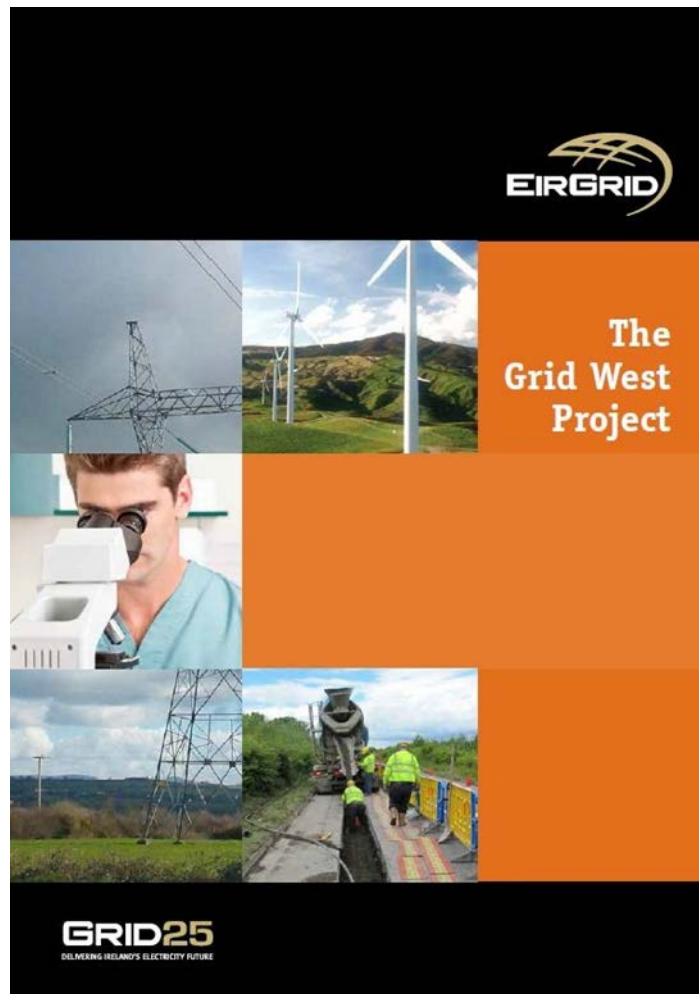


EirGrid

10344 - PSP019 - CABLE STUDIES FOR GRID WEST

Partial AC Underground Solution



**PSP019 - APPENDIX C1 – 99.7 KM, 220 KV CABLE OPTION
WPA/SVB STUDIES**

17th December 2014

REPORT AUTHORISATION SHEET

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Prepared by:

Name: Christopher Ellis
Position: Senior Consultant
Date: 17th December 2014

Name: Amarjit Jhutti
Position: Managing Director
Date: 17th December 2014

Authorised for issue:

Name: Johan Stalmans
Position: Managing Director
Date: 17th December 2014

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1 RESULTS – WINTER PEAK A

Impedance scans and time domain simulations for a 99.7 km of 220 kV cable with sized reactors at both Flagford and North Mayo. The Grid West circuit will consist of this 99.7 km 220 kV cable and a further 10.8 km OHL to complete the entire 110.5 km route.

This appendix presents the results for Winter Peak A generation / demand profile. It will cover the 220 kV 99.7 km cable option with the circuit incorporating 99.7 km of UGC and 10.8 km of OHL. This case has failed due to a high resonance point below the 3rd harmonic of above 1000 Ohms and has also failed due to TOVs exceeding the allowable limits.¹

1.1 Impedance Scans - Length 99.7 km cable / 10.8 km OHL - Winter Peak A – Case 1

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

¹ For the purposes of clarity , in the Time Domain Simulations shown in all the Appendices, the term ‘N-2’ shown in the graphical figure descriptions refer to an ‘N-1-1’ trip-maintenance situation.

Case 1: (N) Normal Operating Condition

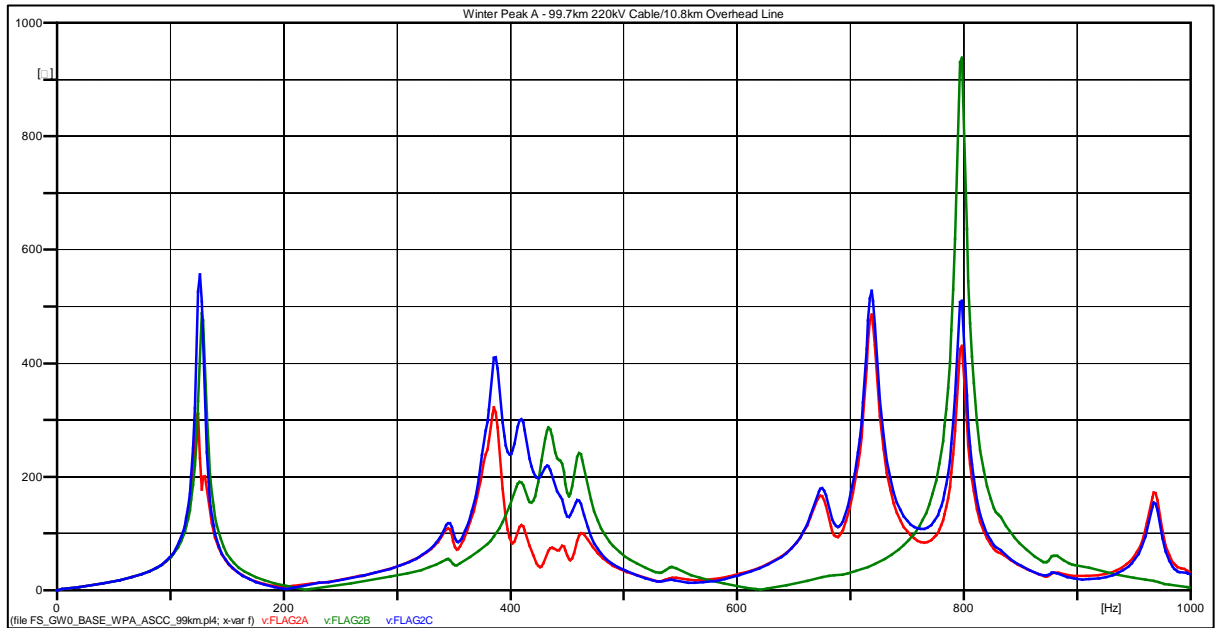


Figure 1: WPA - Length 99.7 km cable / 10.8 km OHL - All lines in service

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
126.01	555.98
387.01	410.56
718.51	527.61
798.01	937.85
969.01	152.34

1.2 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 1

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 1: Energisation of the 220 kV 99.7 km cable from Flagford

System Conditions:

1. Energisation of the cable from Flagford (North Mayo disconnected).
2. Circuit breaker closes at a point on wave of 90° .

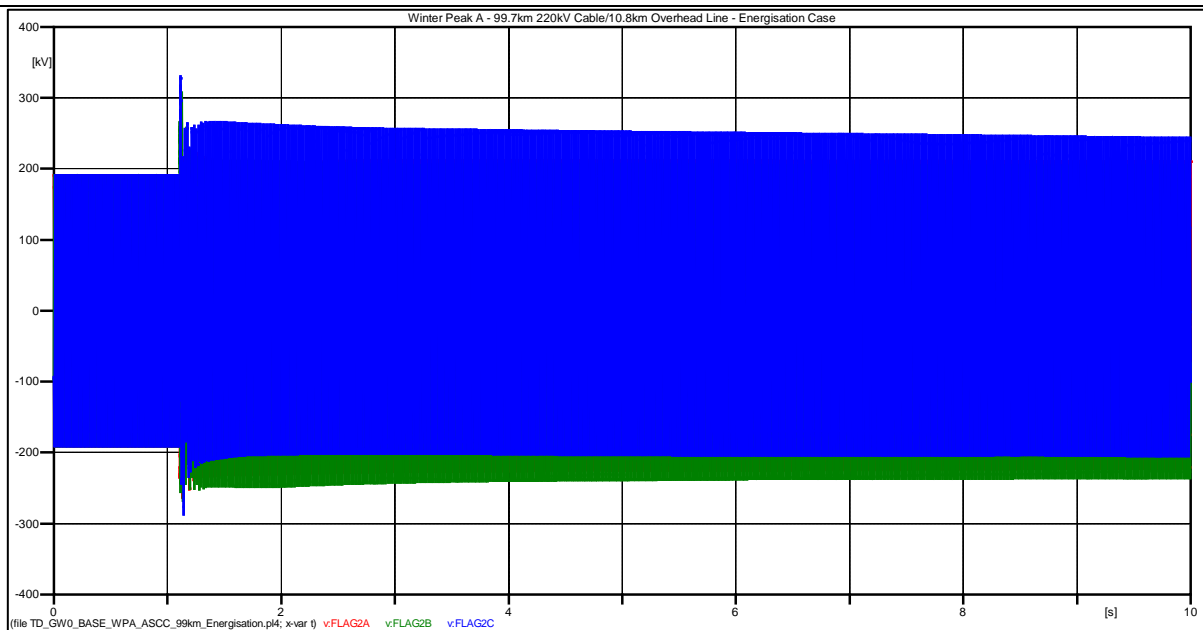


Figure 2: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – Energisation of the cable from Flagford with North Mayo disconnected (0-10s)

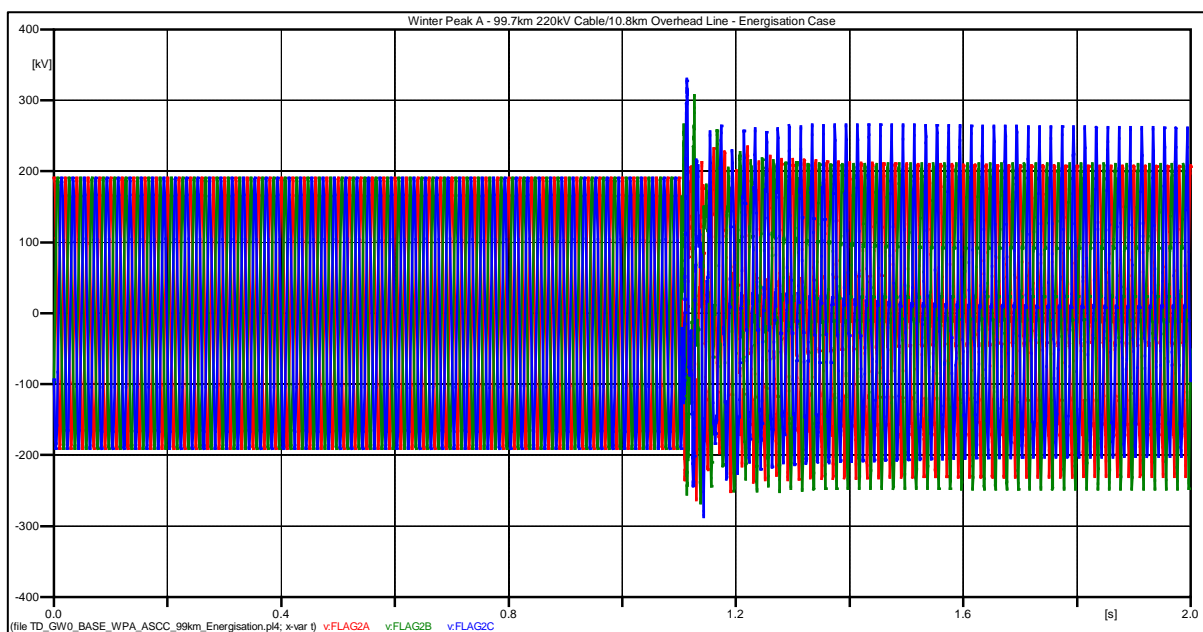


Figure 3: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – Energisation of the cable from Flagford with North Mayo disconnected (0-2s)

Condition	Maximum Value	Limit	Result
Switching	321.89 kV (1.792pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	265.23kV (1.476pu)	287.32 kV(1.6pu)	Pass

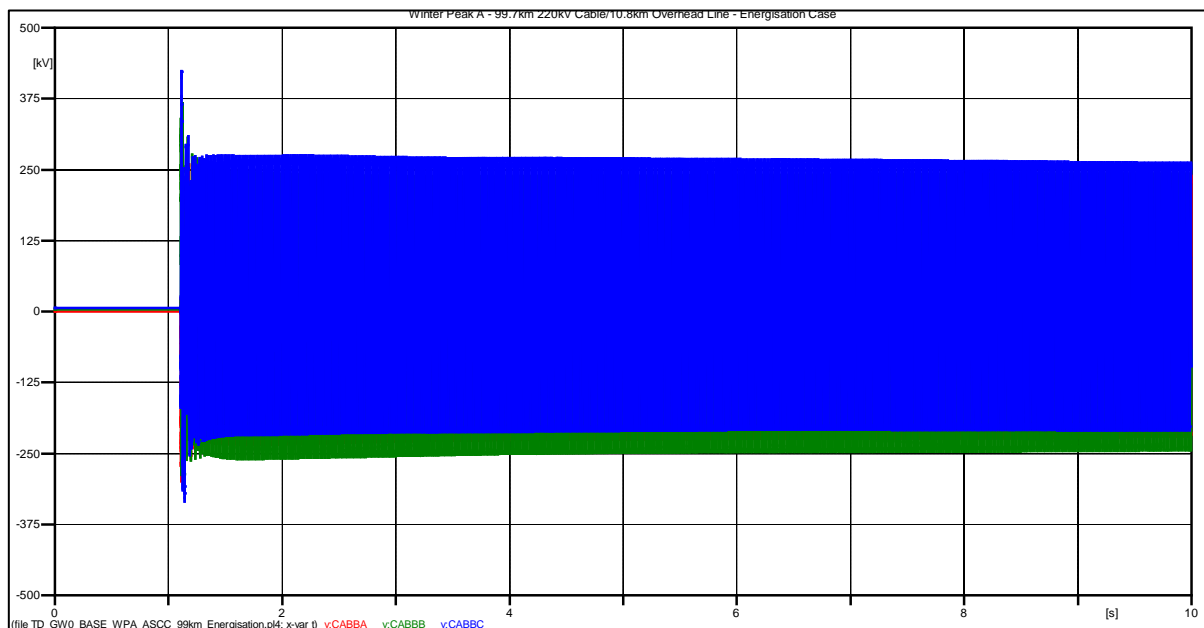


Figure 4: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End – (N-2) – Energisation of the cable from Flagford with North Mayo disconnected (0-10s)

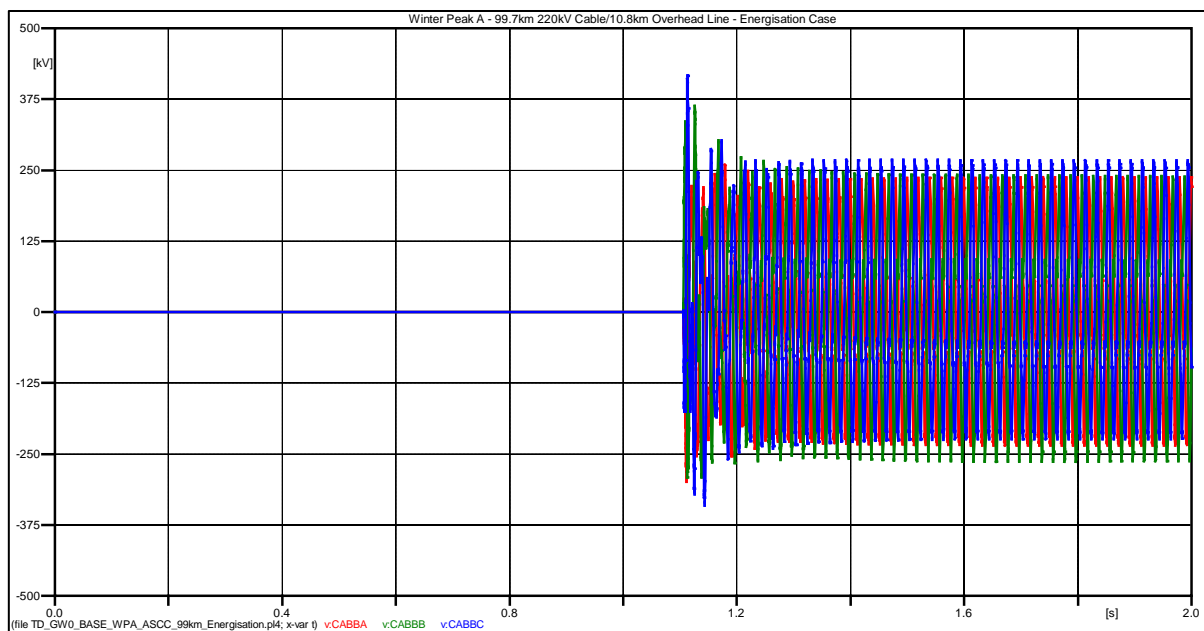


Figure 5: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End – (N-2) – Energisation of the cable from Flagford with North Mayo disconnected (0-2s)

Condition	Maximum Value	Limit	Result
Switching	390.23 kV (2.173 pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	260.59 kV (1.451 pu)	287.32 kV (1.6pu)	Pass

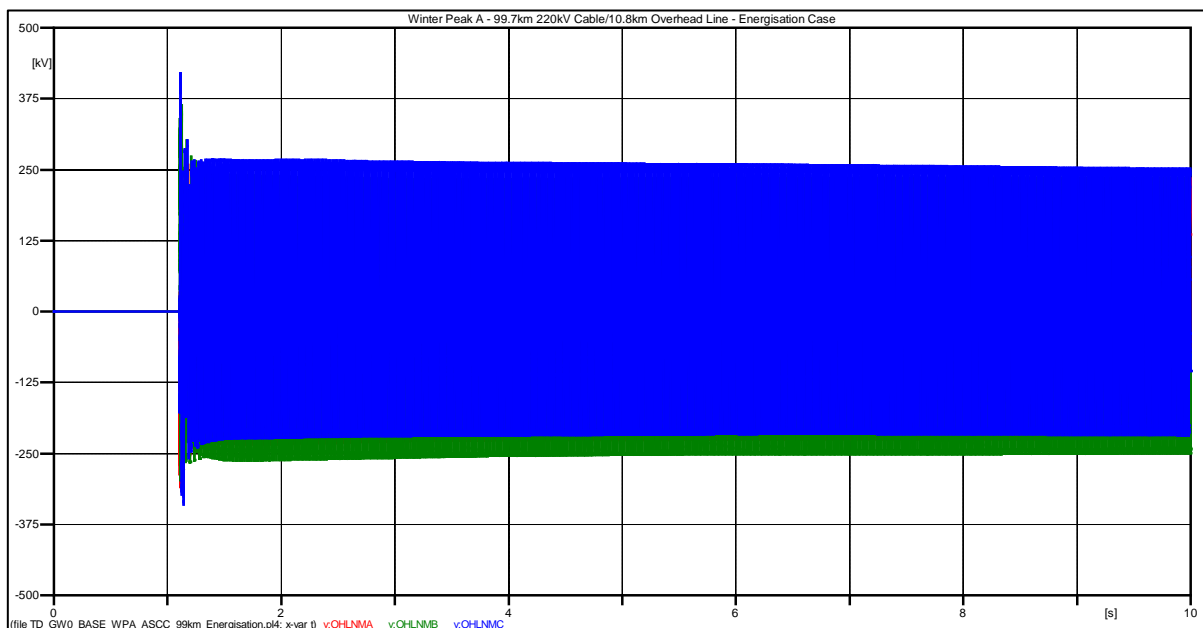


Figure 6: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Energisation of the cable from Flagford with North Mayo disconnected (0-10s)

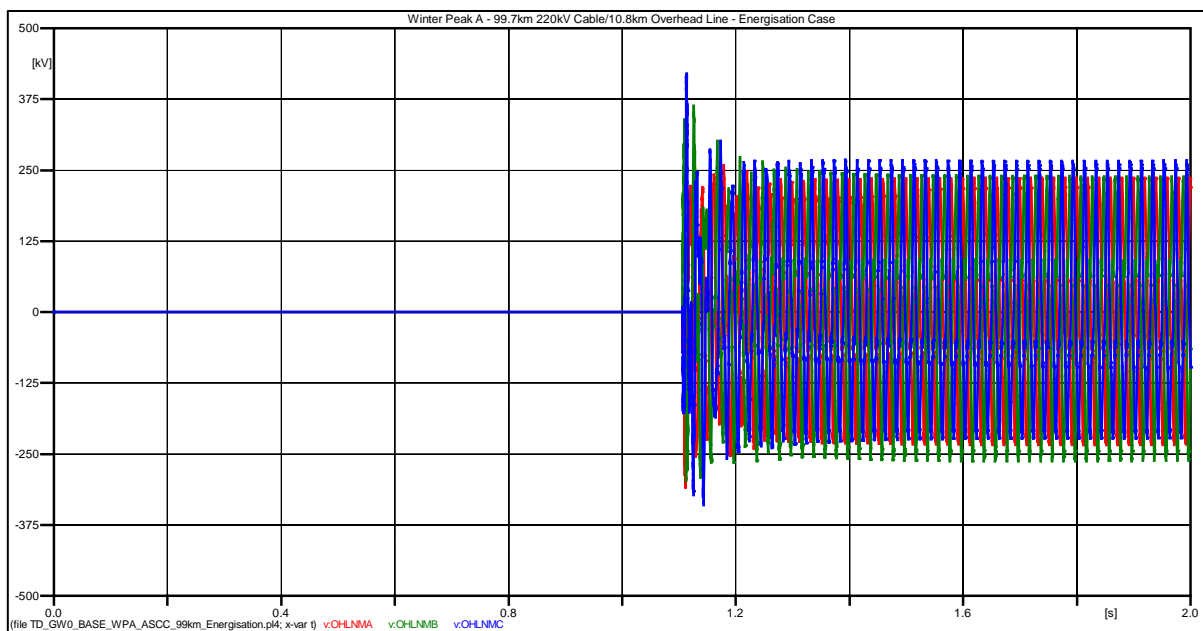


Figure 7: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Energisation of the cable from Flagford with North Mayo disconnected (0-2s)

Condition	Maximum Value	Limit	Result
Switching	401.23 kV (2.234 pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	278.12 kV (1.548 pu)	287.32 kV (1.6pu)	Pass

1.3 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 2

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 2: (N-1) Flagford-Louth 220 kV Line Out

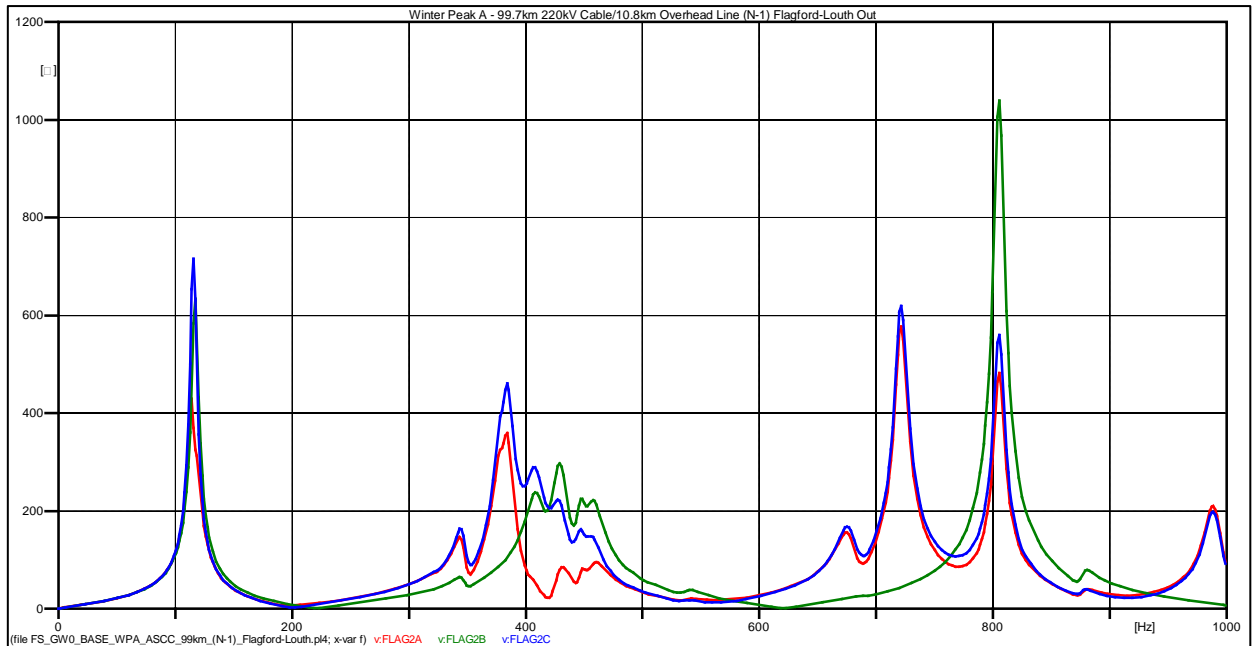


Figure 8: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford-Louth Line Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
115.51	715.55
384.01	461.18
721.51	619.38
805.51	1038.6
988.51	198.24

1.4 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 2

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 2: (N-1) – Autoreclose of the Flagford-Louth line

System Conditions:

1. Fault on Flagford side of Flagford-Louth line. applied at 0.5s, removed at 0.575s.
2. Reclose sequence at 0.575s, dead time 600s, circuit breaker closes 1.175s, point on wave closure at 90°.

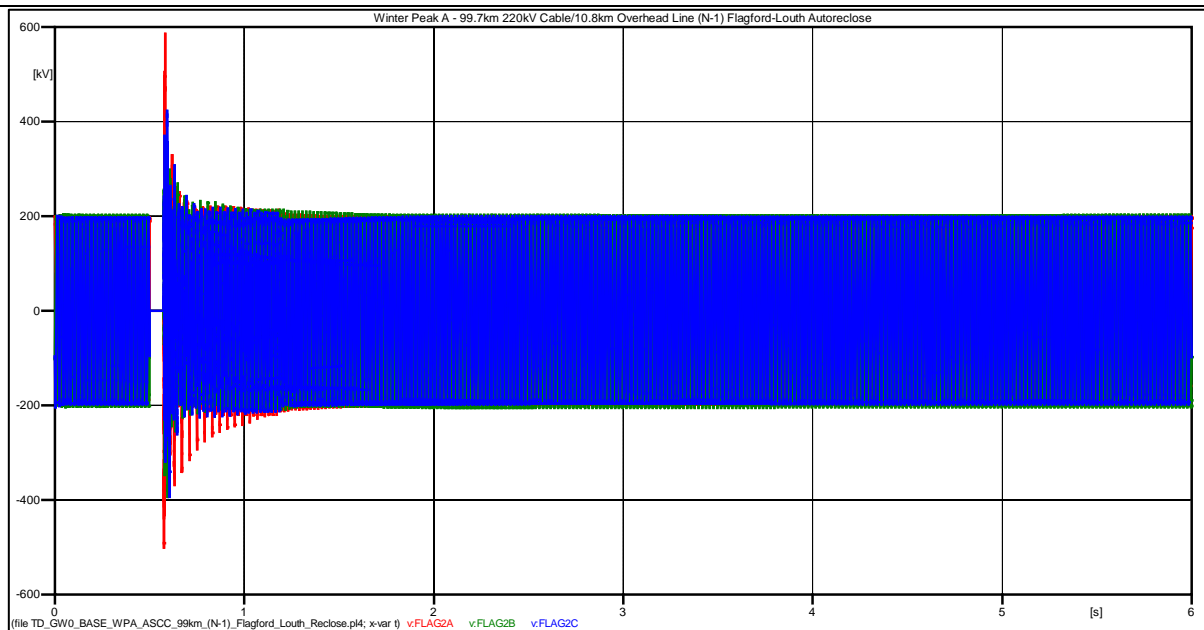


Figure 9: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Flagford/Louth line (0-6s)

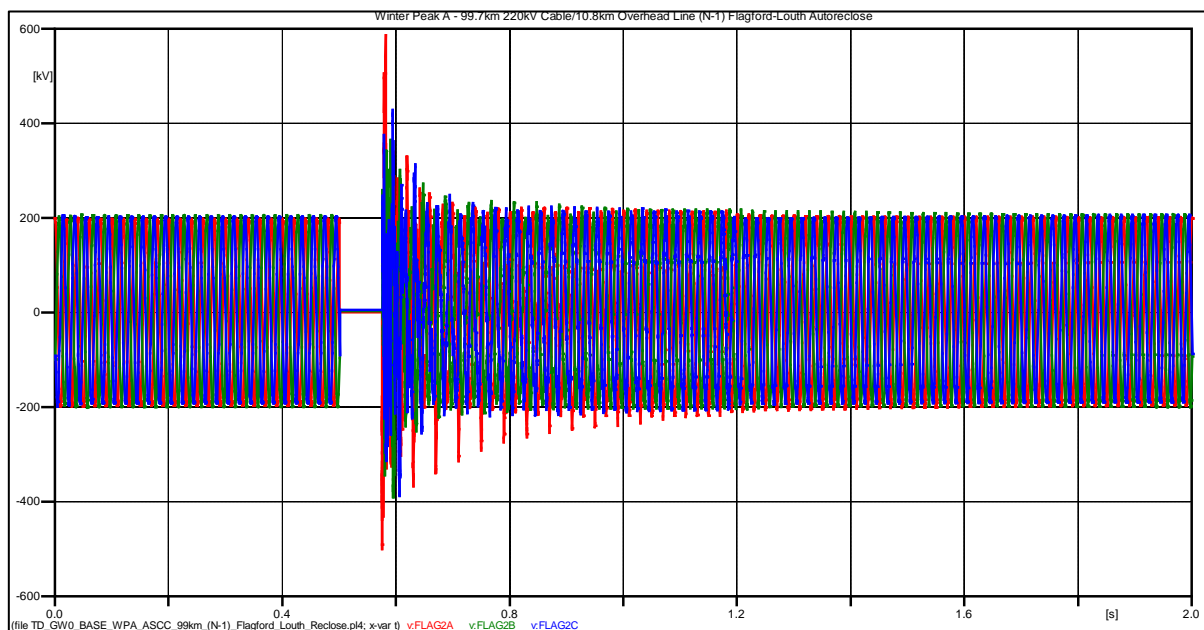


Figure 10: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Flagford-Louth line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	590.23 kV (3.286 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	415.89 kV (2.315 pu)	287.32 kV (1.6pu)	Fail

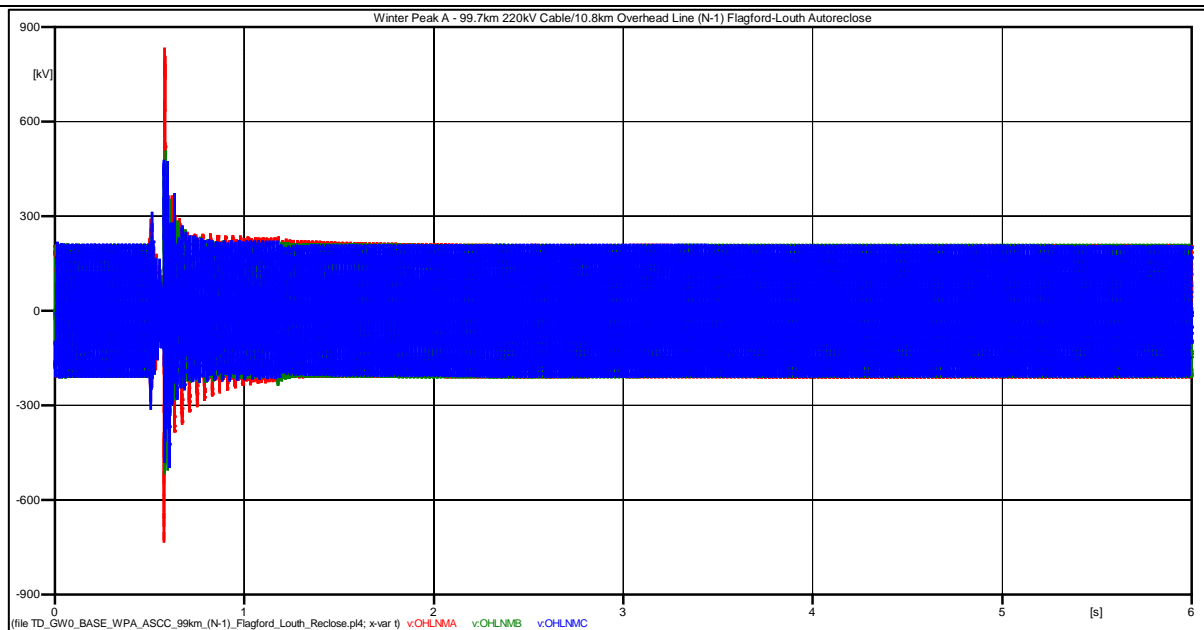


Figure 11: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Flagford-Louth line (0-6s)

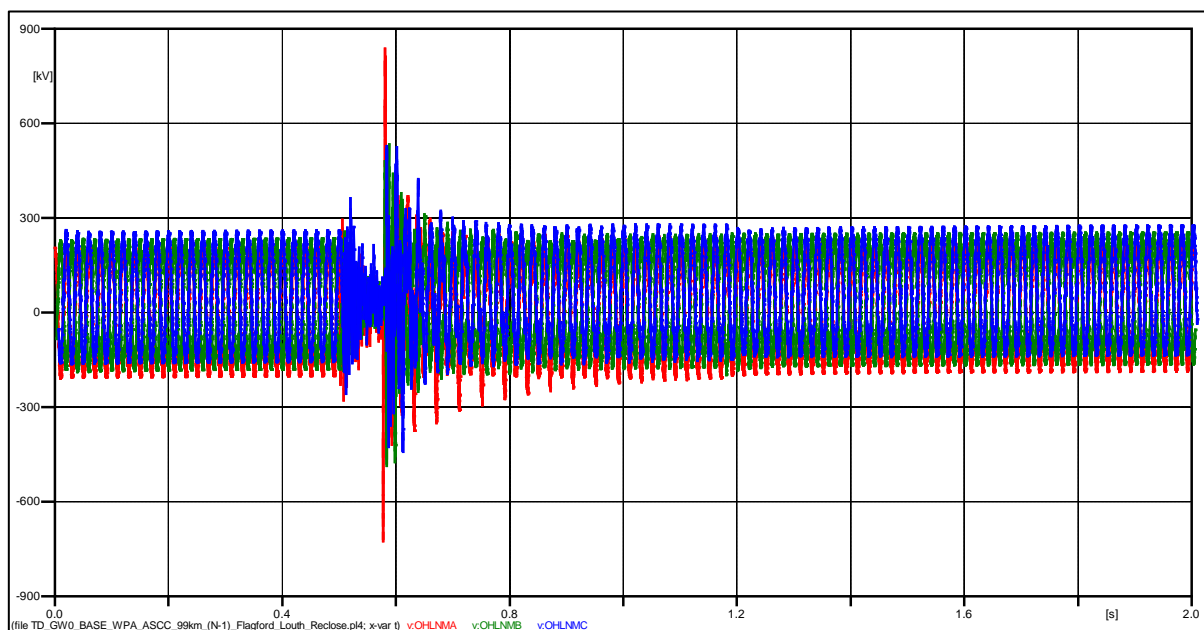


Figure 12: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Flagford-Louth line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	820.13 kV (4.566 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	360.23 kV (2.005 pu)	287.32 kV (1.6pu)	Fail

1.5 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 3

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 3: (N-1) Flagford-Cashla 220 kV Line Out

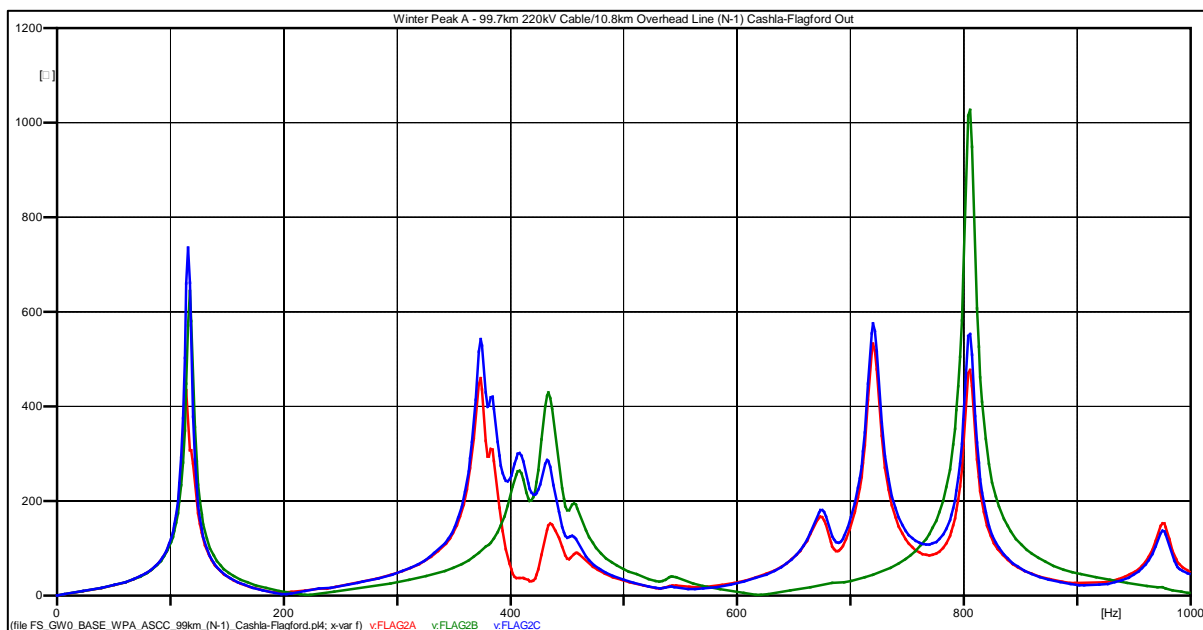


Figure 13: WPA - Length 99.7 km cable / 10.8 km OHL –Flagford-Cashla Line Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
115.51	734.58
373.51	541.22
433.51	429.22
720.01	574.74
805.51	1027.1
976.51	135.16

1.6 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 3

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 3: (N-1) – Autoreclose of the Cashla-Flagford line

System Conditions:

1. Fault on Flagford side of Cashla-Flagford line. applied at 0.5s, removed at 0.575s.
2. Reclose sequence at 0.575s, dead time 600ms, circuit breaker closes 1.175s, point on wave closure at 90°.

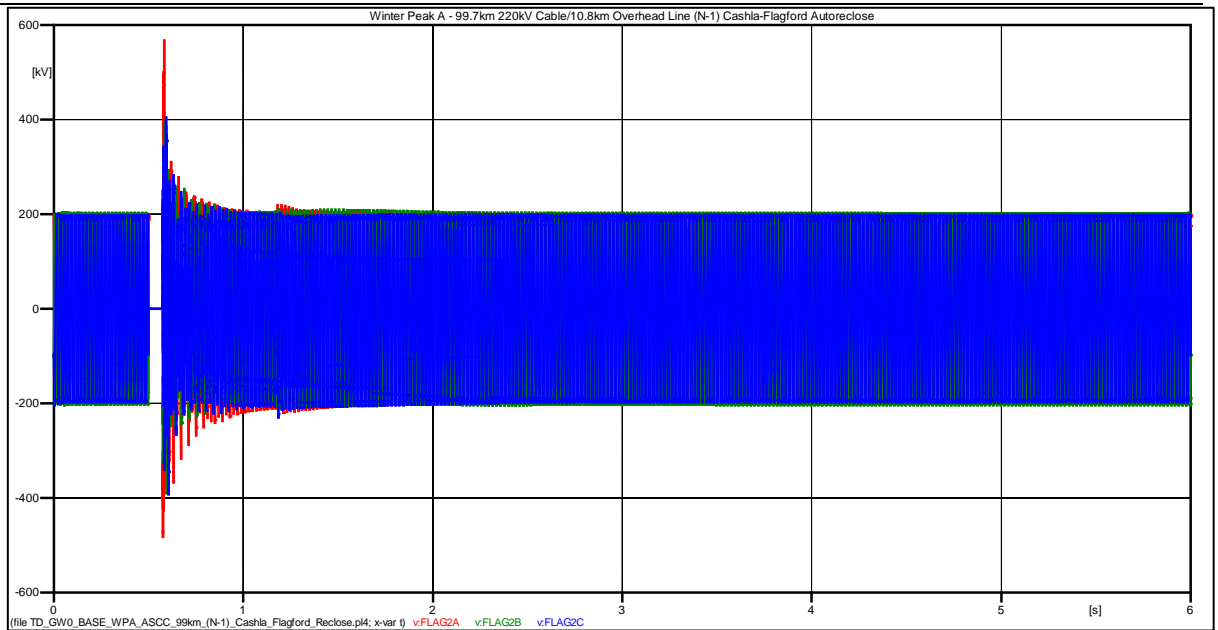


Figure 14: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Cashla-Flagford line (0-6s)

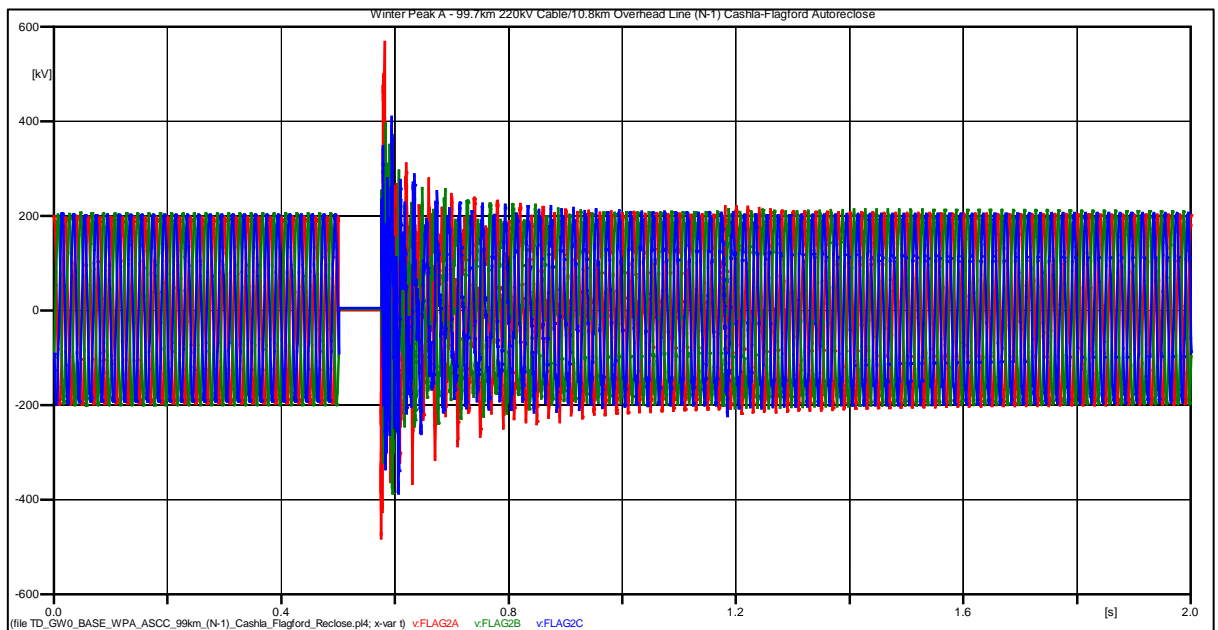


Figure 15: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Cashla-Flagford line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	575.80 kV (3.206 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	310.56 kV (1.729 pu)	287.32 kV (1.6pu)	Fail

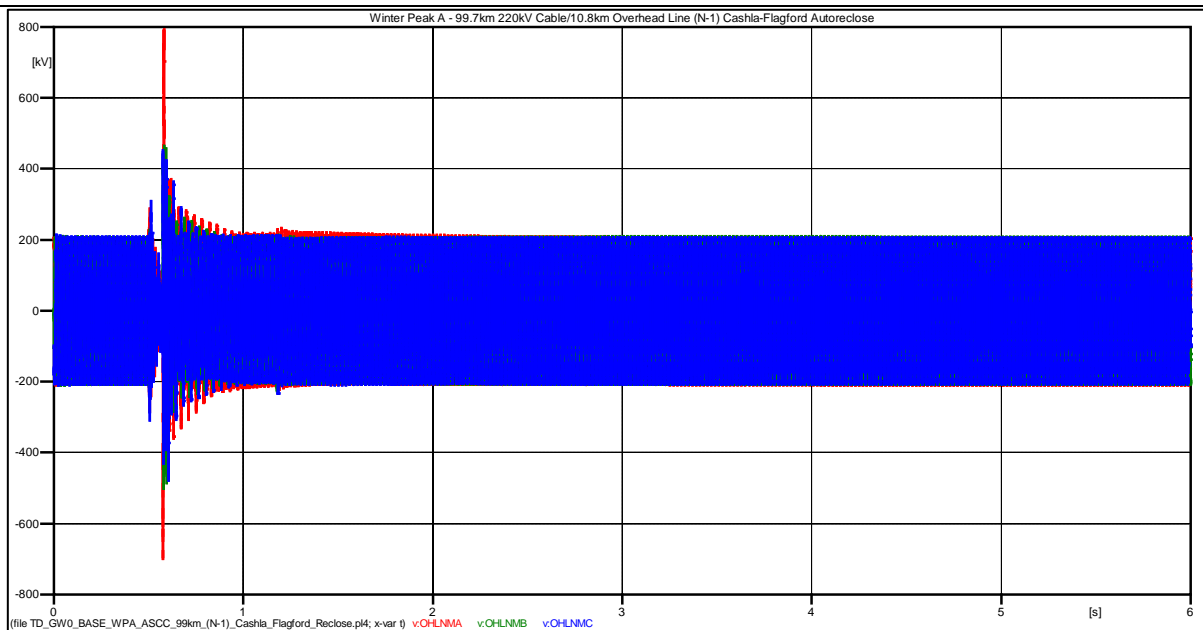


Figure 16: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Cashla-Flagford line (0-6s)

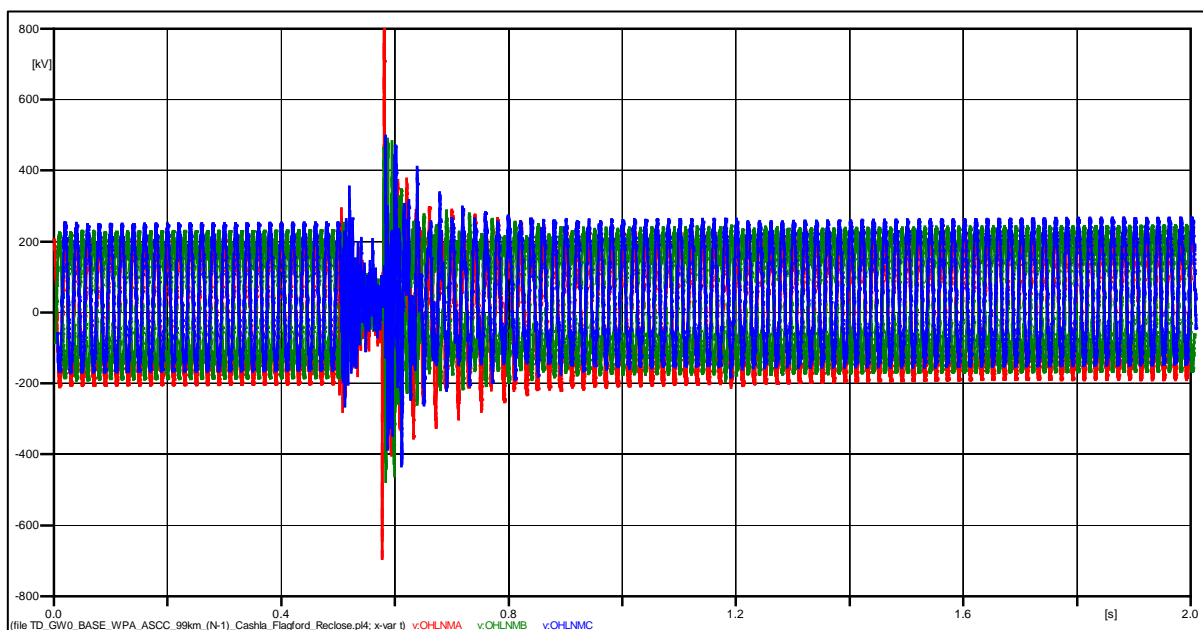


Figure 17: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Cashla-Flagford line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	800.23 kV (4.456 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	415.23 kV (2.312 pu)	287.32 kV (1.6pu)	Fail

1.7 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 4

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 4: (N-1) Flagford-Srananagh 220 kV Line Out

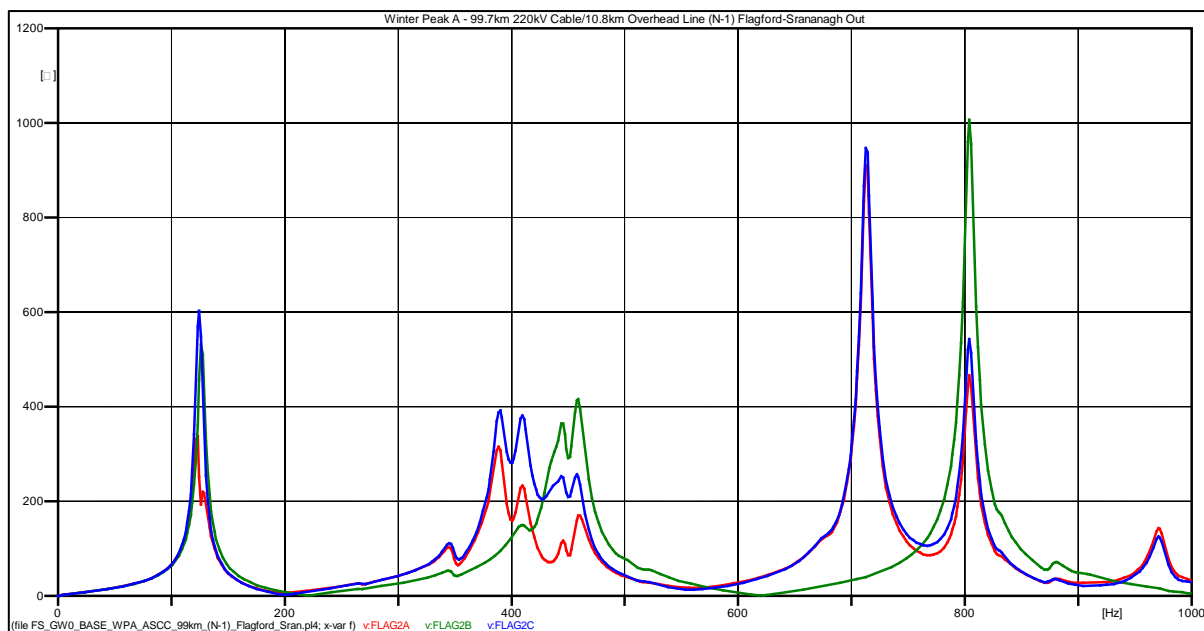


Figure 18: WPA - Length 99.7 km cable / 10.8 km OHL –Flagford-Srananagh Line Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
124.51	602.74
390.01	391.42
459.01	415.38
712.51	947.55
804.01	1006.5
972.01	123.58

1.8 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 4

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 4: (N-1) – Autoreclose of the Flagford-Srananagh line

System Conditions:

1. Fault on Flagford side of Flagford-Srananagh line, applied at 0.5s, removed at 0.575s.
2. Reclose sequence at 0.575s, dead time 0.6s, circuit breaker closes 1.175s, point on wave closure at 90°.

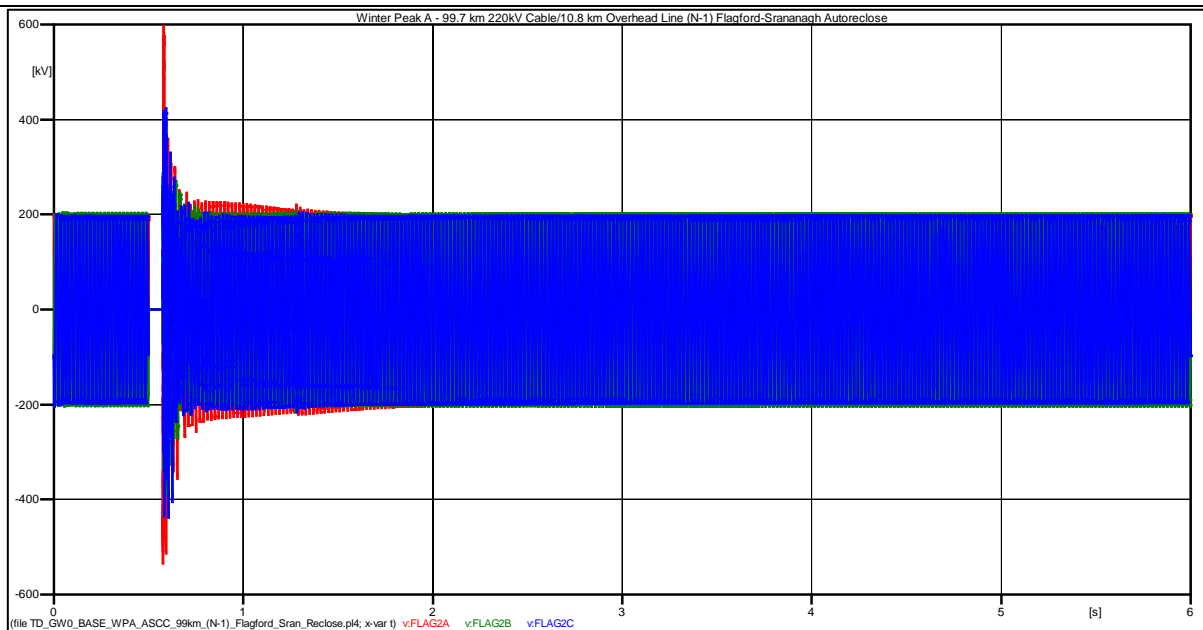


Figure 19: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Flagford-Srananagh line (0-6s)

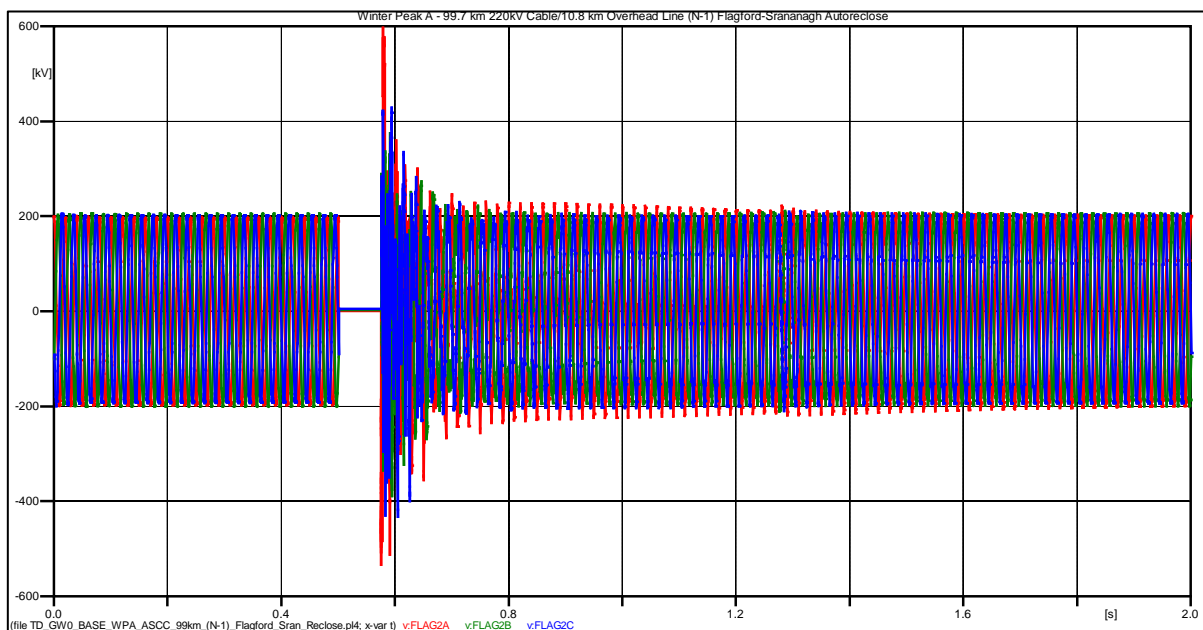


Figure 20: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-1) – Autoreclose of the Flagford-Srananagh line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	600.01 kV (3.341 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	421.36 kV (2.346 pu)	287.32 kV (1.6pu)	Fail

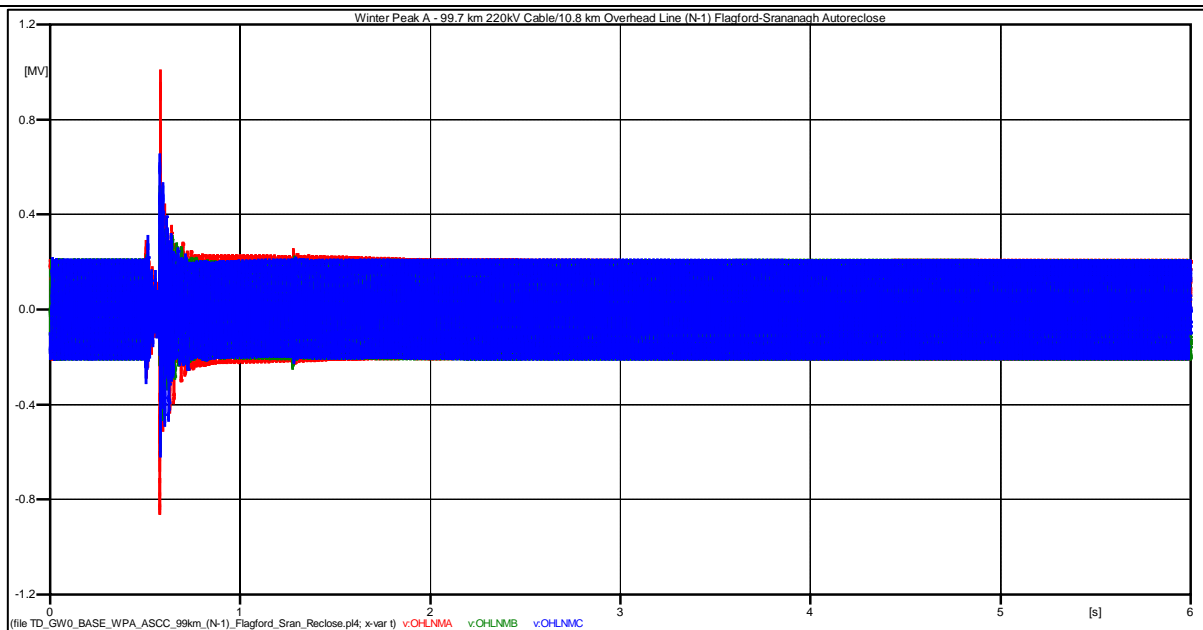


Figure 21: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Flagford-Srananagh line (0-6s)

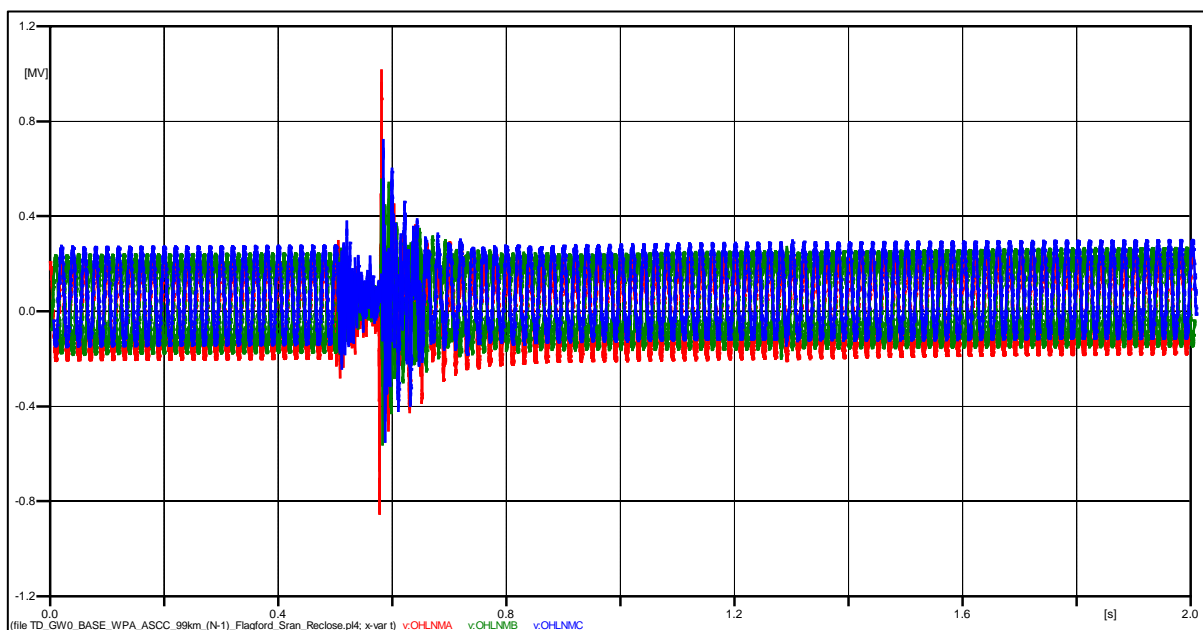


Figure 22: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-1) – Autoreclose of the Flagford-Srananagh line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	1000 kV (5.568 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	510 kV (2.839 pu)	287.32 kV (1.6pu)	Fail

1.9 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 5

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 5: (N-2) Flagford-Louth/Cashla-Flagford 220 kV lines out

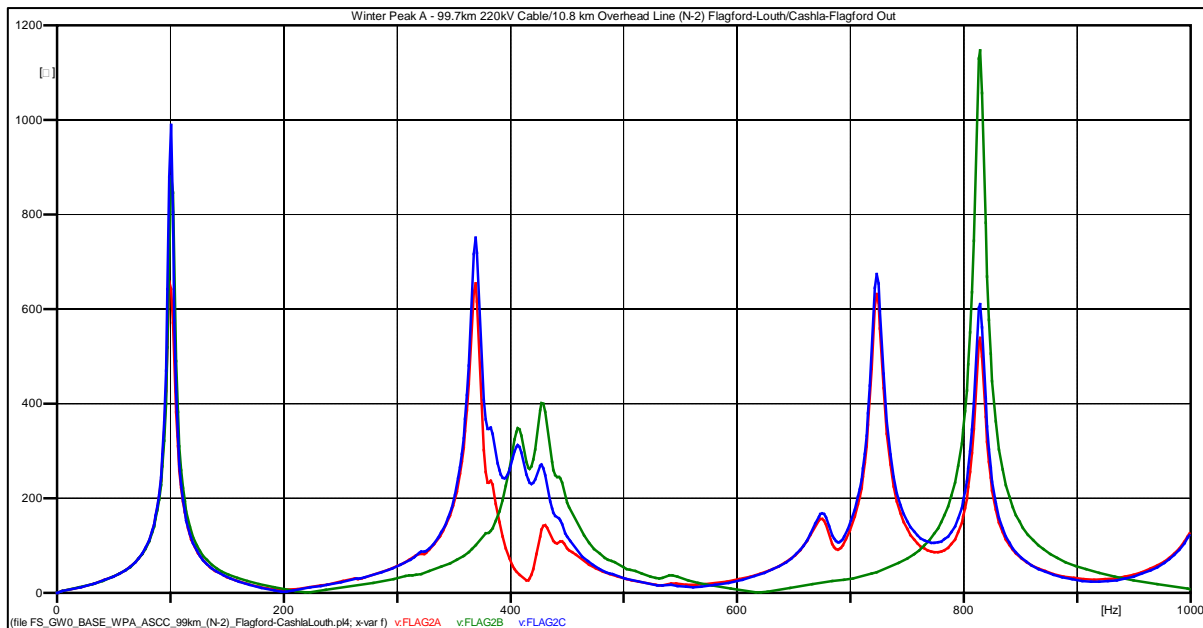


Figure 23: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford-Louth/Cashla-Flagford lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
100.51	990.01
369.01	750.63
429.01	399.47
723.01	674.4
814.51	1147.1

1.10 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 5

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 5: (N-2) – Flagford/Louth Disconnected – Autoreclose of the Cashla-Flagford line

System Conditions:

1. Fault on Flagford side of Cashla – Flagford line, applied at 0.5s.
2. Reclose sequence at 0.575s, dead time 0.6s, circuit breaker closes 1.175s, point on wave closes at 90°.
3. Breaker opens at again at 1.25s.

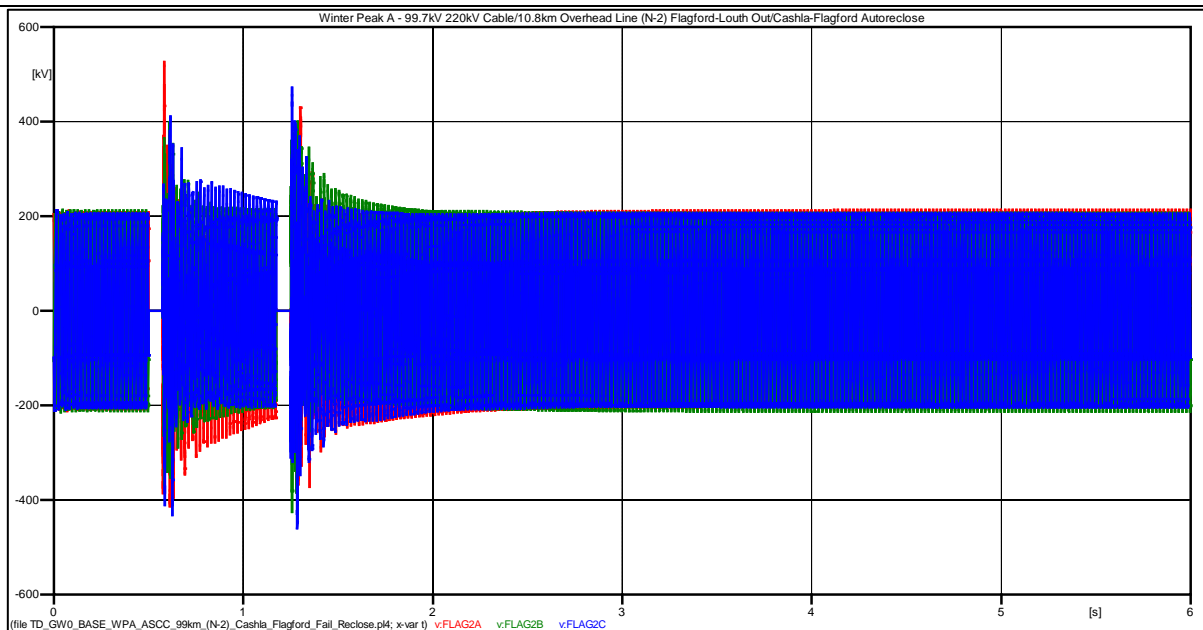


Figure 24: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line (0-6s)

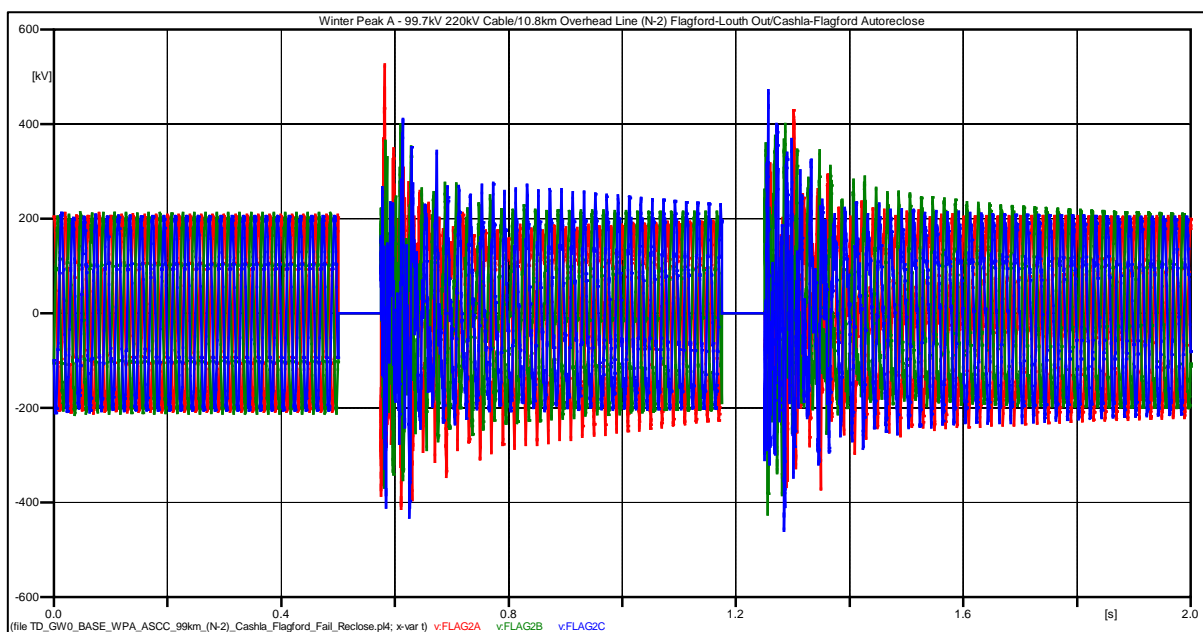


Figure 25: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	510.45 kV (2.842 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	401.23 kV (2.234 pu)	287.32 kV (1.6pu)	Fail

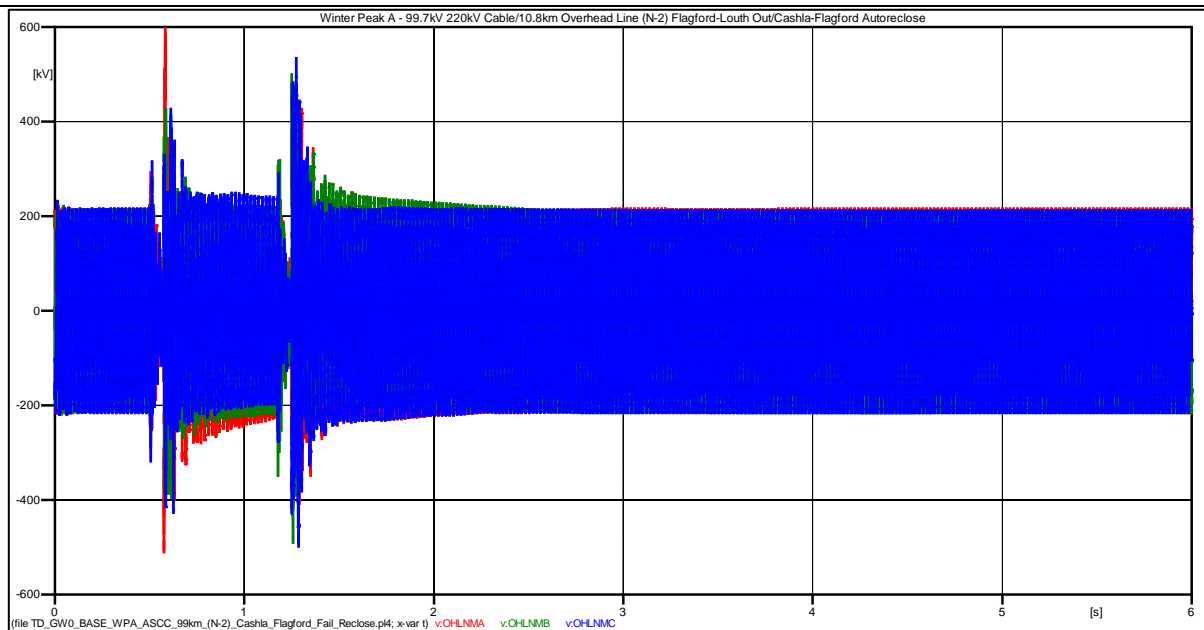


Figure 26: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line (0-6s)

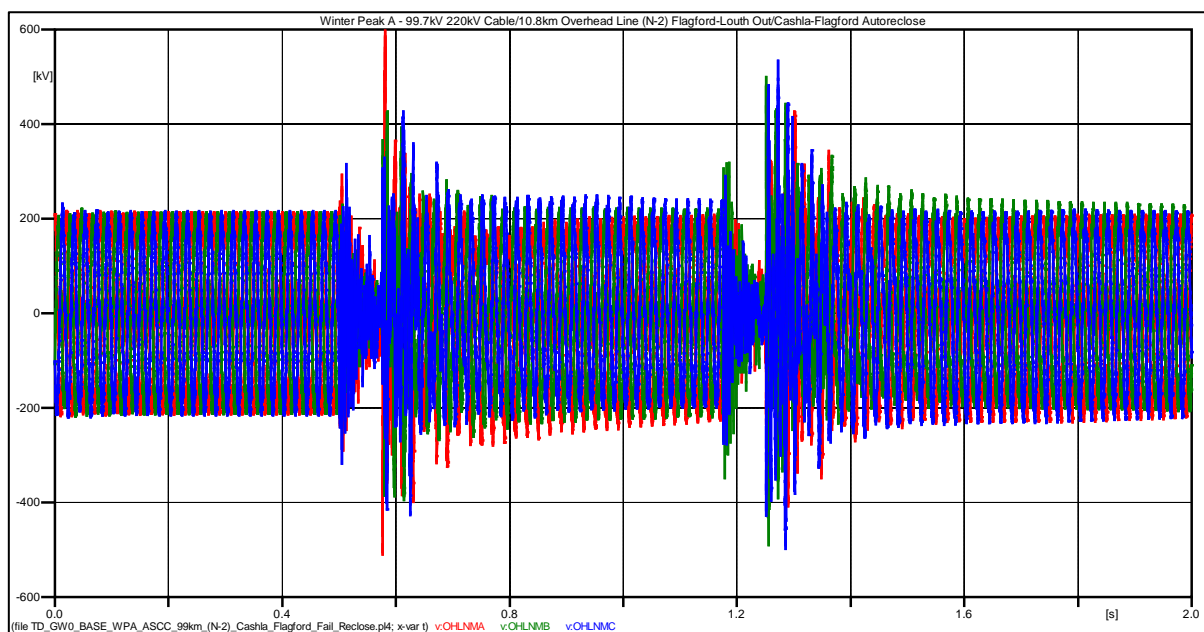


Figure 27: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line (0-2s)

Condition	Maximum Value	Limit	Result
Switching	600.23 kV (3.342 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	410.26 kV (2.284 pu)	287.32 kV (1.6pu)	Fail

1.11 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 6

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

Case 6: (N-2) Flagford-Louth/Cashla-Flagford 220 kV lines out – Extra Tx at Flagford

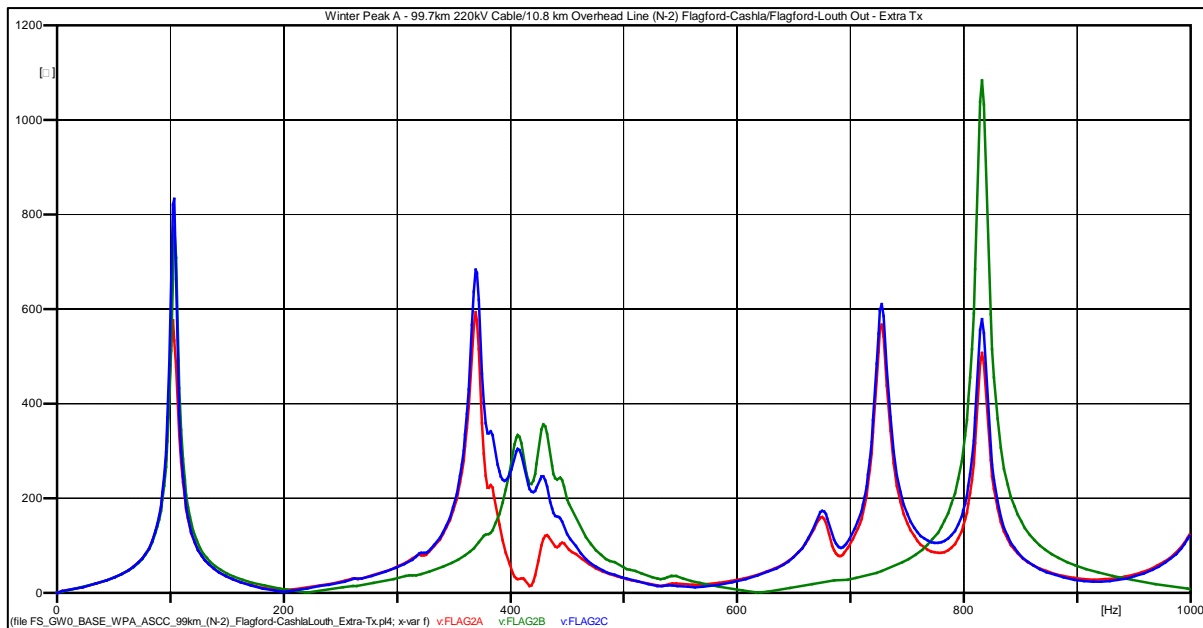


Figure 28: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford-Louth/Cashla-Flagford lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
103.51	832.74
369.01	682.99
435.01	352.52
727.51	611.08
816.01	1083.4

1.12 Impedance Scans – Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 7

Conditions for impedance scan:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar
4. One Flagford transformer on outage.

Case 7: (N-2) Flagford-Louth/Cashla-Flagford 220 kV lines out and one Flagford Tx out

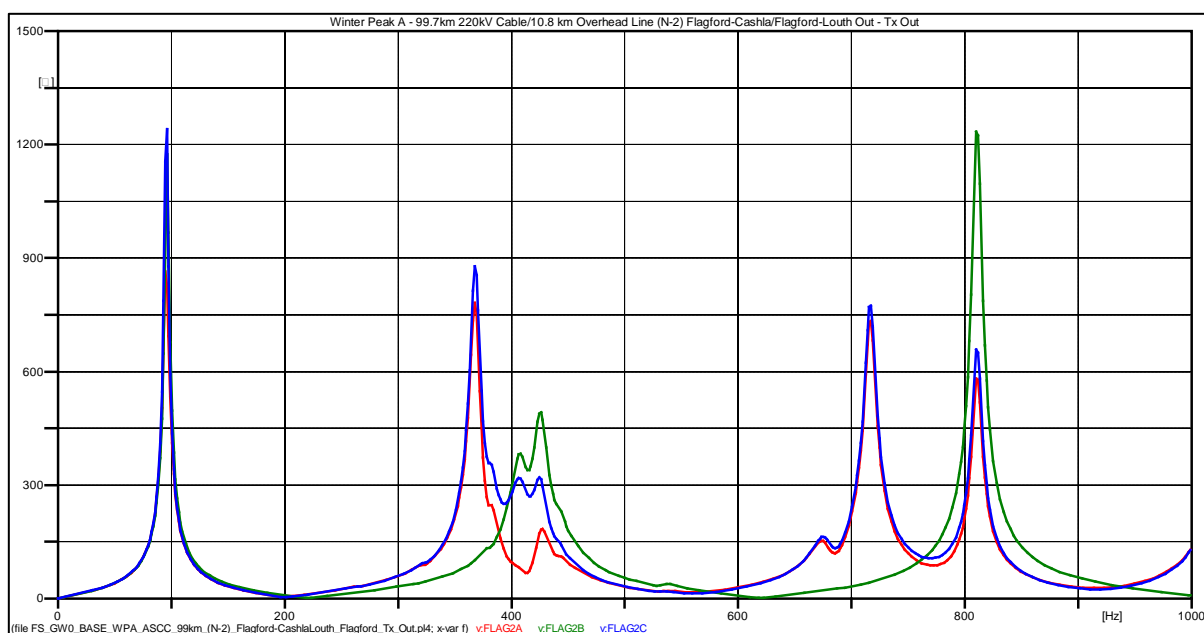


Figure 29: WPA - Length 99.7 km cable / 10.8 km OHL – (N-2) Flagford-Louth/Cashla-Flagford lines Out and Flagford Tx out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
96.01	1240.9
367.51	877.3
491.02	490.02
717.01	773.17
810.01	1234.1

1.13 Time Domain Simulation Length 99.7 km cable / 10.8 km OHL – Winter Peak A – Case 7

Conditions for time domain simulation:

1. Winter peak A network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar
4. One Flagford transformer on outage.

Case 7: (N-2) – Flagford-Louth disconnected - Autoreclose Cashla-Flagford 220 kV onto fault and trip Flagford – One Tx out

System Conditions:

1. Fault on Flagford side of Flagford-Cashla line, applied at 0.5s.
2. Reclose sequence at 0.575s, dead time 0.6s, circuit breaker closes 1.175s, point on wave closes at 90°.
3. Breaker opens at again at 1.25s.

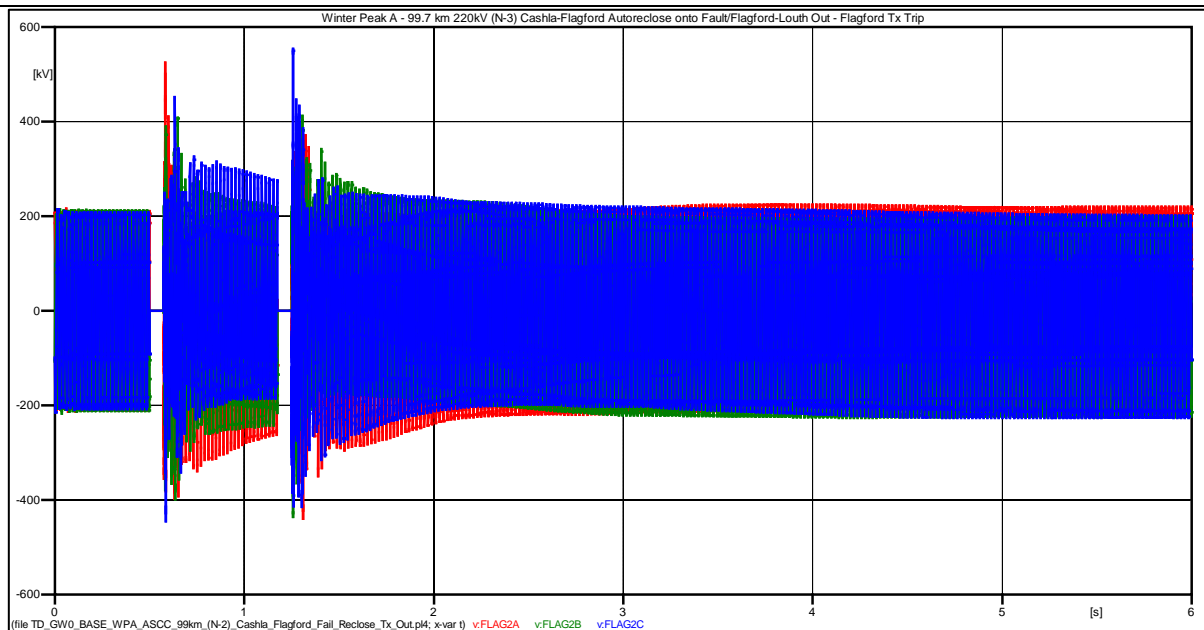


Figure 30: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) - Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx (0-6s)

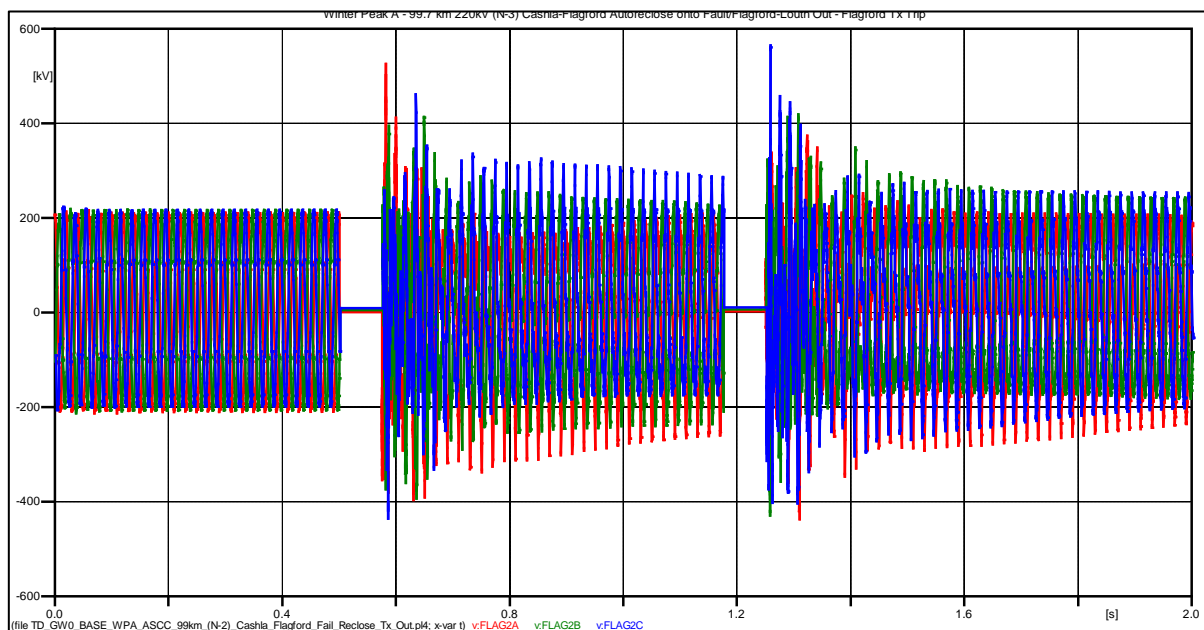


Figure 31: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx (0-2s)

Condition	Maximum Value	Limit	Result
Switching	512.23 kV (2.852 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	420.56 kV (2.341 pu)	287.32 kV (1.6pu)	Fail

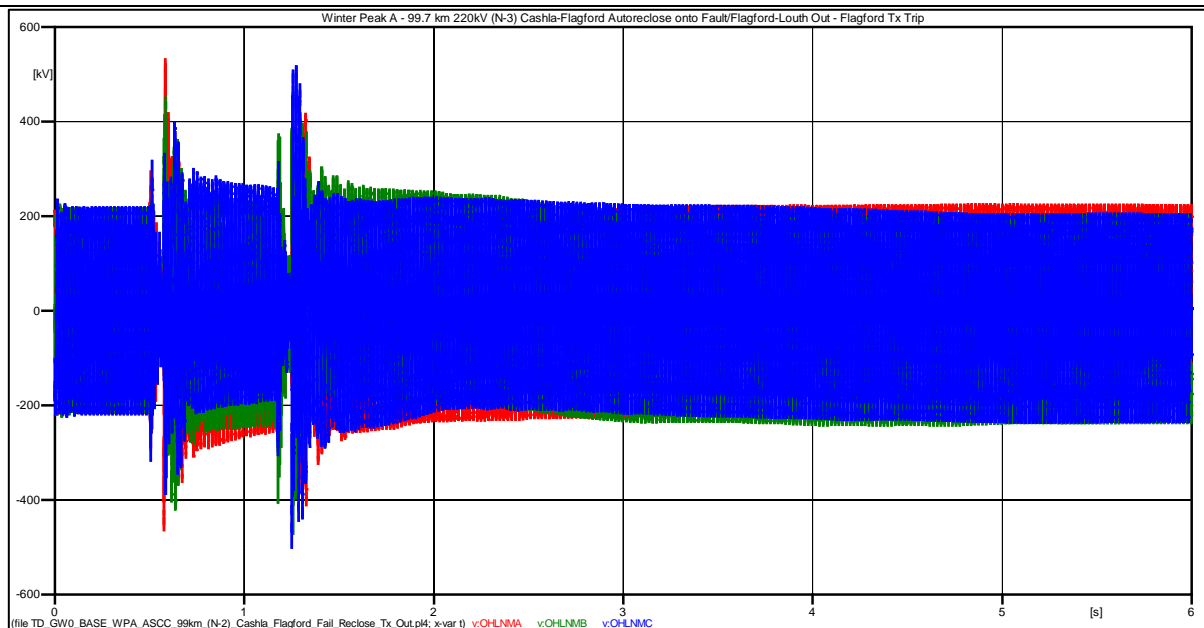


Figure 32: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx (0-6s)

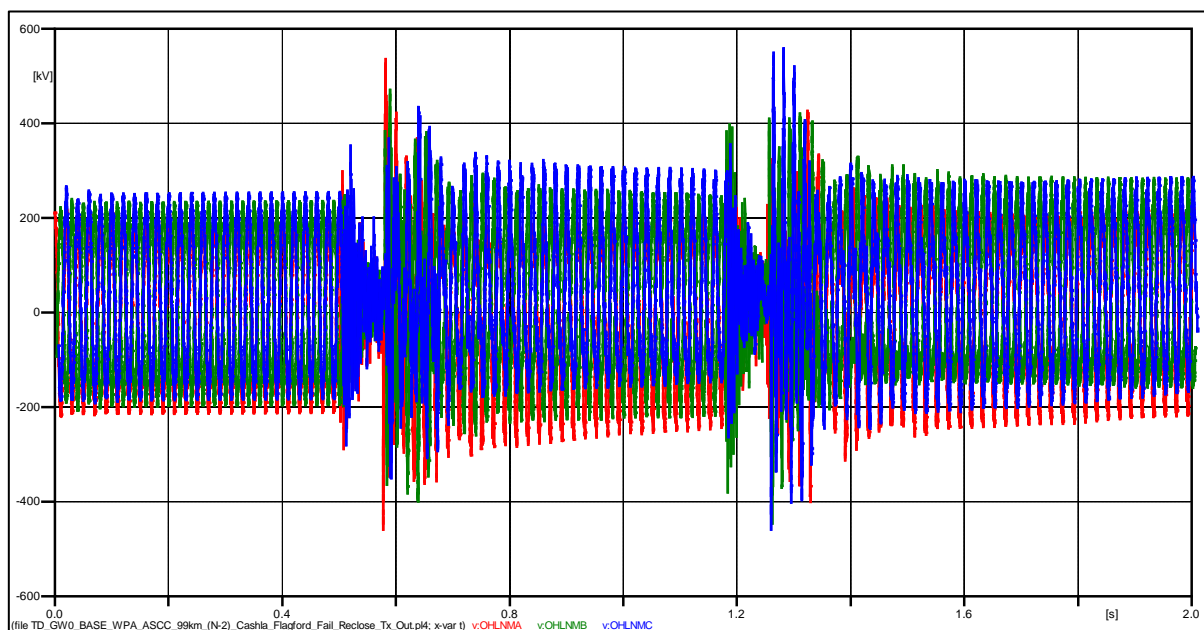


Figure 33: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx (0-2s)

Condition	Maximum Value	Limit	Result
Switching	501.23 kV (2.791 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	401.23 kV (2.234 pu)	287.32 kV (1.6pu)	Fail

1.14 Results – Summer Valley B

Impedance scans and time domain simulations for a 99.7 km 220 kV cable with sized reactors at both Flagford and North Mayo. The Grid West circuit will consist of this 99.7 km 220 kV cable and a further 10.8 km OHL to complete the entire 110.5 km route.

This appendix presents the results for Case 7 (Flagford-Louth disconnected and autoreclose of the Cashla-Flagford line and trip of Flagford Tx) for summer valley B generation / demand profile.

1.15 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Summer Valley B – Case 7

Conditions for time domain simulation:

1. Summer Valley B network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar
4. One Flagford transformer on outage.

Case 7: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line onto fault and one disconnected Flagford Transformer

System Conditions:

1. Fault on Flagford side of Flagford-Cashla line, applied at 0.5s.
2. Reclose sequence at 0.575s, dead time 0.6s, circuit breaker closes 1.175s, point on wave closes at 90°.
3. Breaker opens at again at 1.25s.

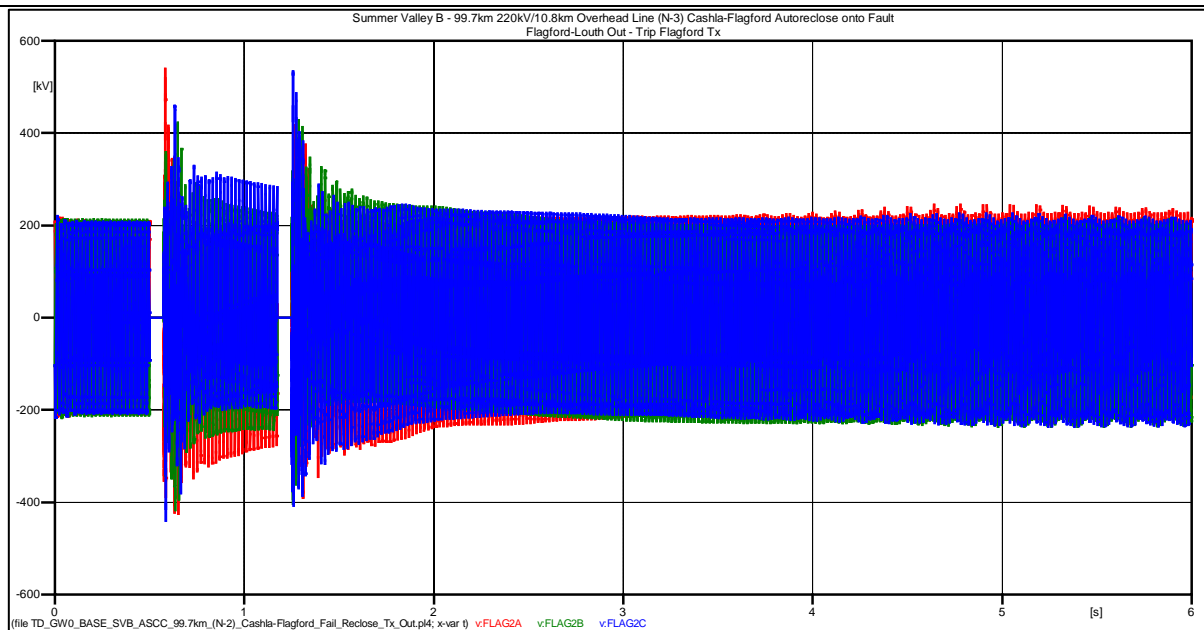


Figure 34: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-6s)

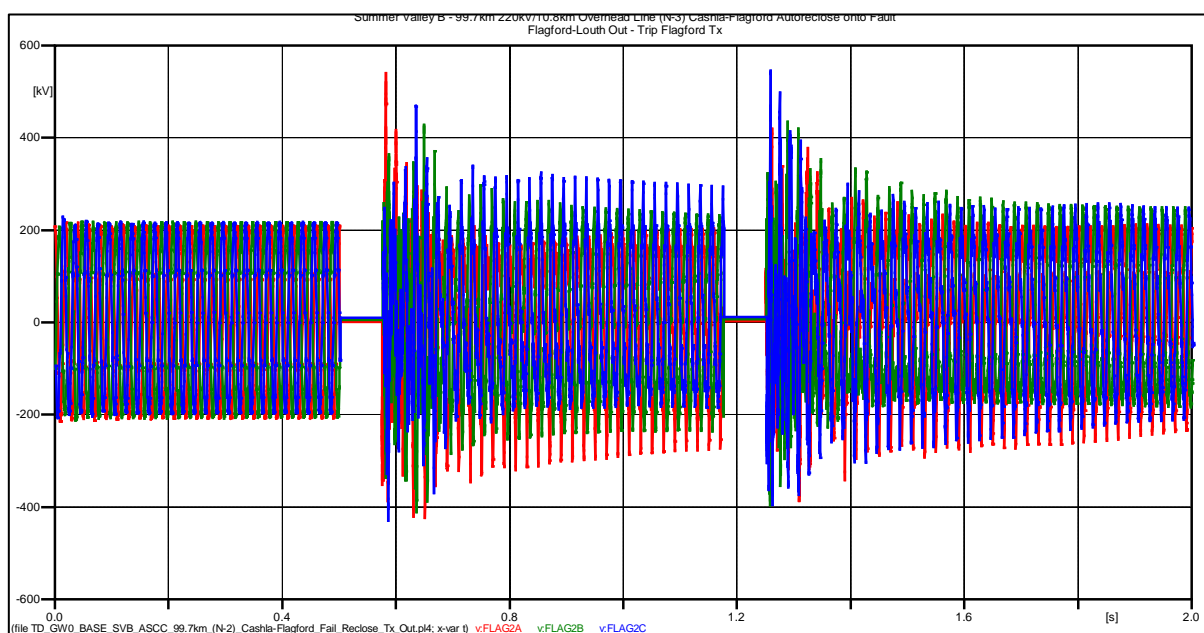


Figure 35: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-2s)

Condition	Maximum Value	Limit	Result
Switching	525.23 kV (2.924 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	435.26 kV (2.423 pu)	287.32 kV(1.6pu)	Fail

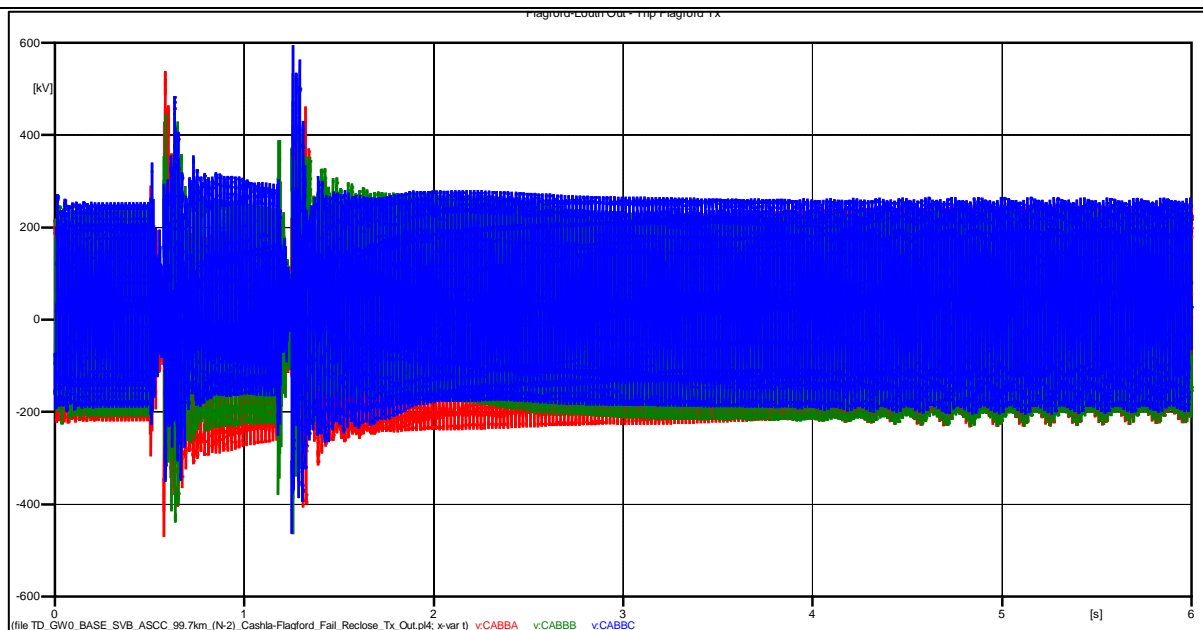


Figure 36: SVB - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-6s)

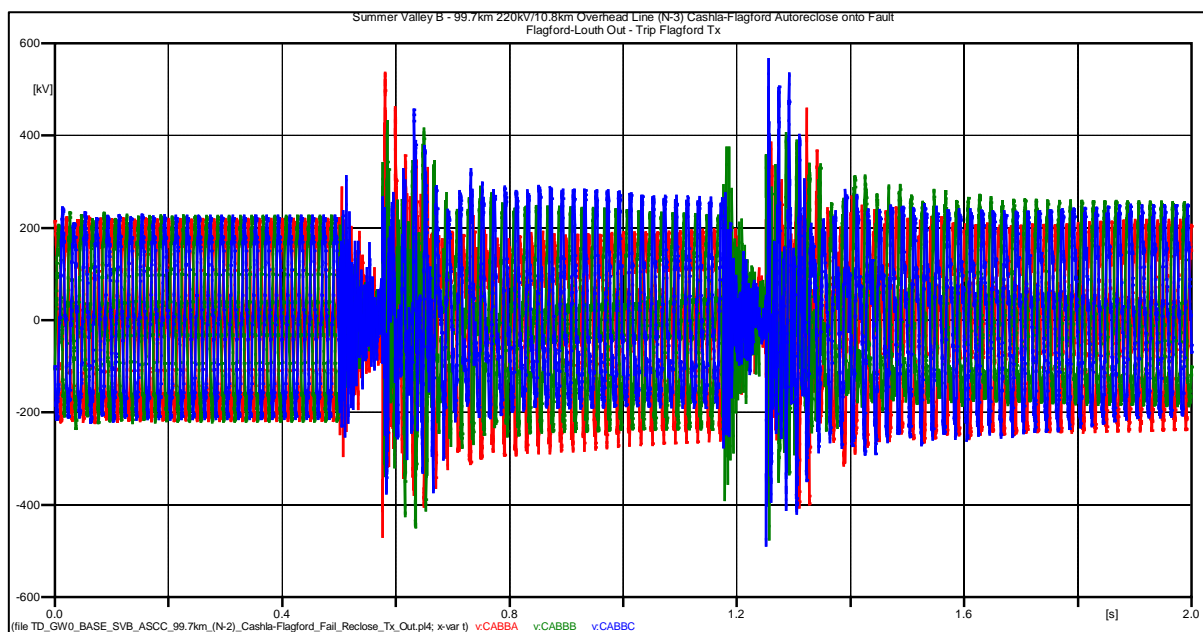


Figure 37: SVB - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-2s)

Condition	Maximum Value	Limit	Result
Switching	531.28 kV (2.958 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	423.56 kV (2.358pu)	287.32 kV(1.6pu)	Fail

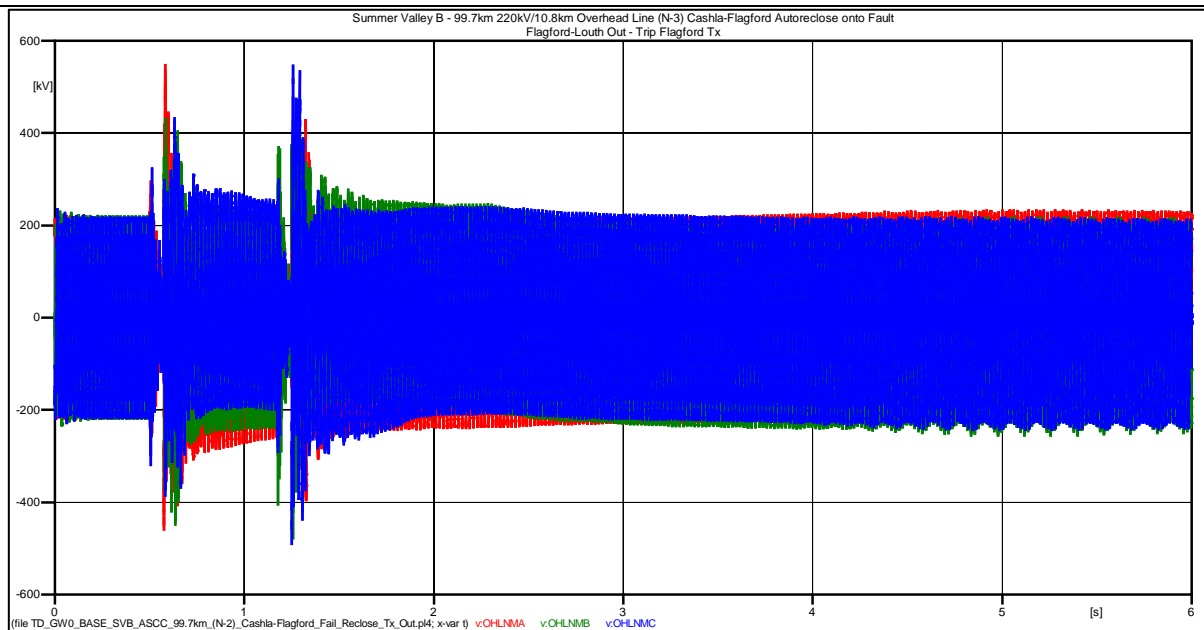


Figure 38: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-6s)

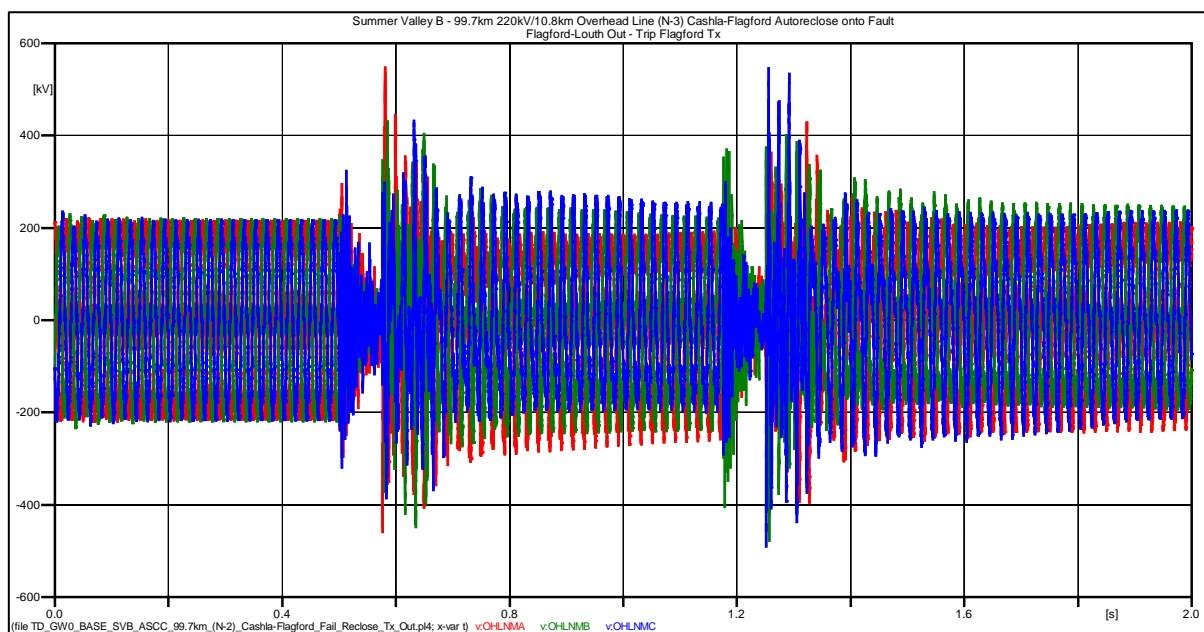


Figure 39: SVB - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line onto fault and trip Flagford Tx(0-2s)

Condition	Maximum Value	Limit	Result
Switching	540.56 kV (3.010 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	415.69 kV (2.314 pu)	287.32 kV(1.6pu)	Fail