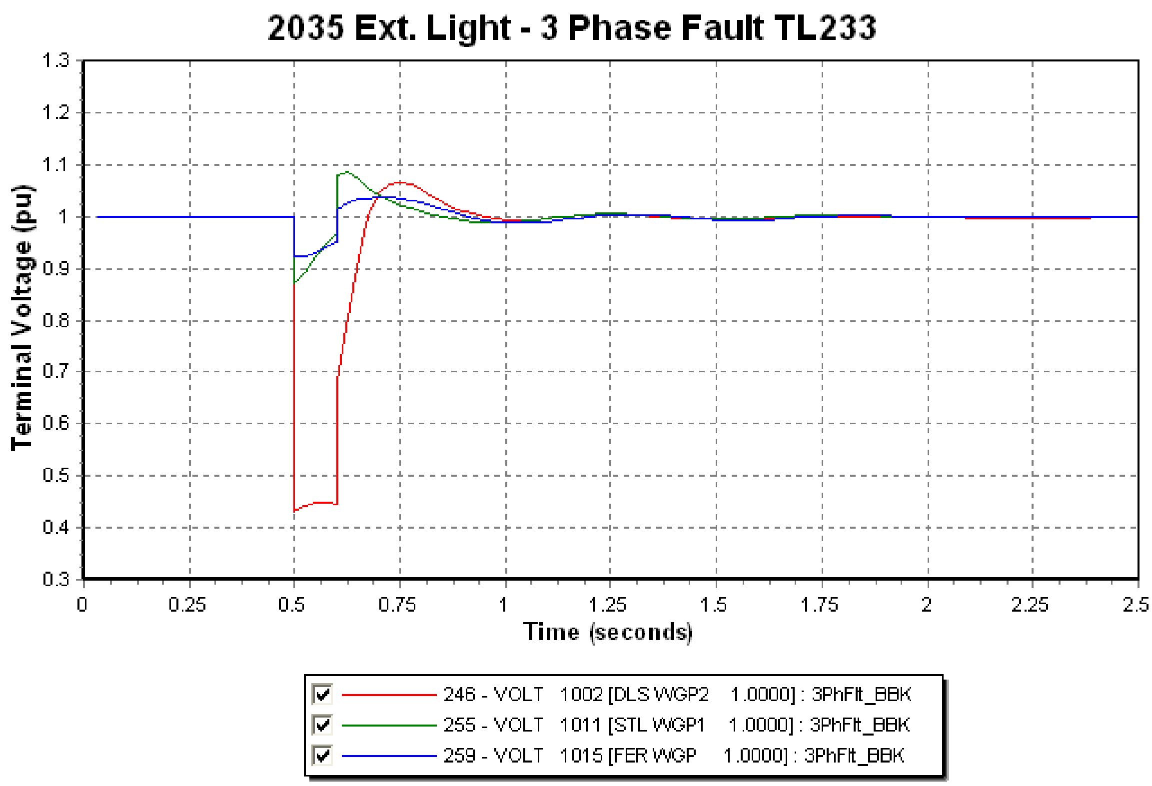

2035 Ext. Light - 3 Phase Fault TL231
Generator Rotor Angle wrt BDE5 (degrees)
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_SSD
5 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_SSD
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_SSD

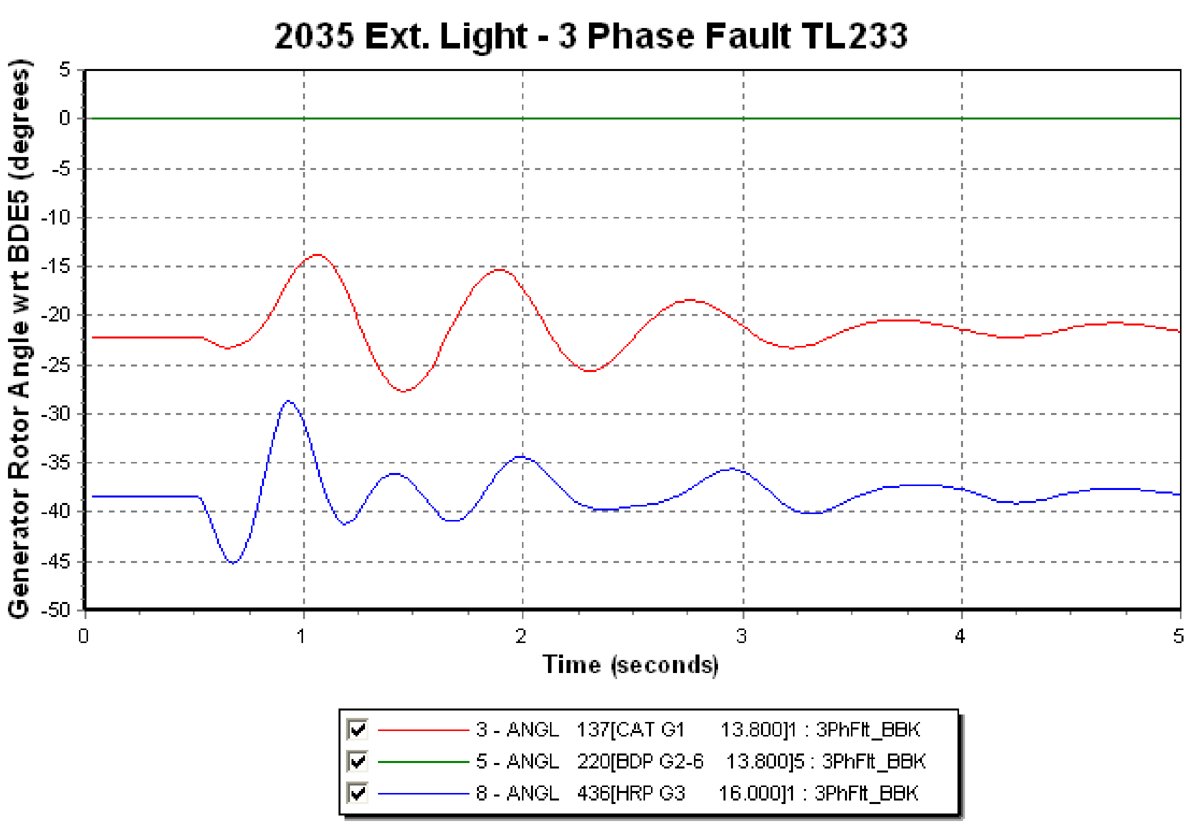
Case 7 – 3 Phase Fault at BBK (6 cycles – Trip TL233)

For this contingency a three phase fault has been applied on TL233 near Bottom Brook terminal station for 6 cycles, followed by the tripping of TL233 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



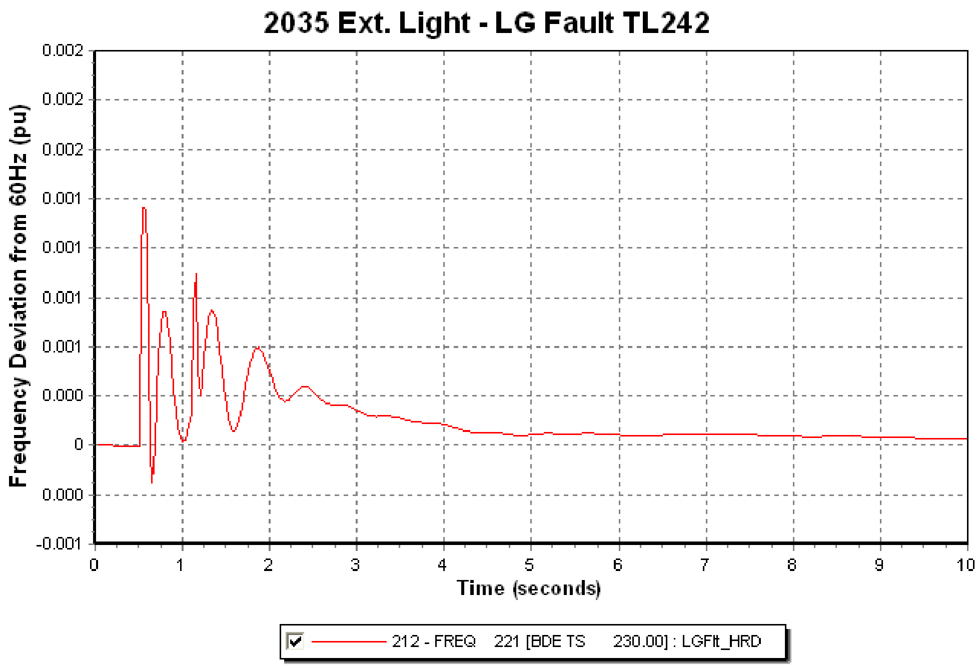


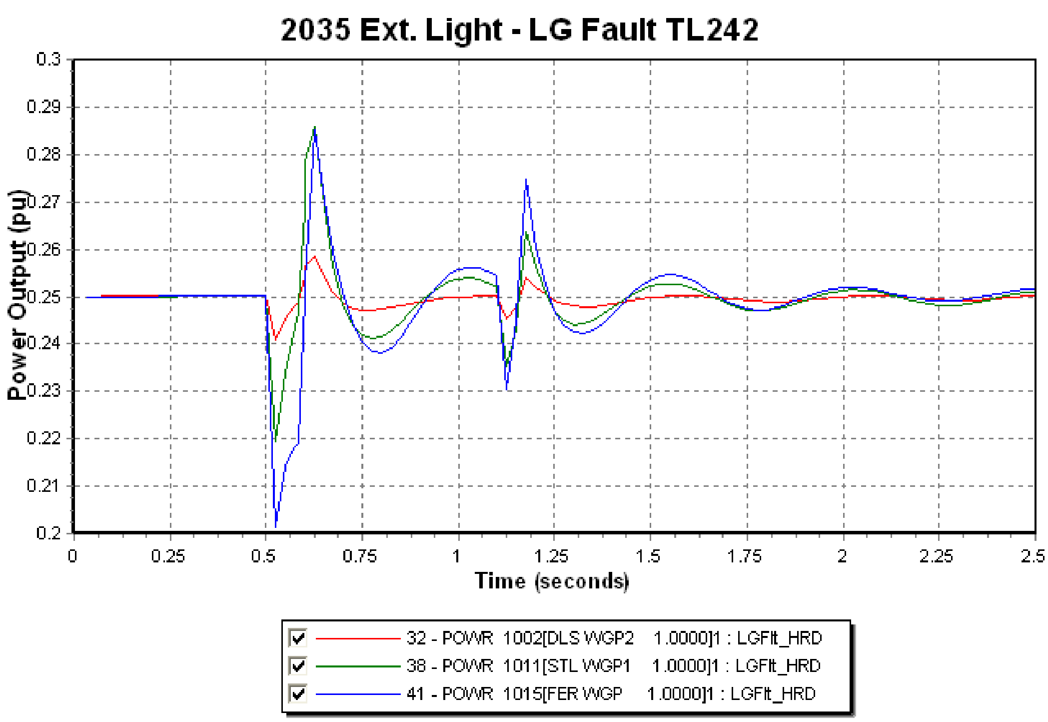

2035 Ext. Light - 3 Phase Fault TL233
Terminal Voltage (pu)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : 3PhFlt_BBK
255 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_BBK
259 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_BBK

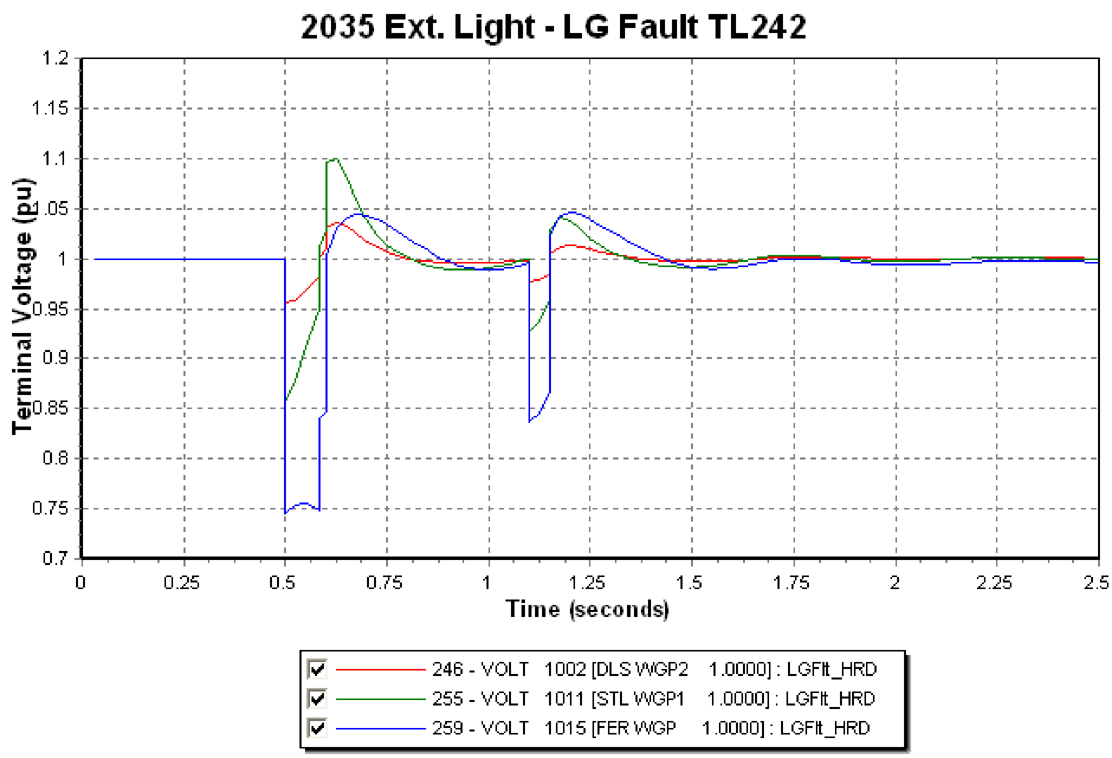

2035 Ext. Light - 3 Phase Fault TL233
Generator Rotor Angle wrt BDE5 (degrees)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_BBK
5 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_BBK
8 - ANGL 436[HRP G3 16.000]1 : 3PhFlt_BBK

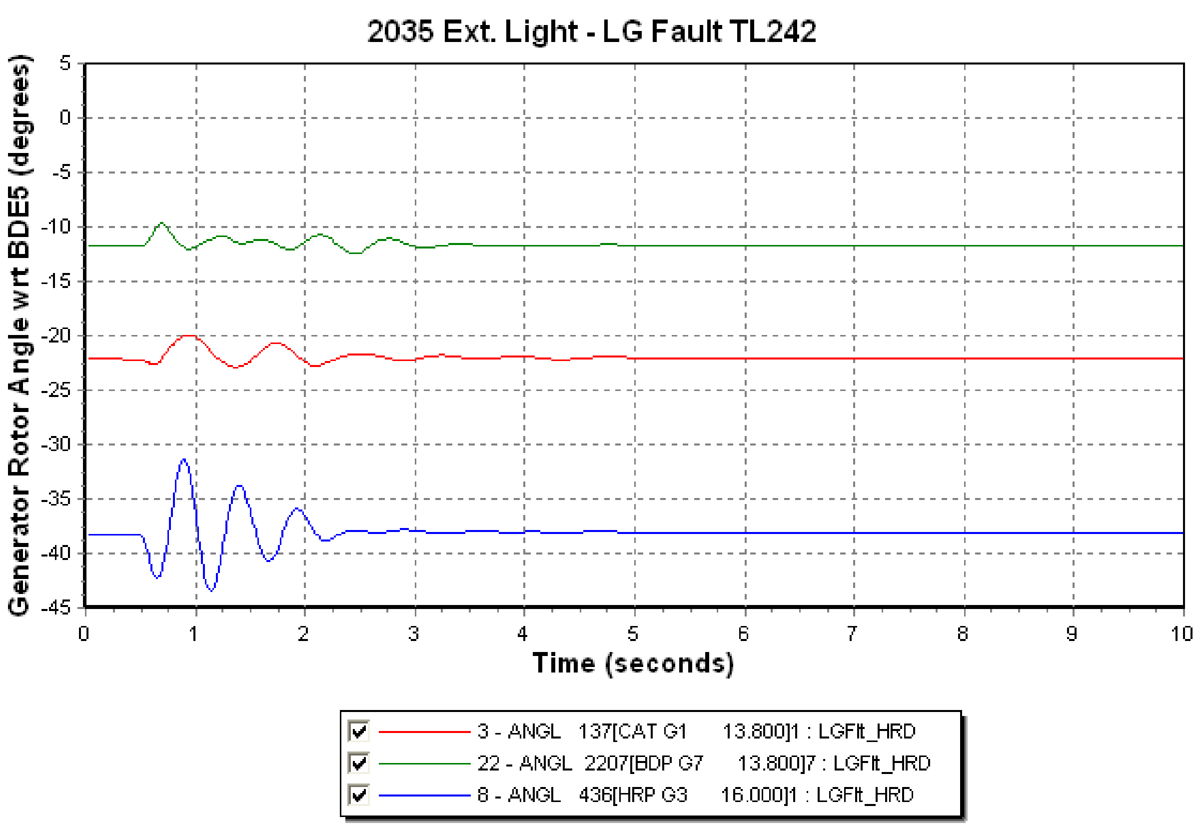
Case 8 – LG Fault at TL242 Near HRD

For this contingency a line to ground fault has been applied on TL242 near Holyrood Generating station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL242 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.



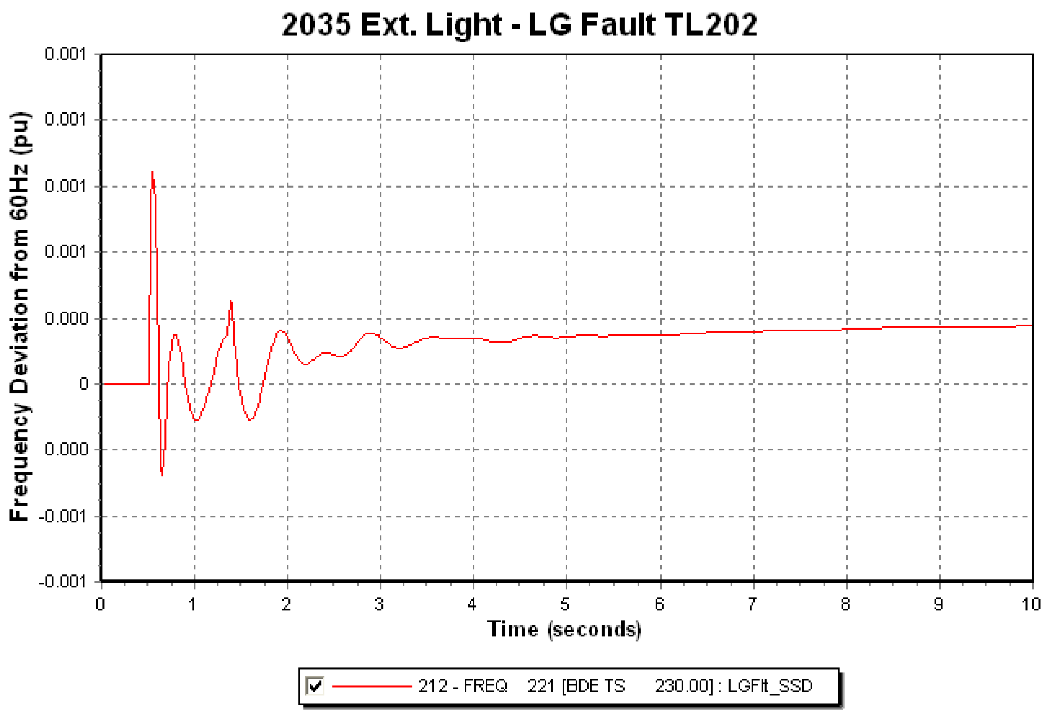


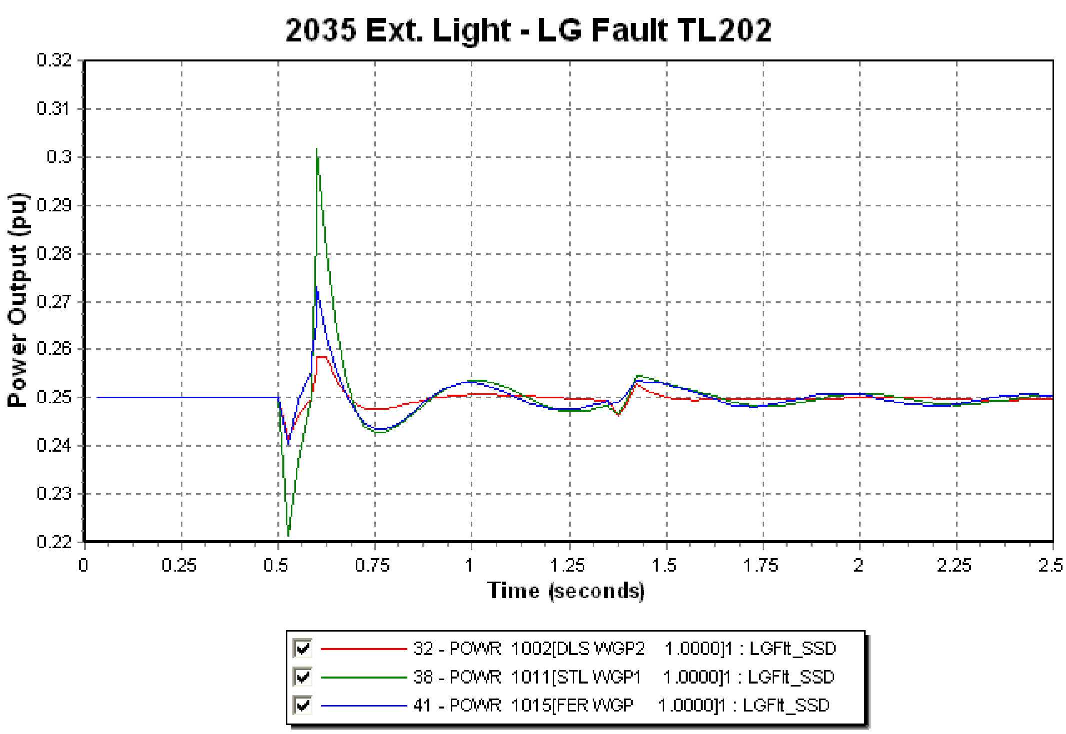

2035 Ext. Light - LG Fault TL242
Terminal Voltage (pu)
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : LGFlt_HRD
255 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_HRD
259 - VOLT 1015 [FER WGP 1.0000] : LGFlt_HRD

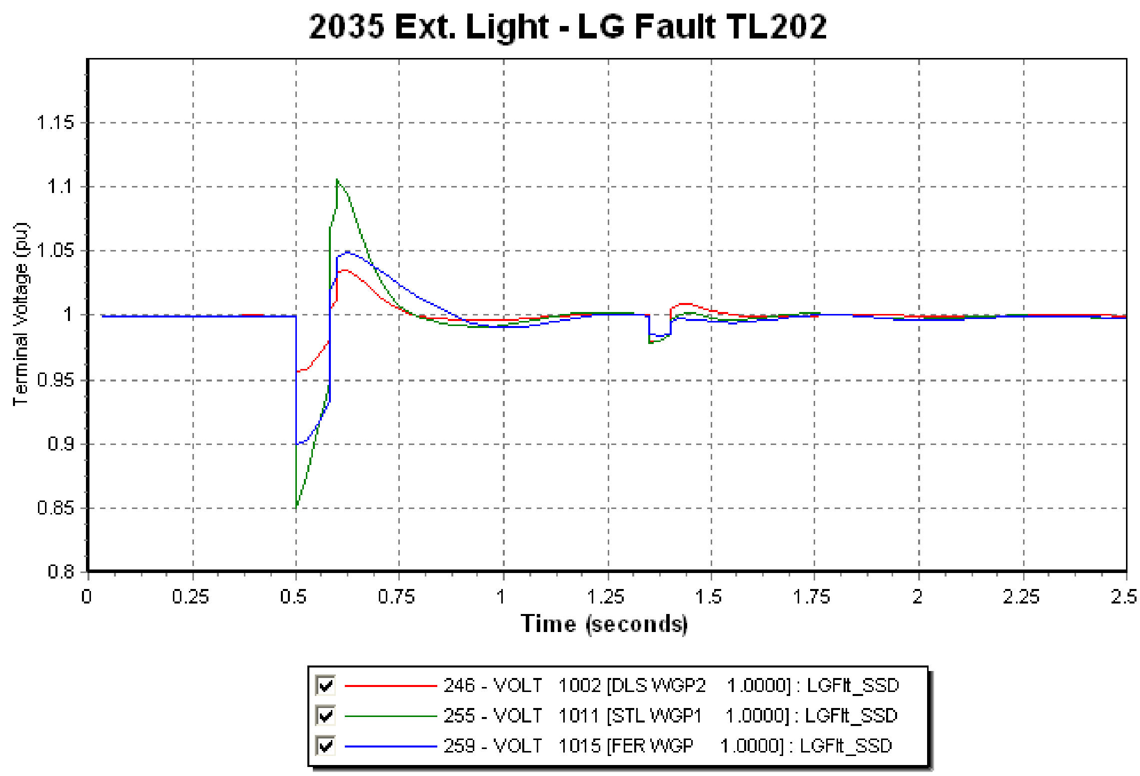

2035 Ext. Light - LG Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : LGFlt_HRD
22 - ANGL 2207[BDP G7 13.800]7 : LGFlt_HRD
8 - ANGL 436[HRP G3 16.000]1 : LGFlt_HRD

Case 9 – LG Fault at TL202 Near SSD

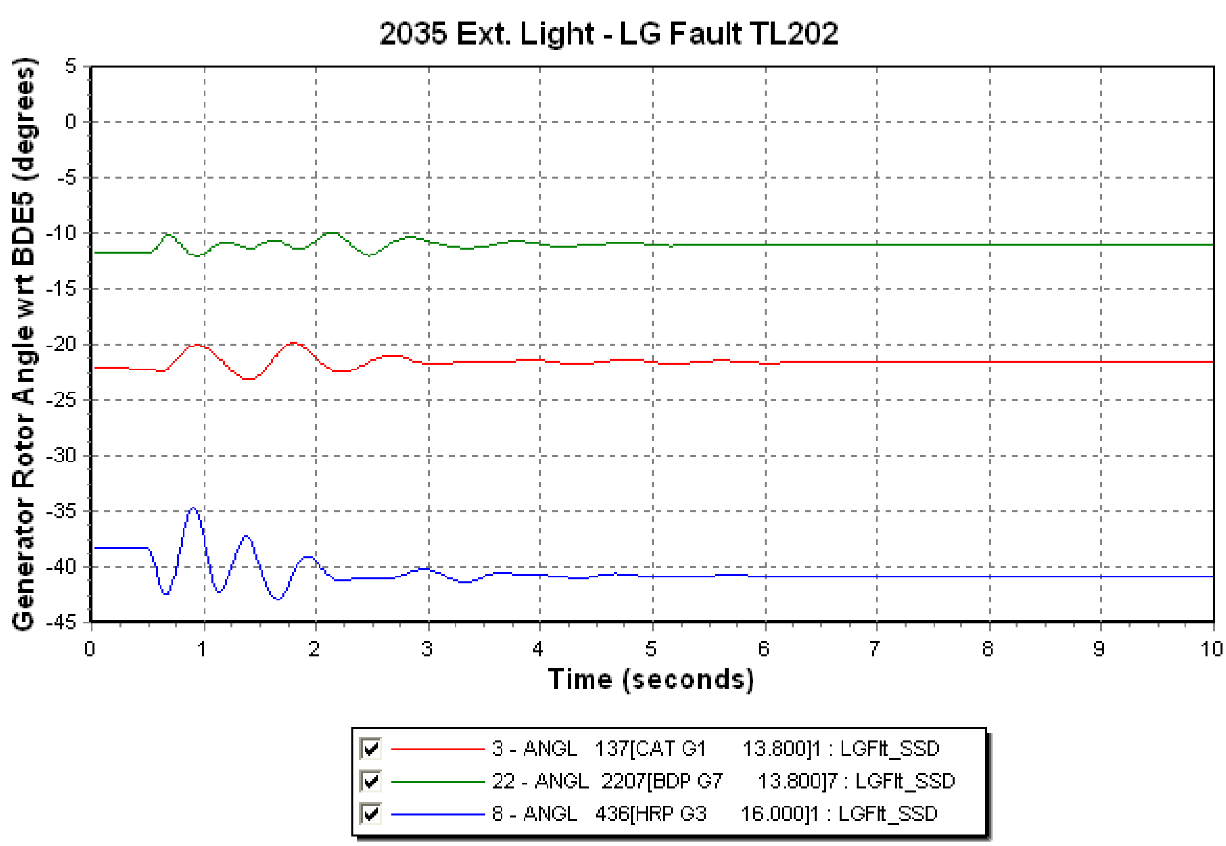
For this contingency a line to ground fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL202 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency as well as wind turbine power output and voltage at terminals of the machines. The LVRT capability of the wind turbines enable them to ride through the fault condition.







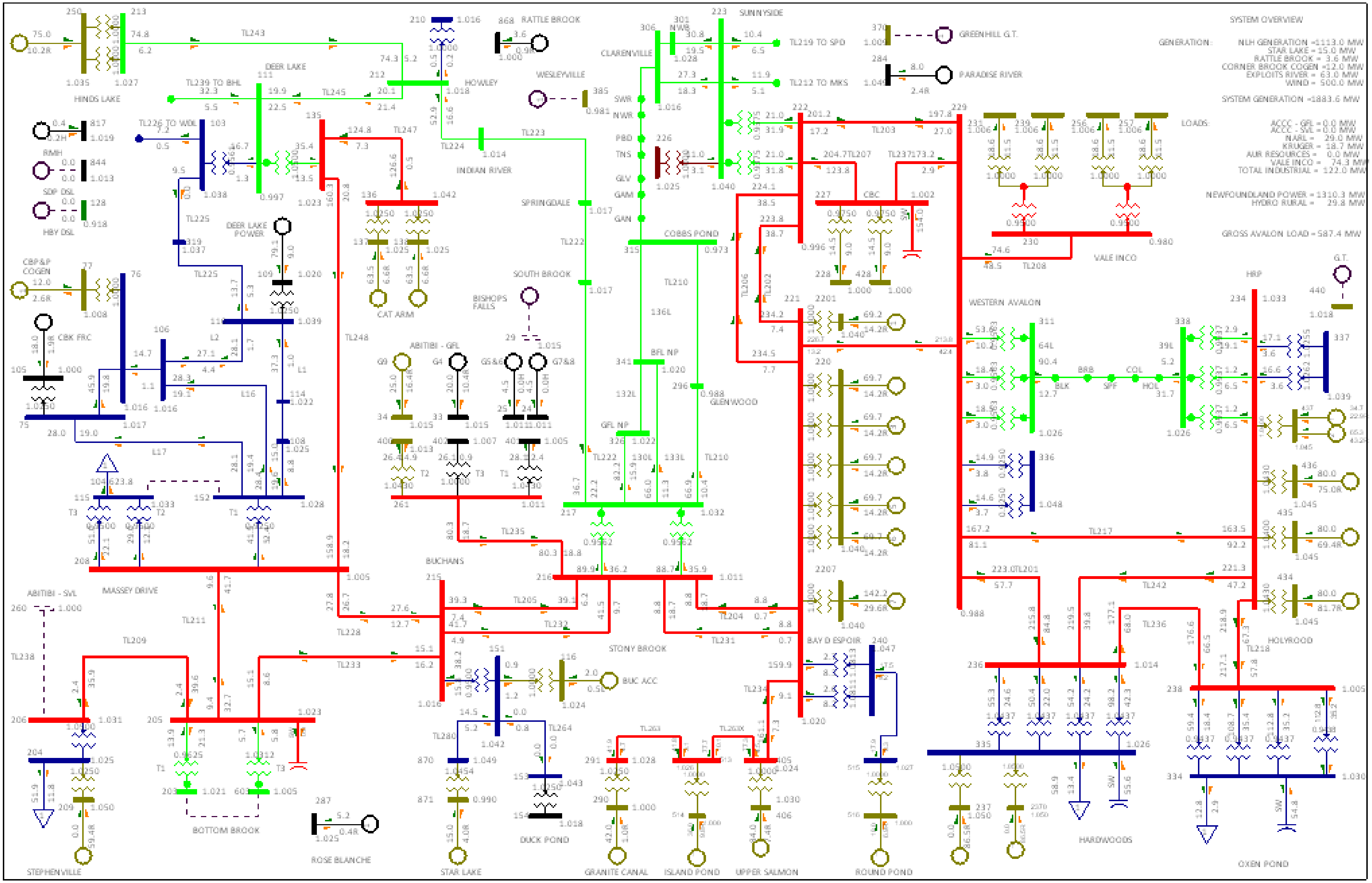
2035 Ext. Light - LG Fault TL202
Terminal Voltage (pu)
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
246 - VOLT 1002 [DLS WGP2 1.0000] : LGFlt_SSD
255 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_SSD
259 - VOLT 1015 [FER WGP 1.0000] : LGFlt_SSD



2035 Ext. Light - LG Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : LGFlt_SSD
22 - ANGL 2207[BDP G7 13.800]7 : LGFlt_SSD
8 - ANGL 436[HRP G3 16.000]1 : LGFlt_SSD

APPENDIX K - STABILITY RESULTS 2035 PEAK LOAD

500 MW WIND GENERATION



2035 PEAK BASE CASE - 500MW WIND

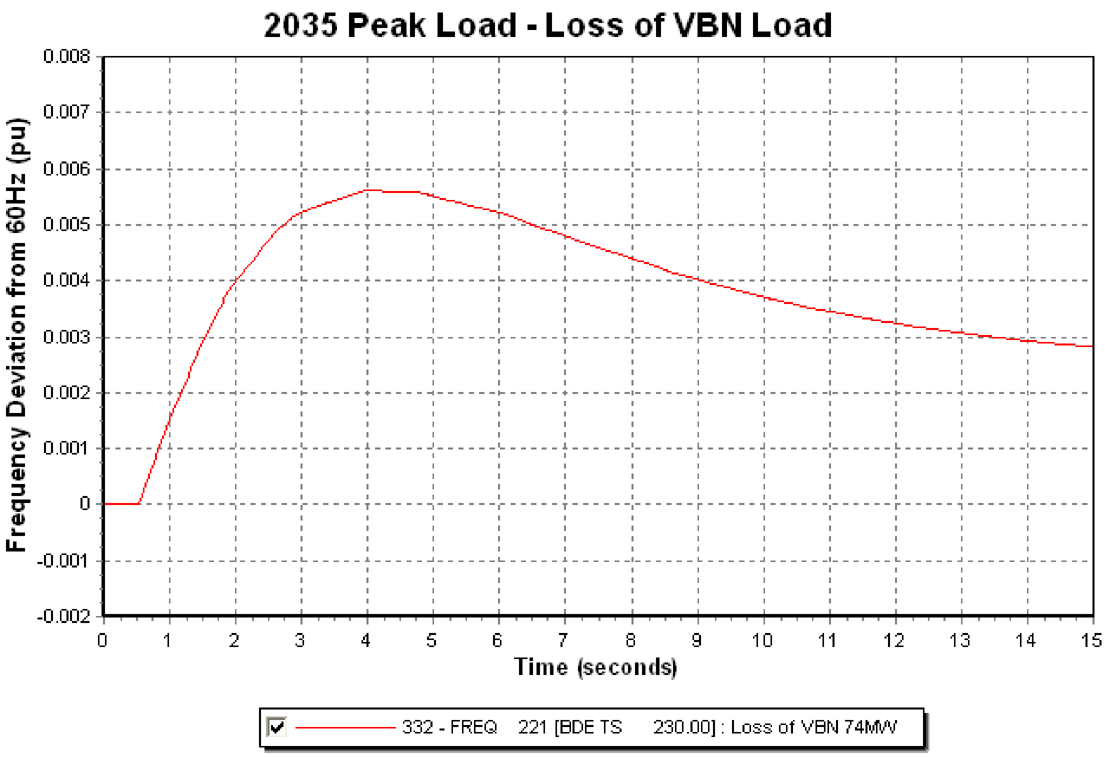
THU, AUG 16 2012 13:56

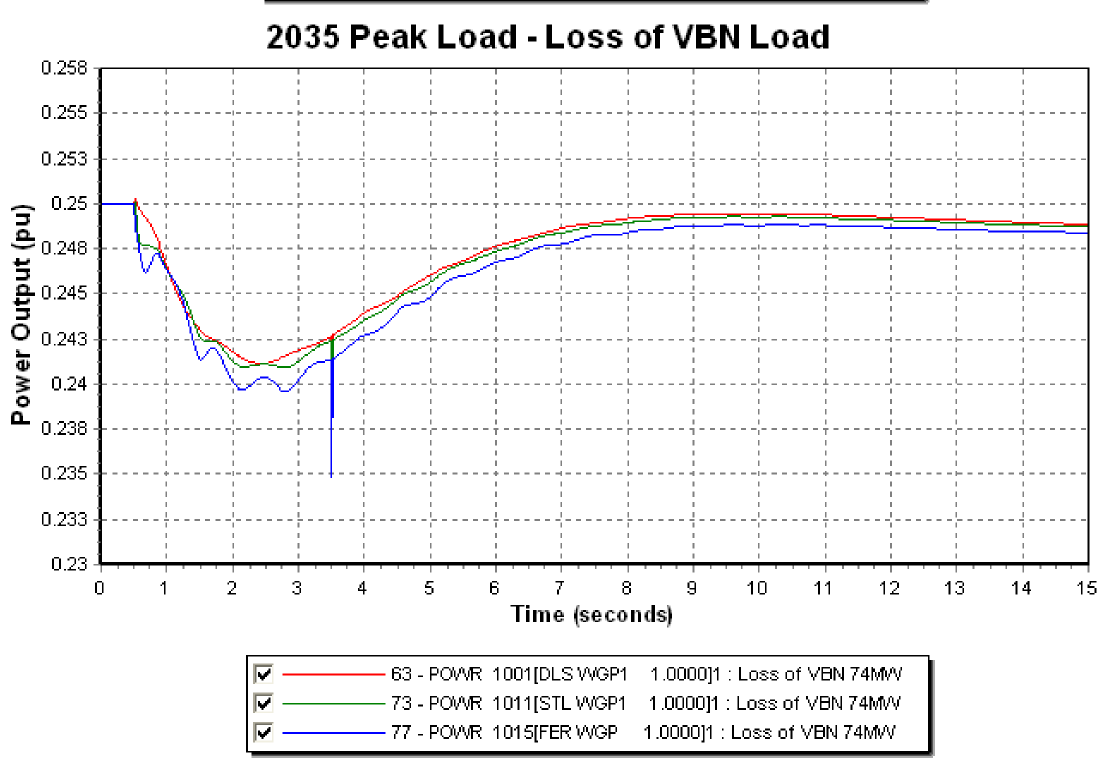
Bus - VOLTAGE (PU)
Branch - MW/Mvar
Equipment - MW/Mvar

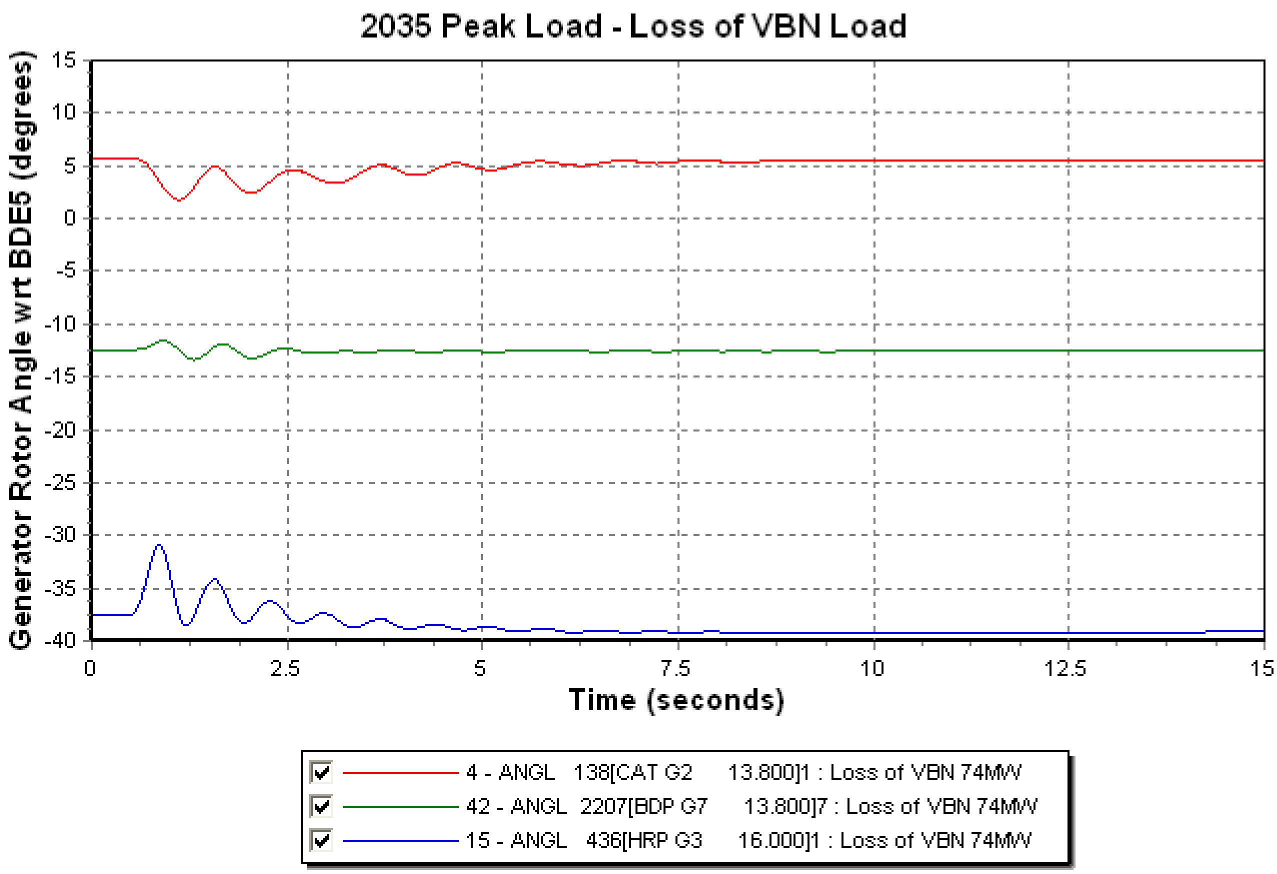
2035 Peak Load – 500MW Wind – Generation Dispatch Prior to Dynamic Simulations

Case 1 – Loss of 74.3MW load at VBN

This causes an over frequency condition that reaches a maximum of 60.3Hz. All wind turbines remain on line as frequency doesn't reach 60.6Hz which is first wind turbine trip setpoint. The following plots show system frequency response and power output from 3 wind turbine plants. Spikes in wind turbine power are numerical in nature caused by stopping and starting the simulation at that point in time.

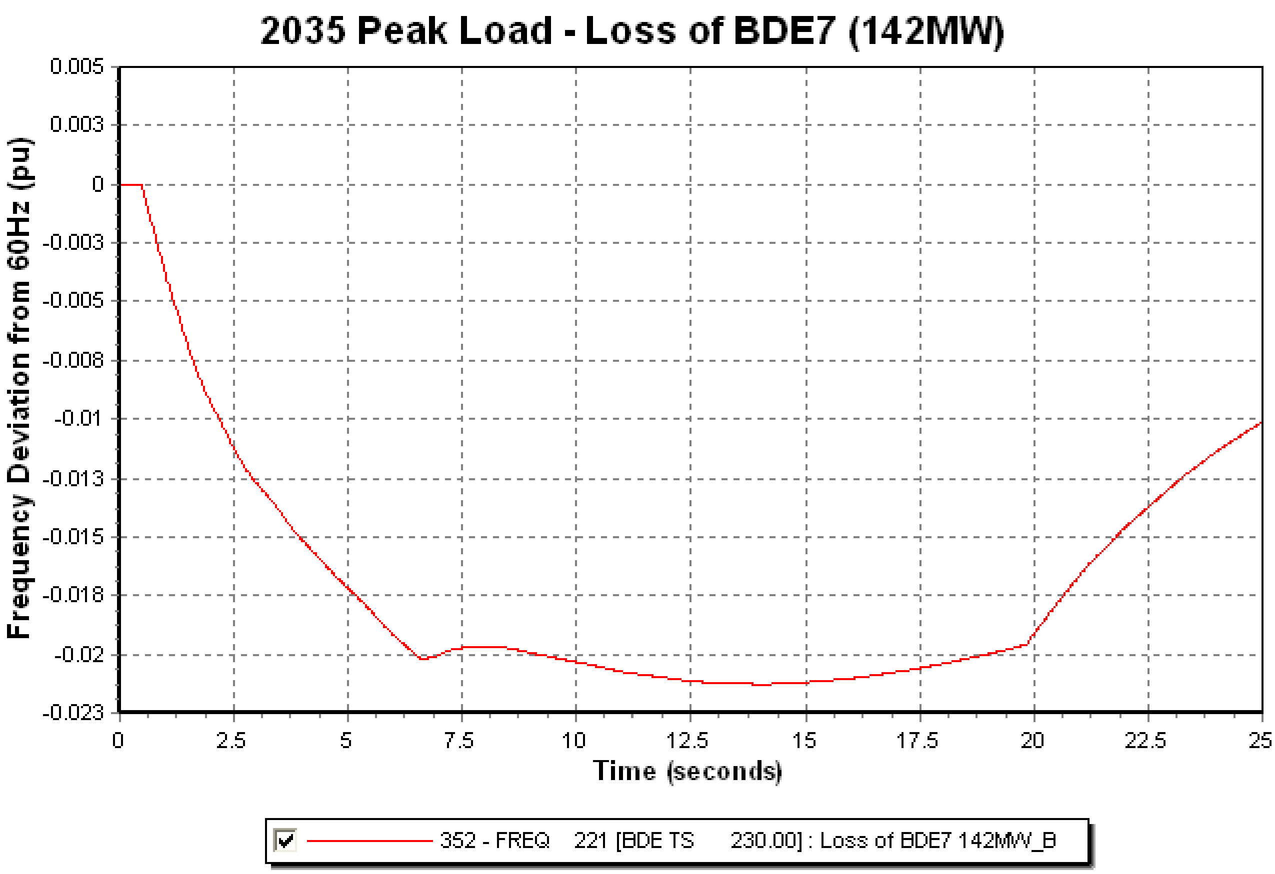


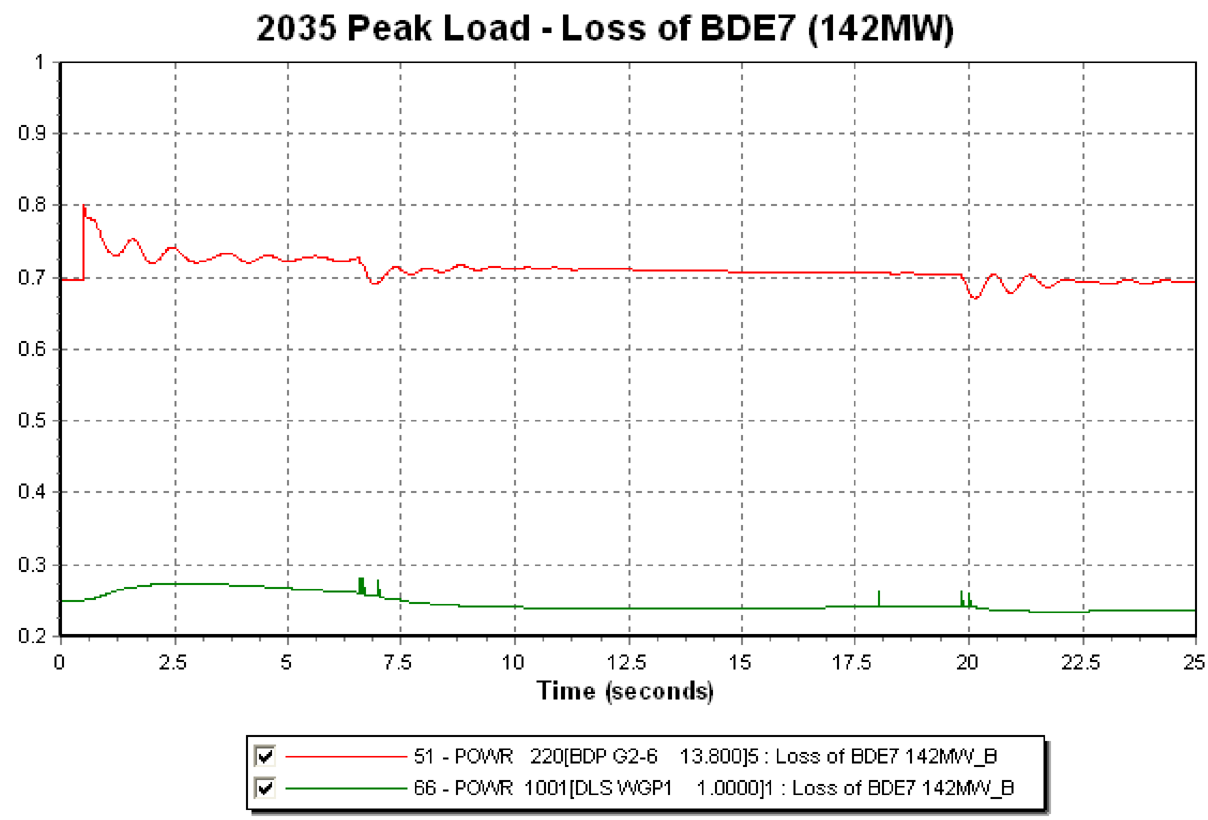



2035 Peak Load - Loss of VBN Load
Generator Rotor Angle wrt BDE5 (degrees)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
2.5
5
7.5
10
12.5
15
Time (seconds)
4 - ANGL 138[CAT G2 13.800]1 : Loss of VBN 74MW
42 - ANGL 2207[BDP G7 13.800]7 : Loss of VBN 74MW
15 - ANGL 436[HRP G3 16.000]1 : Loss of VBN 74MW

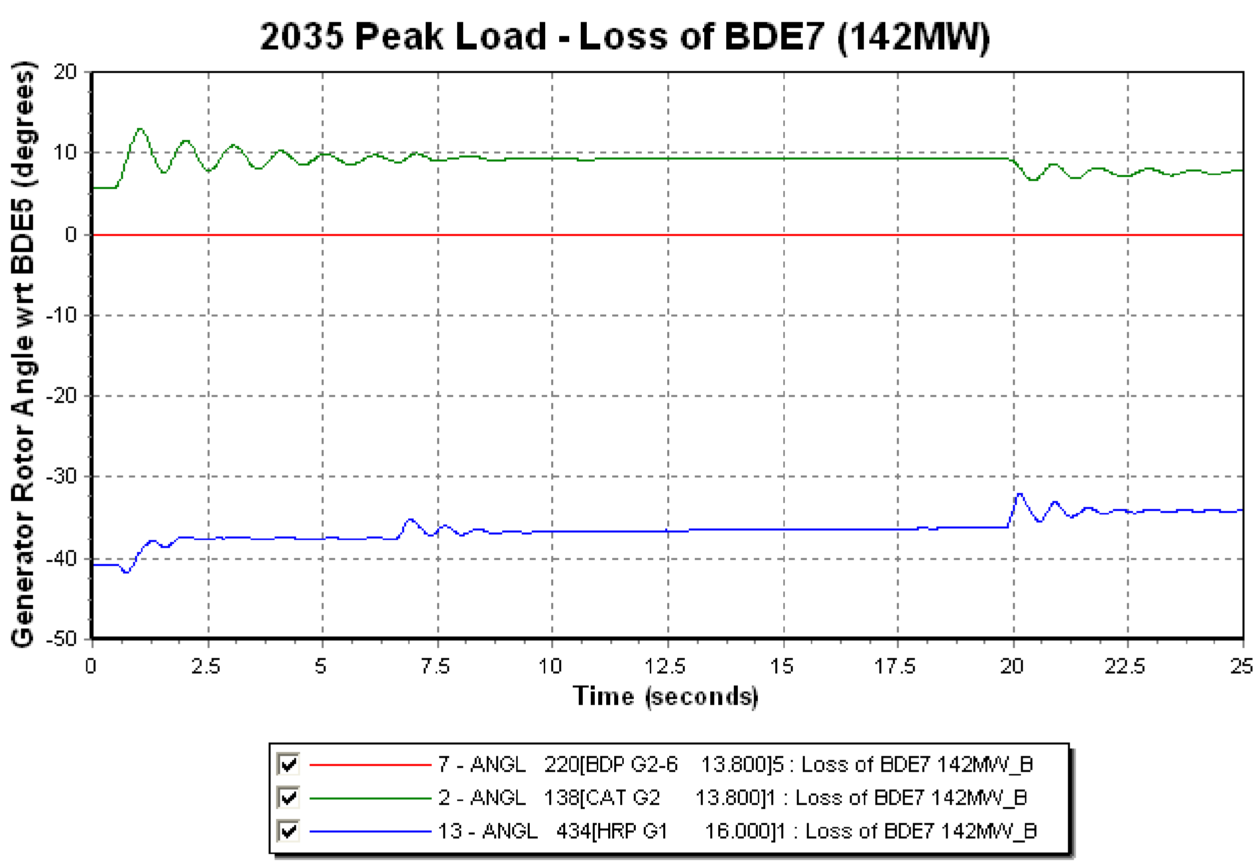
Case 2 – Loss of Largest Unit (BDE 7 at 110 MW)

For this contingency, the system is stable and all wind turbines remain connected to the grid. Frequency decline reaches 58.8 Hz and is arrested by operation of 35MW of load shedding. The plots below outline the system frequency, wind turbine / Bay d'Espoir Unit 5 power output and some key generator rotor angle with respect to Bay d'Espoir Unit 5.





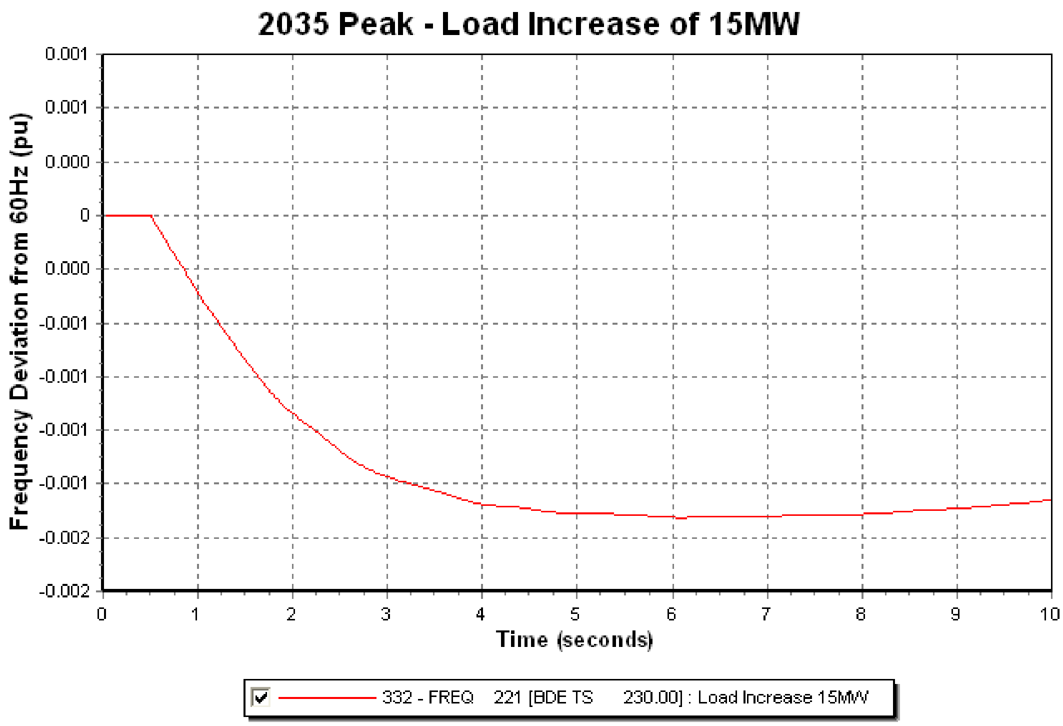
2035 Peak Load - Loss of BDE7 (142MW)
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
Time (seconds)
51 - POWR 220[BDP G2-6 13.800]5 : Loss of BDE7 142MW_B
66 - POWR 1001[DLS WGP1 1.0000]1 : Loss of BDE7 142MW_B

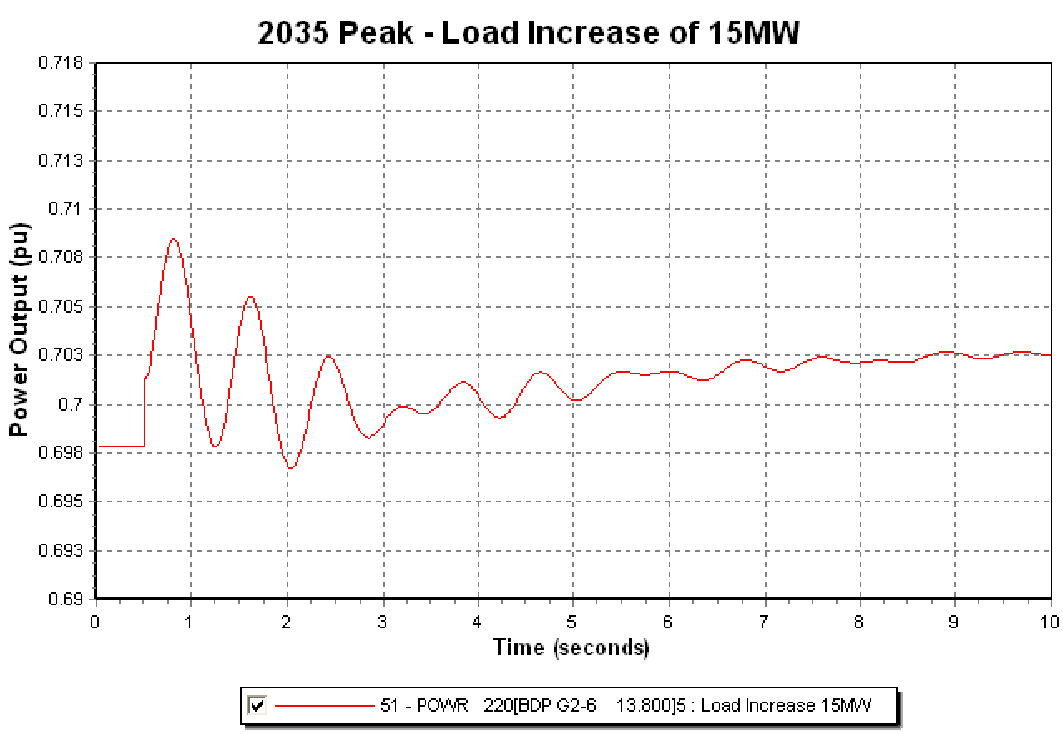


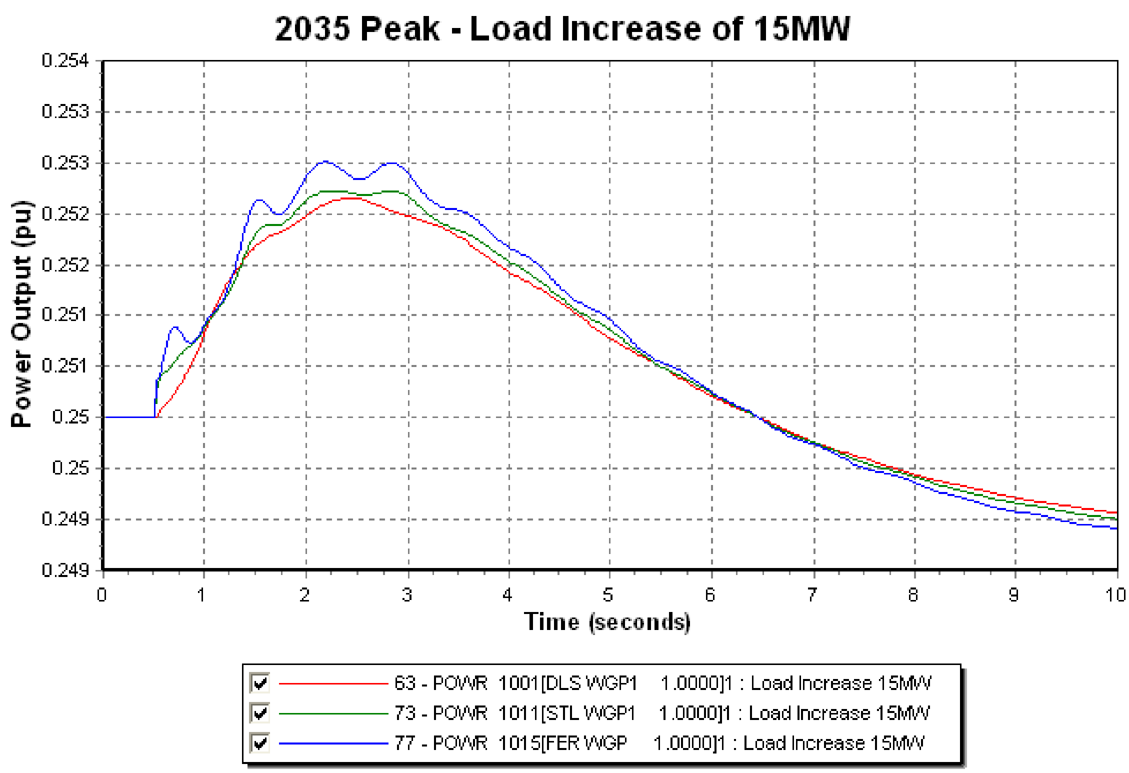
2035 Peak Load - Loss of BDE7 (142MW)
Generator Rotor Angle wrt BDE5 (degrees)
20
10
0
-10
-20
-30
-40
-50
0
2.5
5
7.5
10
12.5
15
17.5
20
22.5
25
Time (seconds)
7 - ANGL 220[BDP G2-6 13.800]5 : Loss of BDE7 142MW_B
2 - ANGL 138[CAT G2 13.800]1 : Loss of BDE7 142MW_B
13 - ANGL 434[HRP G1 16.000]1 : Loss of BDE7 142MW_B

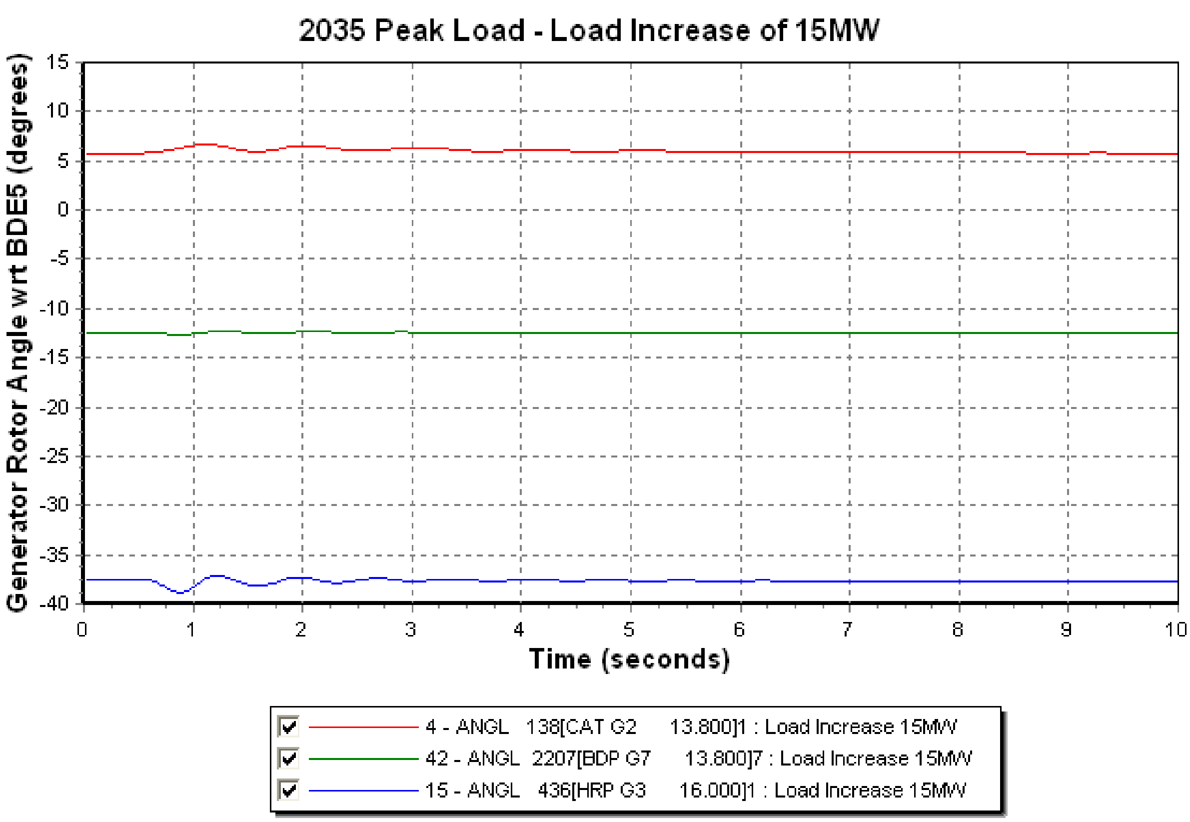
Case 3 – Sudden Load Increase of 15 MW

For this event, system frequency reaches a minimum level 59.9 Hz, which is not close to the first stage under frequency load shedding stage of 59.5 Hz. This load increase has no impact on system operations with respect to wind turbine operation. The plots below outline the system frequency, Bay d'Espoir Unit 5 and some wind turbine power output responses.



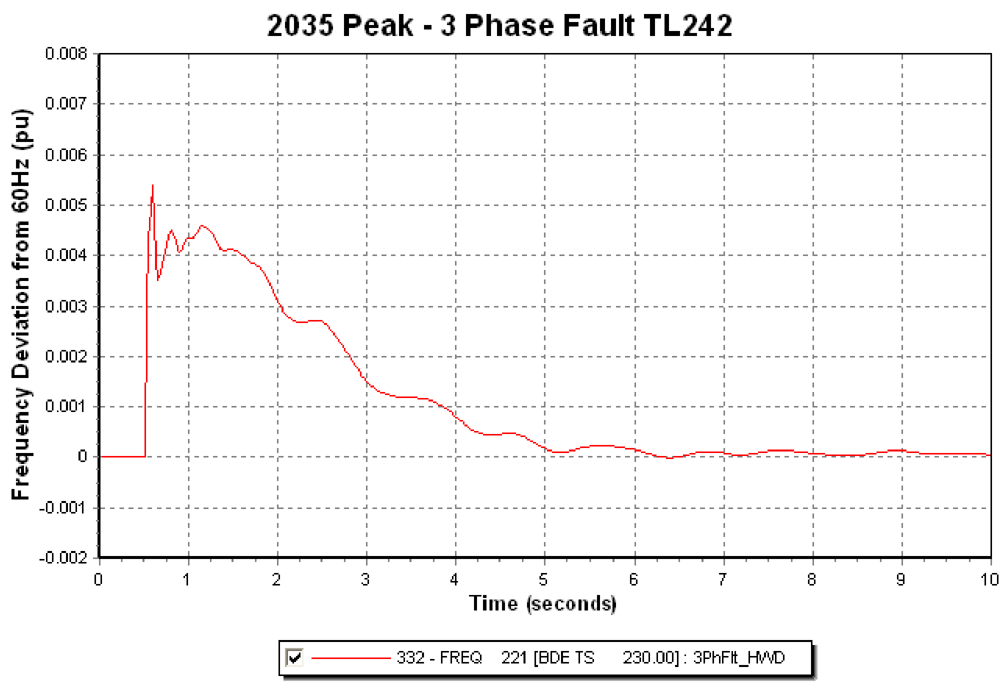


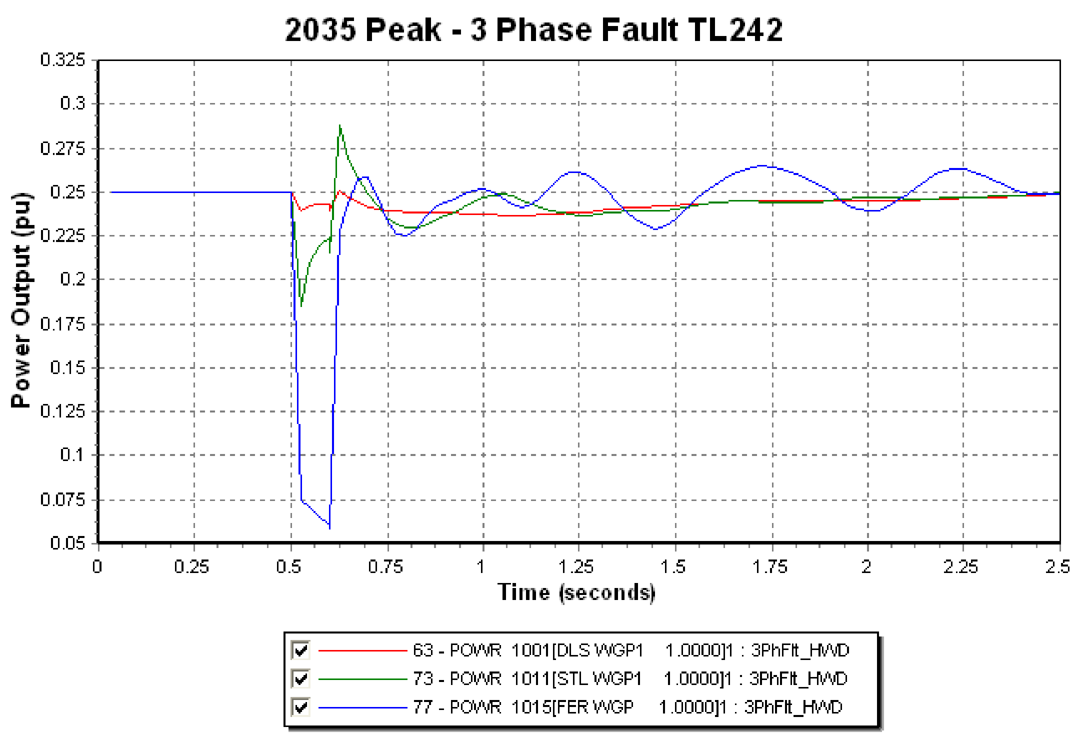

2035 Peak - Load Increase of 15MW
Power Output (pu)
0.254
0.253
0.253
0.252
0.252
0.251
0.251
0.25
0.25
0.249
0.249
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
63 - POWR 1001[DLS WGP1 1.0000]1 : Load Increase 15MW
73 - POWR 1011[STL WGP1 1.0000]1 : Load Increase 15MW
77 - POWR 1015[FER WGP 1.0000]1 : Load Increase 15MW

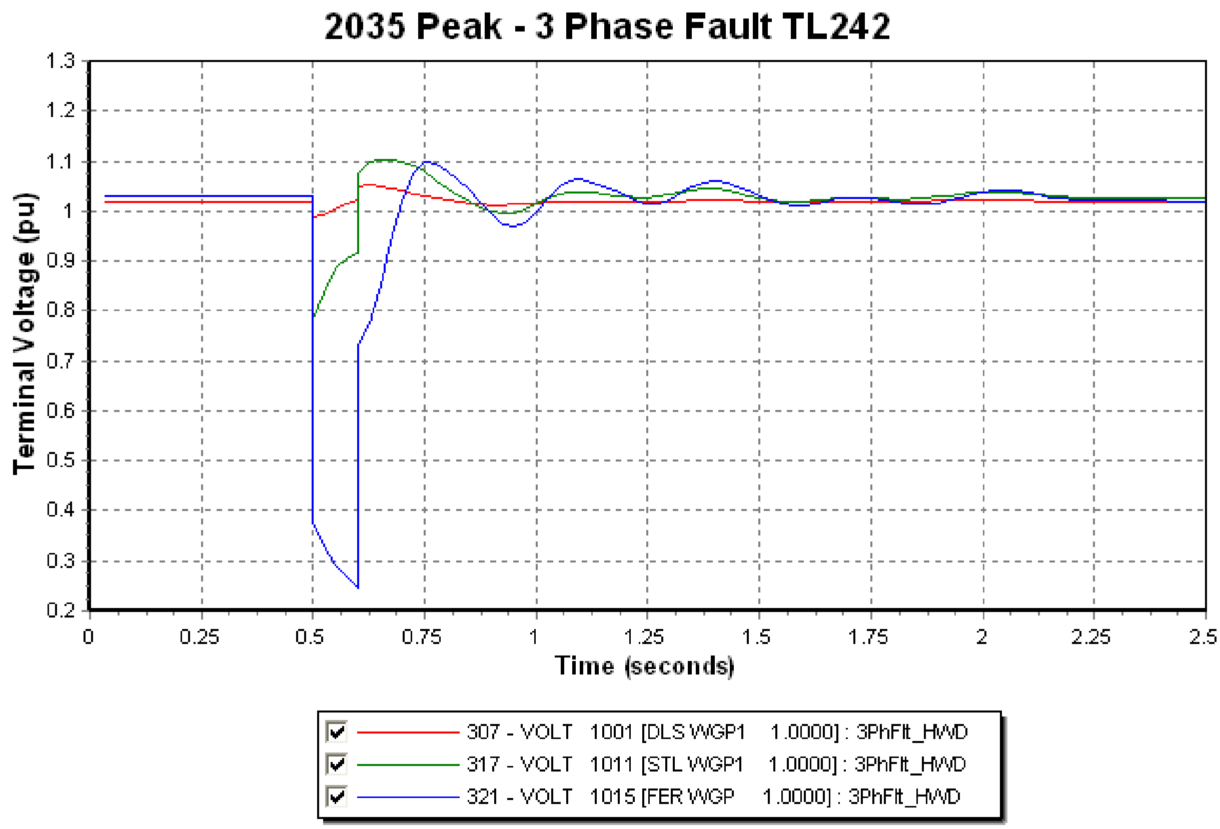

2035 Peak Load - Load Increase of 15MW
Generator Rotor Angle wrt BDE5 (degrees)
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
4 - ANGL 138[CAT G2 13.800]1 : Load Increase 15MW
42 - ANGL 2207[BDP G7 13.800]7 : Load Increase 15MW
15 - ANGL 436[HRP G3 16.000]1 : Load Increase 15MW

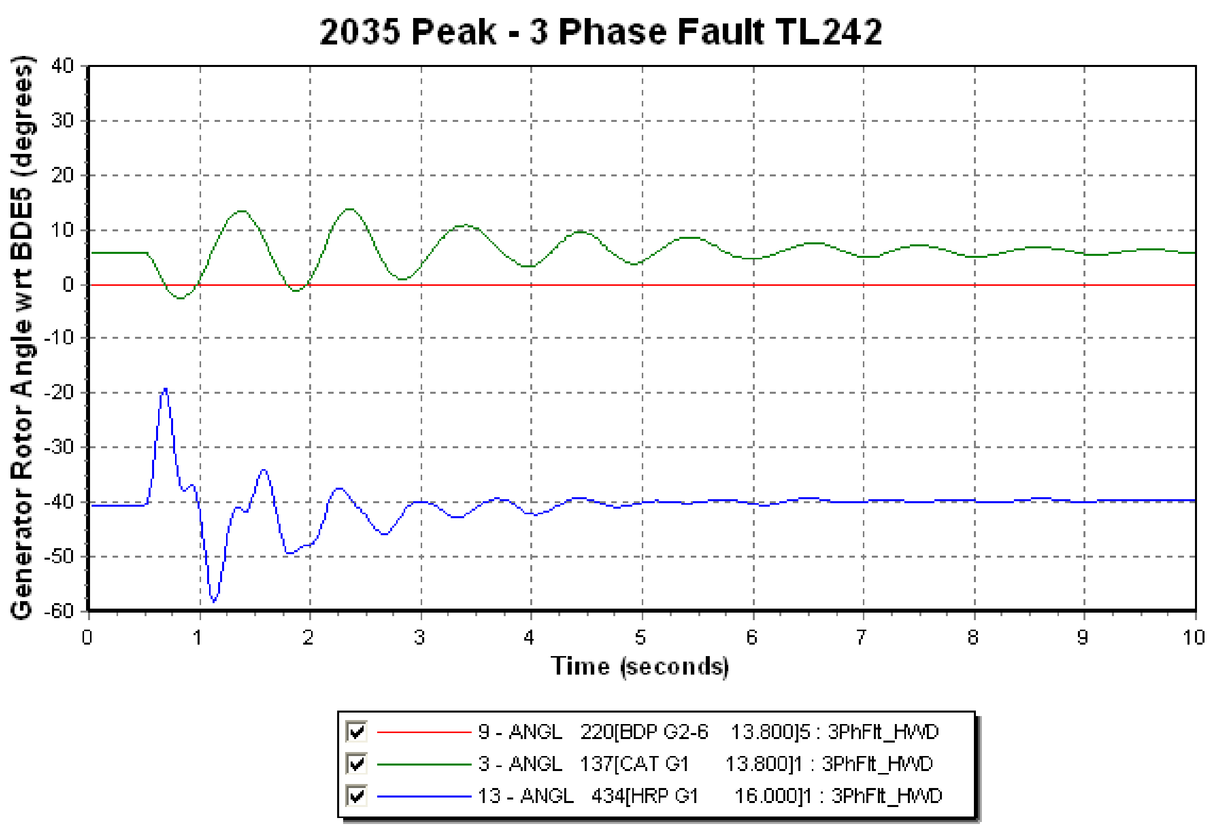
Case 4 – 3 Phase Fault at HWD (6 cycles – Trip TL242)

For this contingency a three phase fault has been applied on TL242 near Hardwoods terminal station for 6 cycles, followed by the tripping of TL242 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



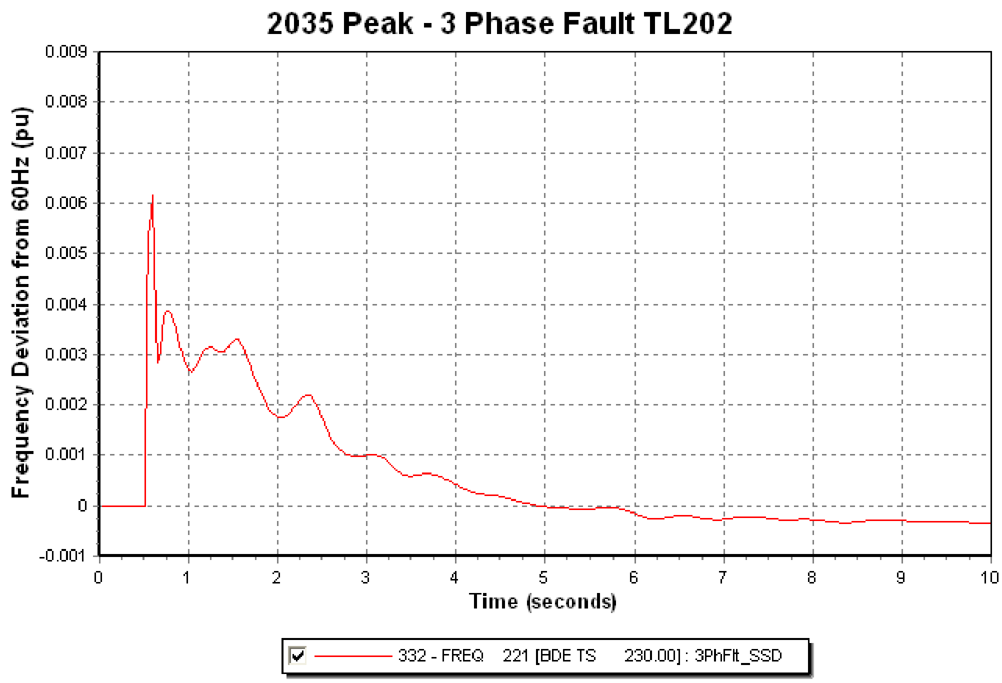


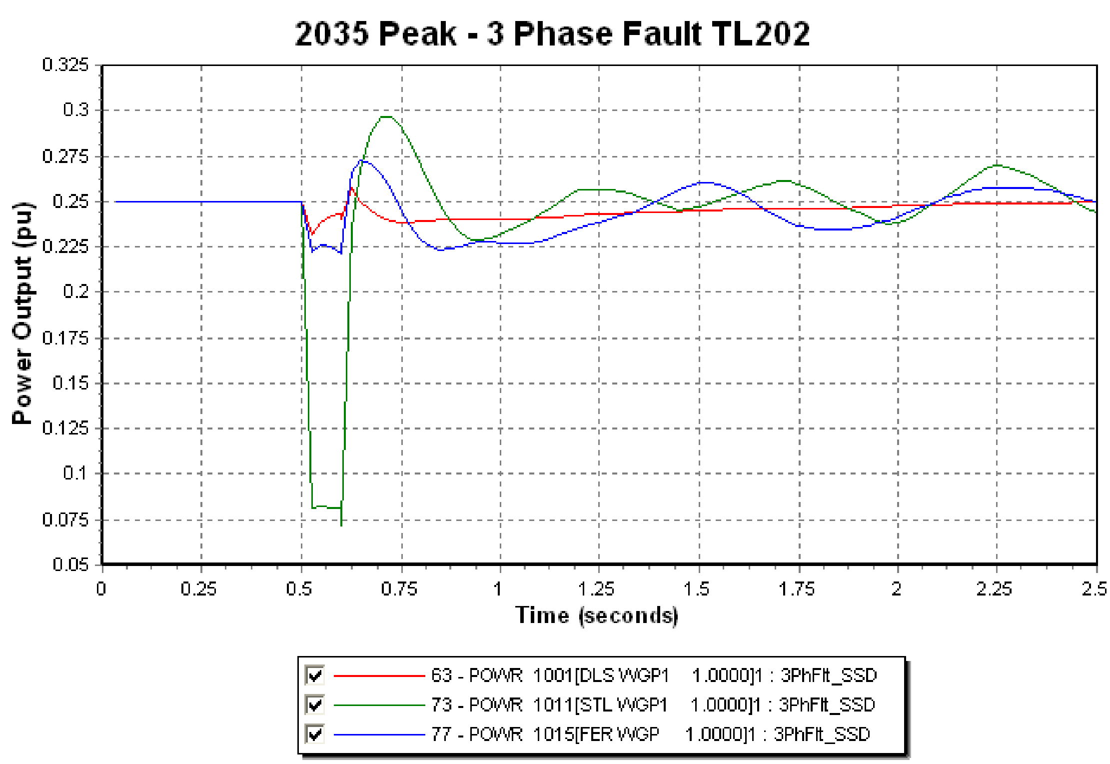

2035 Peak - 3 Phase Fault TL242
Terminal Voltage (pu)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
307 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_HWD
317 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_HWD
321 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_HWD

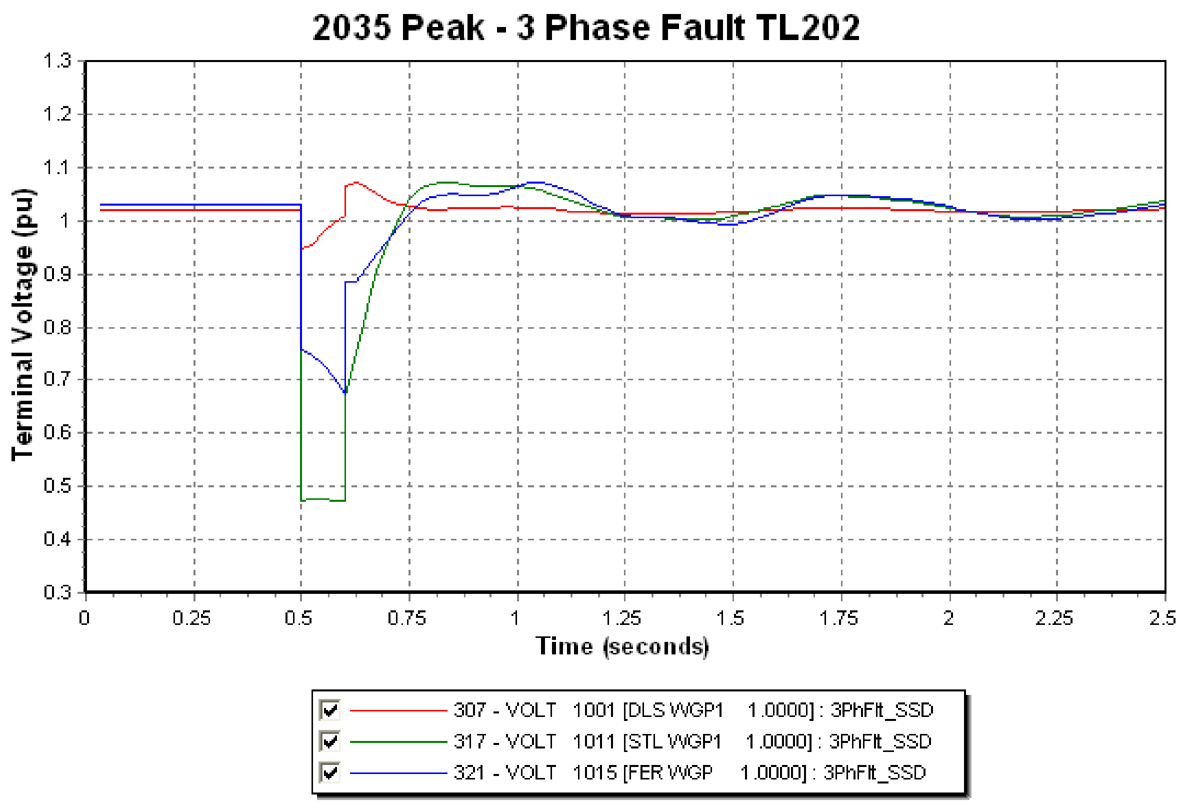

2035 Peak - 3 Phase Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
40
30
20
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
7
8
9
10
Time (seconds)
9 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_HWD
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_HWD
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_HWD

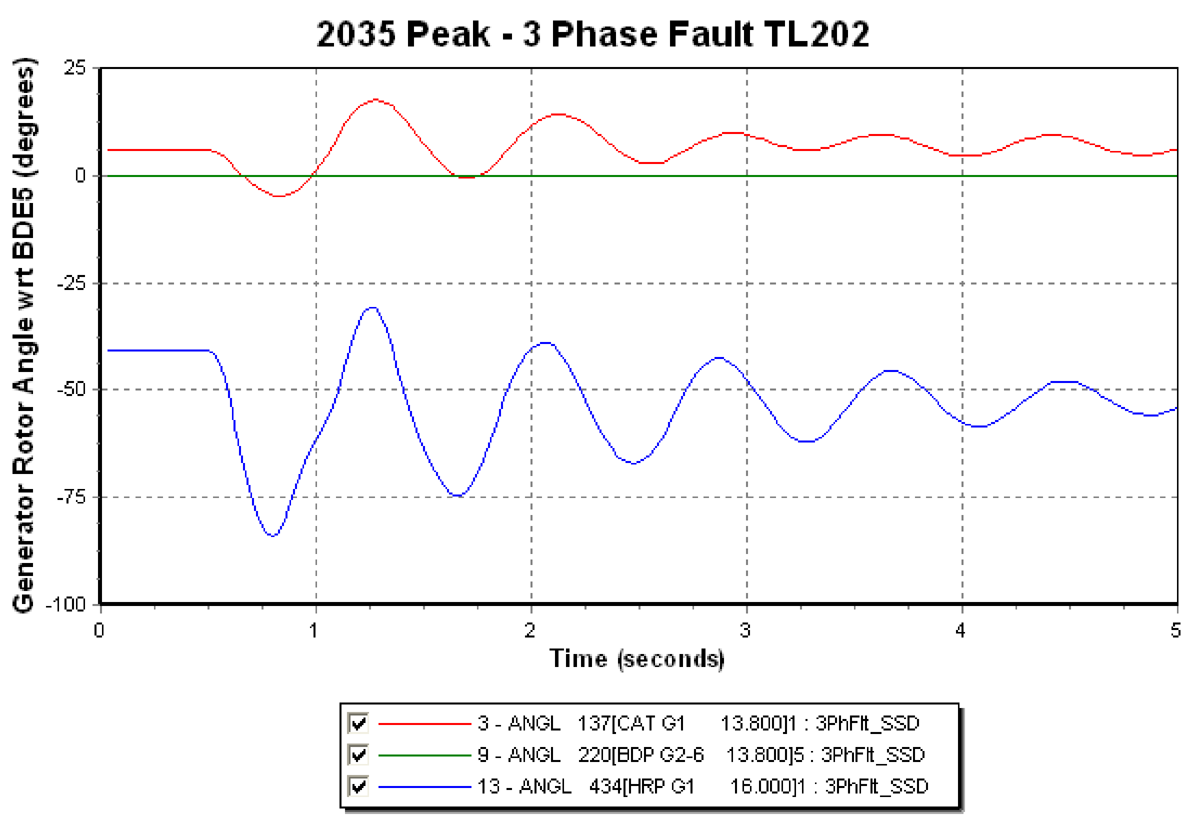
Case 5 – 3 Phase Fault at SSD (6 cycles – Trip TL202)

For this contingency a three phase fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the tripping of TL202 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



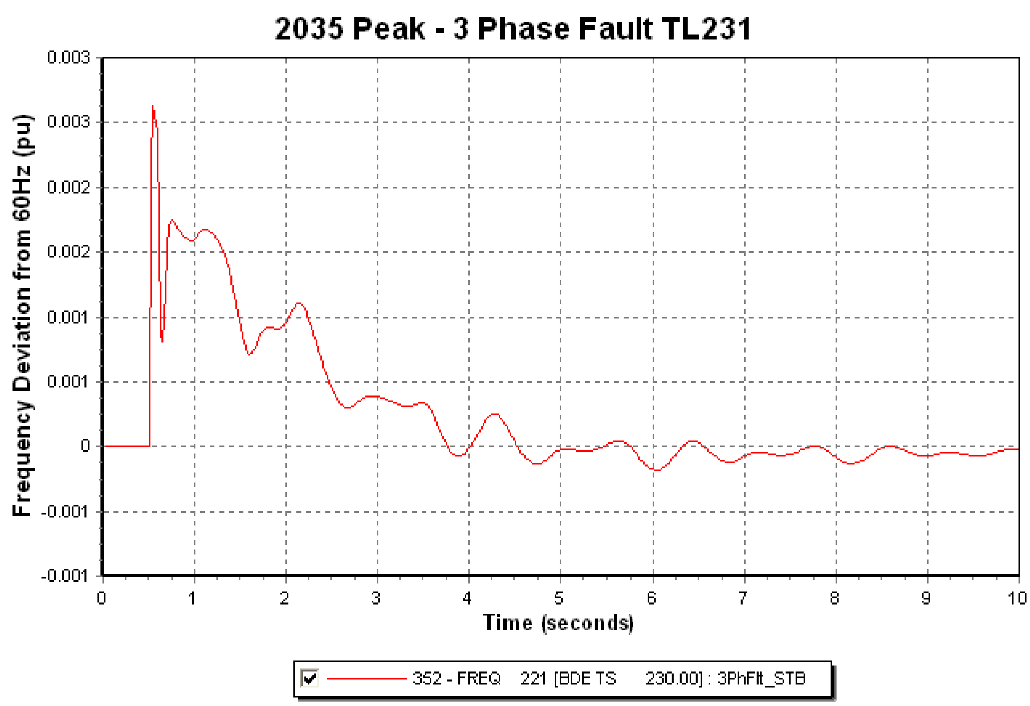


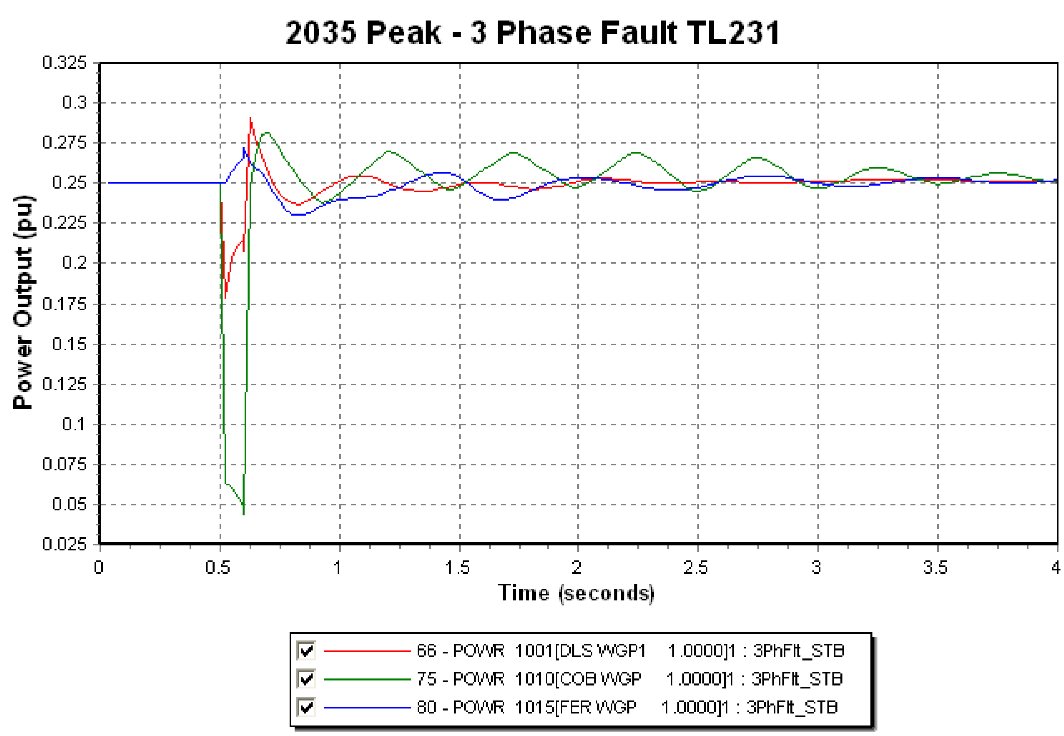

2035 Peak - 3 Phase Fault TL202
Terminal Voltage (pu)
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
307 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_SSD
317 - VOLT 1011 [STL WGP1 1.0000] : 3PhFlt_SSD
321 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_SSD

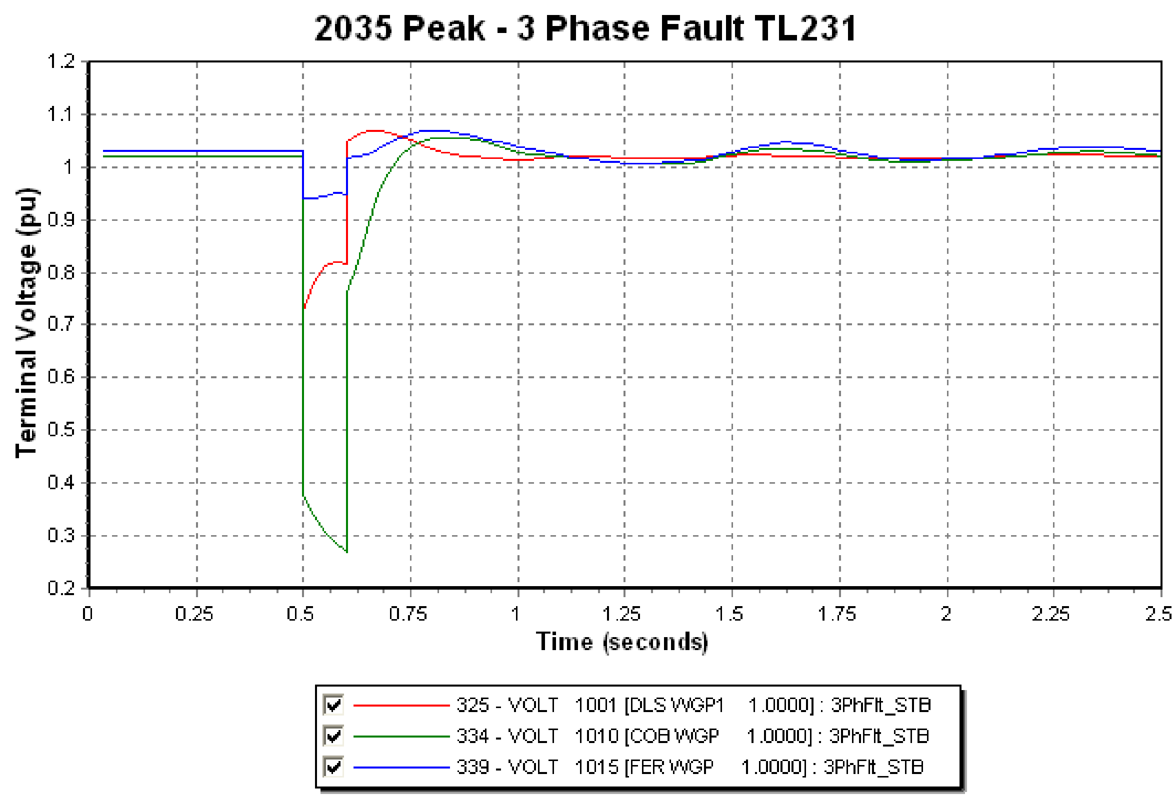

2035 Peak - 3 Phase Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
25
0
-25
-50
-75
-100
0
1
2
3
4
5
Time (seconds)
3 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_SSD
9 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_SSD
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_SSD

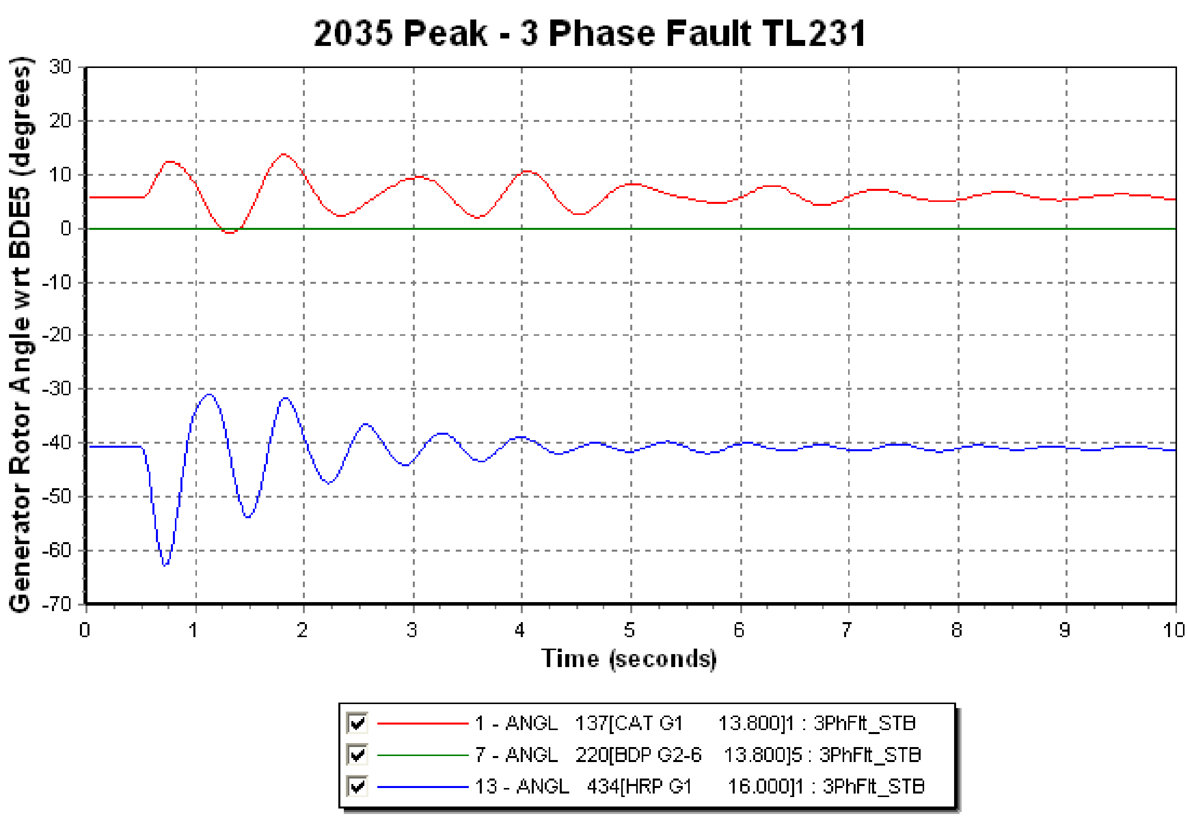
Case 6 – 3 Phase Fault at STB (6 cycles – Trip TL231)

For this contingency a three phase fault has been applied on TL231 near Stony Brook terminal station for 6 cycles, followed by the tripping of TL231 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power output and voltage at terminals of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



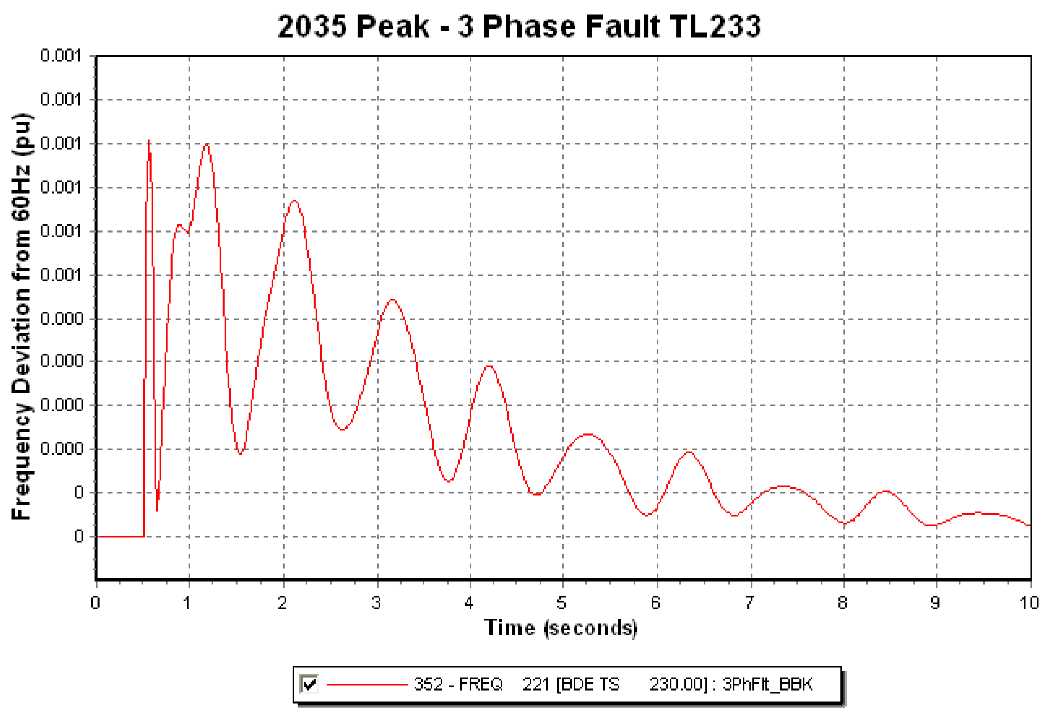


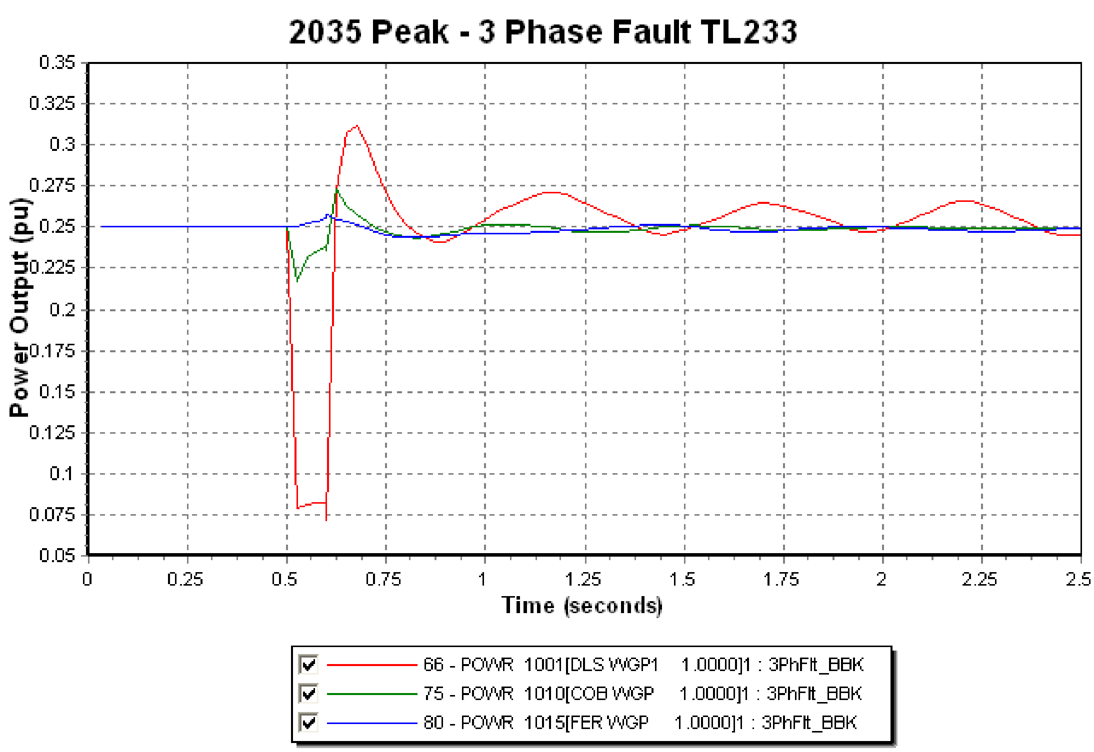

2035 Peak - 3 Phase Fault TL231
Terminal Voltage (pu)
Time (seconds)
325 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_STB
334 - VOLT 1010 [COB WGP 1.0000] : 3PhFlt_STB
339 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_STB

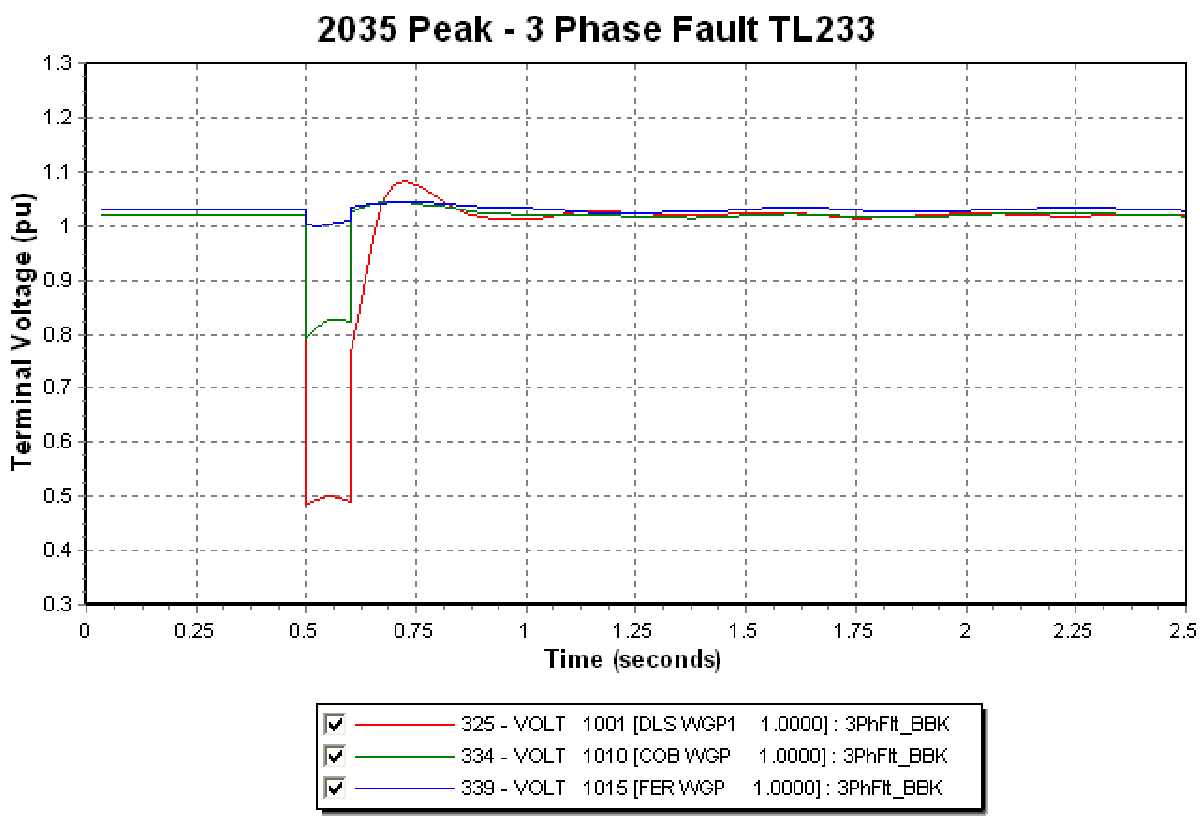

2035 Peak - 3 Phase Fault TL231
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_STB
7 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_STB
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_STB

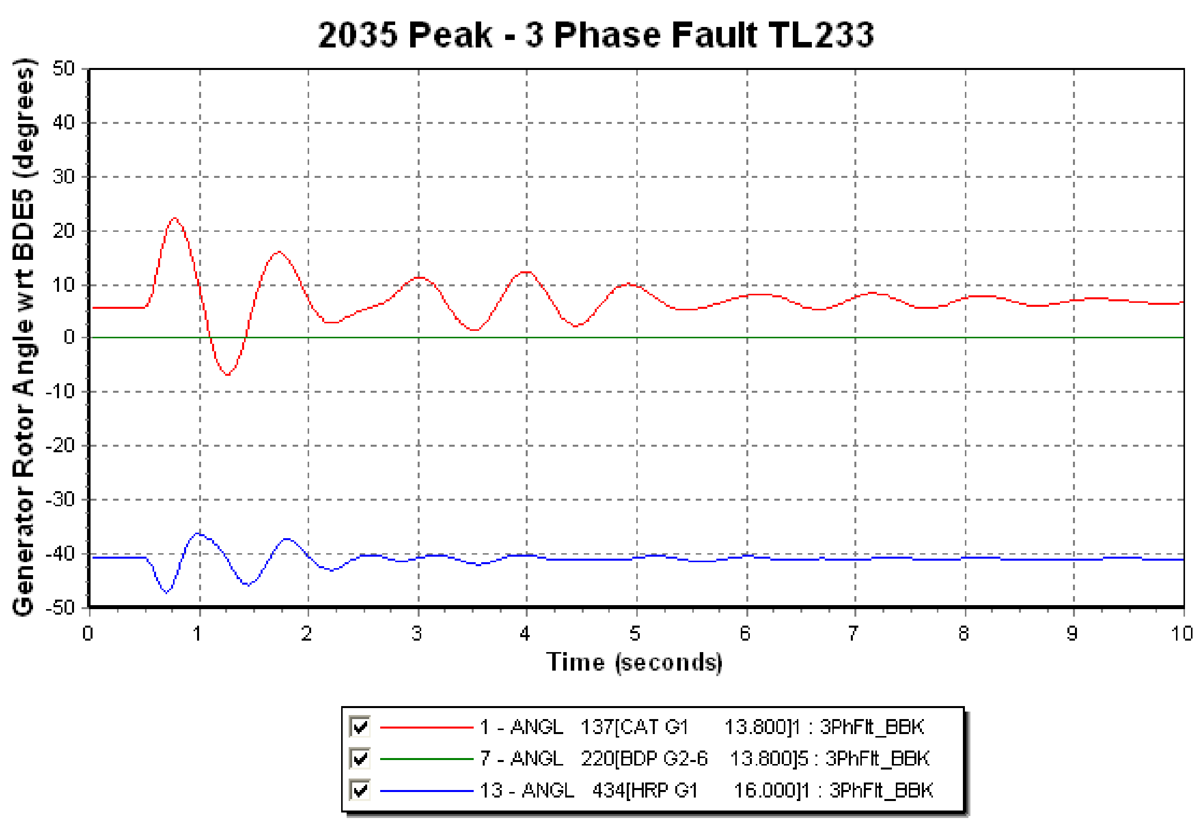
Case 7 – 3 Phase Fault at BBK (6 cycles – Trip TL233)

For this contingency a three phase fault has been applied on TL233 near Bottom Brook terminal station for 6 cycles, followed by the tripping of TL233 to isolate the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power and terminal voltage of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



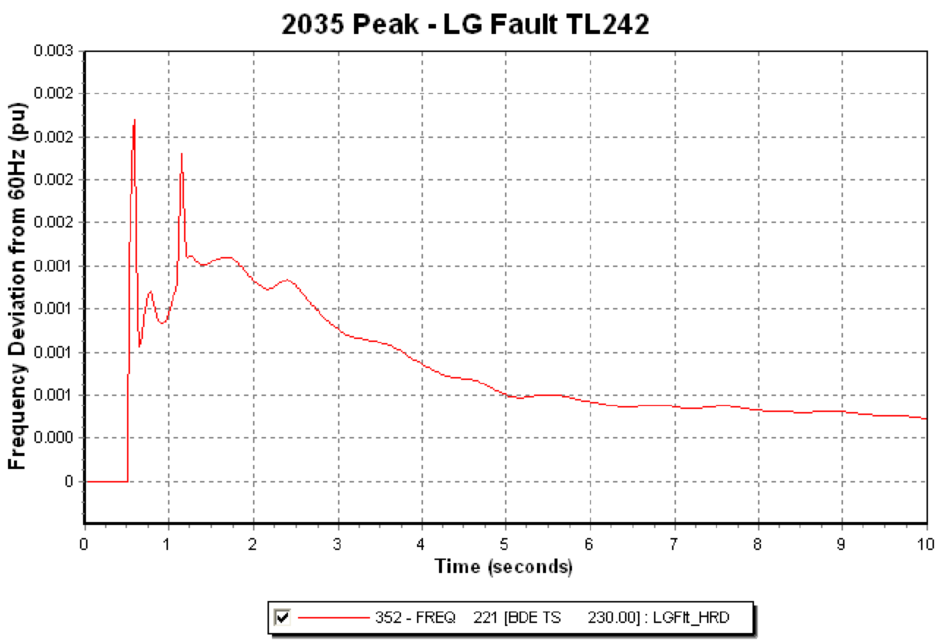


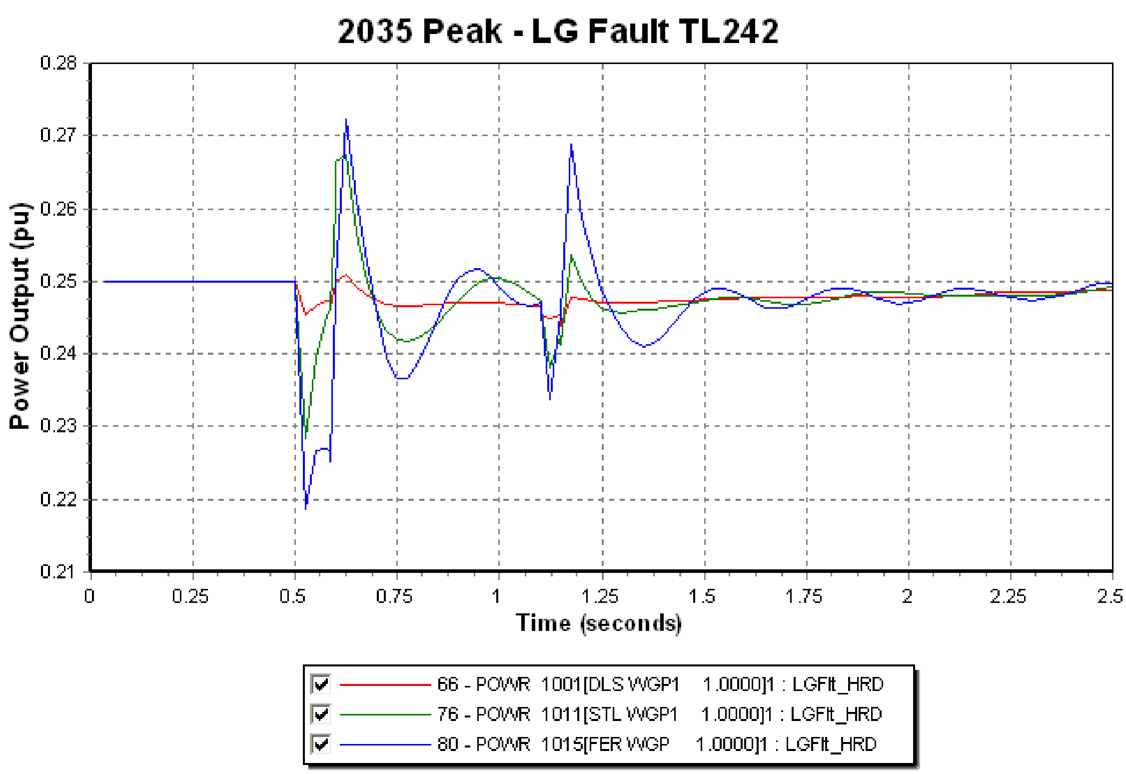

2035 Peak - 3 Phase Fault TL233
Terminal Voltage (pu)
Time (seconds)
325 - VOLT 1001 [DLS WGP1 1.0000] : 3PhFlt_BBK
334 - VOLT 1010 [COB WGP 1.0000] : 3PhFlt_BBK
339 - VOLT 1015 [FER WGP 1.0000] : 3PhFlt_BBK

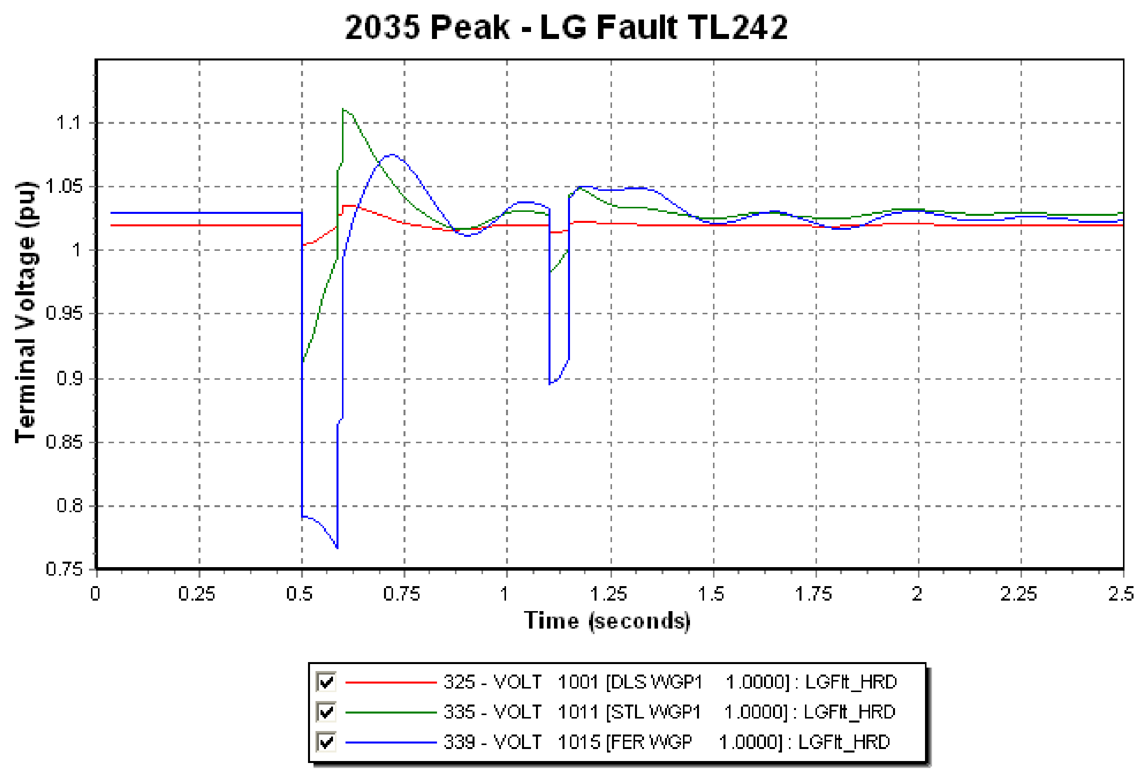

2035 Peak - 3 Phase Fault TL233
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : 3PhFlt_BBK
7 - ANGL 220[BDP G2-6 13.800]5 : 3PhFlt_BBK
13 - ANGL 434[HRP G1 16.000]1 : 3PhFlt_BBK

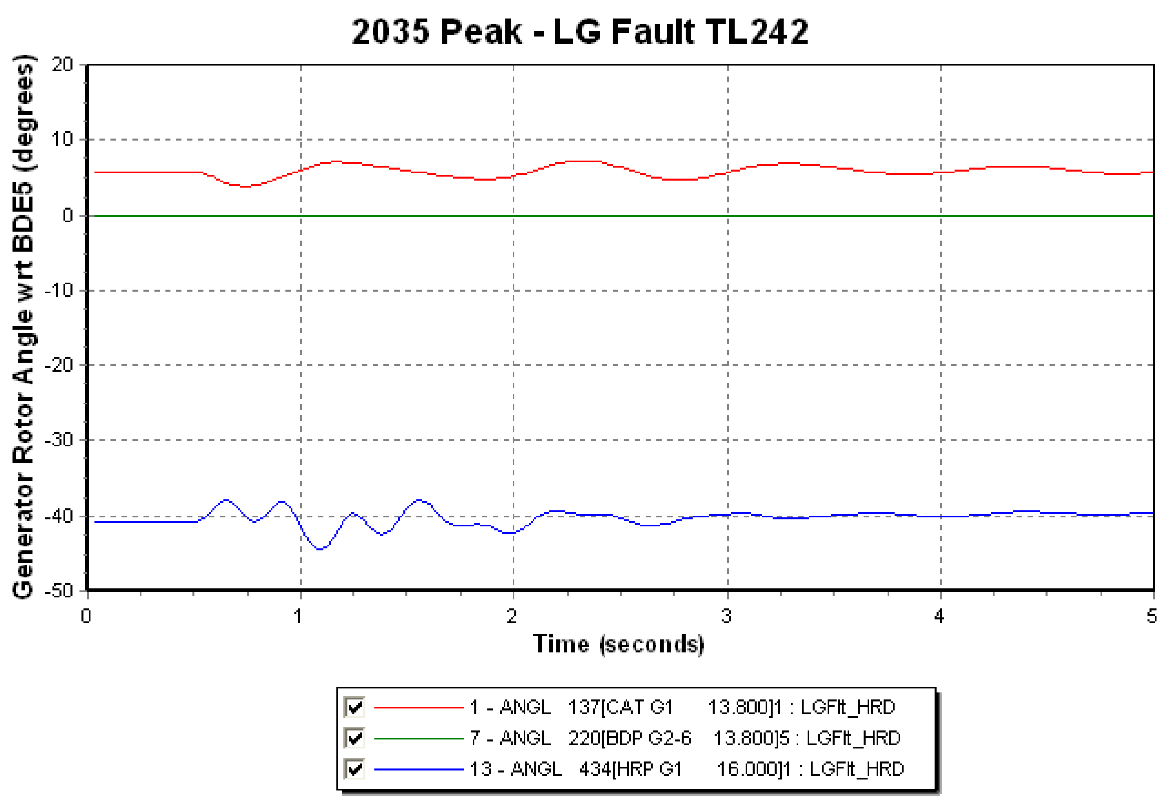
Case 8 – LG Fault at TL242 Near HRD

For this contingency a line to ground fault has been applied on TL242 near Holyrood Generating station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL242 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power and terminal voltage of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.



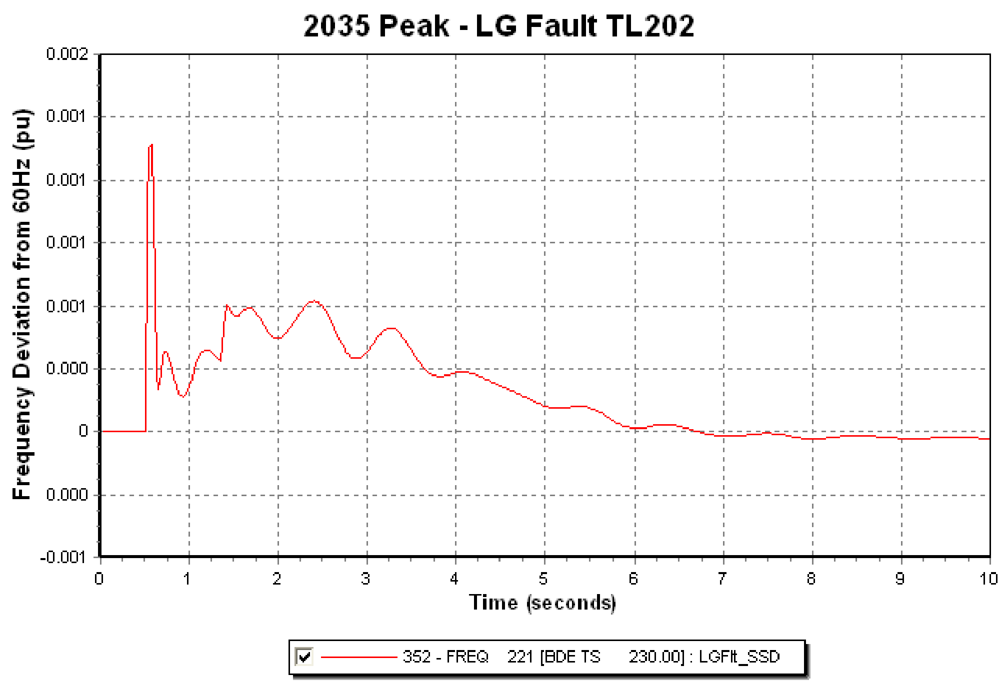


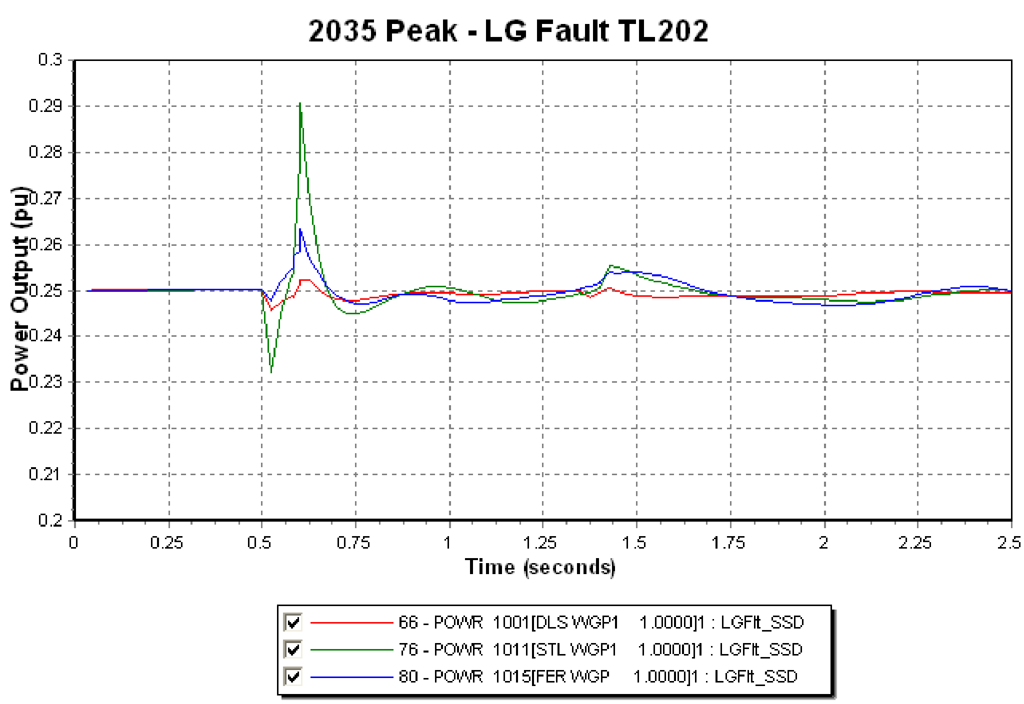

2035 Peak - LG Fault TL242
Terminal Voltage (pu)
Time (seconds)
325 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_HRD
335 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_HRD
339 - VOLT 1015 [FER WGP 1.0000] : LGFlt_HRD

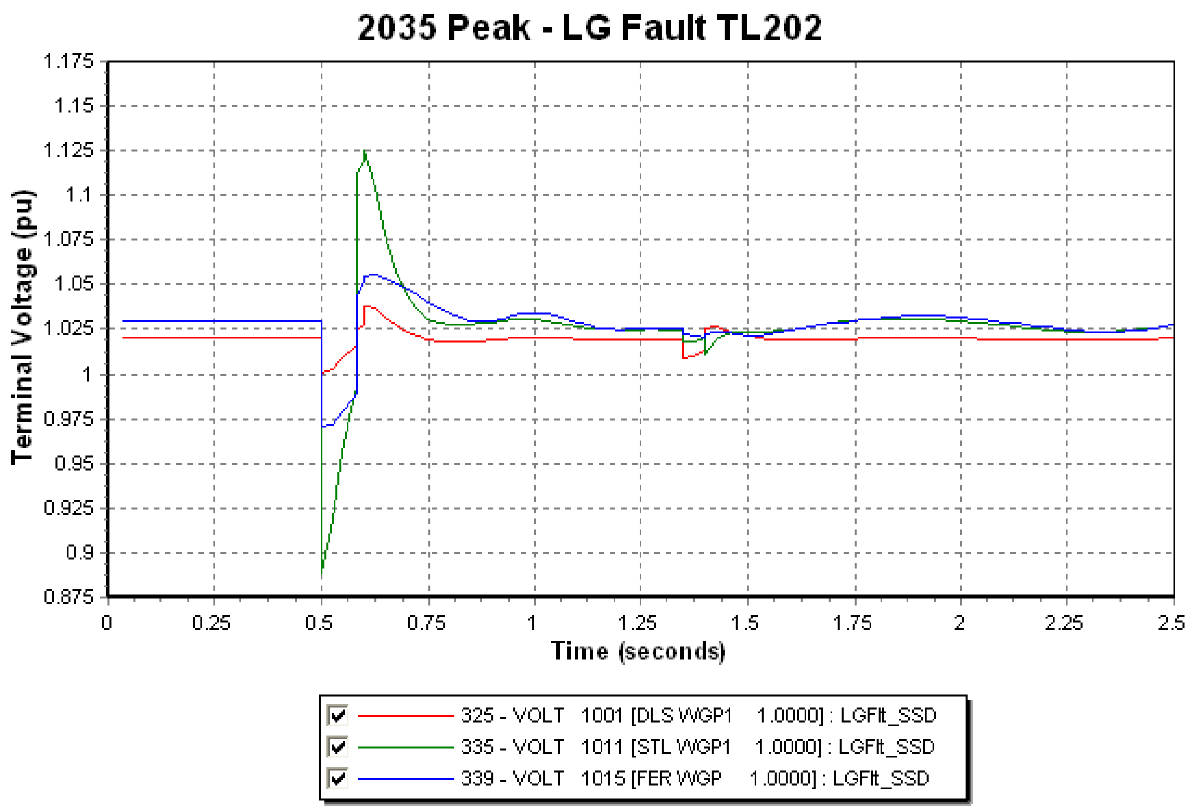

2035 Peak - LG Fault TL242
Generator Rotor Angle wrt BDE5 (degrees)
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : LGFlt_HRD
7 - ANGL 220[BDP G2-6 13.800]5 : LGFlt_HRD
13 - ANGL 434[HRP G1 16.000]1 : LGFlt_HRD

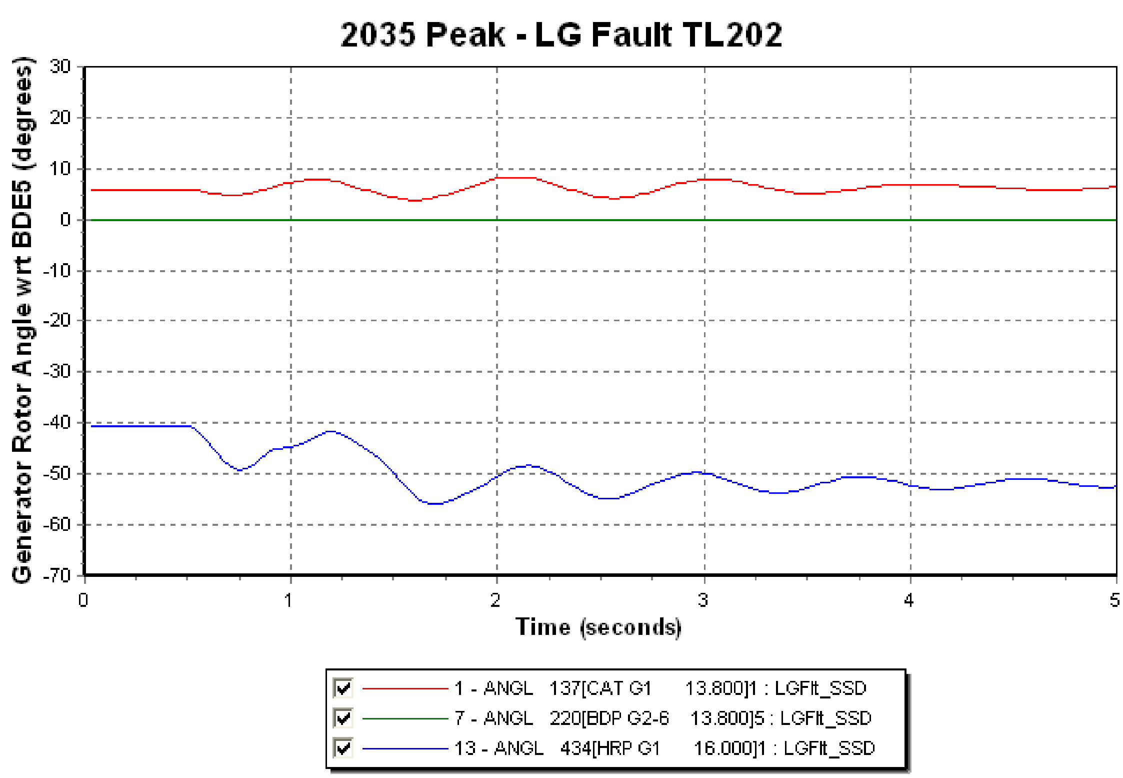
Case 9 – LG Fault at TL202 Near SSD

For this contingency a line to ground fault has been applied on TL202 near Sunnyside terminal station for 6 cycles, followed by the single phase, then an unsuccessful reclose after 30 seconds. All 3 phases of TL202 are finally tripped after the unsuccessful clearing of the fault. The results indicate that the system maintains synchronism and all wind turbines ride through the under voltage disturbance. The plots below show the system frequency, wind turbine power and terminal voltage of 3 wind turbines and select generator rotor angles relative to Bay d'Epoir Unit #5. The LVRT capability of the wind turbines enable them to ride through the fault condition.





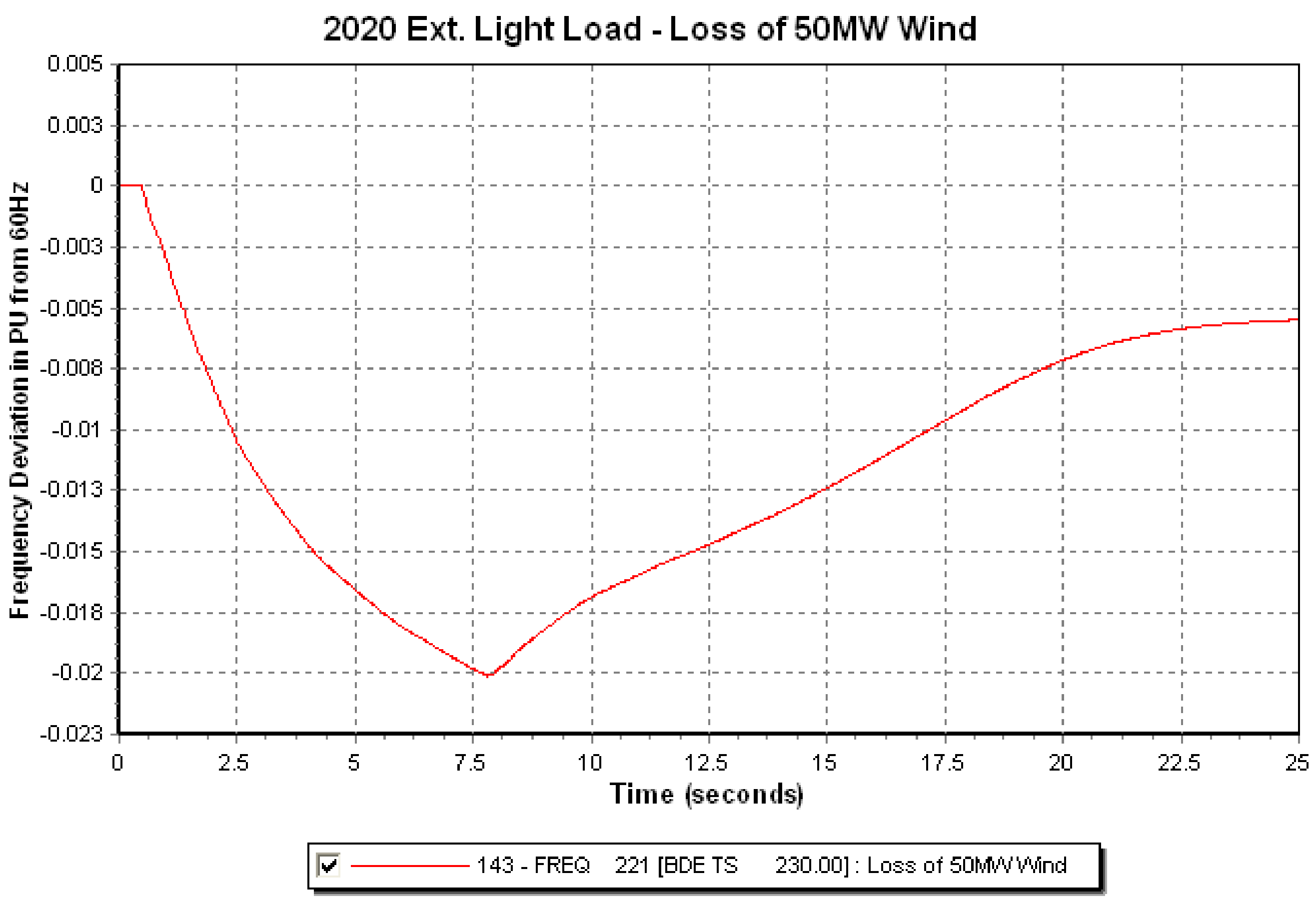

2035 Peak - LG Fault TL202
Terminal Voltage (pu)
1.175
1.15
1.125
1.1
1.075
1.05
1.025
1
0.975
0.95
0.925
0.9
0.875
0
0.25
0.5
0.75
1
1.25
1.5
1.75
2
2.25
2.5
Time (seconds)
325 - VOLT 1001 [DLS WGP1 1.0000] : LGFlt_SSD
335 - VOLT 1011 [STL WGP1 1.0000] : LGFlt_SSD
339 - VOLT 1015 [FER WGP 1.0000] : LGFlt_SSD


2035 Peak - LG Fault TL202
Generator Rotor Angle wrt BDE5 (degrees)
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
0
1
2
3
4
5
Time (seconds)
1 - ANGL 137[CAT G1 13.800]1 : LGFlt_SSD
7 - ANGL 220[BDP G2-6 13.800]5 : LGFlt_SSD
13 - ANGL 434[HRP G1 16.000]1 : LGFlt_SSD

APPENDIX L – LOSS OF MULTIPLE WIND FARMS

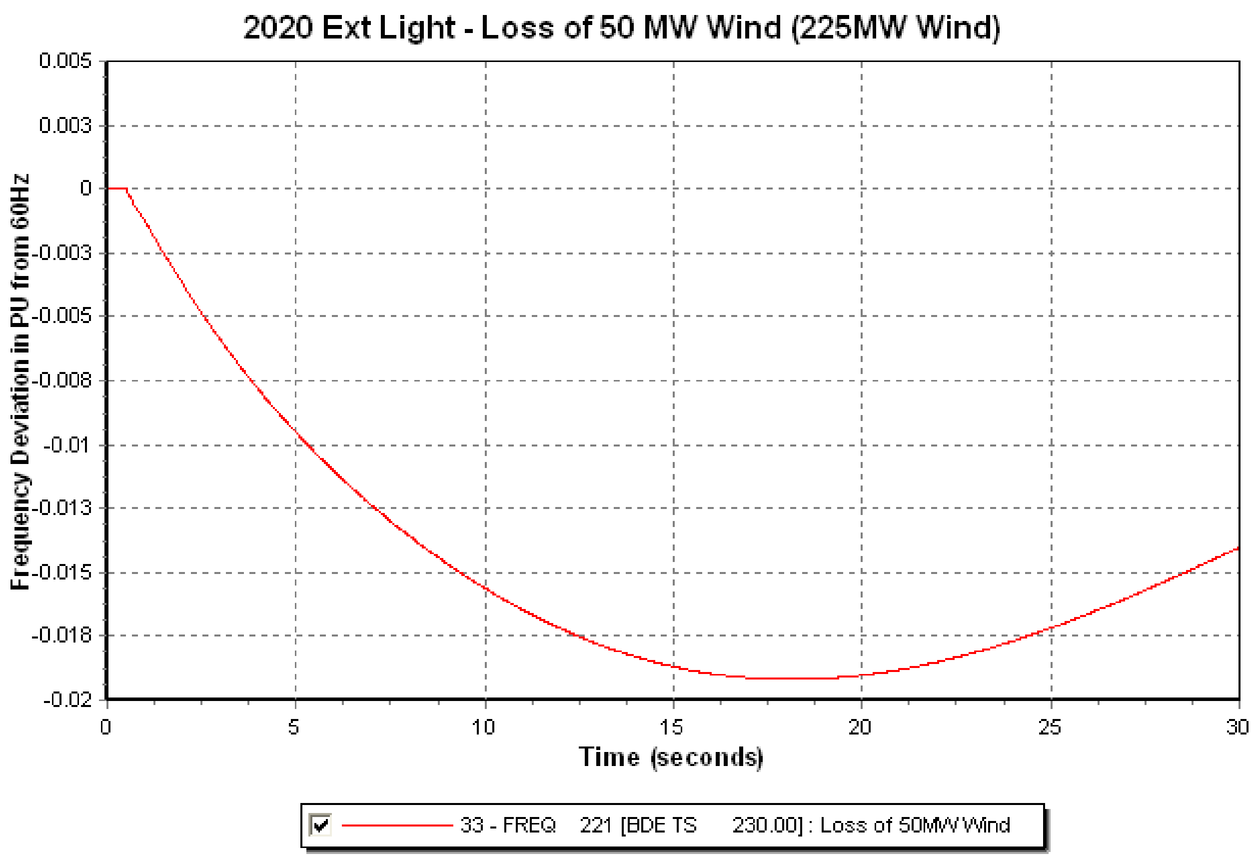
Case 1 – Loss of Two 25MW Wind Farms

This event causes an under frequency condition that reaches a minimum of 58.79Hz. The frequency decline is arrested as a result of 9MW of load shedding due to the 58.8Hz under frequency load shed protection scheme. The following plot shows system frequency response over a 25 second time period.



Case 2 – Loss of Two 25MW Wind Farms with Added Inertia

This event causes an under frequency condition that reaches a minimum of 58.79Hz. The frequency decline is arrested as a result of 9MW of load shedding due to the 58.8Hz under frequency load shed protection scheme. The following plot shows system frequency response over a 25 second time period.



Case 3 – Loss of Three 25MW Wind Farms with Added Inertia

This event causes an under frequency condition that reaches a minimum of 58.79Hz. The frequency decline is arrested as a result of 9MW of load shedding due to the 58.8Hz under frequency load shed protection scheme. The following plot shows system frequency response over a 25 second time period.