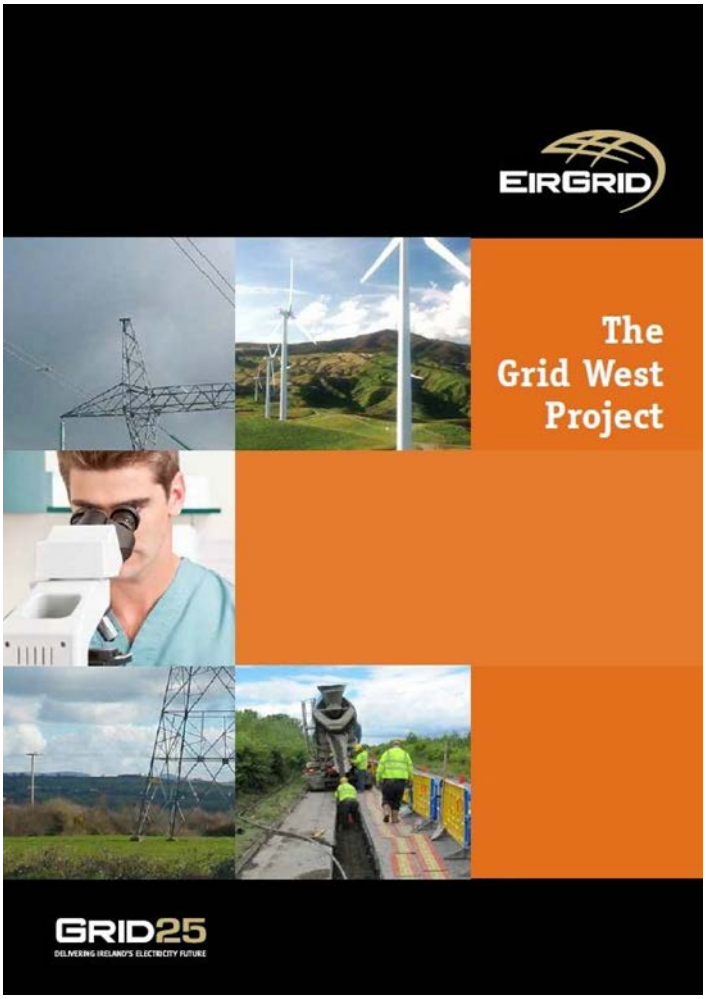
EirGrid

10344 - PSP019 - CABLE STUDIES FOR GRID WEST

Partial AC Underground Solution



APPENDIX F – SPLIT CABLES

17th December 2014

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REPORT AUTHORISATION SHEET

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Contents

1 RESULTS

Impedance scans and time domain simulations for a range of lengths of 220 kV cable split into sections along the total 108.5 km Grid West route. Suitably sized reactors were located at Flagford and North Mayo for each of the cable lengths.

The appendix presents result for Summer Valley B generation / demand scenario. It will cover a split cable option with 30 km of cable total. The Grid West circuit comprises of an 8 km cable from Flagford, a 64 km OHL, a 20 km mid-span cable section, a 11 km OHL and then a 2 km cable into North Mayo station. However, the cases have failed due to a high resonance point just below the 3rd harmonic of above 1000 Ohms and TOVs very slightly exceeding the allowable limits.

Results of a 23 km route of split cable are also given below with an 8 km cable from Flagford, a 64 km OHL, a 20 km mid-span cable section, an 11 km OHL and then a 2 km cable into North Mayo station. However, the cases have failed due to TOVs very slightly exceeding the allowable limits.[1]

[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.

1.1 Impedance Scans - Length 30km (8+20+2) – Summer Valley B – Case 1

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 80MVar/Flagford 45MVar

Case 1: (N-2) Cashla-Flagford/Flagford-Louth Lines Out

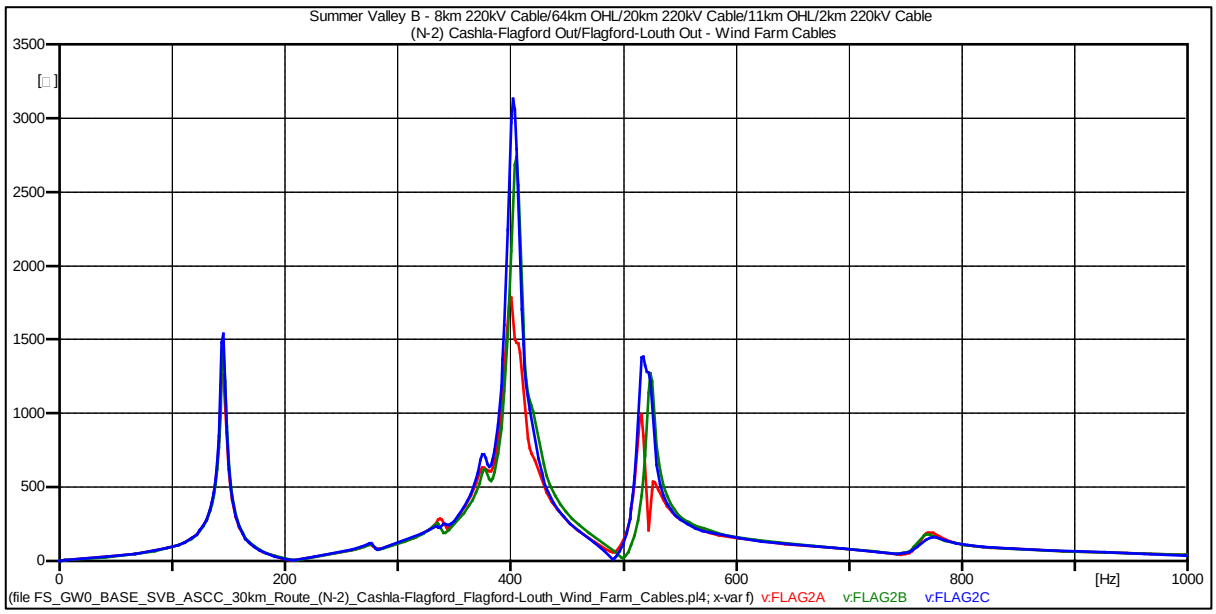

Figure 1: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
145.01	1538.0
402.51	3132.8
517.51	1384.0

1.2 Time Domain Simulation - Length 30km (8+20+2) – Summer Valley B – Case 1

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 80MVar/Flagford 45MVar

Case 1: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

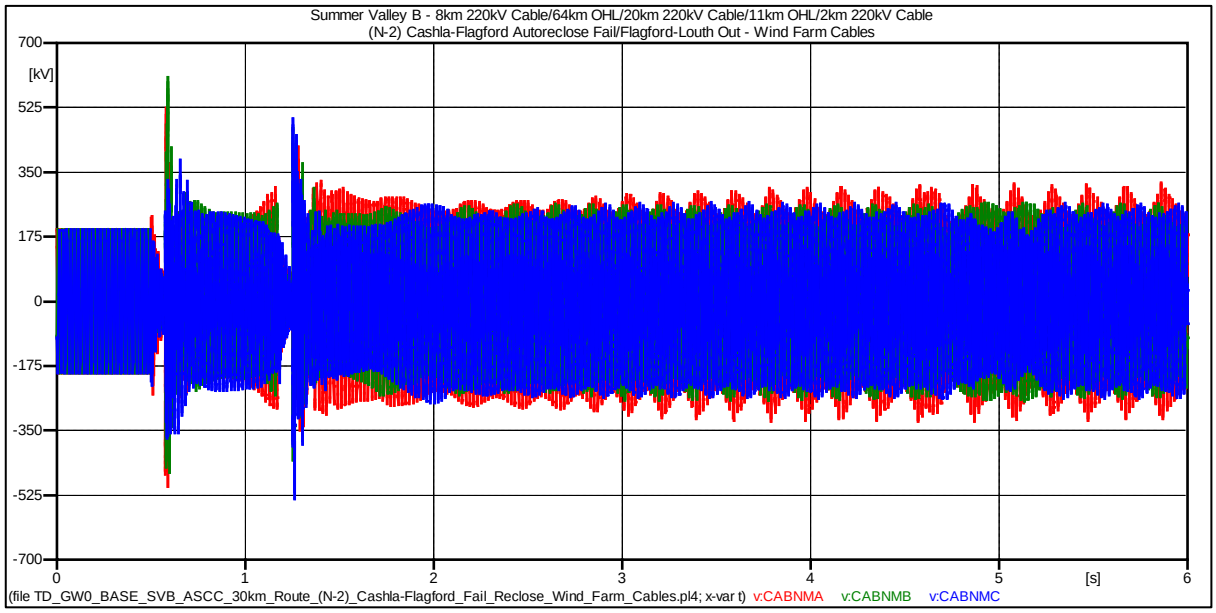

Figure 2: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

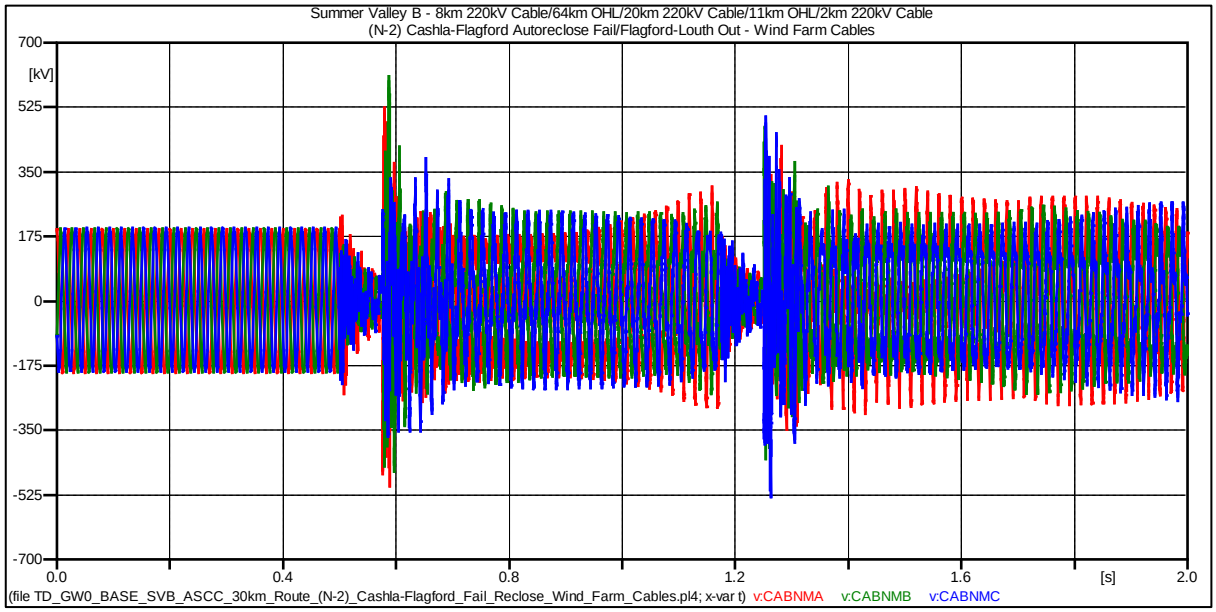

Figure 3: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	603.5 kV (3.360 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	391.25 kV (2.1786 pu)	287.32 kV (1.6 pu)	Fail
Unstable oscillation – Fail			

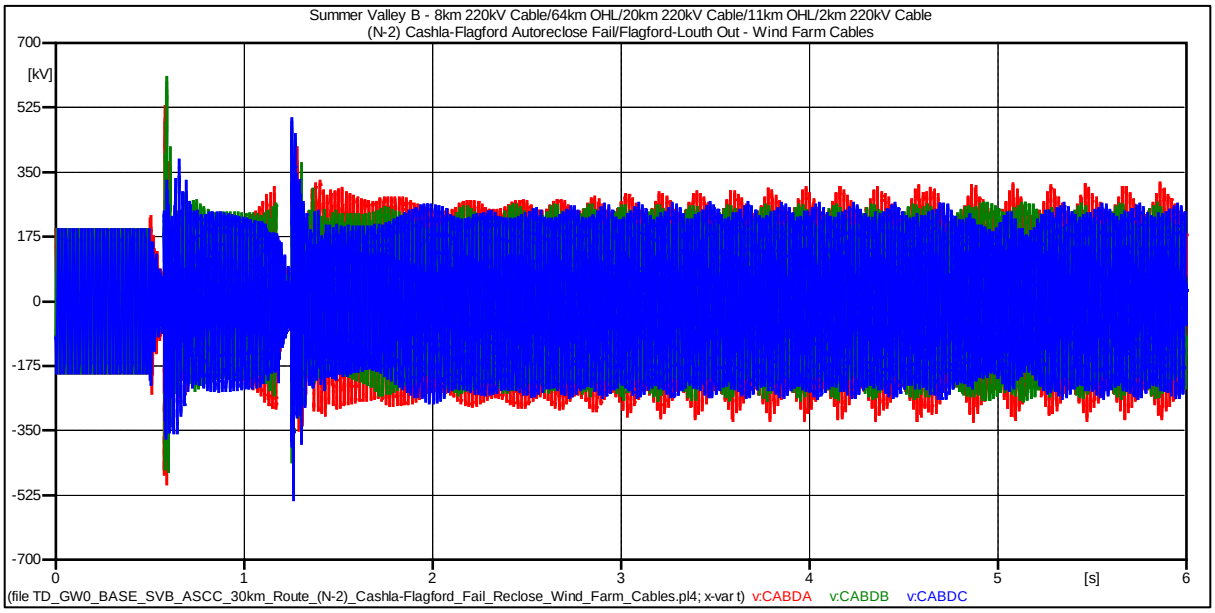

Figure 4: SVB - Length 30km – Cable Mid Point D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

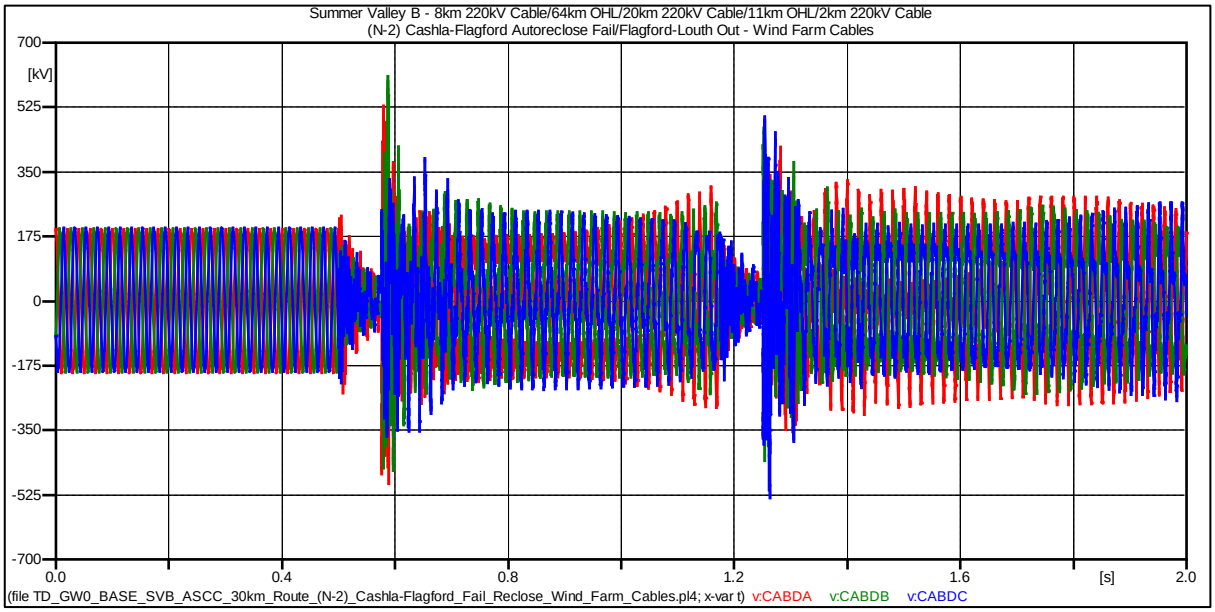

Figure 5: SVB - Length 30km – Cable Mid Point D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	633.78 kV (3.5292 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	381.67 kV (2.1253 pu)	287.32 kV (1.6 pu)	Fail
Unstable oscillation - Fail			

*Pass can be achieved with surge arrestors.

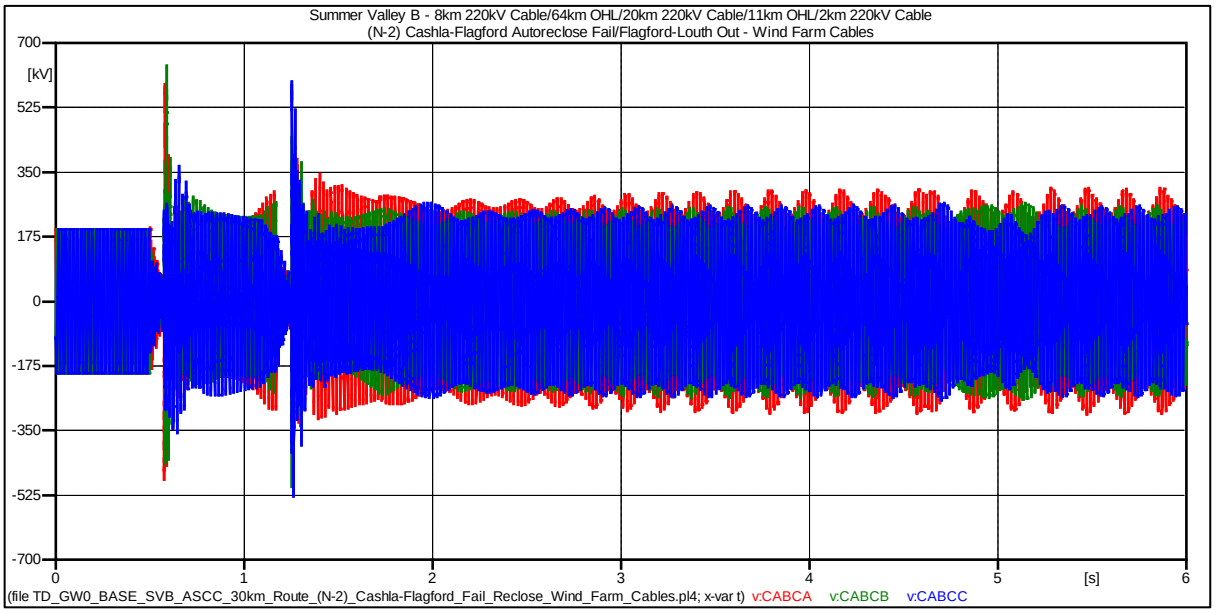

Figure 6: SVB - Length 30km – Cable Mid Point C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

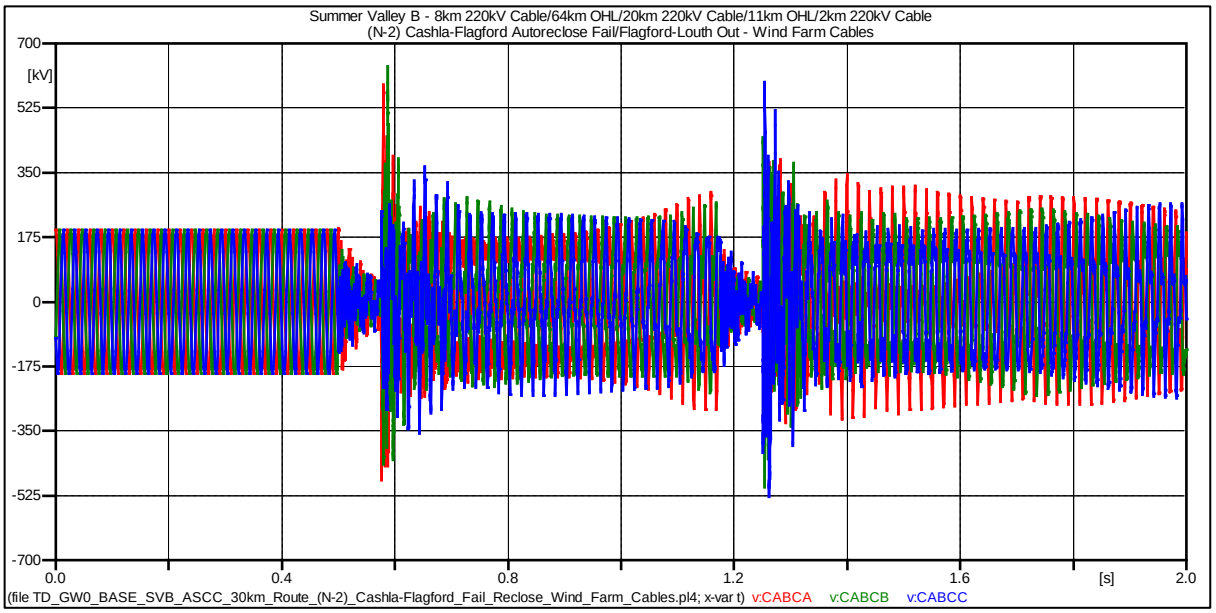

Figure 7: SVB - Length 30km – Cable Mid Point C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	641.23 kV (3.5707 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	340.26 kV (1.8947 pu)	287.32 kV (1.6 pu)	Fail
Unstable oscillation - Fail			

*Pass can be achieved with the application of surge arrestors

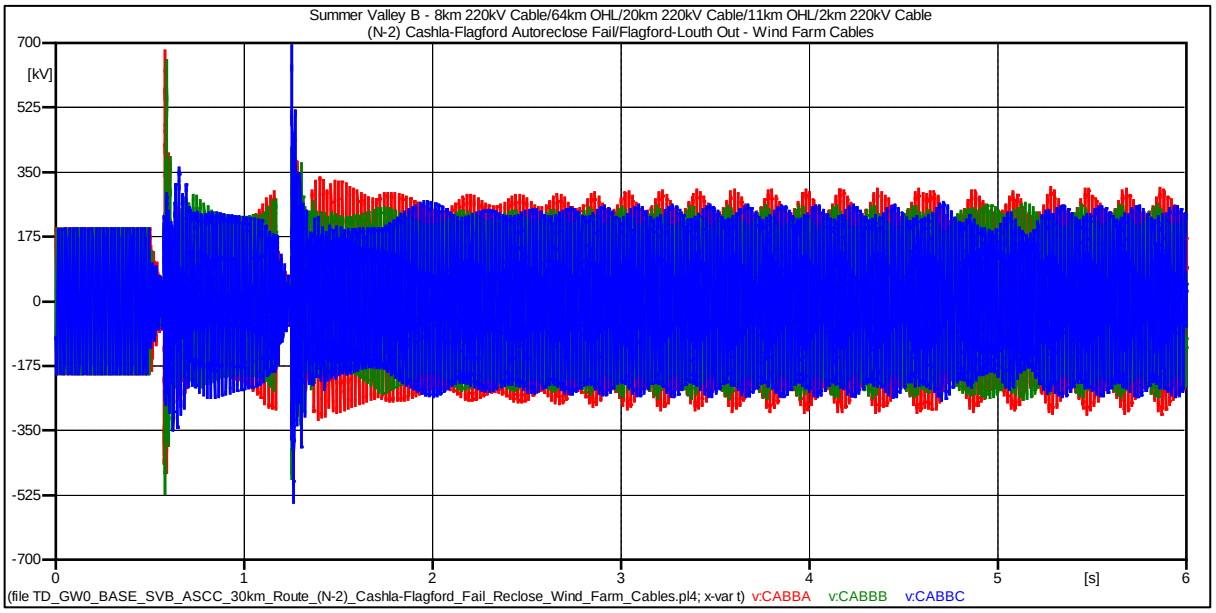

Figure 8: SVB - Length 30km – Cable Mid Point B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

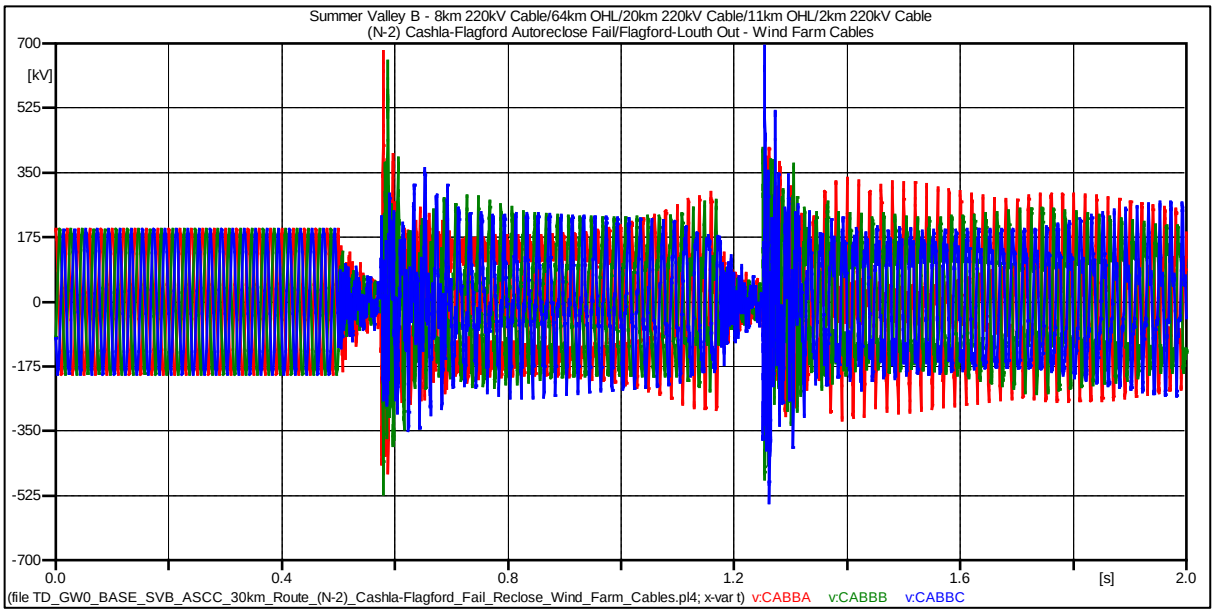

Figure 9: SVB - Length 30km – Cable Mid Point B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	680.78 kV (3.7909 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	339.58 kV (1.8909 pu)	287.32 kV (1.6 pu)	Fail
Unstable oscillation - Fail			

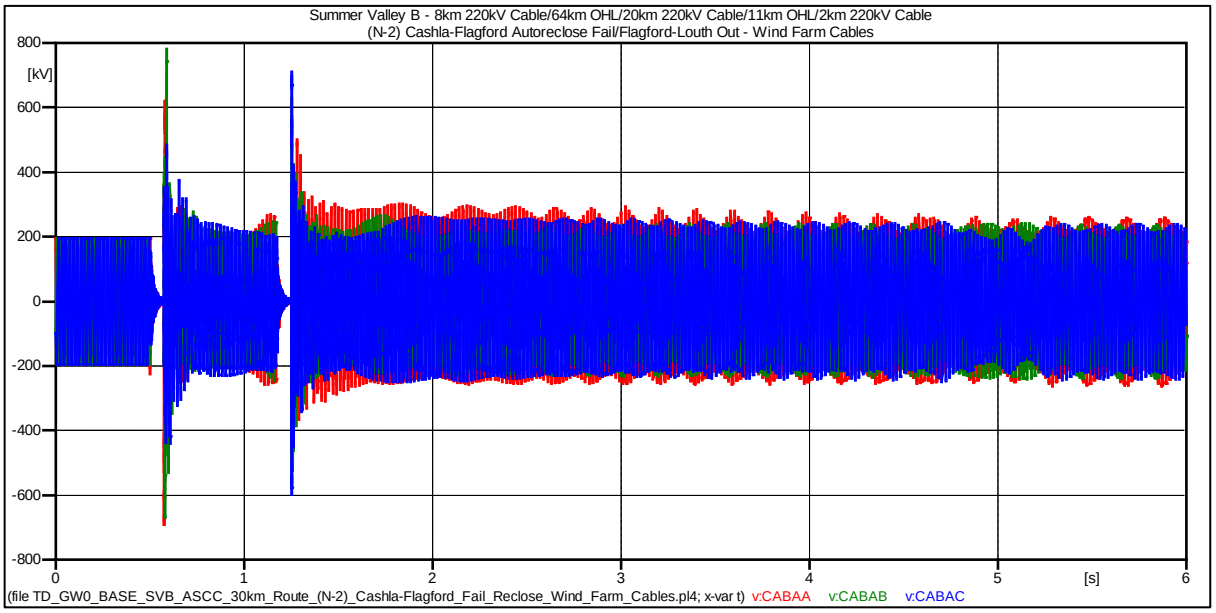

Figure 10: SVB - Length 30km – Cable Mid Point A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

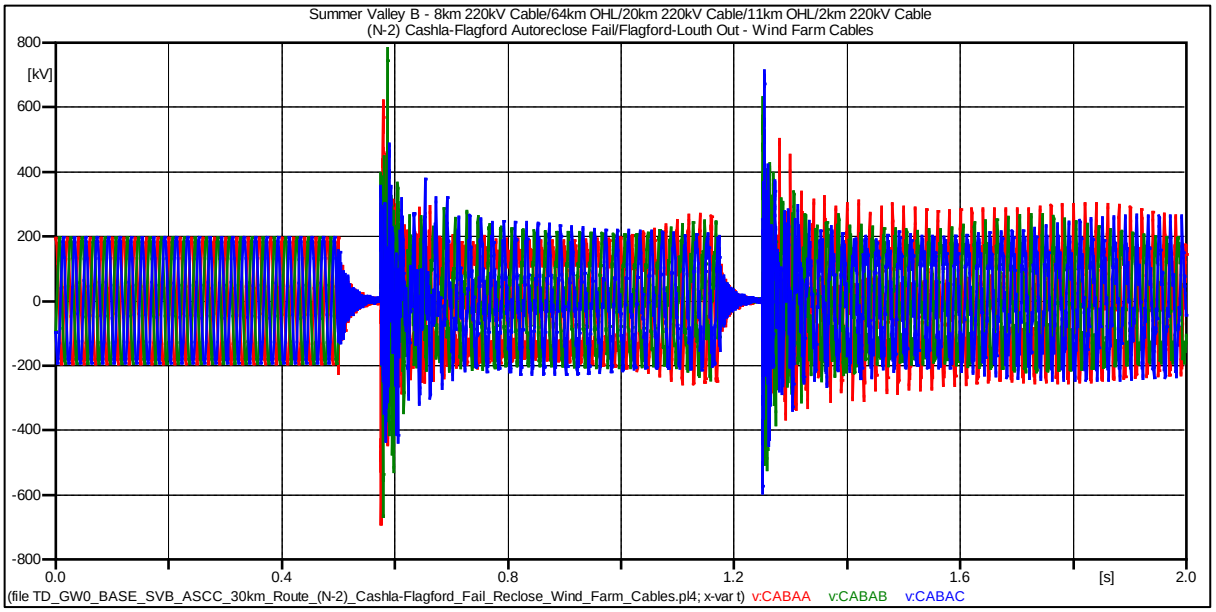

Figure 11: SVB - Length 30km – Cable Mid Point A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	790.51 kV (4.4019 pu)	449.07 kV (2.5 pu)	Fail*
Temporary Overvoltage	310.58 kV (1.7294 pu)	287.32 kV (1.6 pu)	Fail
Unstable oscillation - Fail			

*Pass can be achieved with the application of surge arrestors

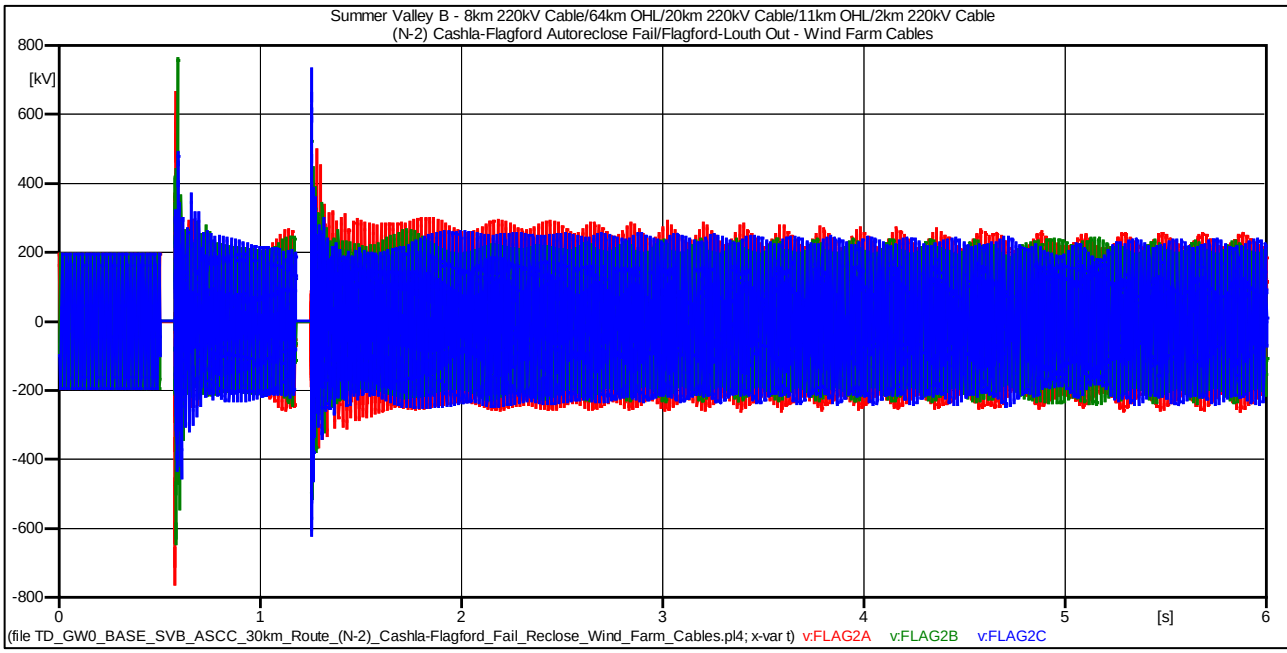

Figure 12: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

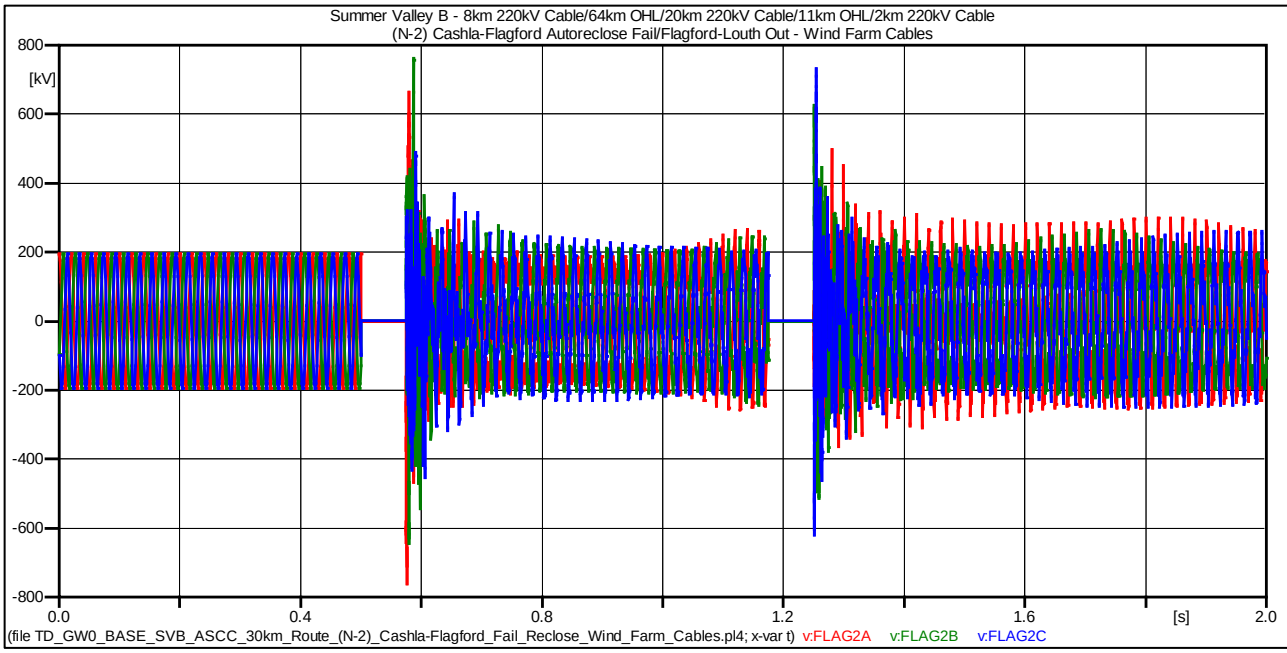

Figure 13: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	788.26 kV (4.3894 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	305.12 kV (1.6990 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

1.3 Impedance Scans - Length 30km (8+20+2) – Summer Valley B – Case 2

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 45MVar

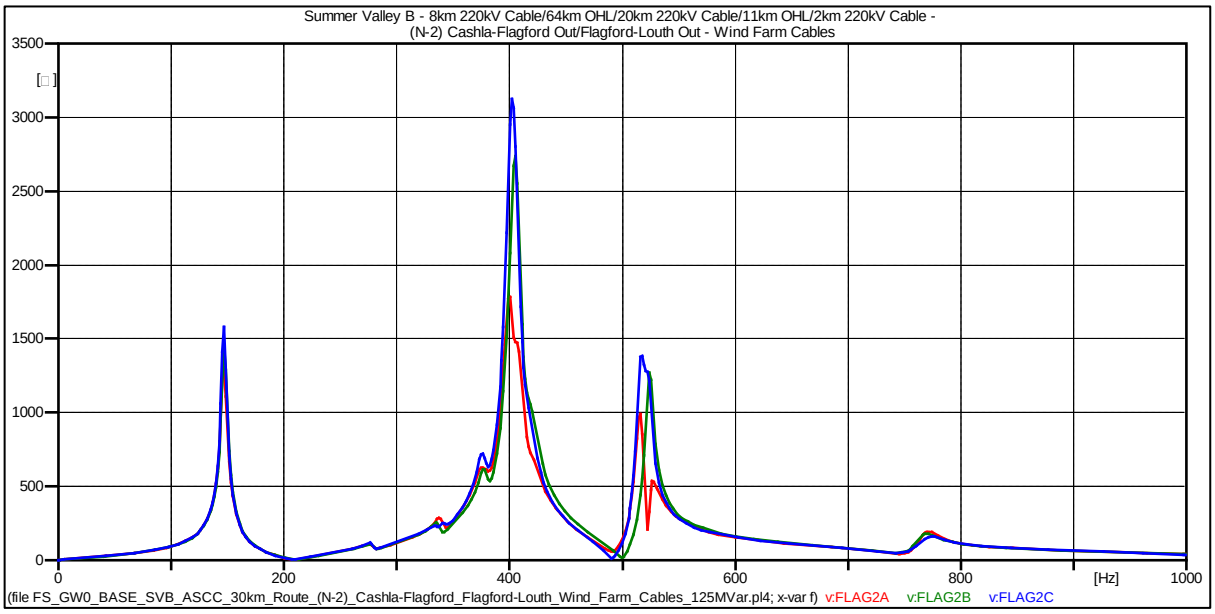

Figure 14: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out – Increased Reactor

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
147.01	1578.9
402.01	3126.8
517.51	1384.9

1.4 Time Domain Simulation - Length 30km (8+20+2) – Summer Valley B – Case 2

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 45Mvar

Case 2: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

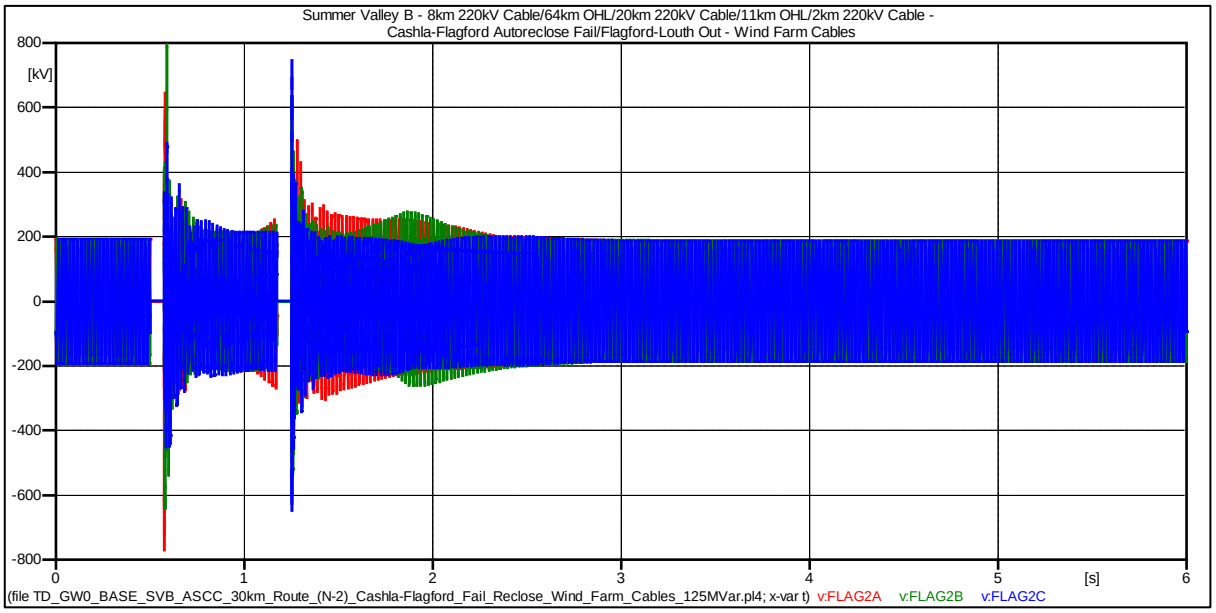

Figure 15: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

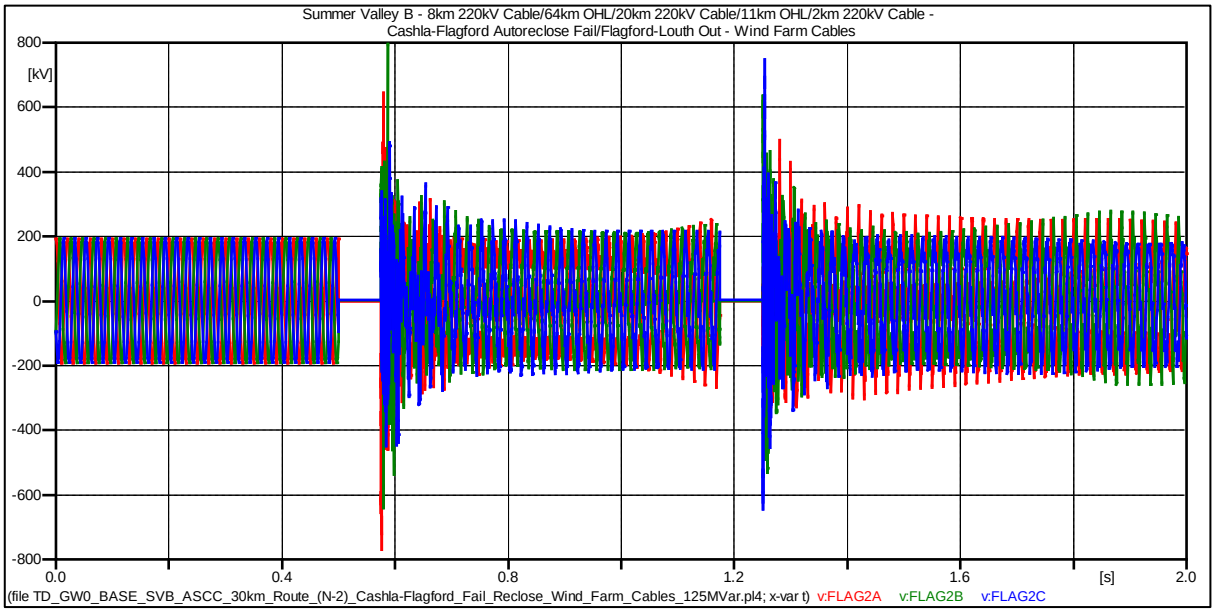

Figure 16: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	790.12 kV (4.3998 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	355.21 kV (1.9780 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

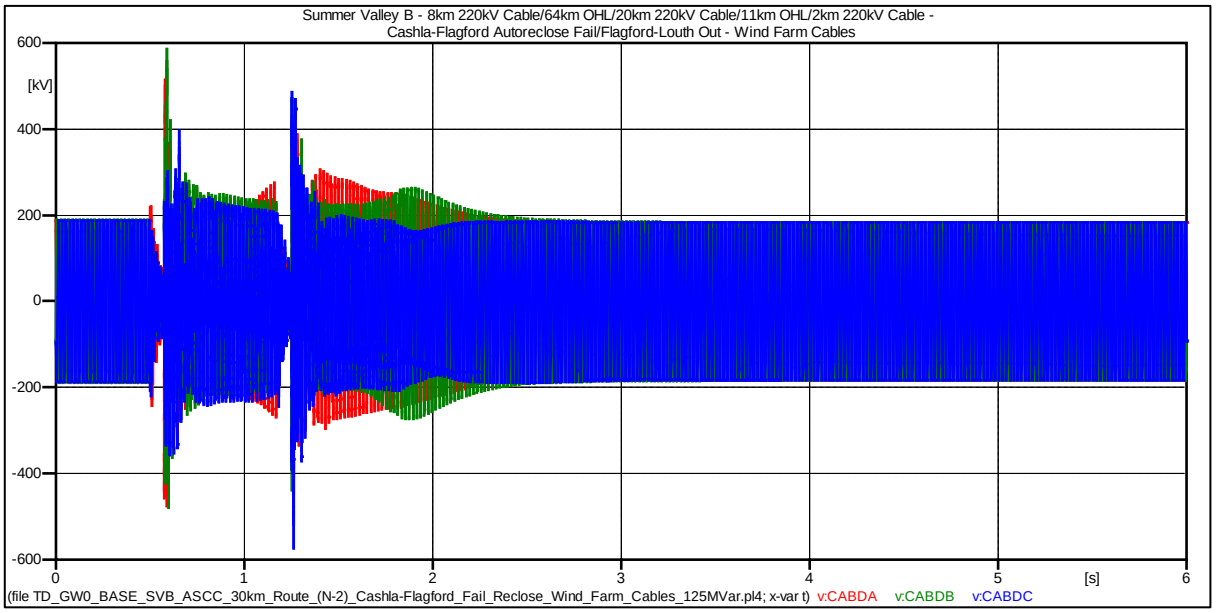

Figure 17: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

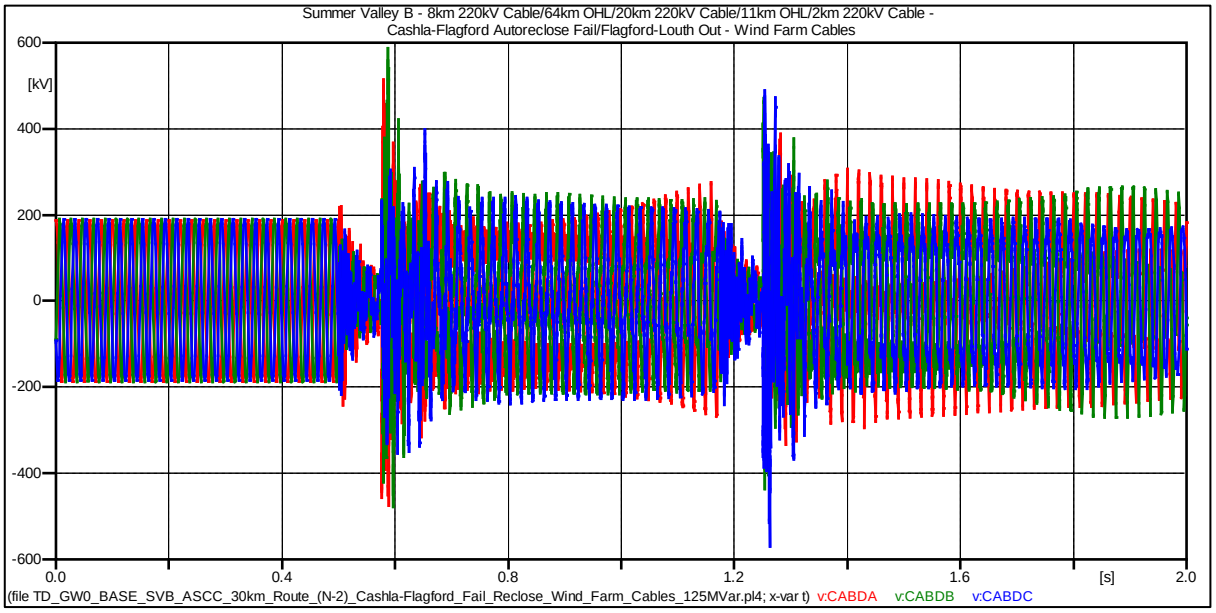

Figure 18: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	595.56 kV (3.3164 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	400.23 kV (2.2287 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

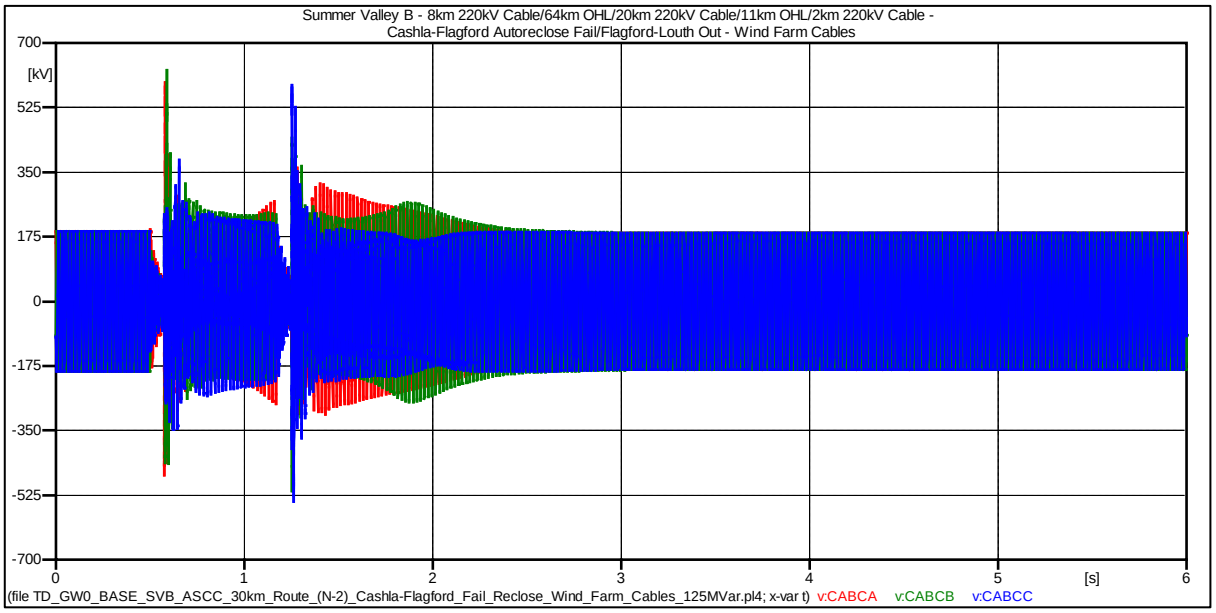

Figure 19: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

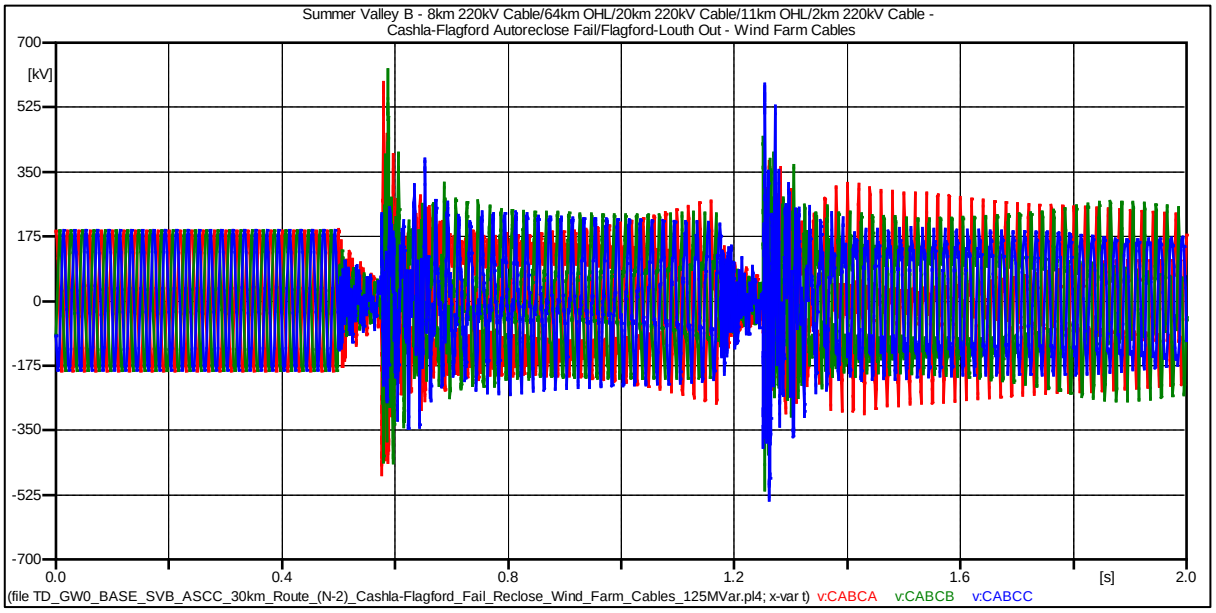

Figure 20: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	595.56 kV (3.3164 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	400.23 kV (2.2287 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

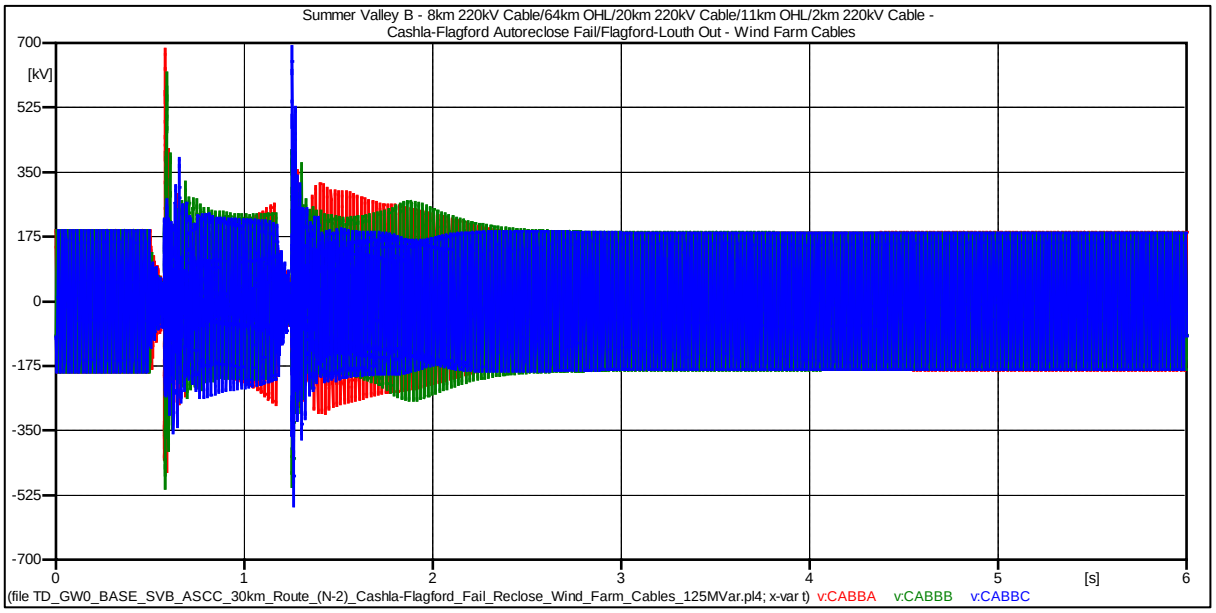

Figure 21: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

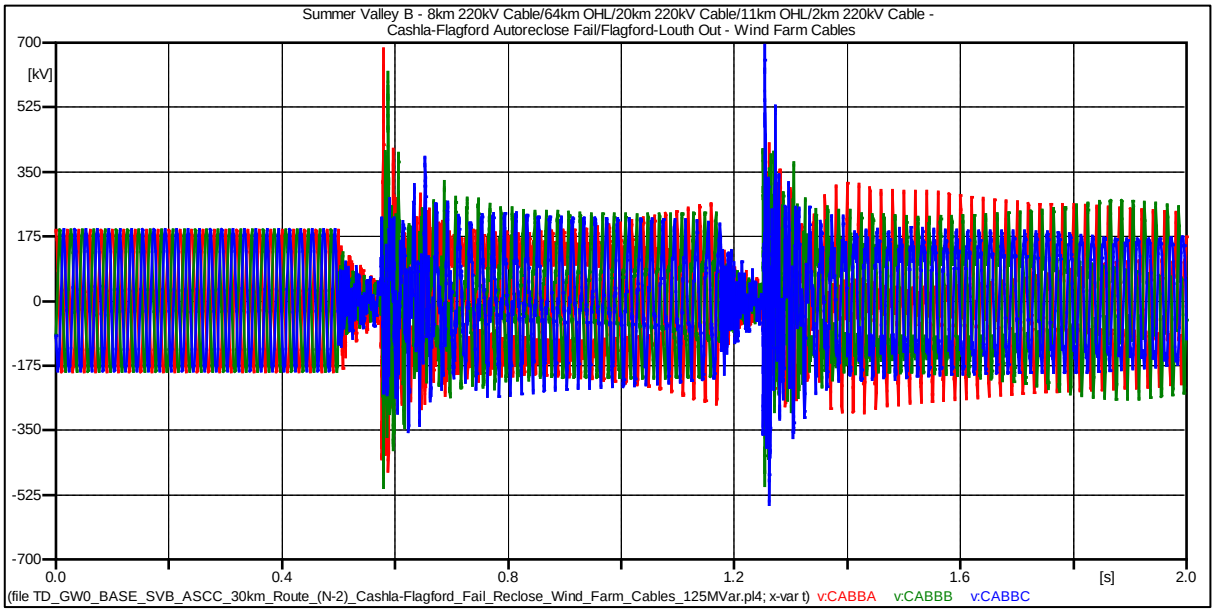

Figure 22: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	690.78 kV (3.8466 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	378.56 kV (2.1080 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

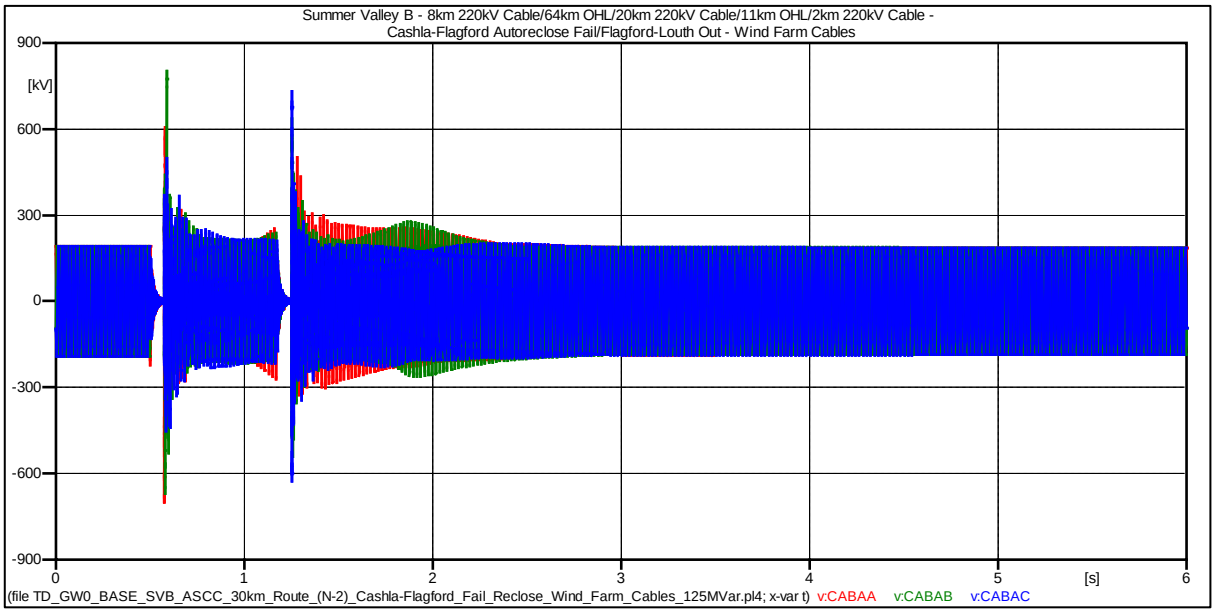

Figure 23: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

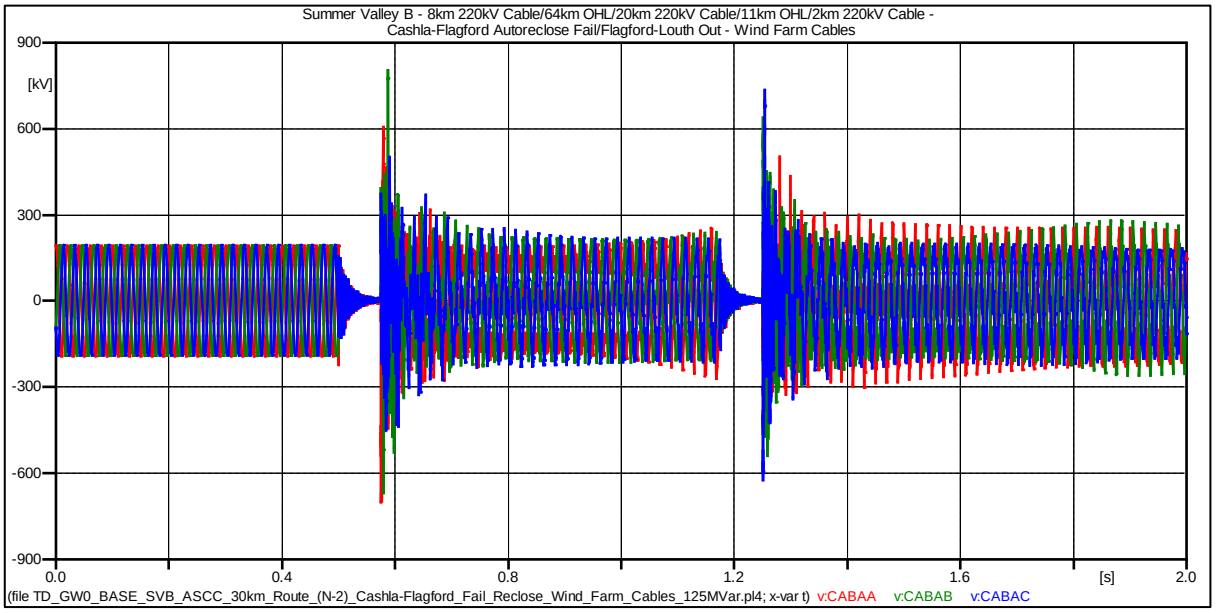

Figure 24: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	690.78 kV (3.8466 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	378.56 kV (2.1080 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

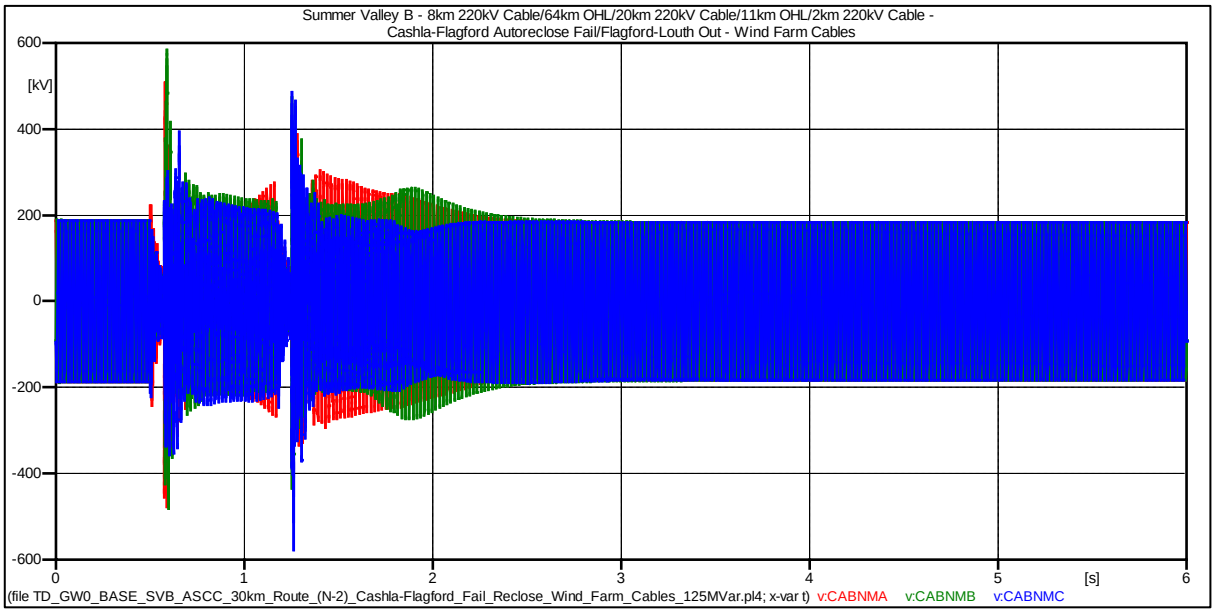

Figure 25: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

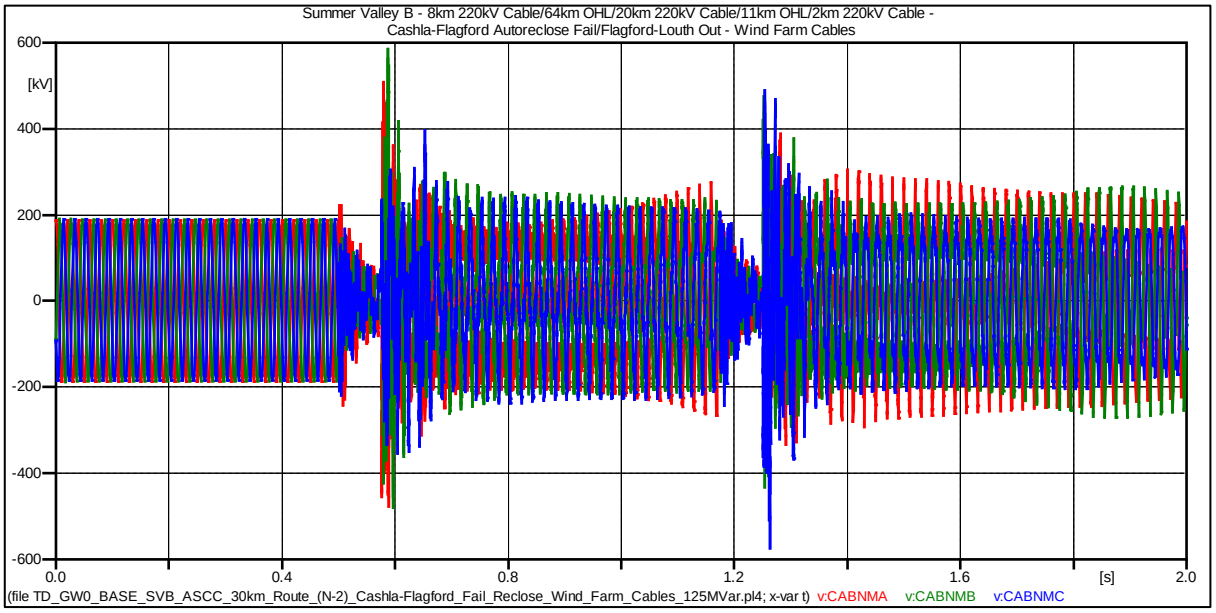

Figure 26: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	590.81 kV (3.2899 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	341.78 kV (1.9032 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

1.5 Impedance Scans - Length 30km (8+20+2) – Summer Valley B – Case 3

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar

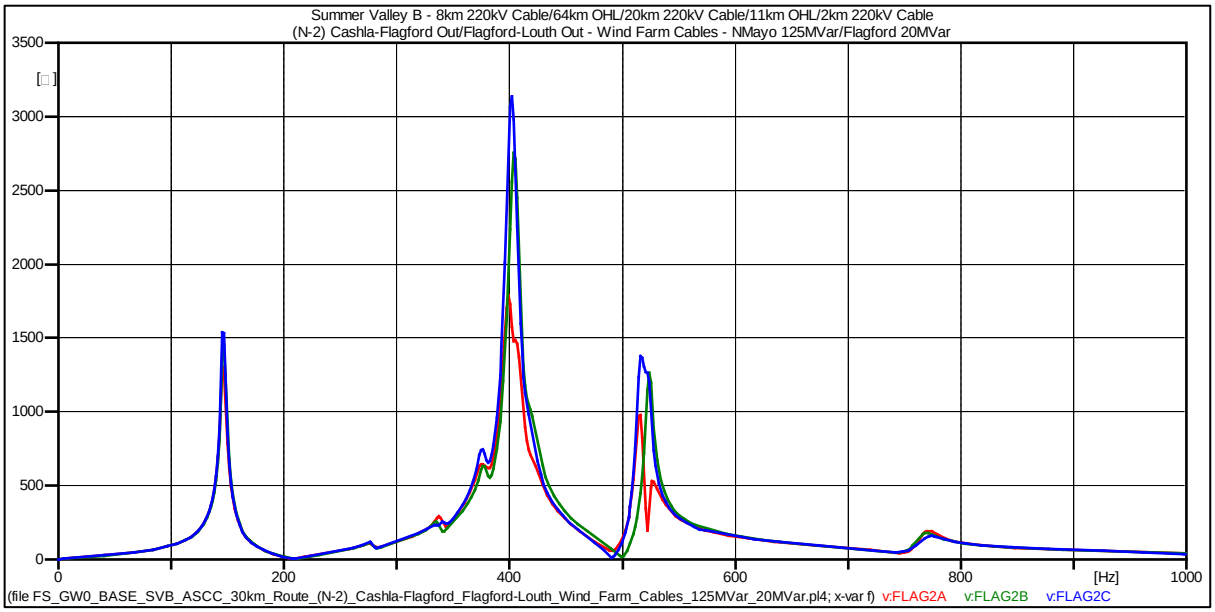

Figure 27: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
145.51	1535.5
402.01	3138.0
517.51	1367.8

1.6 Time Domain Simulation - Length 30km (8+20+2) – Summer Valley B – Case 3

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar
4. Voltages in steady state at North Mayo, 188.50kV, 4.9 % Overvoltage
5. Voltages in steady state at Flagford, 194.70kV, 8.4 % Overvoltage

Case 3: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

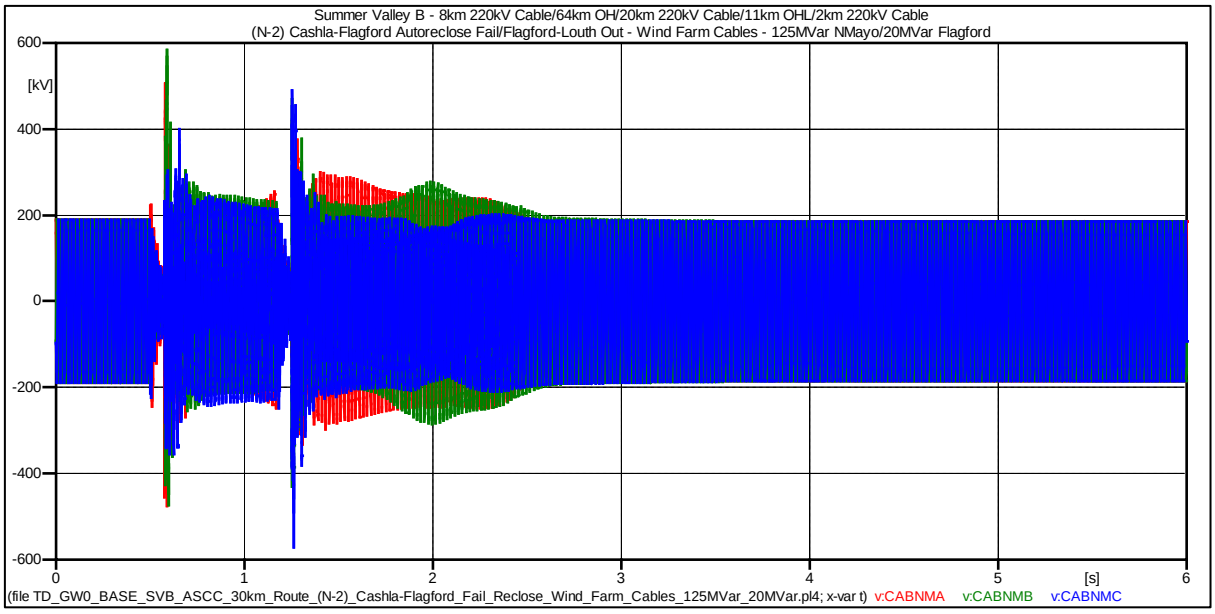

Figure 28: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

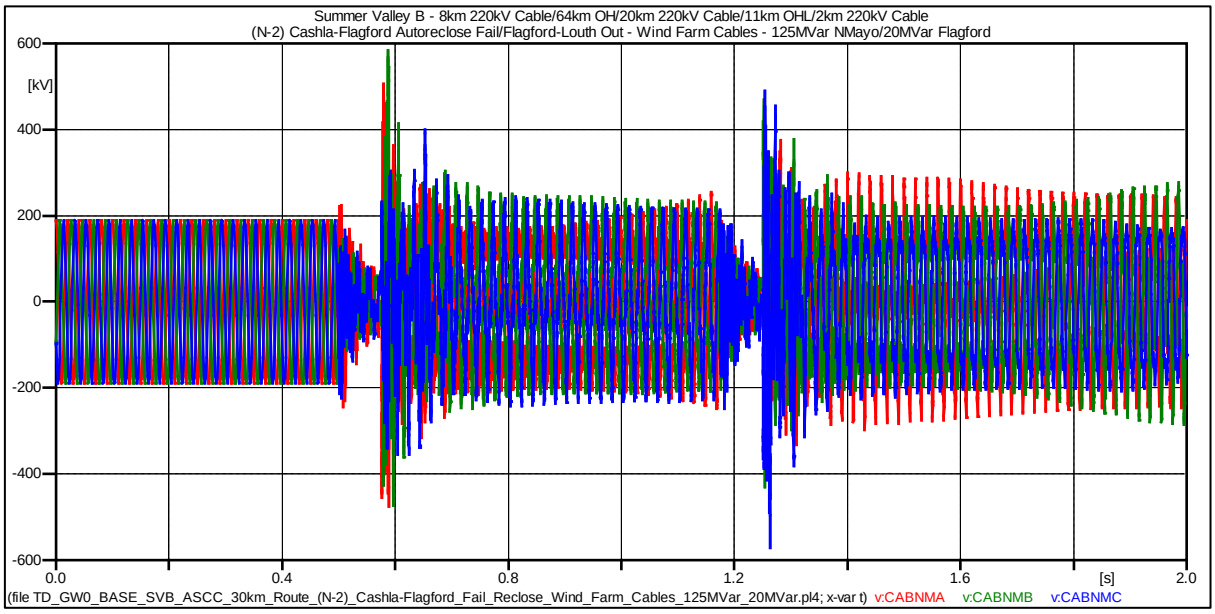

Figure 29: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	592.71 kV (3.3005 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	401.21 kV (2.2341 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

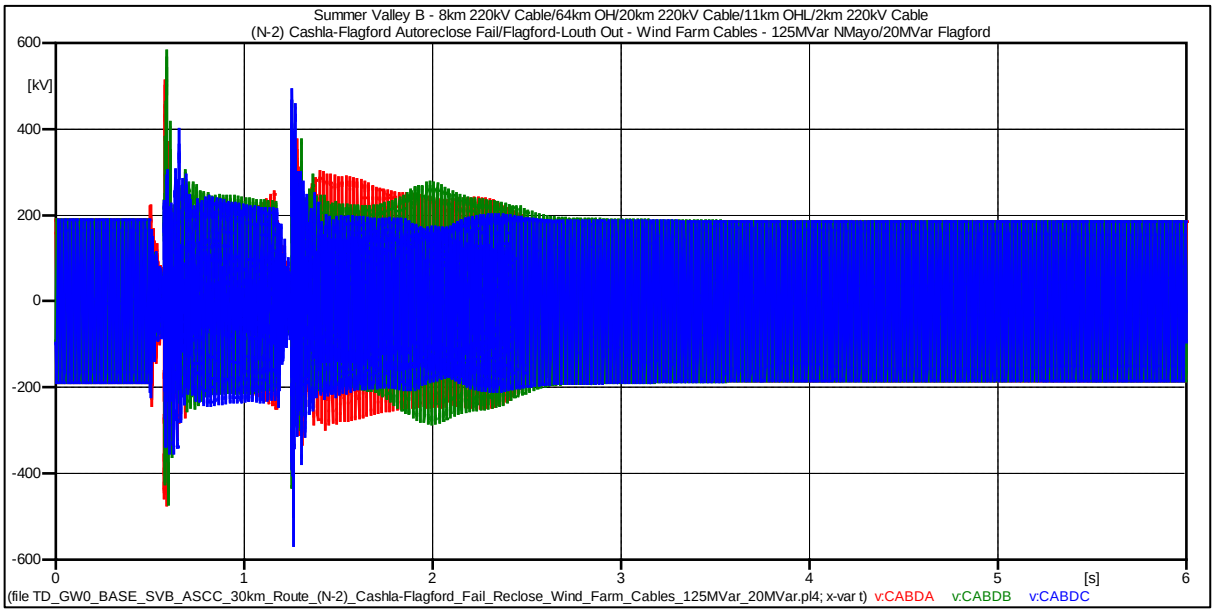

Figure 30: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

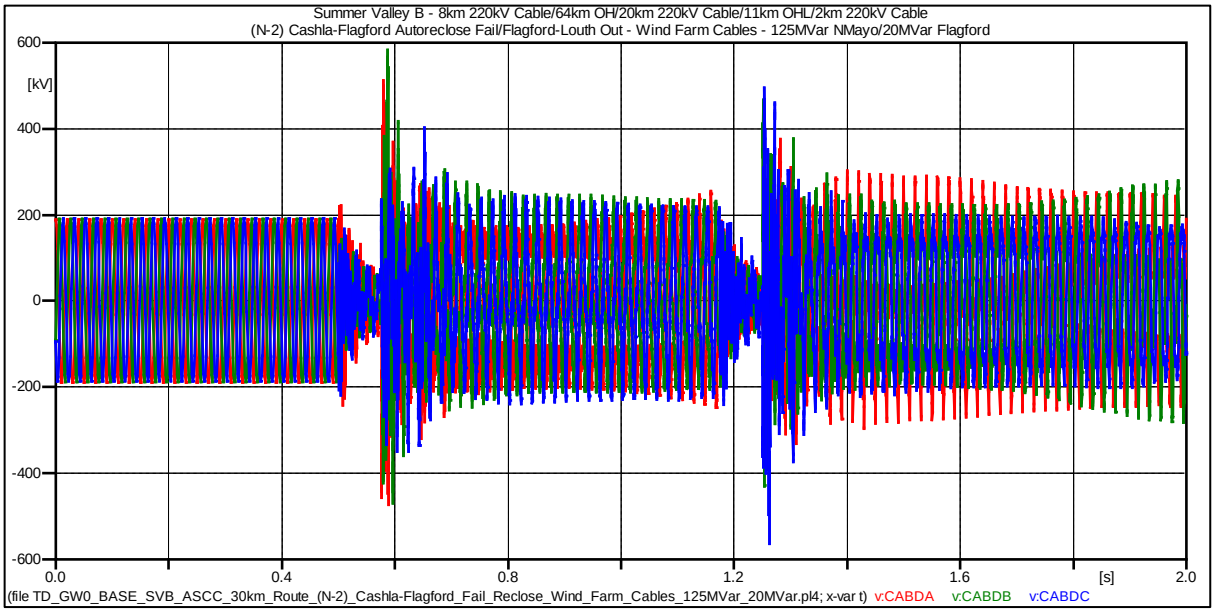

Figure 31: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	582.71 kV (3.2448 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	401.41 kV (2.2352 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

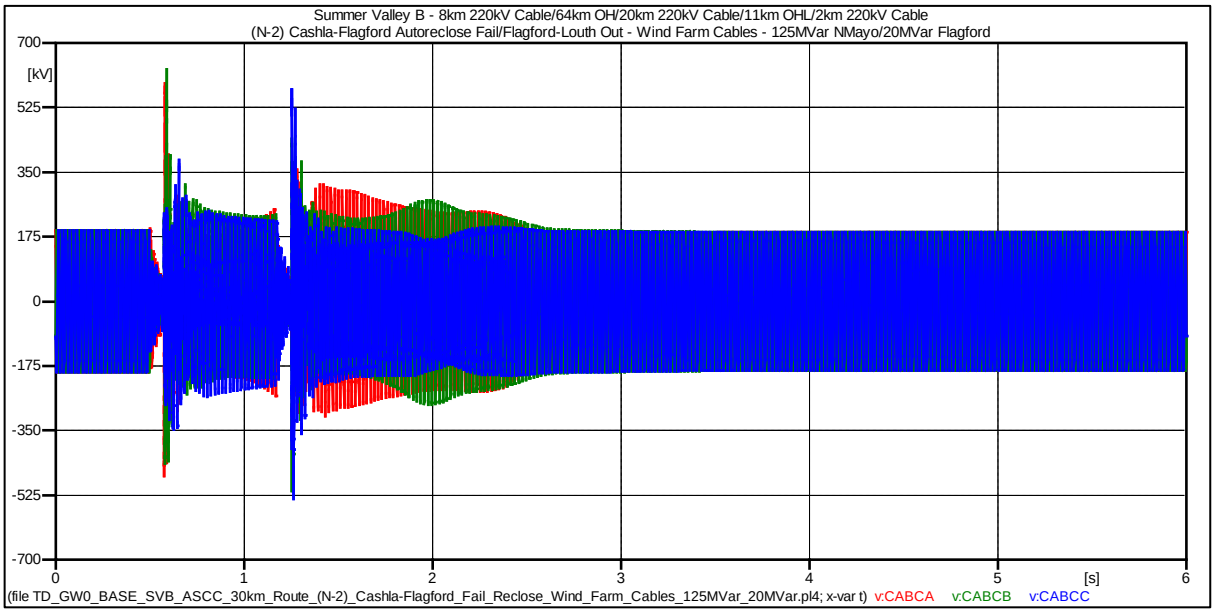

Figure 32: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

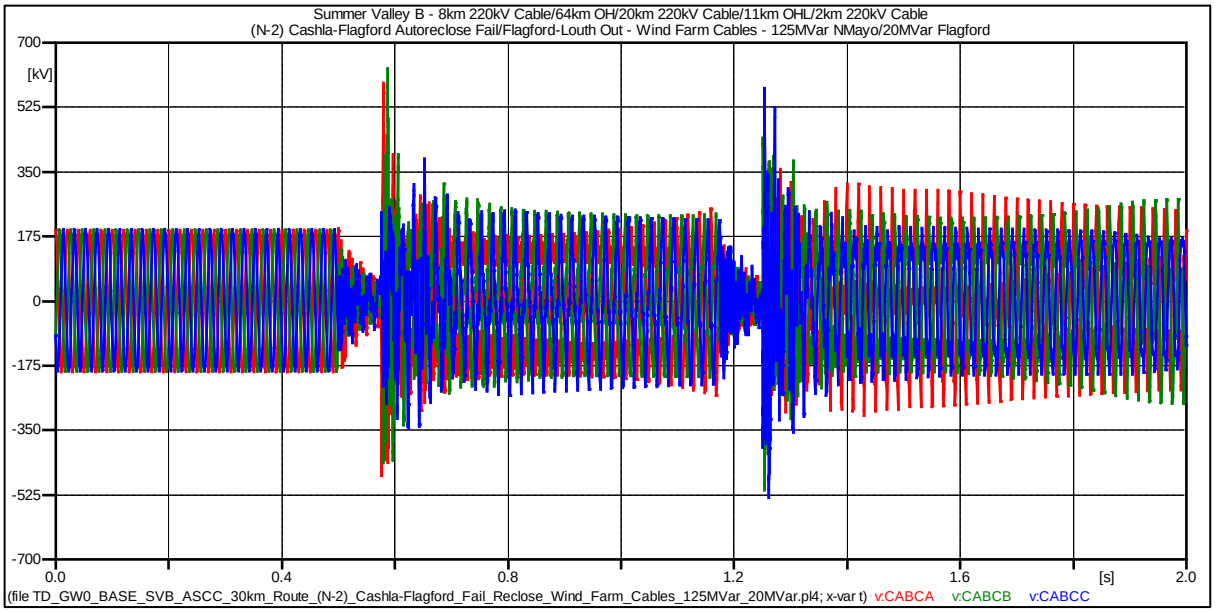

Figure 33: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	598.56 kV (3.3331 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	402.21 kV (2.2397 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

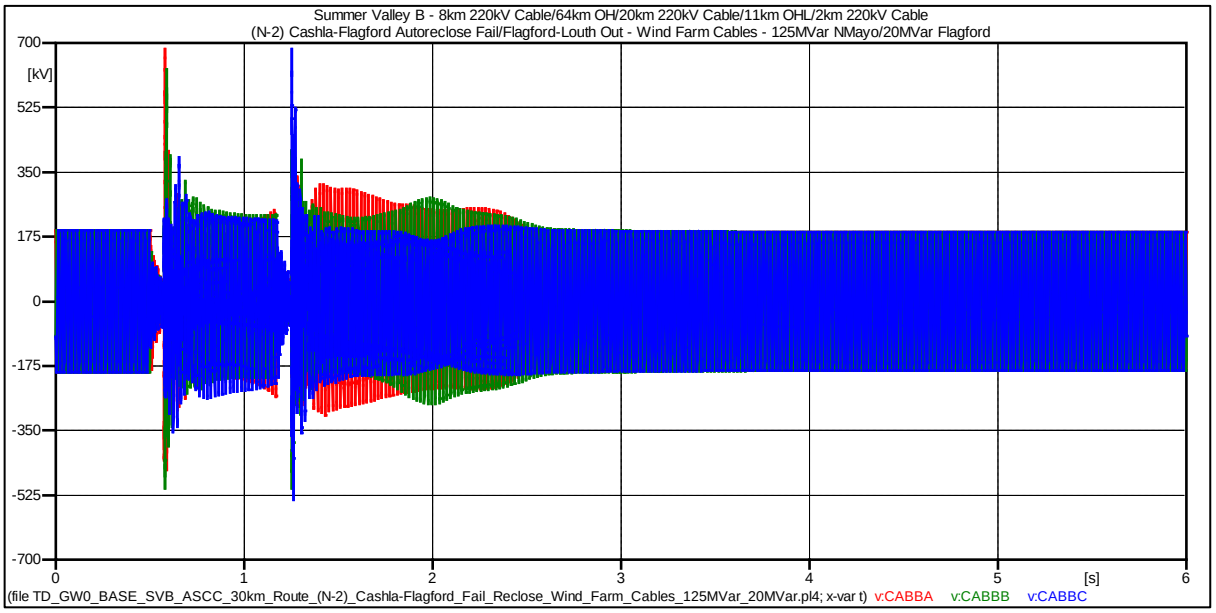

Figure 34: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

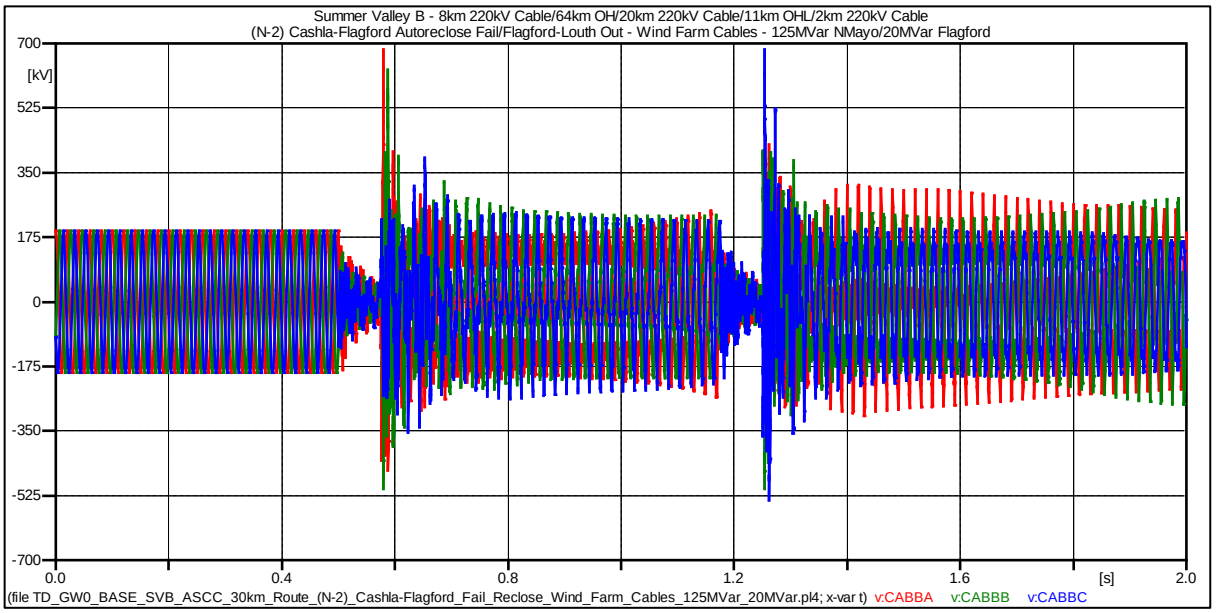

Figure 35: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	598.56 kV (3.3331 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	402.21 kV (2.2397 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

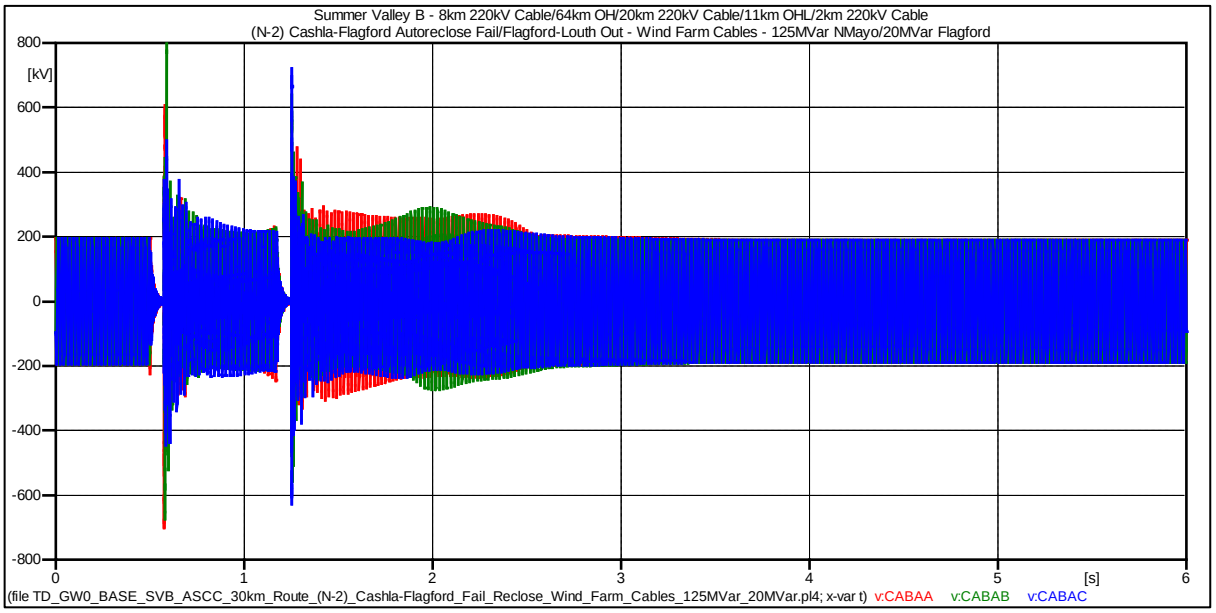

Figure 36: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

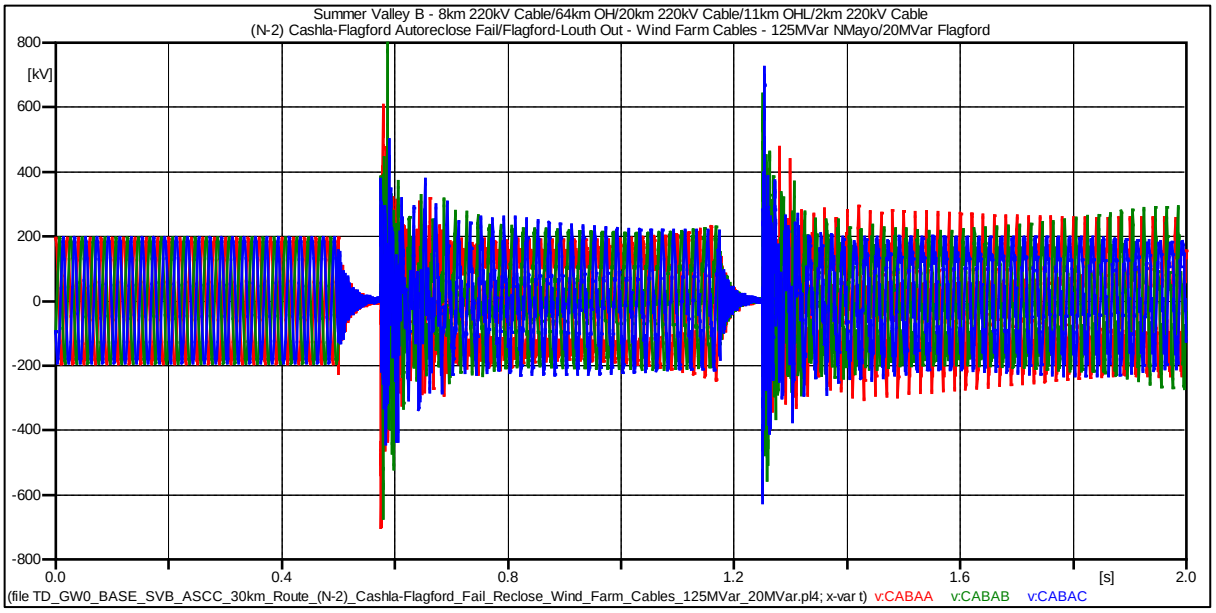

Figure 37: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	801.23 kV (4.4616 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	394.23 kV (2.1952 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

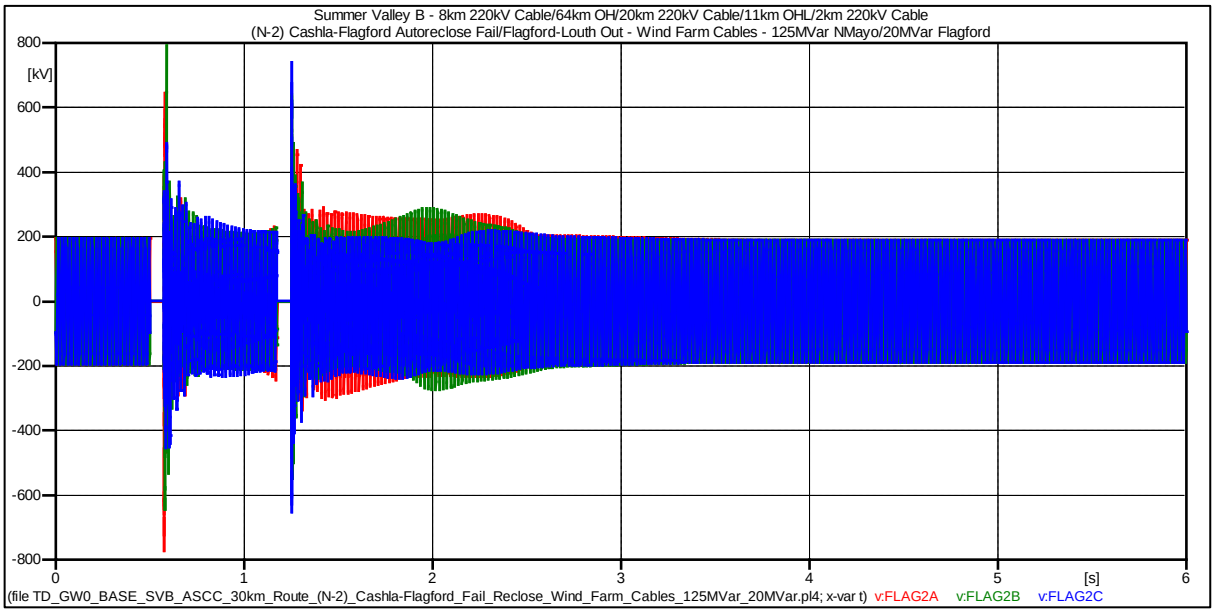

Figure 38: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Reduced reactor

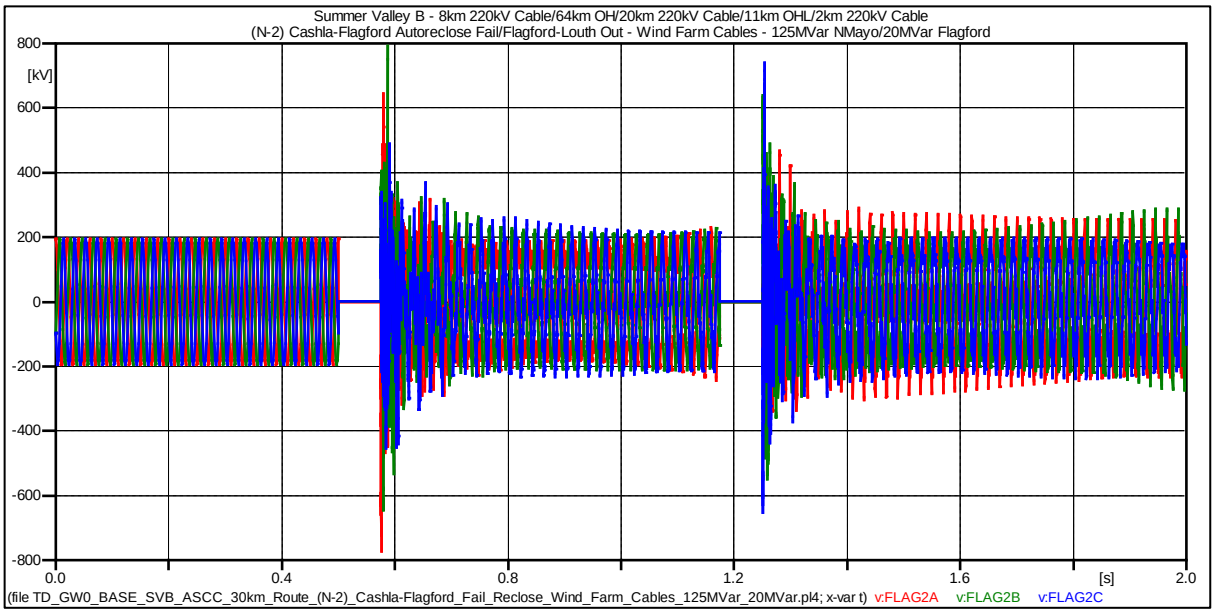

Figure 39: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Reduced reactor

Condition	Maximum Value	Limit	Result
Switching	798.18 kV (4.444 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	384.23 kV (2.1396 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

1.7 Impedance Scans - Length 30km (8+20+2) – Summer Valley B – Case 4

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar
4. Filter added for 3rd Harmonic. Filter connected to 220kV bar at North Mayo, L = 1.2324H, C = 0.9134 uF Assuming rating of 125MVar

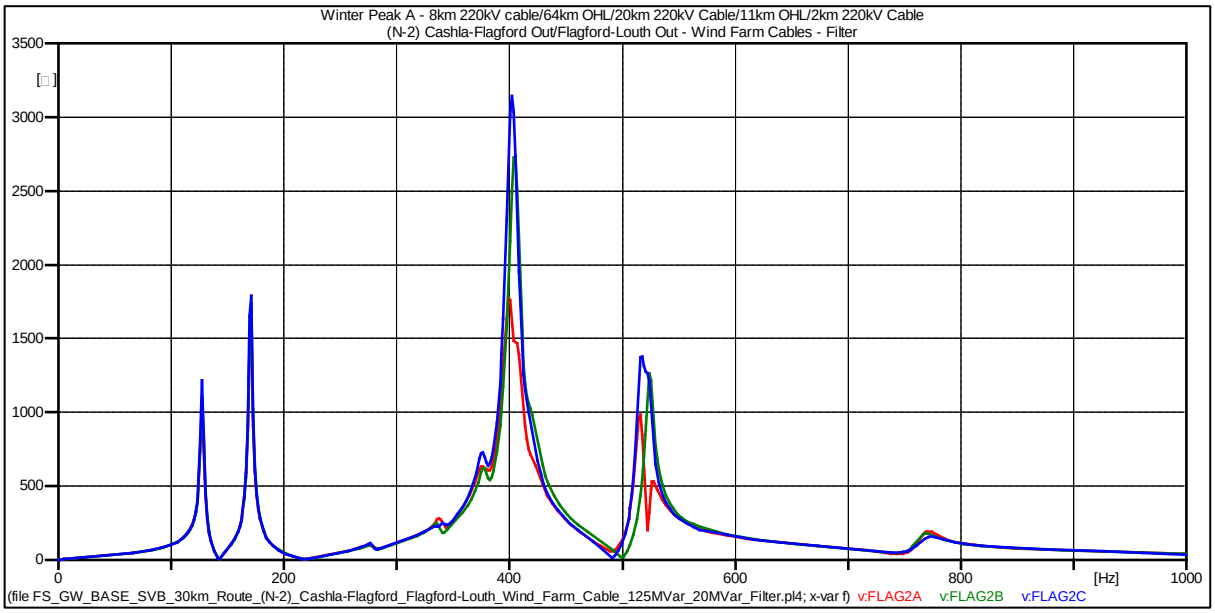

Figure 40: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
127.51	1214.2
171.01	1787.6
403.51	3032.2
517.51	1376.1

1.8 Time Domain Simulation - Length 30km (8+20+2) – Summer Valley B – Case 4

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar
4. Filter added for 3rd Harmonic. Filter connected to 220kV bar at North Mayo, L = 1.2324H, C = 0.9134 uF Assuming rating of 125MVar

Case 4: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

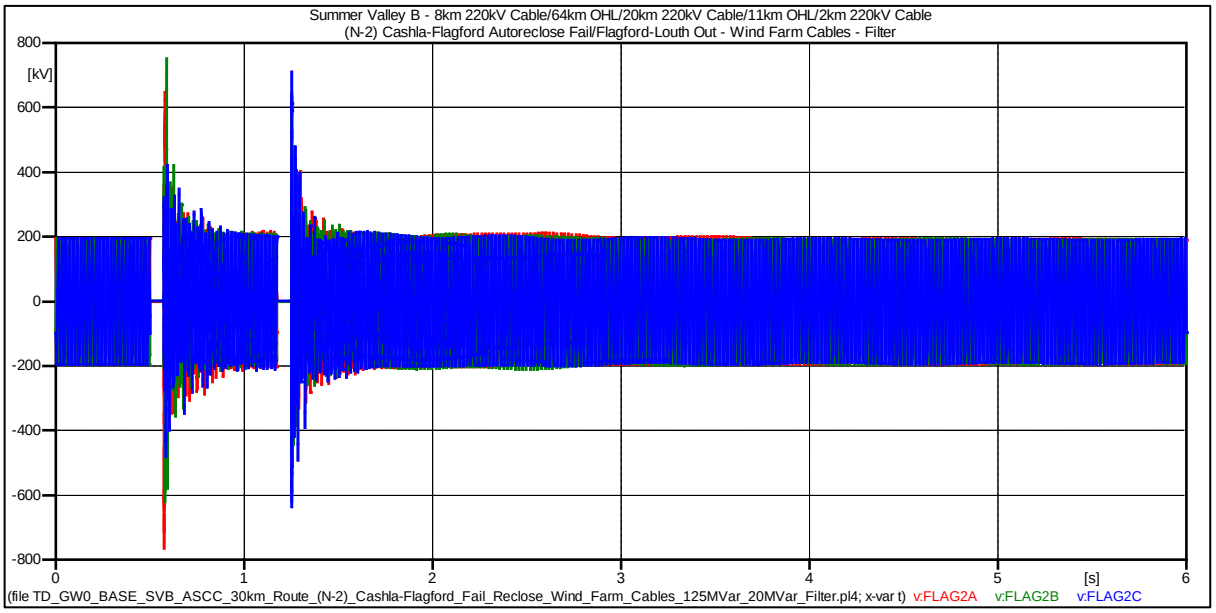

Figure 41: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

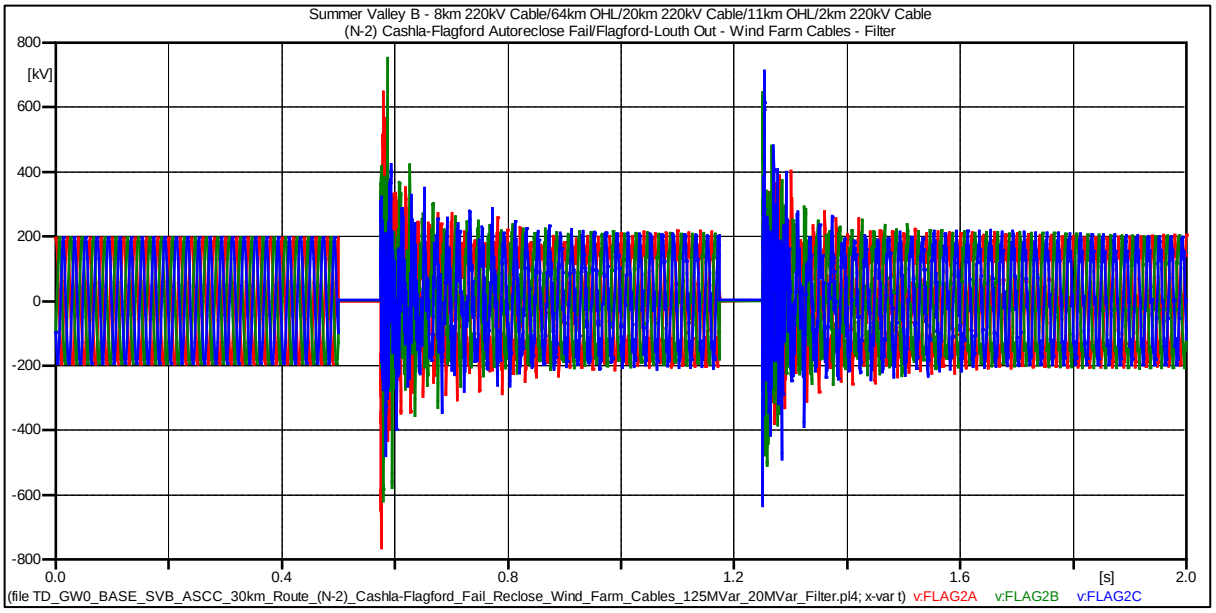

Figure 42: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	781.18 kV (4.3500 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	410.89 kV (2.2880 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

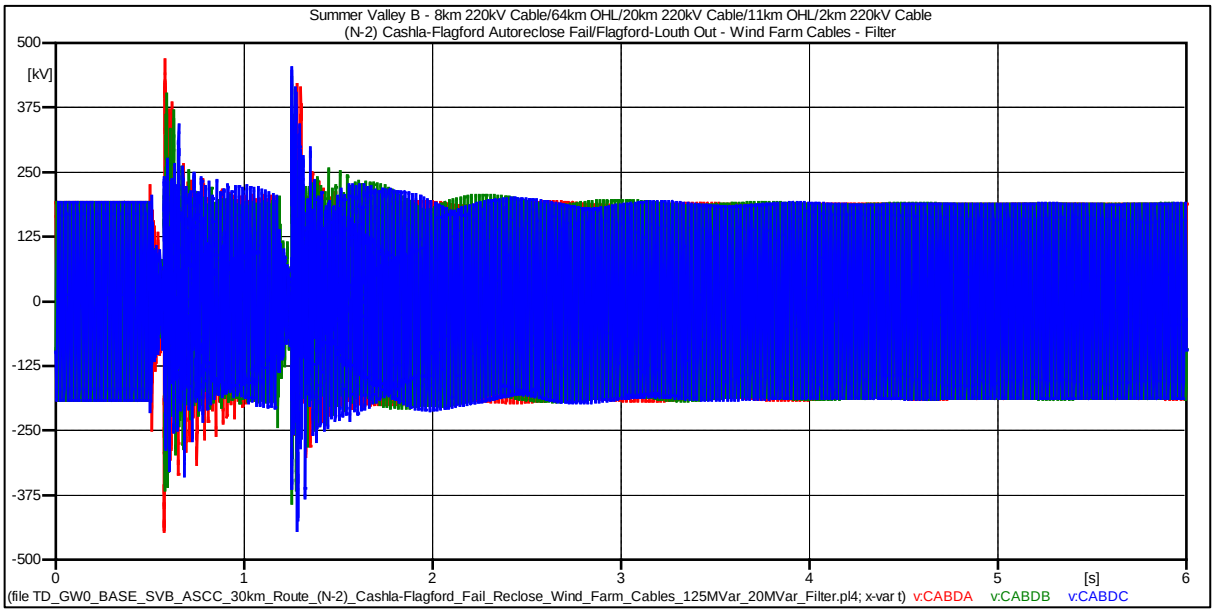

Figure 43: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

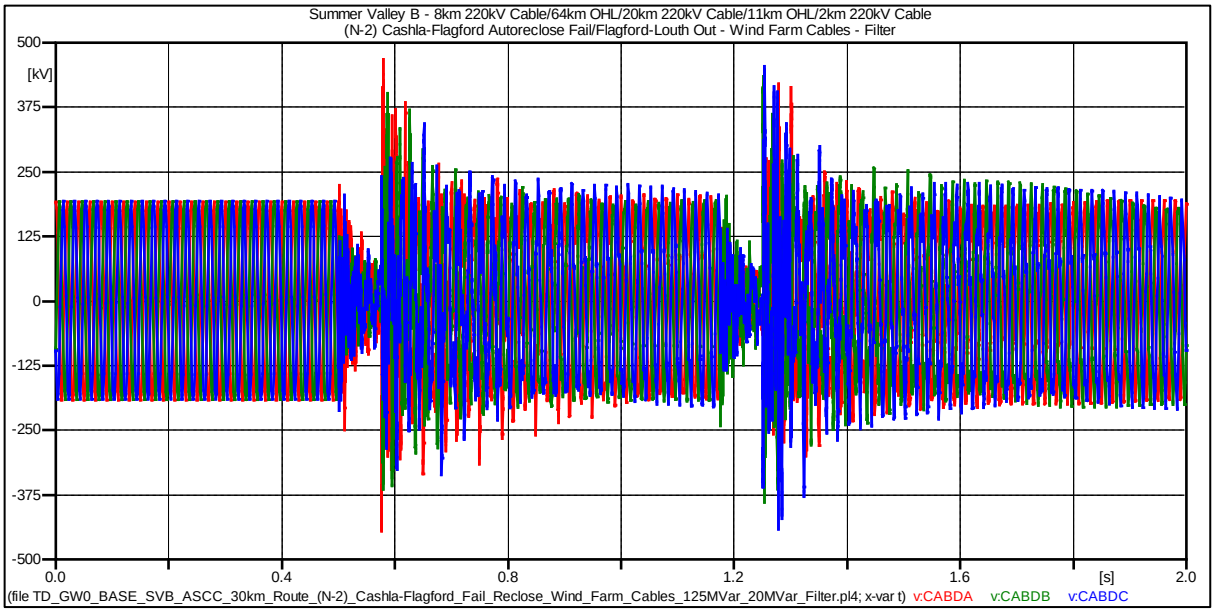

Figure 44: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	475.65 kV (2.6486 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	380.23 kV (2.1173 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

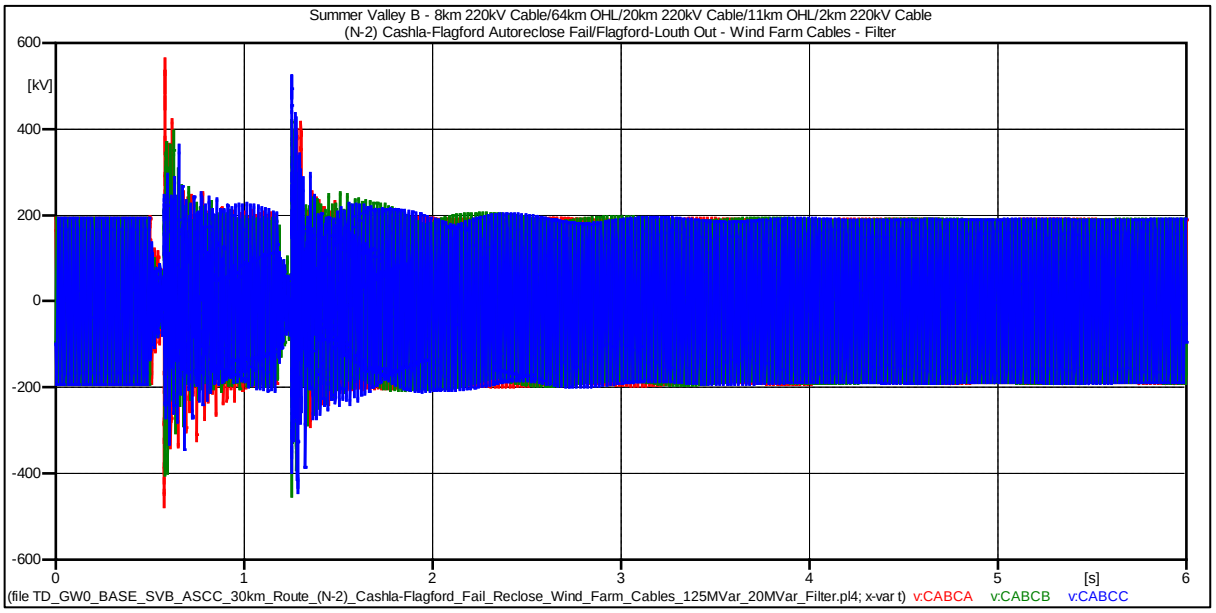

Figure 45: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

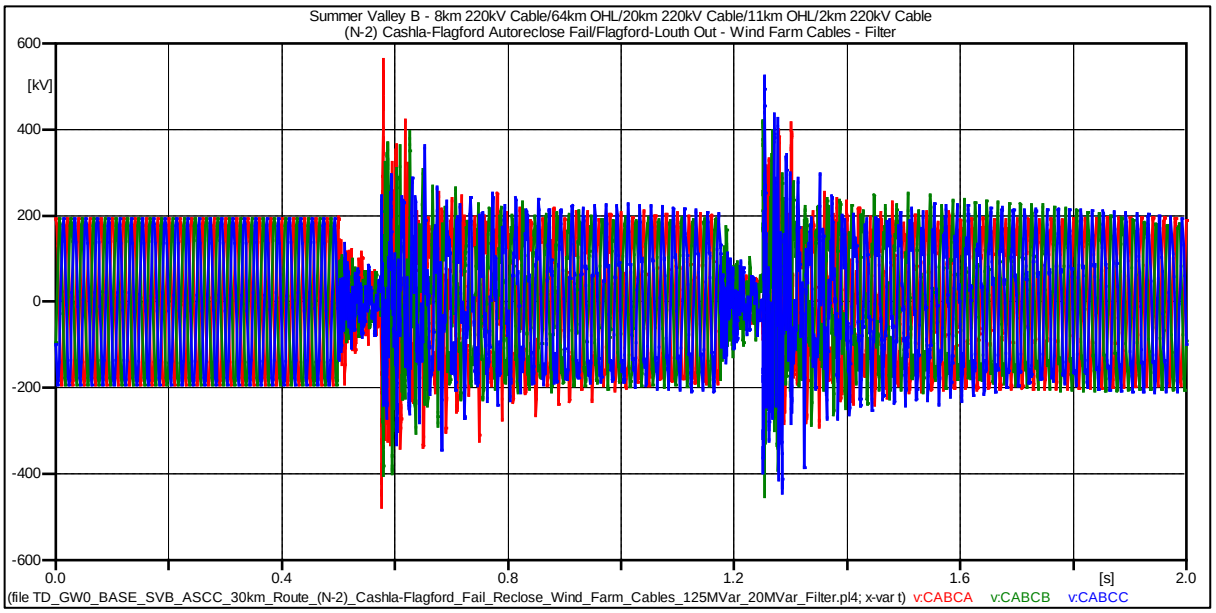

Figure 46: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	580.23 kV (3.2310 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	246.89 kV (1.3748 pu)	287.32 kV (1.6 pu)	Pass

*Pass can be achieved with the application of surge arrestors

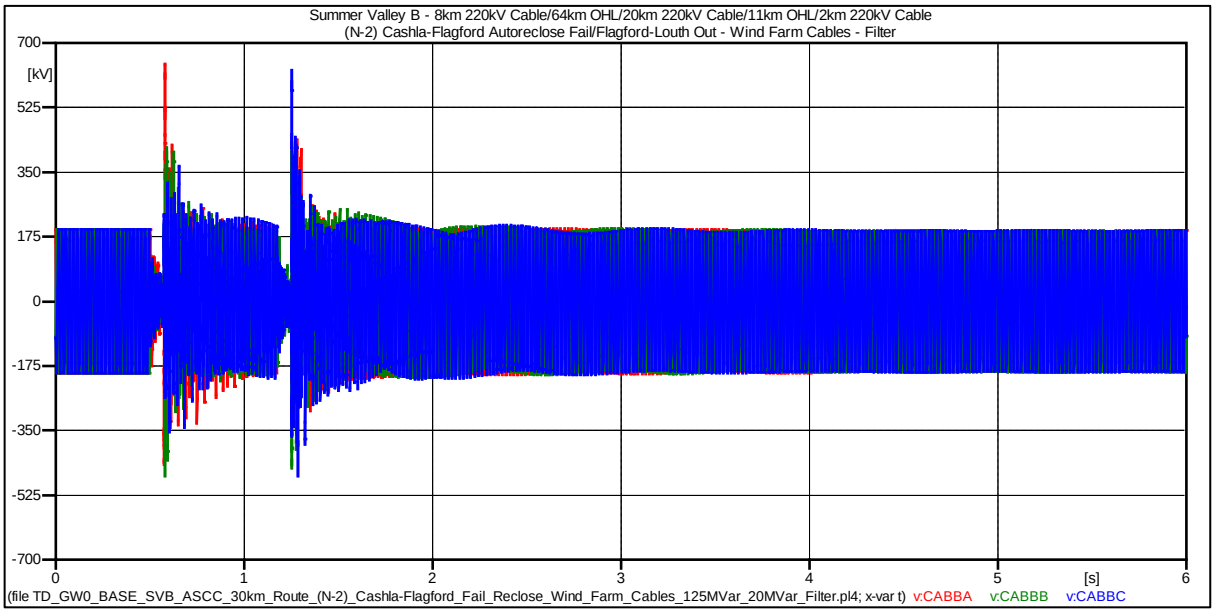

Figure 47: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

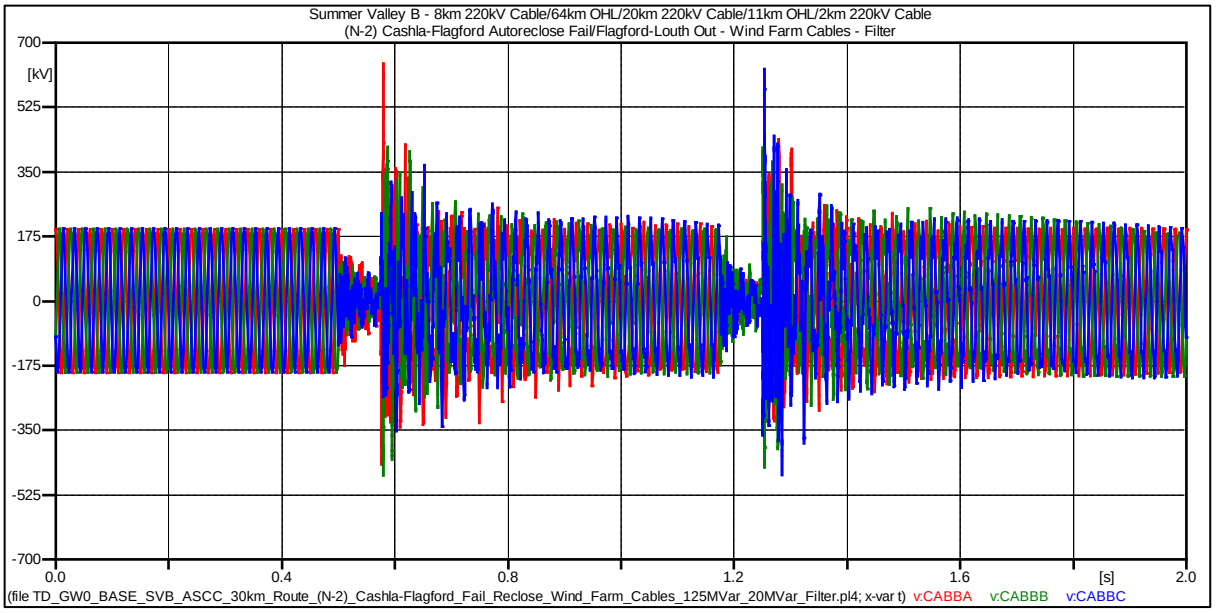

Figure 48: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	620.36 kV (3.4493 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	350.69 kV (1.9528 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

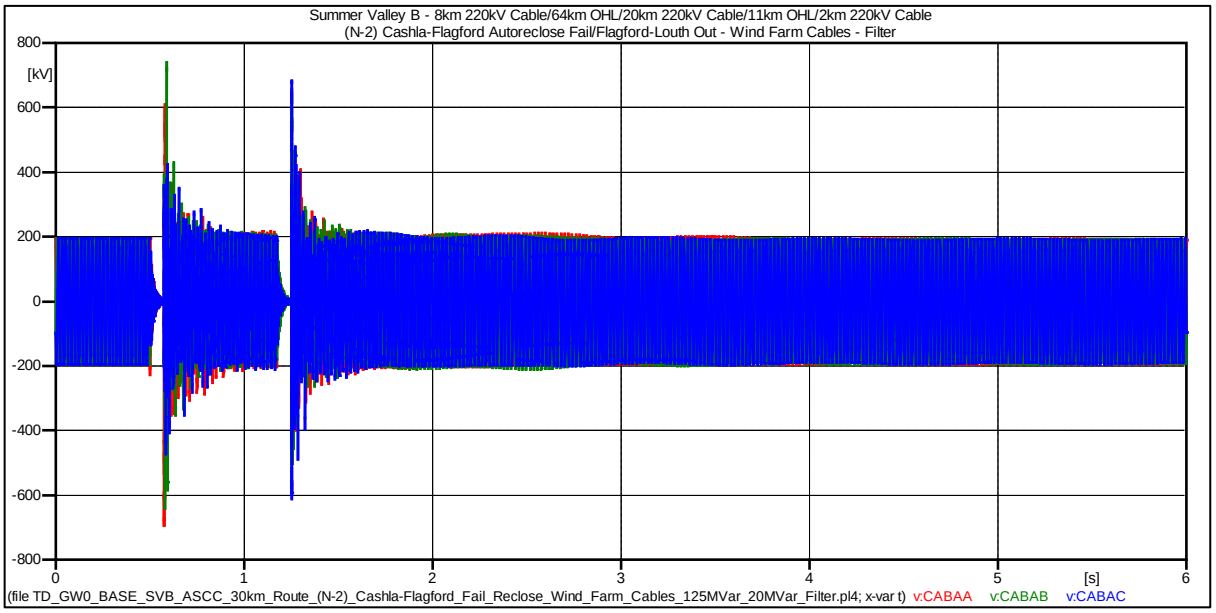

Figure 49: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

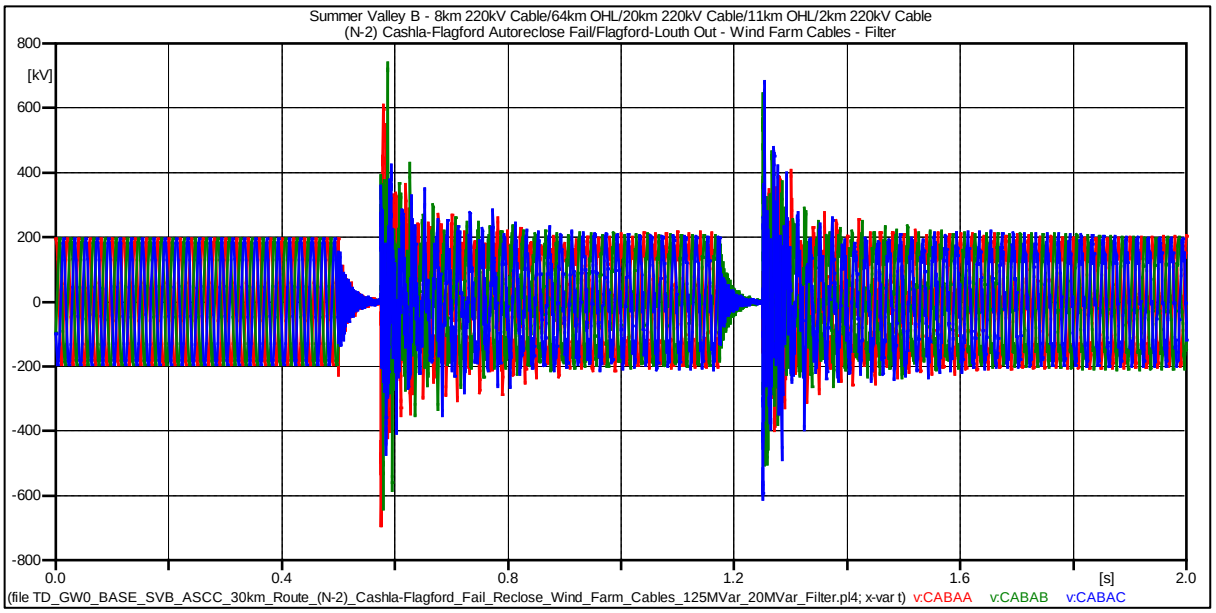

Figure 50: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	720.62 kV (4.0128 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	420.15 kV (2.3396 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

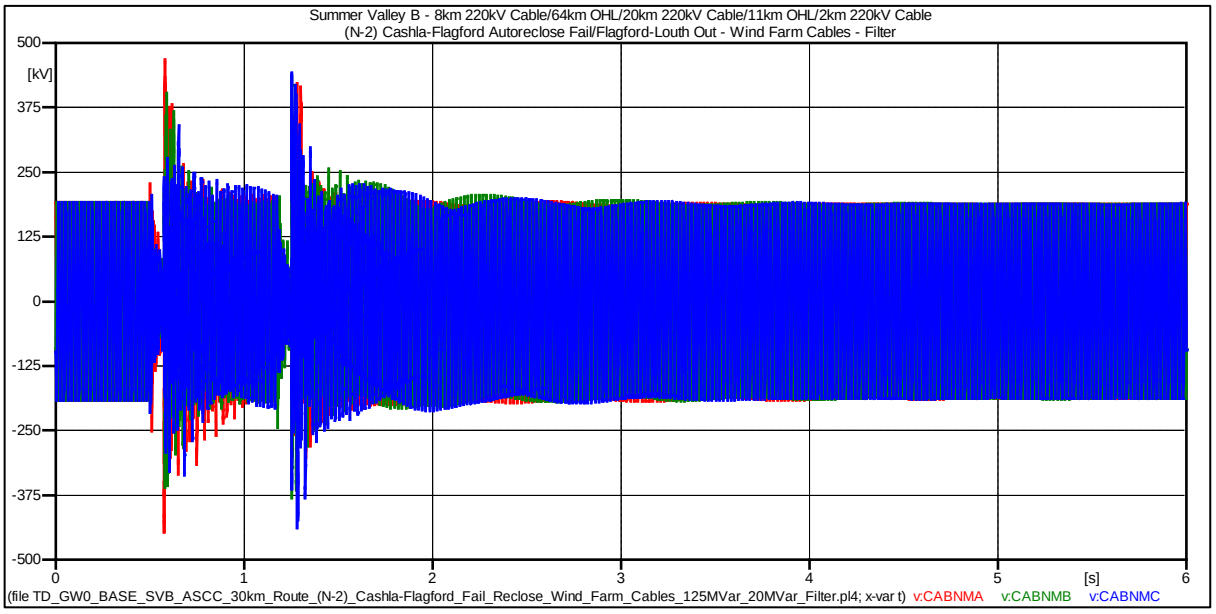

Figure 51: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

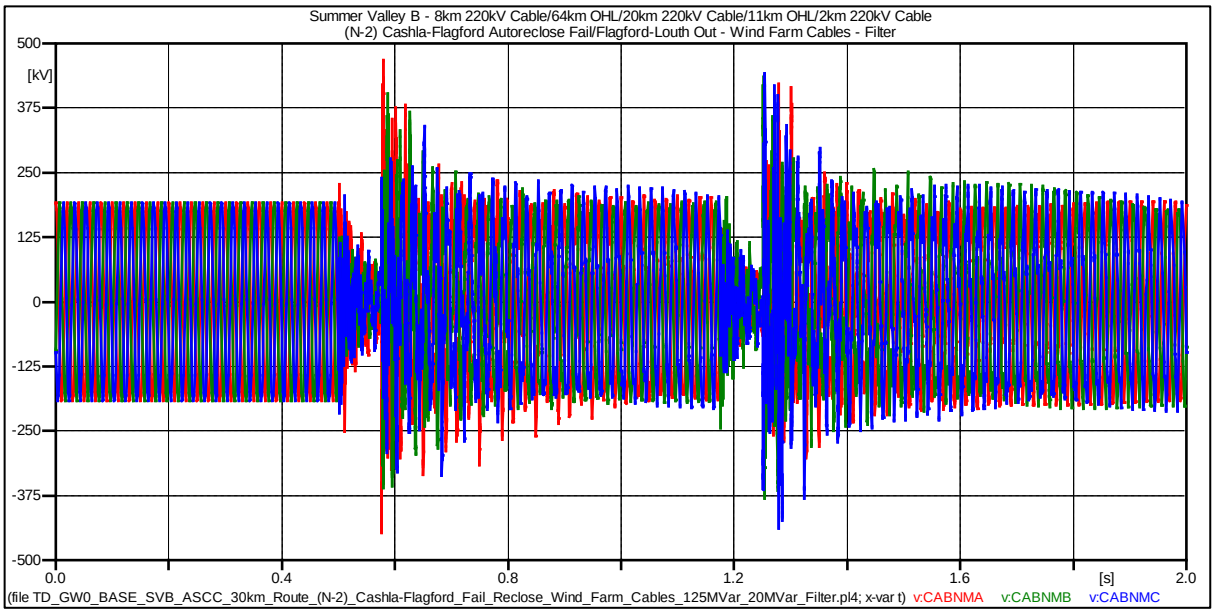

Figure 52: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	461.89 kV (2.5720 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	340.25 kV (1.8946 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

1.9 Impedance Scans - Length 30km (8+20+2) – Winter Peak A – Case 5

Conditions for impedance scan:

1. Winter Peak A network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar
4. Filter added for 3rd Harmonic. Filter connected to 220kV bar at North Mayo, L = 1.2324H, C = 0.9134 uF Assuming rating of 125MVar

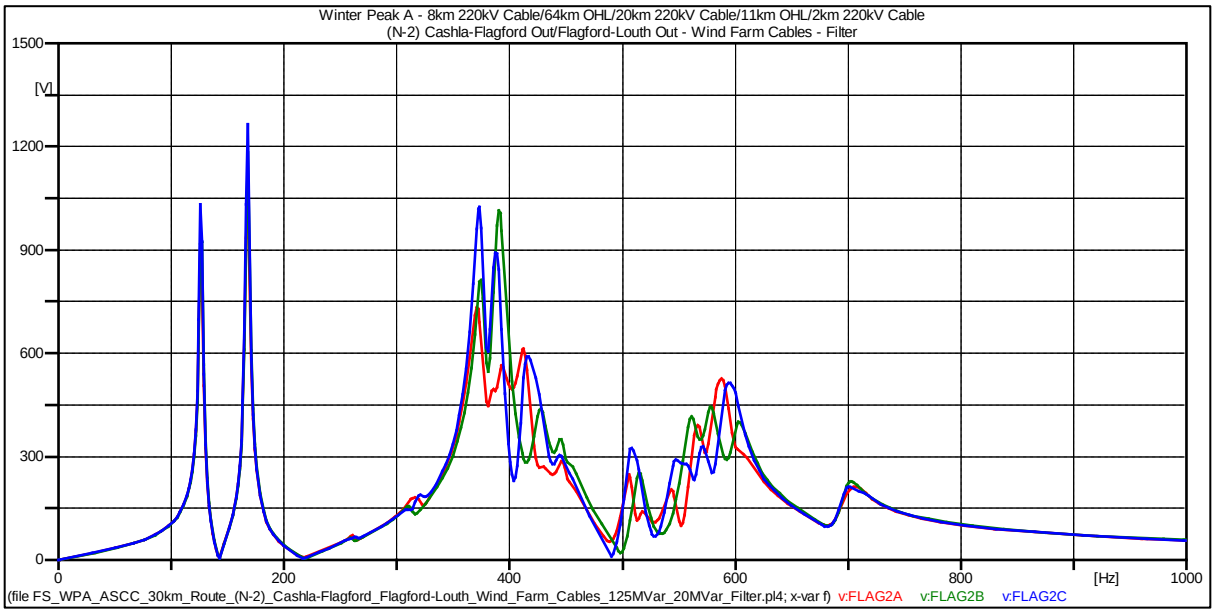

Figure 53: WPA - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
126.01	1032.1
168.01	1264.0
373.51	1025.6
588.01	525.4

1.10 Time Domain Simulation - Length 30km (8+20+2) – Winter Peak A – Case 5

Conditions for time domain simulation:

1. Winter Peak A network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 125MVar/Flagford 20MVar
4. Filter added for 3rd Harmonic. Filter connected to 220kV bar at North Mayo, L = 1.2324H, C = 0.9134 uF Assuming rating of 125MVar

Case 5: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

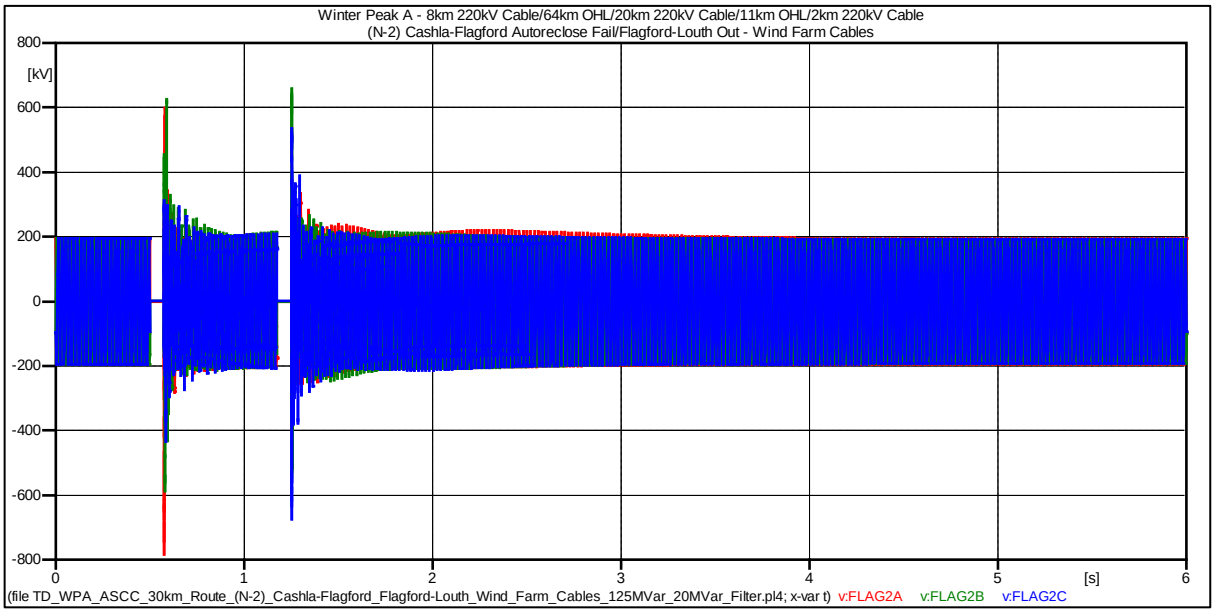

Figure 54: WPA - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

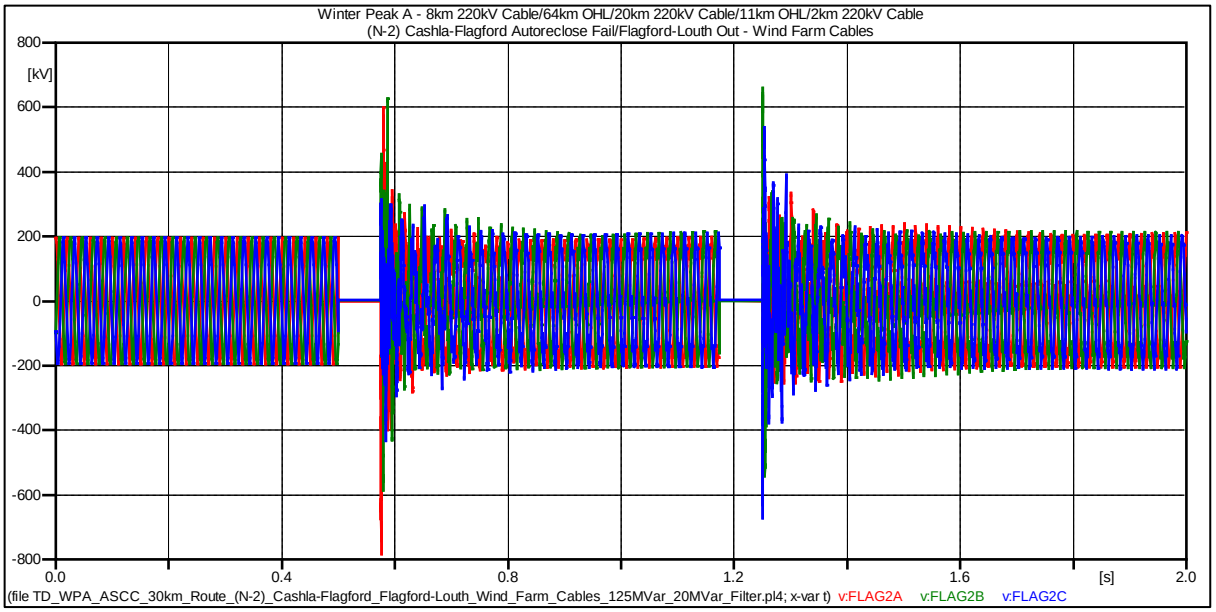

Figure 55: WPA - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	790.58 kV (4.4023 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	310.89 kV (1.7312 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

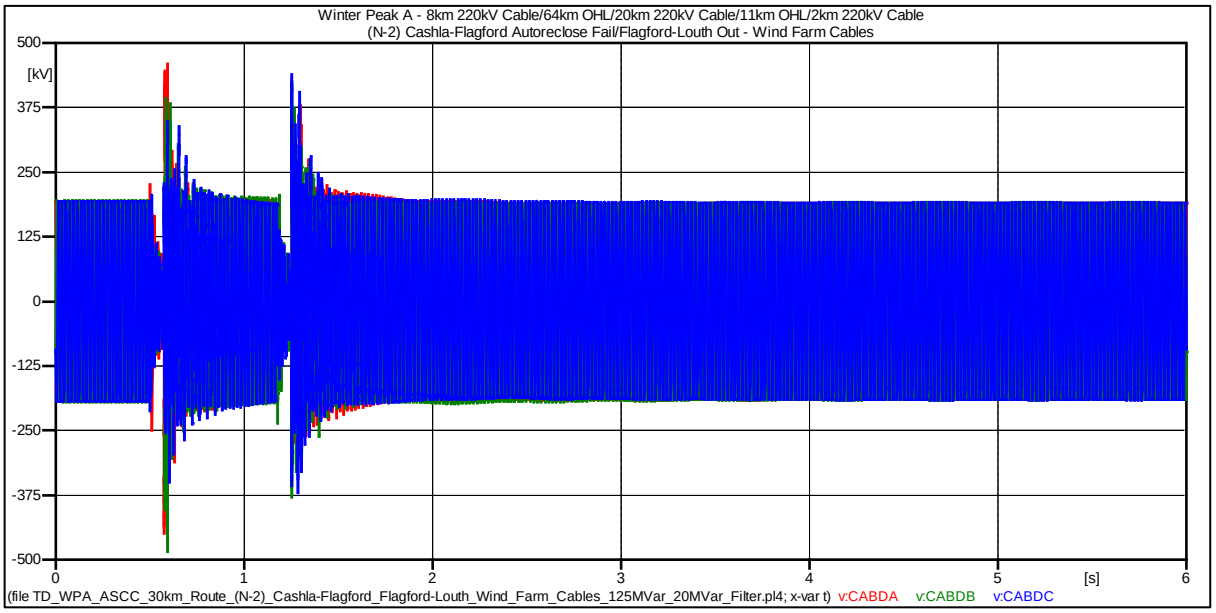

Figure 56: WPA - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

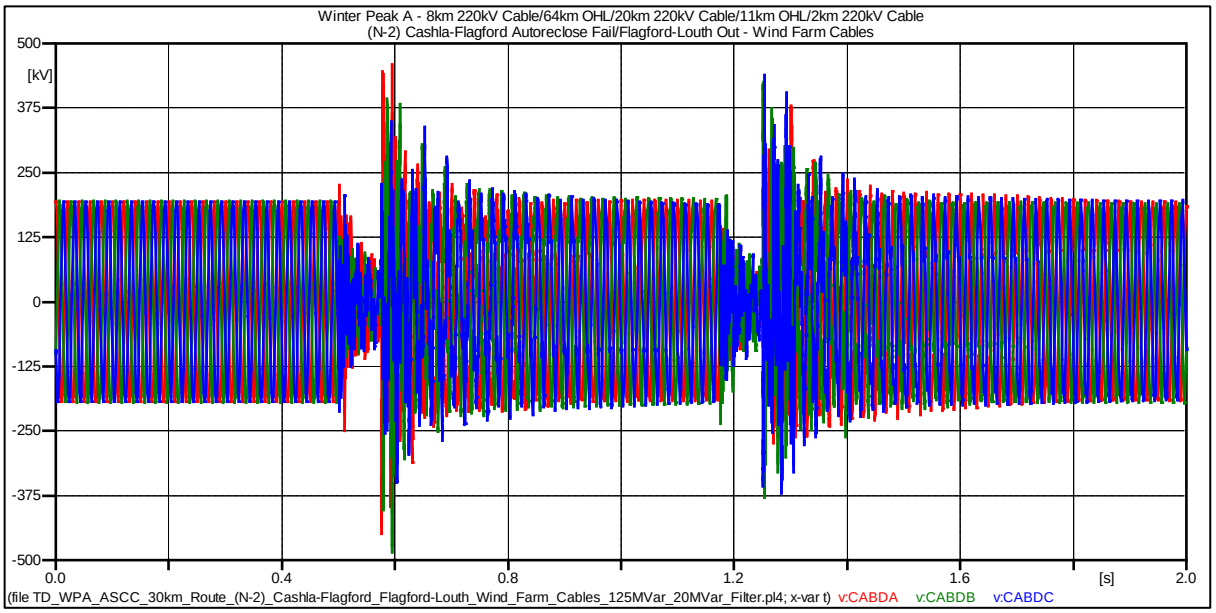

Figure 57: WPA - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	790.58 kV (4.4023 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	310.89 kV (1.7312 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

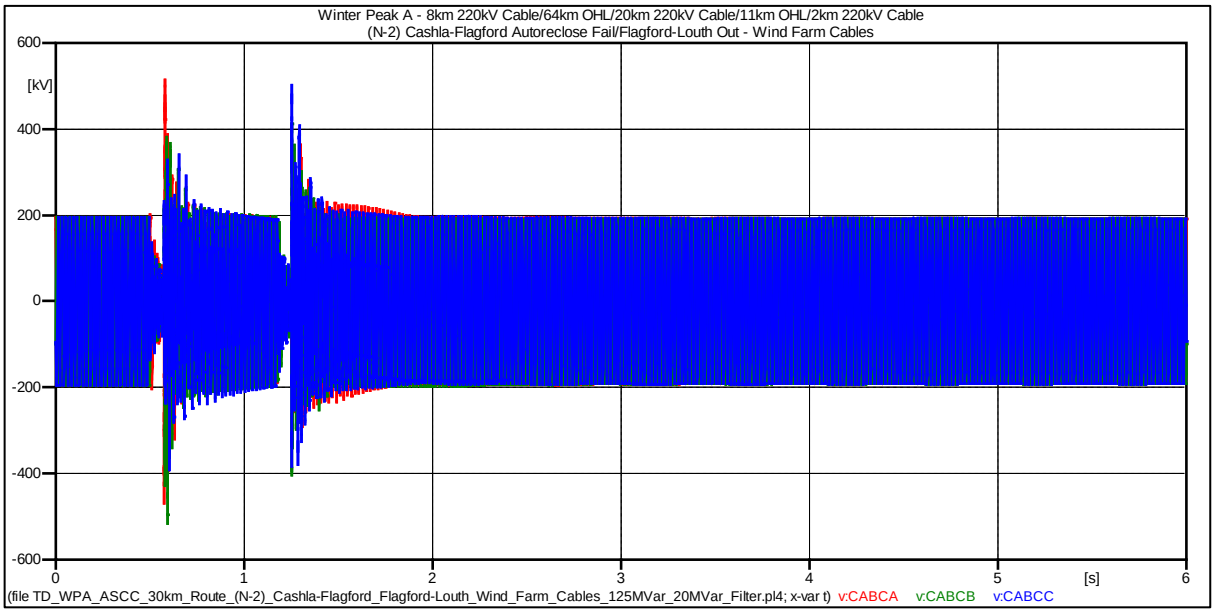

Figure 58: WPA - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

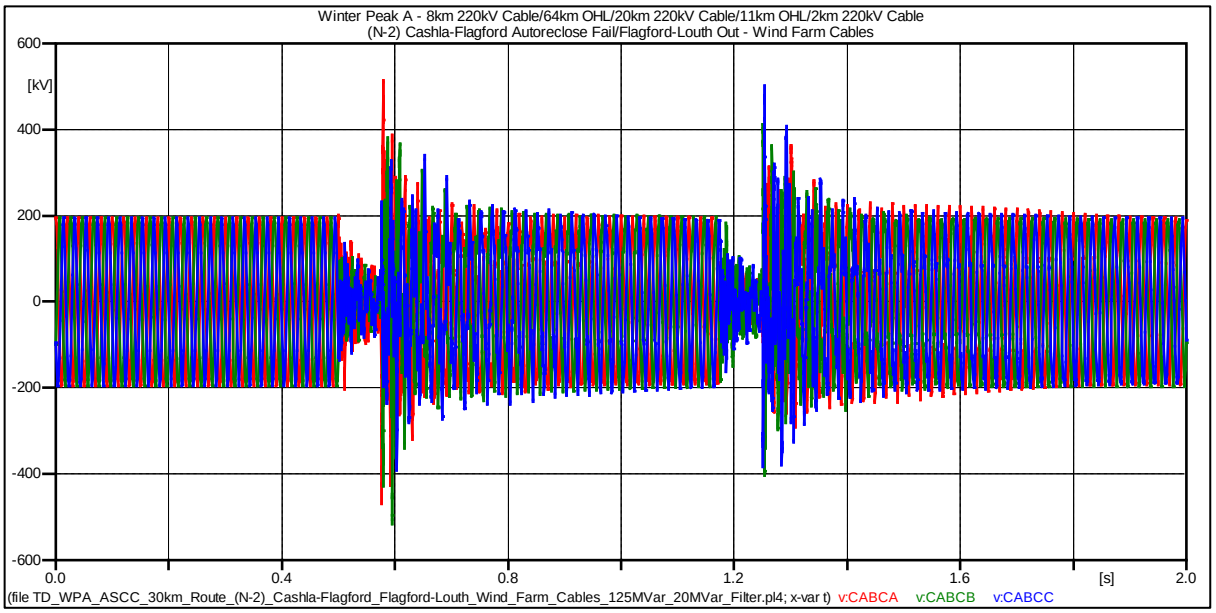

Figure 59: WPA - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	510.23 kV (2.841 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	341.58 kV (1.902 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

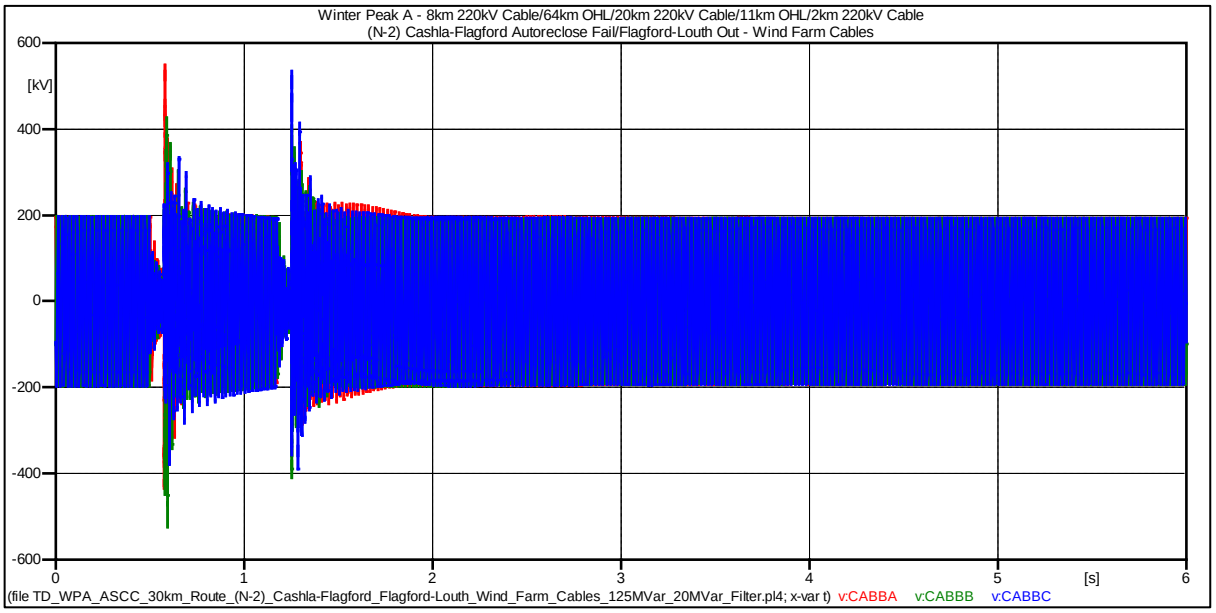

Figure 60: WPA - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

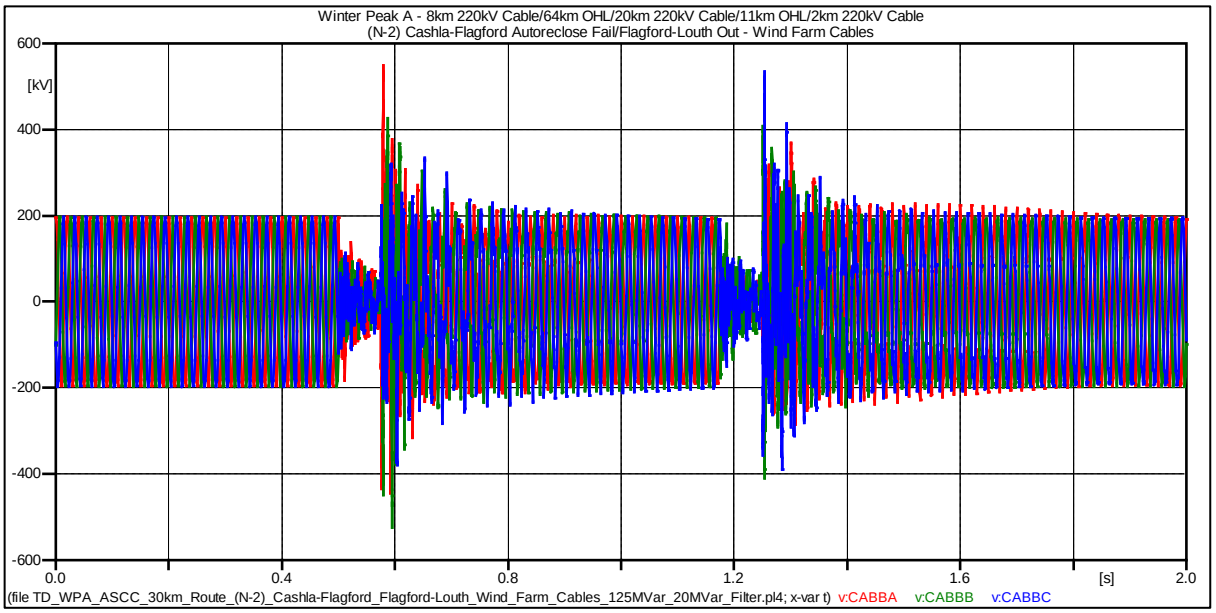

Figure 61: WPA - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	561.23 kV (3.125 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	315.89 kV (1.759 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

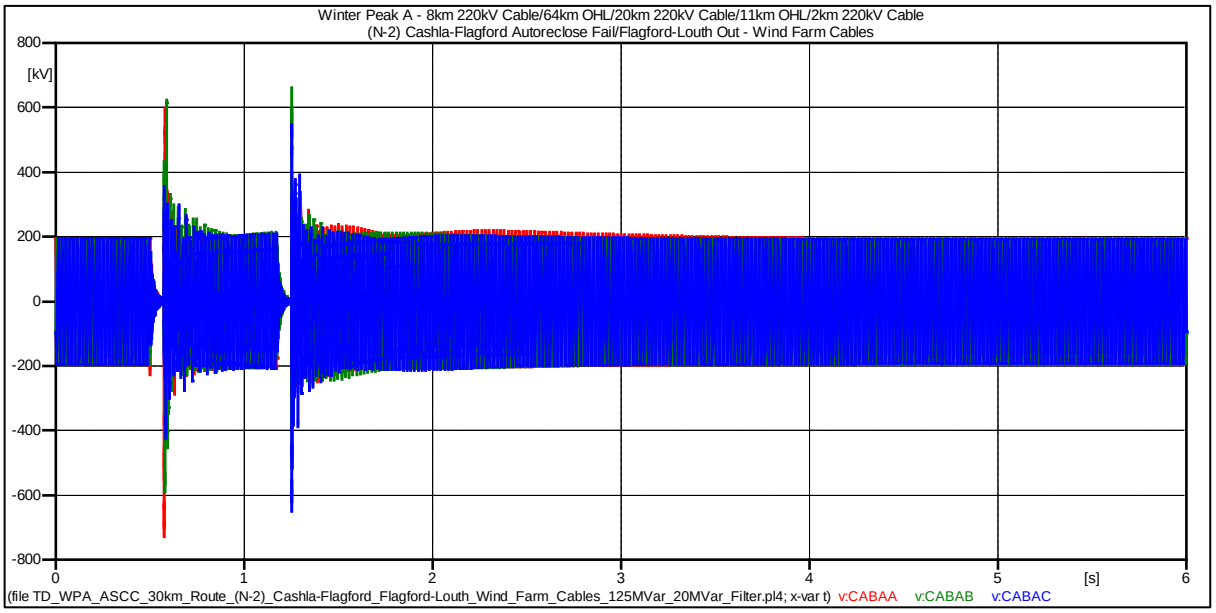

Figure 62: WPA - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

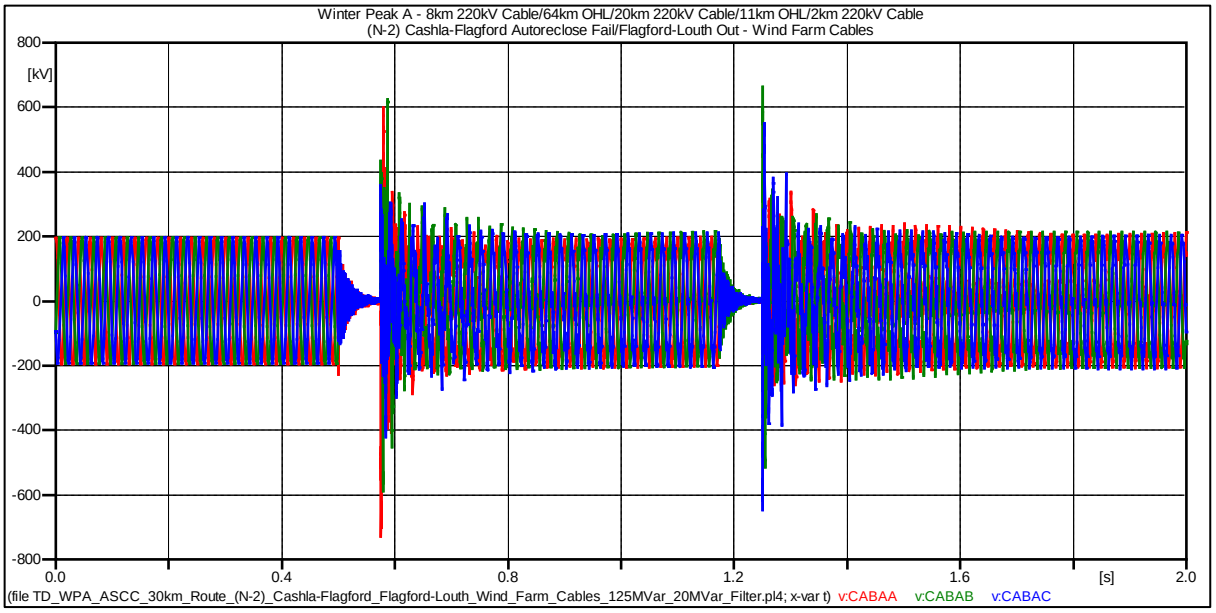

Figure 63: WPA - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	725.23 kV (4.038 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	316.58 kV (1.762 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

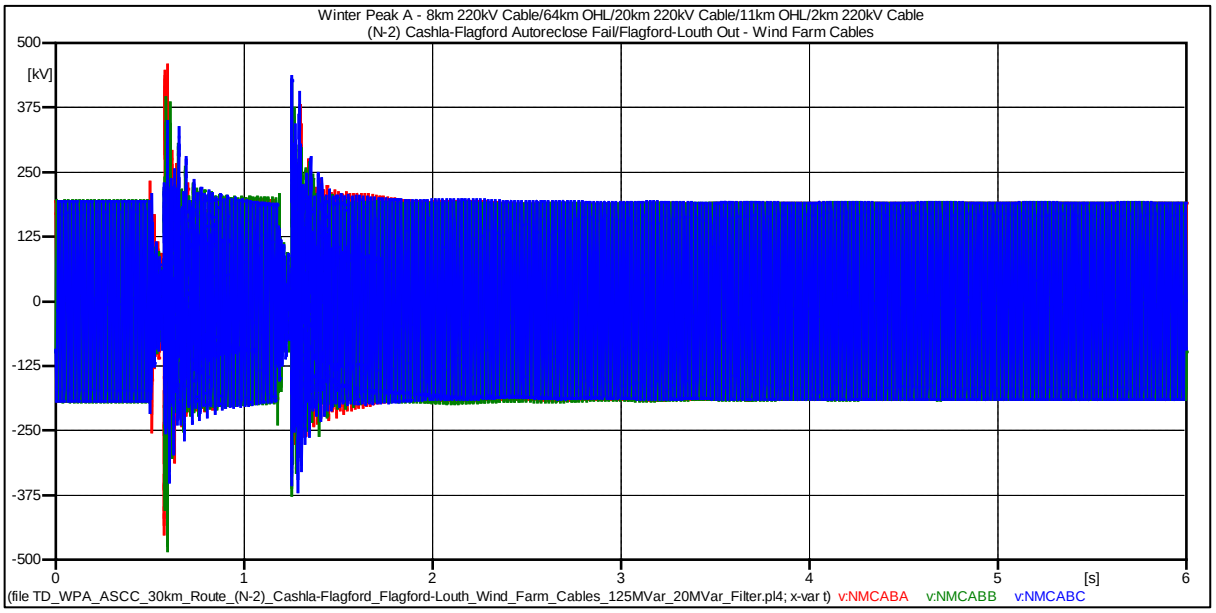

Figure 64: WPA - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Filter

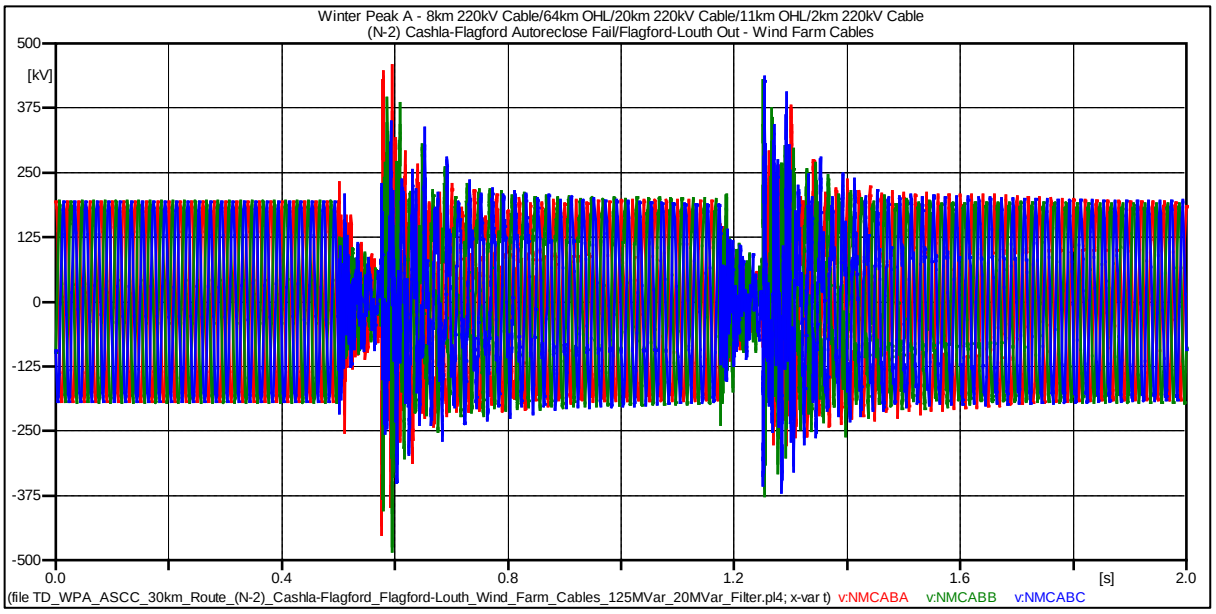

Figure 65: WPA - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Filter

Condition	Maximum Value	Limit	Result
Switching	481.25 kV (2.679 pu)	449.073 kV (2.5pu)	Fail*
Temporary Overvoltage	342.18 kV (1.905 pu)	287.32 kV (1.6 pu)	Fail

*Pass can be achieved with the application of surge arrestors

1.11 Impedance Scans - Length 30km – Summer Valley B – Case 6

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 80MVar/Flagford 45MVar

Case 6: (N-2) Cashla-Flagford/Flagford-Louth Lines Out

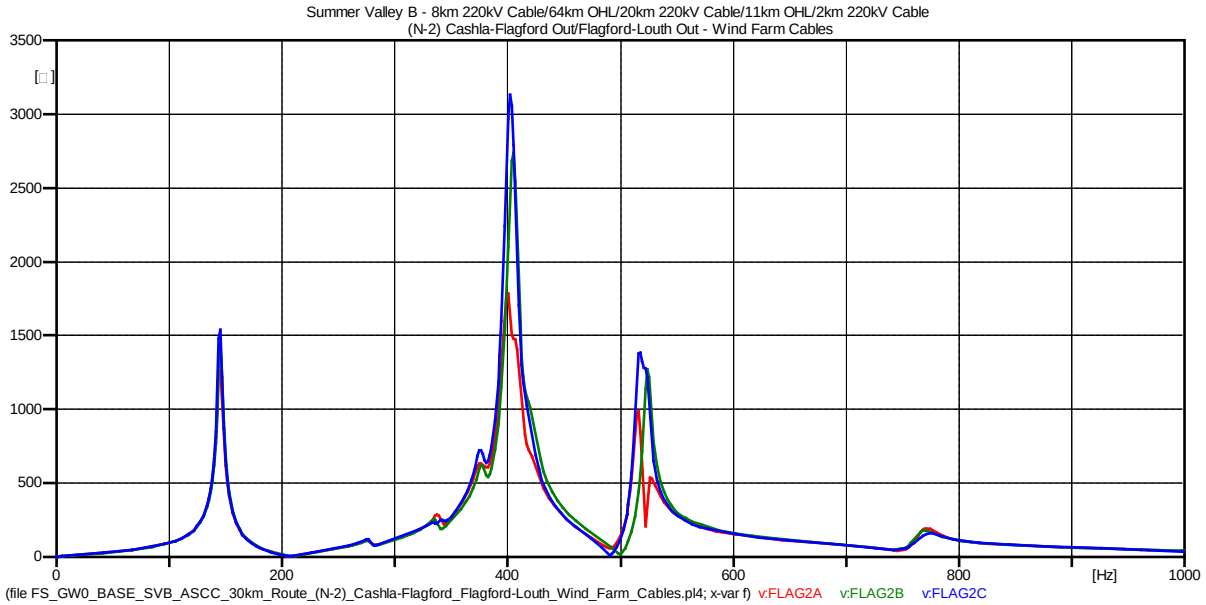

Figure 66: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
145.01	1538.0
402.51	3132.8
517.51	1384.0

1.12 Time Domain Simulation - Length 30km – Summer Valley B – Case 6

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 80MVar/Flagford 45MVar

Case 6: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

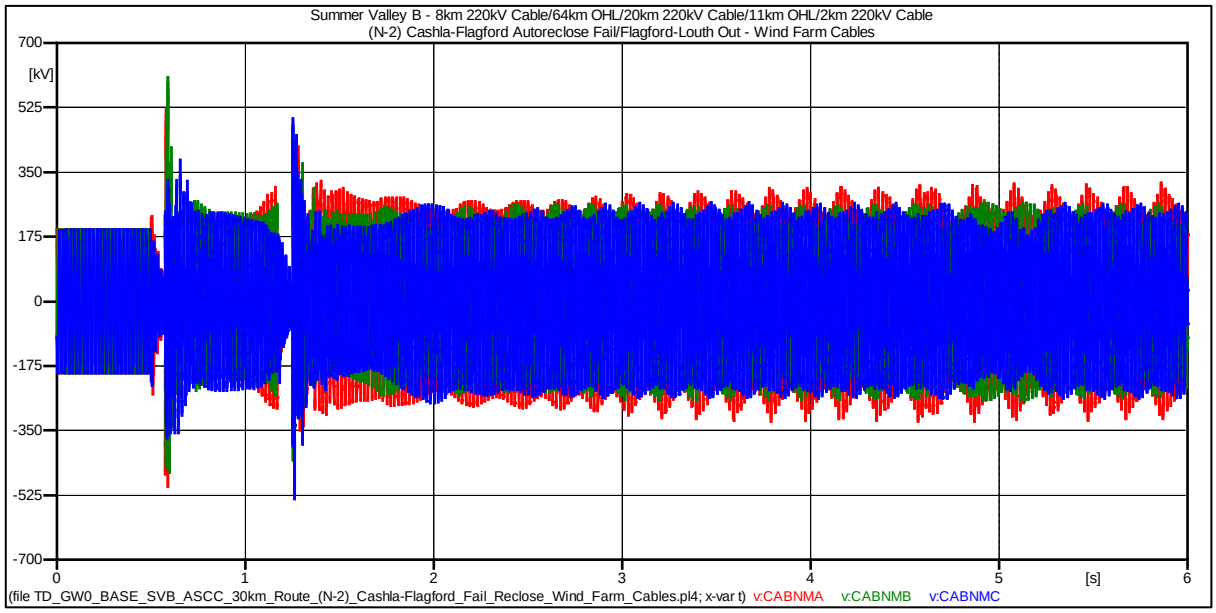

Figure 67: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

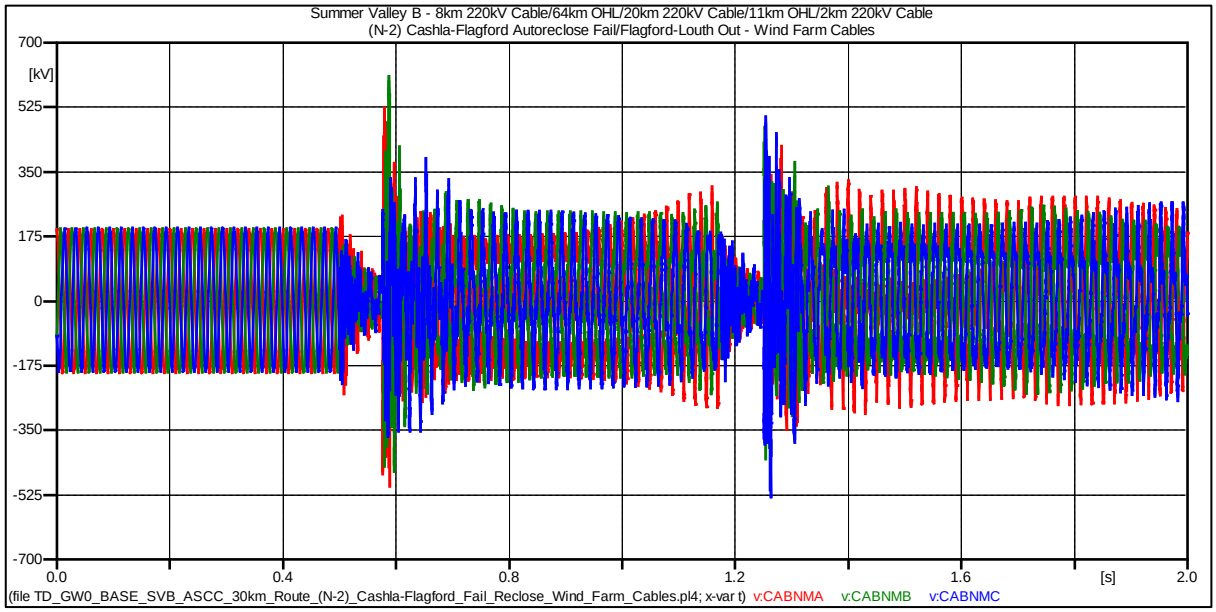

Figure 68: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	623.5 kV (3.471 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	391.25 kV (2.178 pu)	287.32 kV (1.6 pu)	Fail

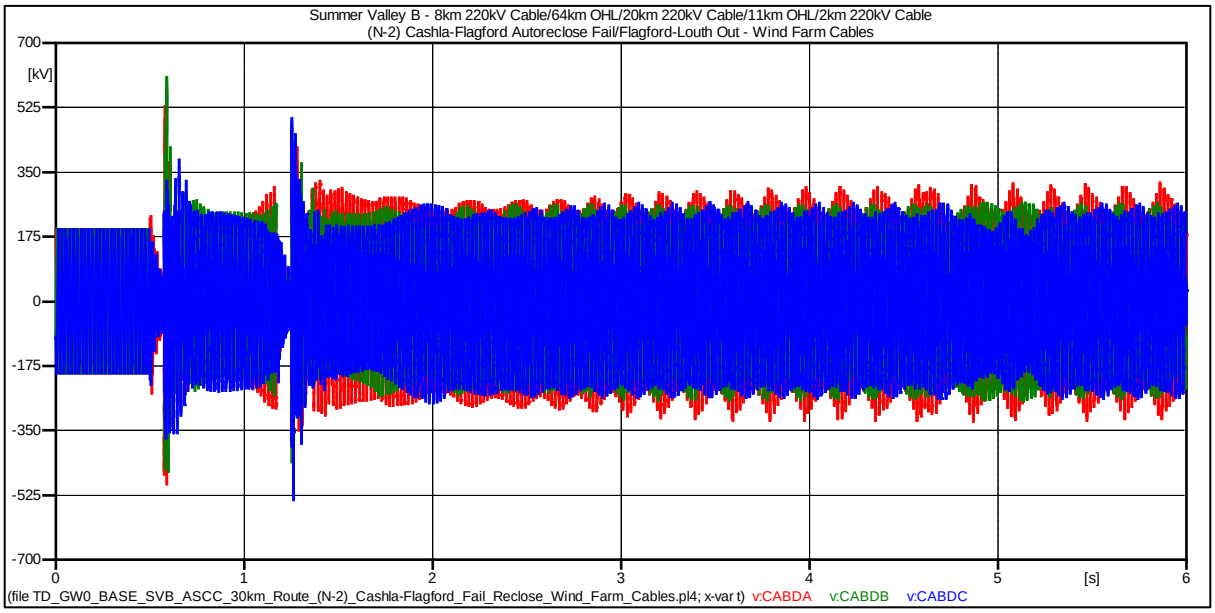

Figure 69: SVB - Length 30km – Cable Mid Point D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

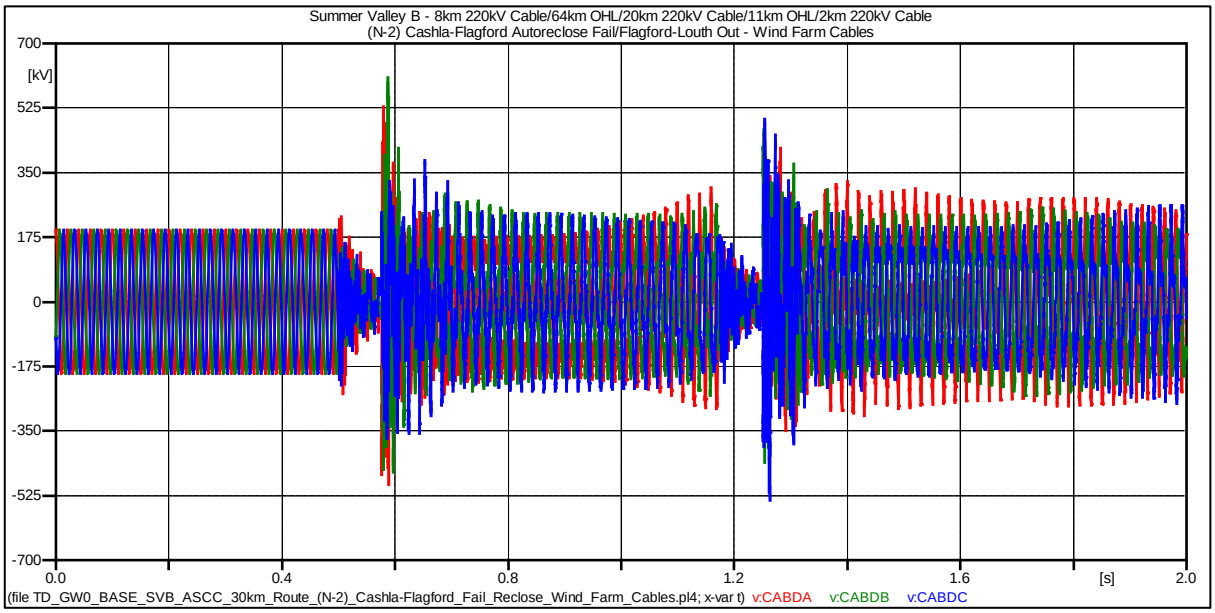

Figure 70: SVB - Length 30km – Cable Mid Point D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	633.78 kV (3.529 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	381.67 kV (2.125 pu)	287.32 kV (1.6 pu)	Fail

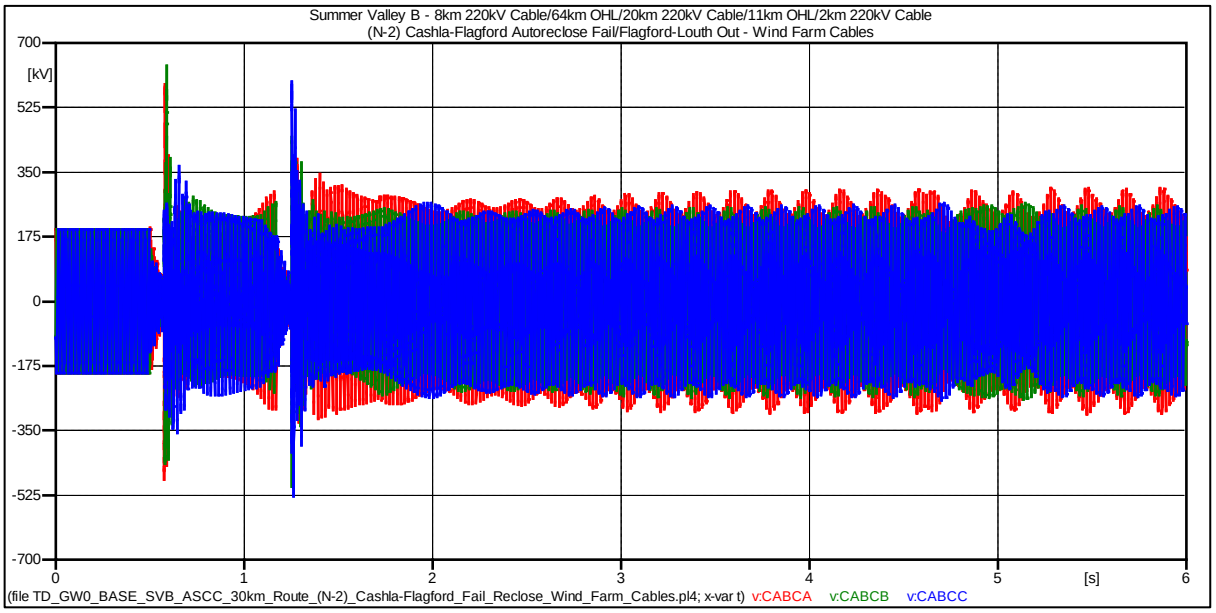

Figure 71: SVB - Length 30km – Cable Mid Point C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

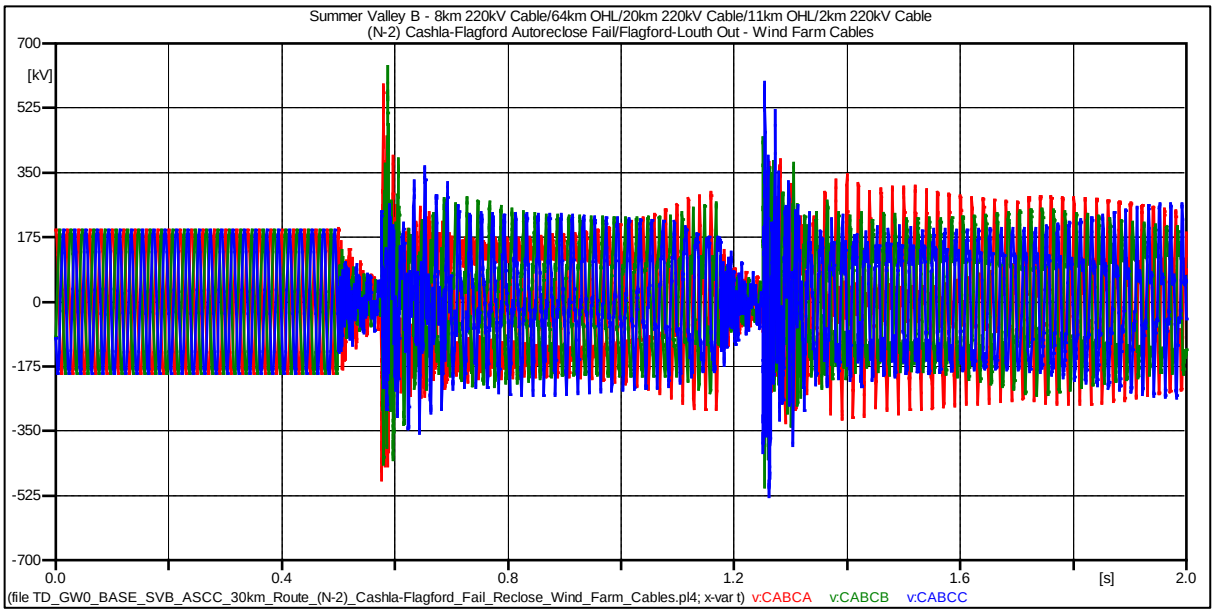

Figure 72: SVB - Length 30km – Cable Mid Point C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	641.23 kV (3.570 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	360.26 kV (2.006 pu)	287.32 kV (1.6 pu)	Fail

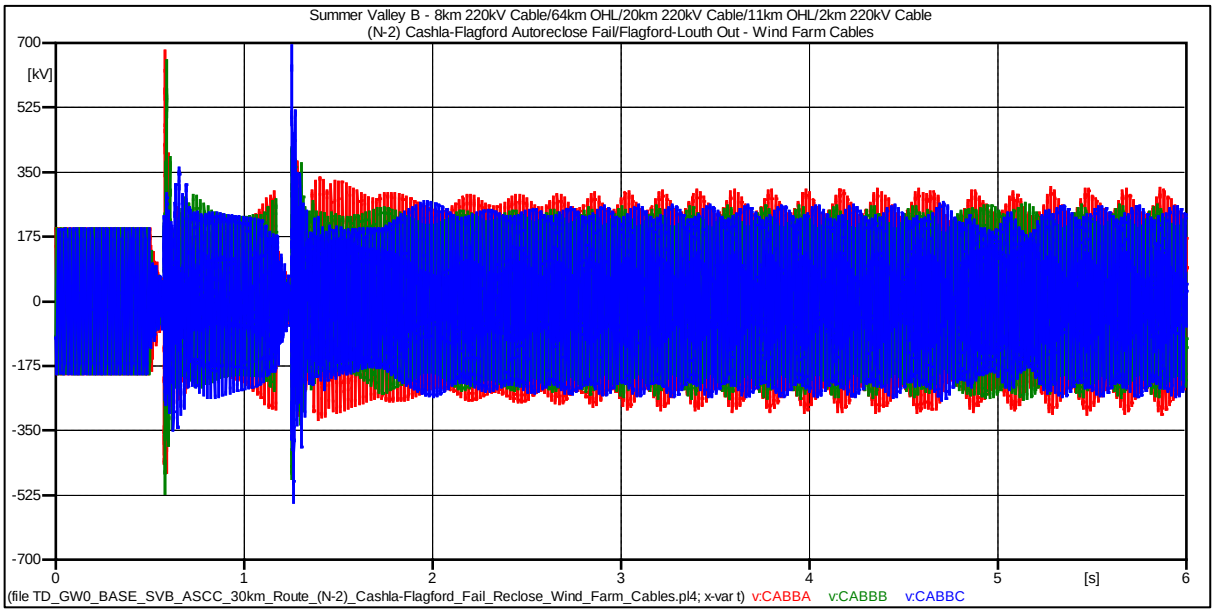

Figure 73: SVB - Length 30km – Cable Mid Point B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

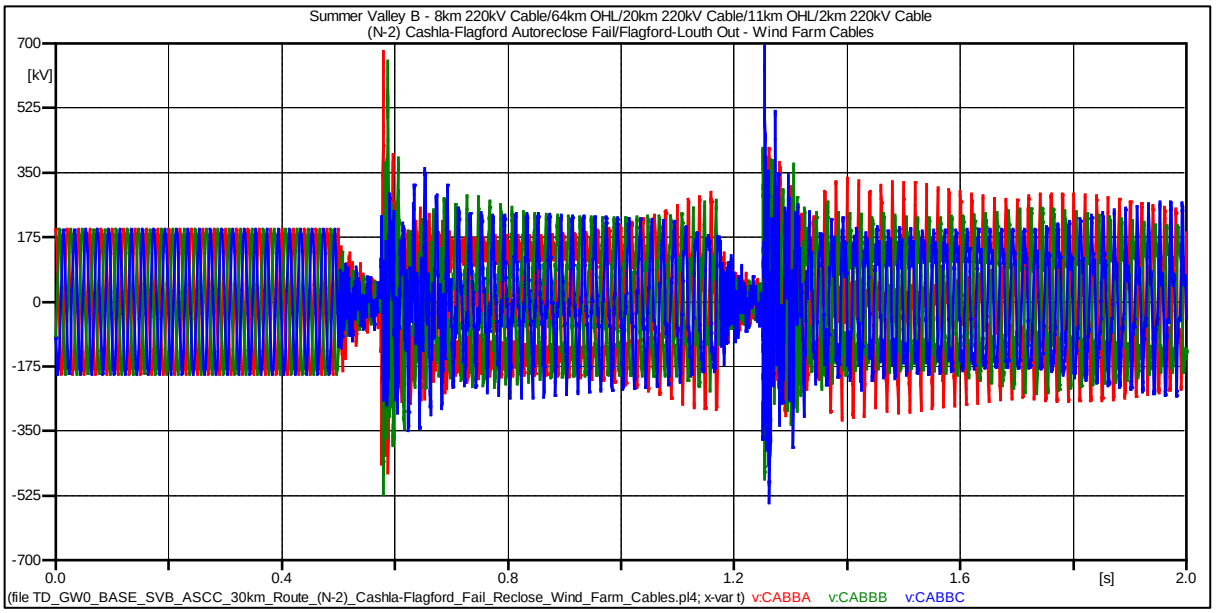

Figure 74: SVB - Length 30km – Cable Mid Point B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	680.78 kV (3.791 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	339.58 kV (1.890 pu)	287.32 kV (1.6 pu)	Fail

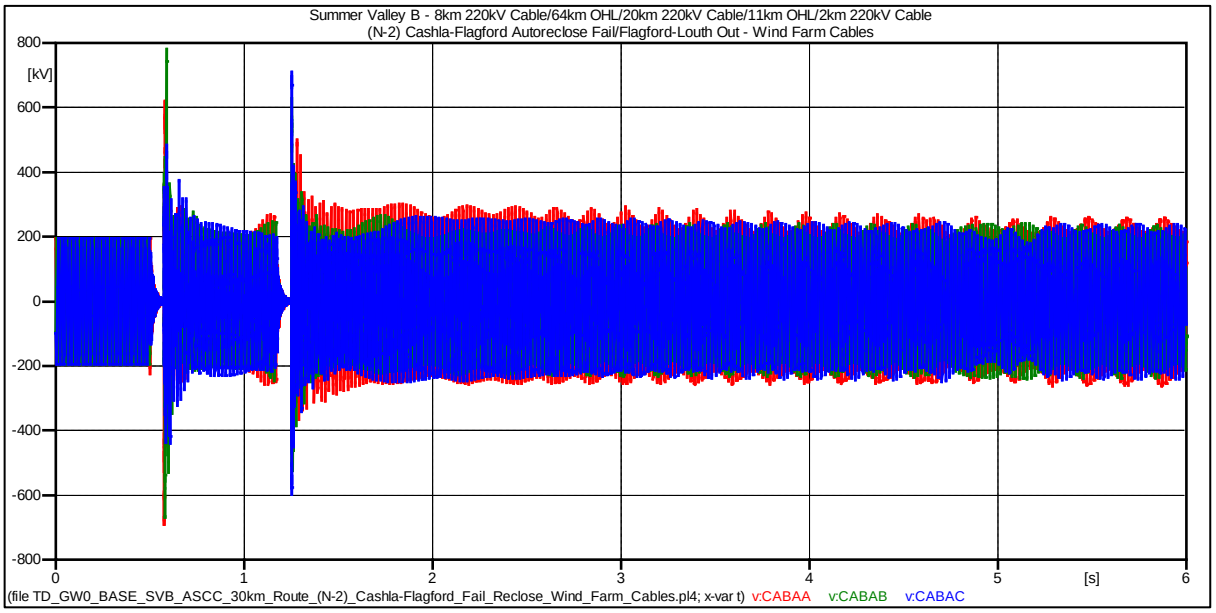

Figure 75: SVB - Length 30km – Cable Mid Point A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

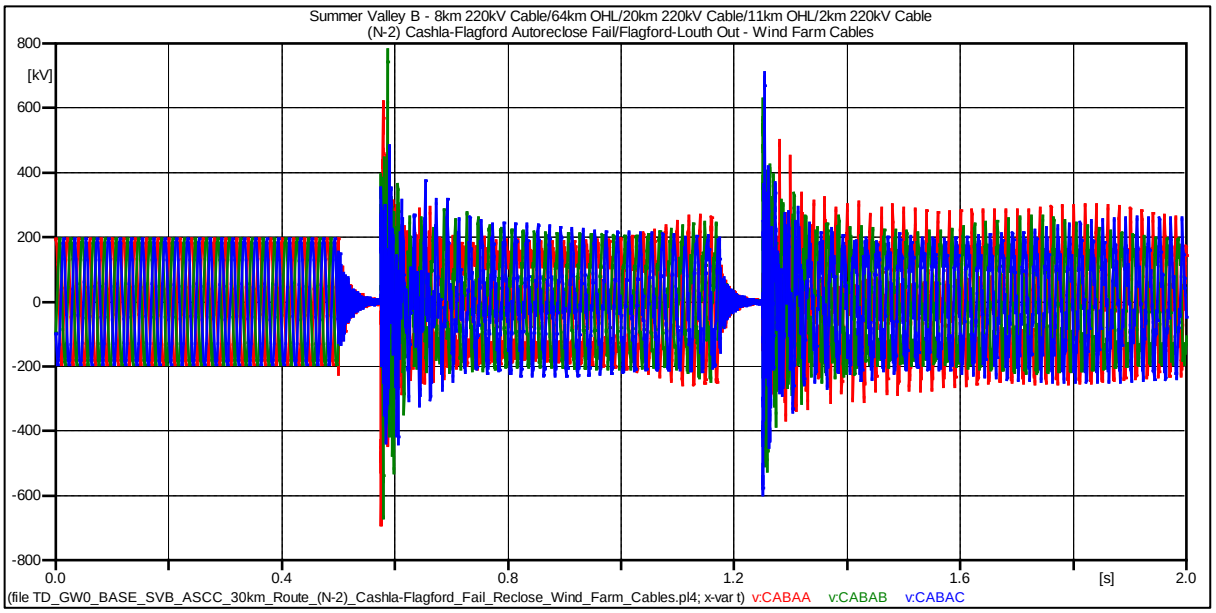

Figure 76: SVB - Length 30km – Cable Mid Point A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	790.51 kV (4.401 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	380.58 kV (2.119 pu)	287.32 kV (1.6 pu)	Fail

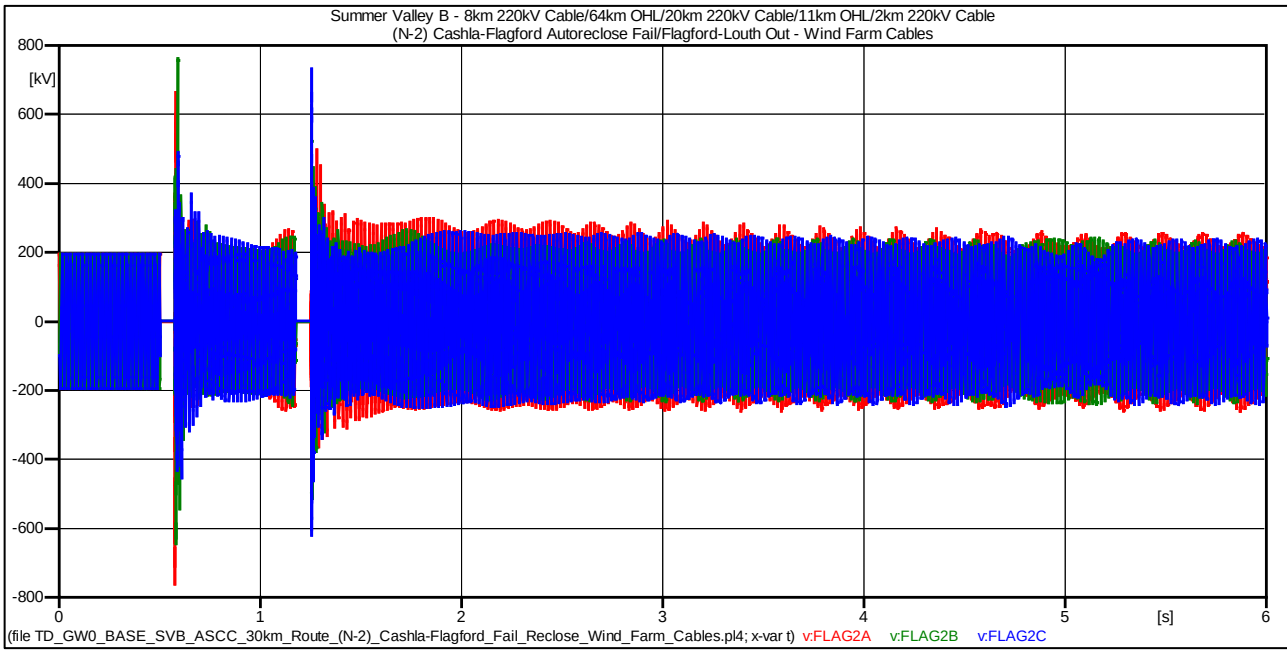

Figure 77: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

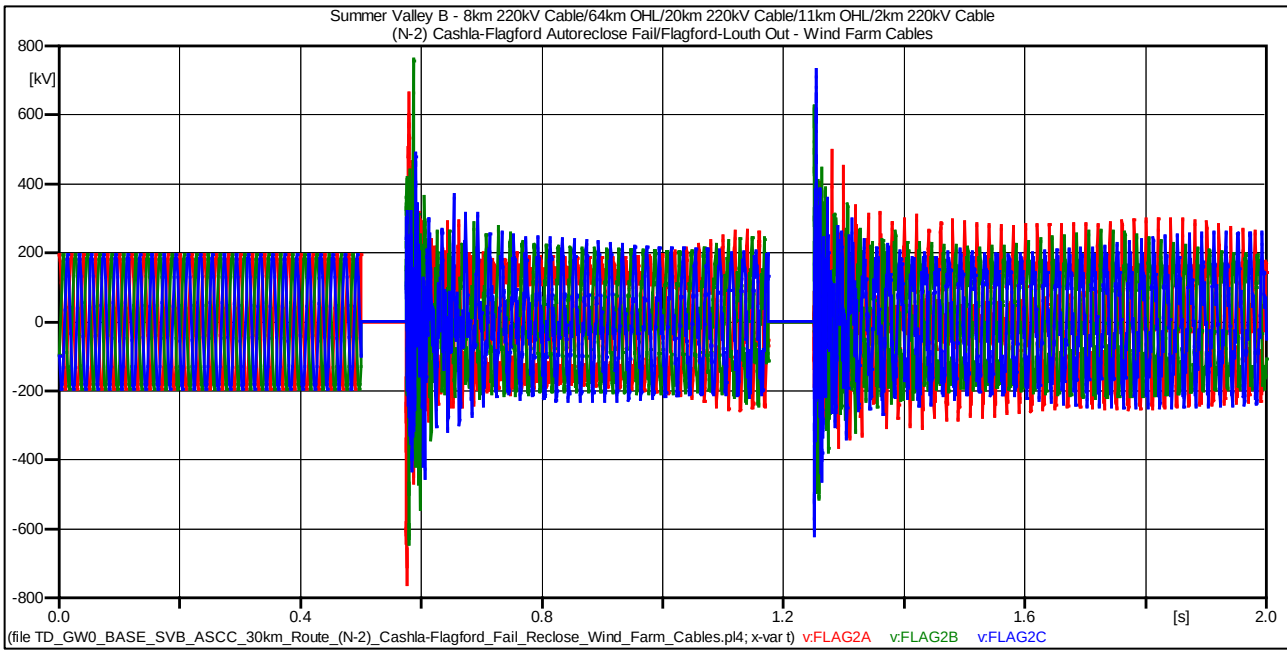

Figure 78: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	788.26 kV (4.389 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	375.12 kV (2.088 pu)	287.32 kV (1.6 pu)	Fail

1.13 Impedance Scans - Length 30km – Summer Valley B – Increased Reactor – Case 7

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 200MVar/Flagford 125MVar
4. Increased the reactor size to 100MVar at North Mayo, still transformer saturation, 45Mvar Flagford reactor, therefore the reactor size was increased to 125MVar at North Mayo, 45Mvar Flagford reactor.

Case 7: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

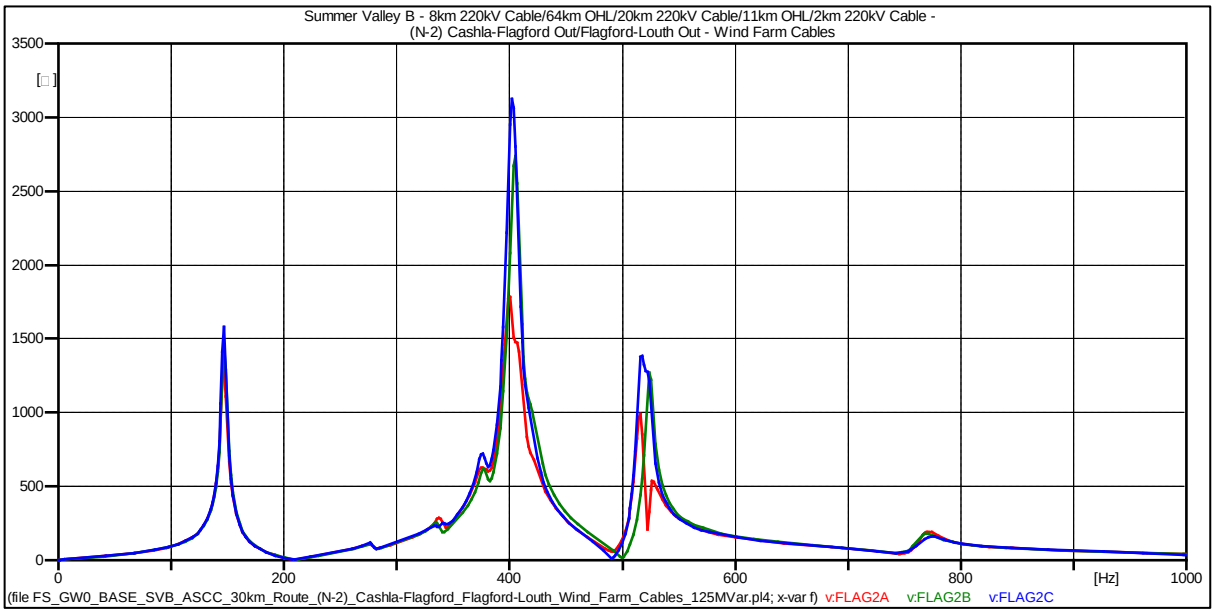

Figure 79: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out – Increased reactor

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
147.01	1578.9
402.01	3126.8
517.51	1384.9

1.14 Time Domain Simulation - Length 30km – Summer Valley B – Increased Reactor – Case 7

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – Increased North Mayo 200MVar/Flagford 125MVar
4. Increased the reactor size to 100MVar at North Mayo, still transformer saturation, 45Mvar Flagford reactor, therefore the reactor size was increased to 125MVar at North Mayo, 45Mvar Flagford reactor.

Case 7: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

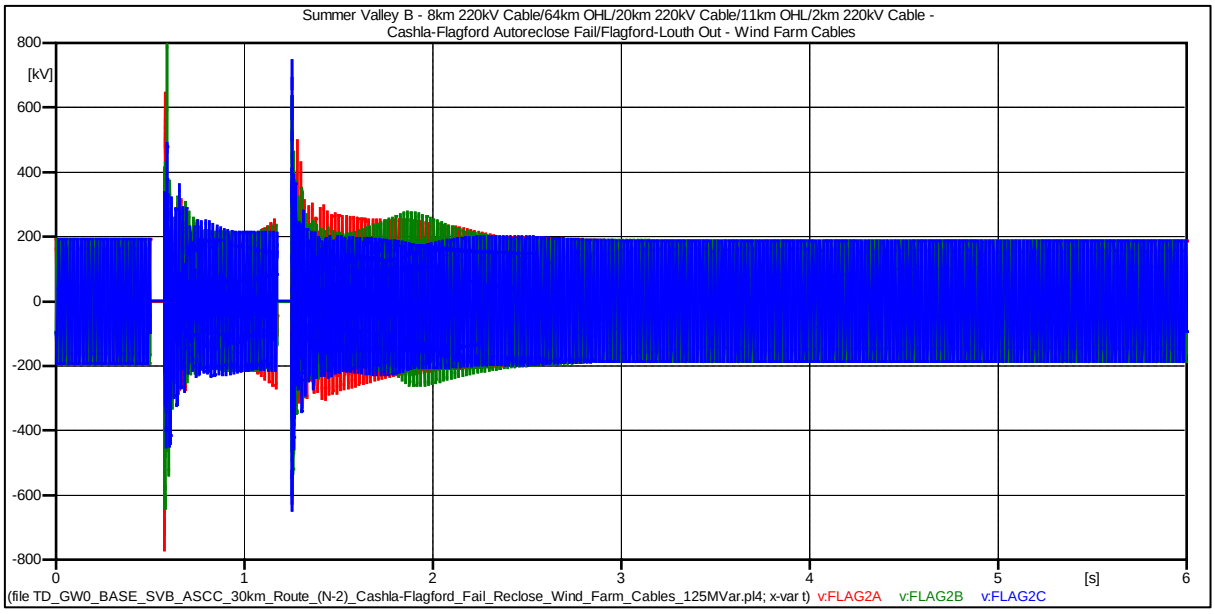

Figure 80: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

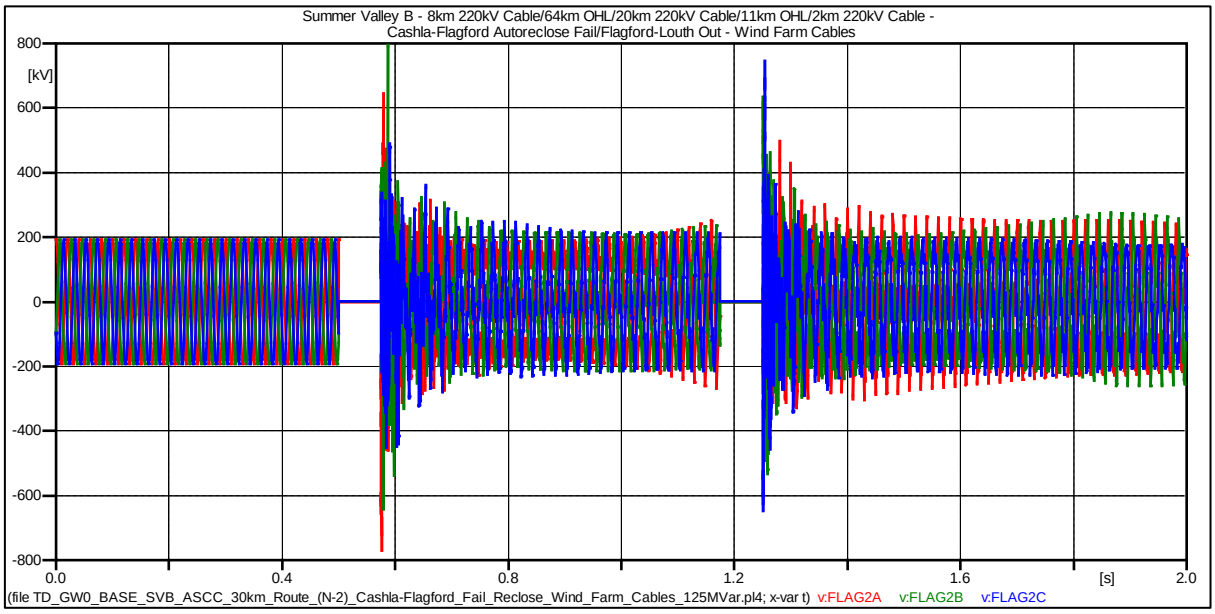

Figure 81: SVB - Length 70km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	800.01 kV (4.454 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	460.59 kV (2.564 pu)	287.32 kV (1.6 pu)	Fail

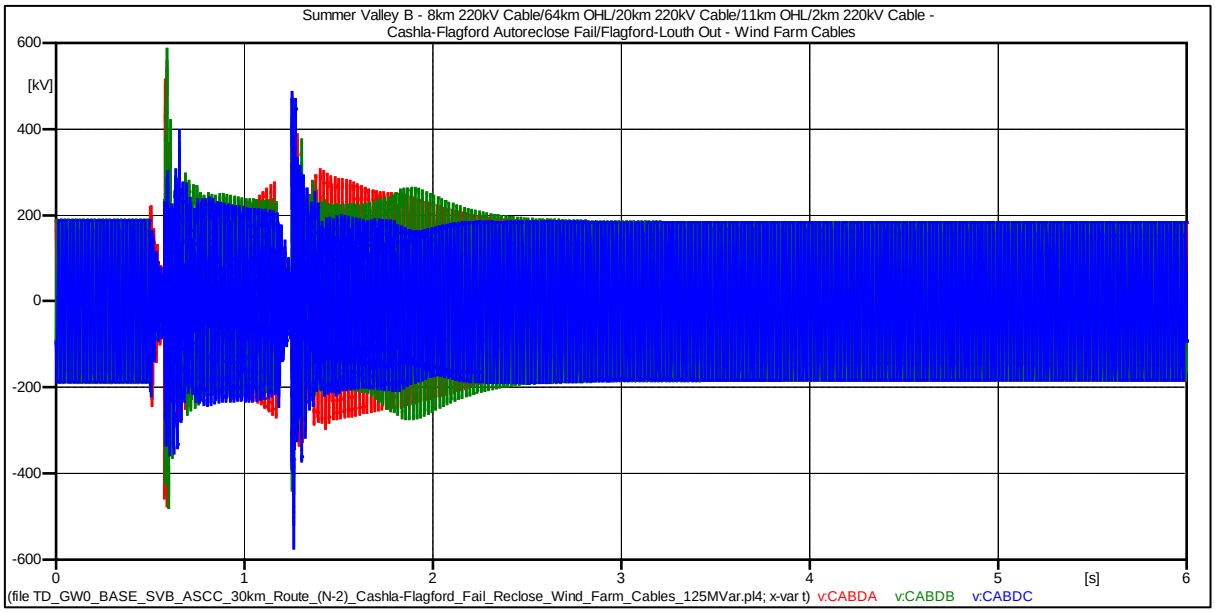

Figure 82: SVB - Length 70km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

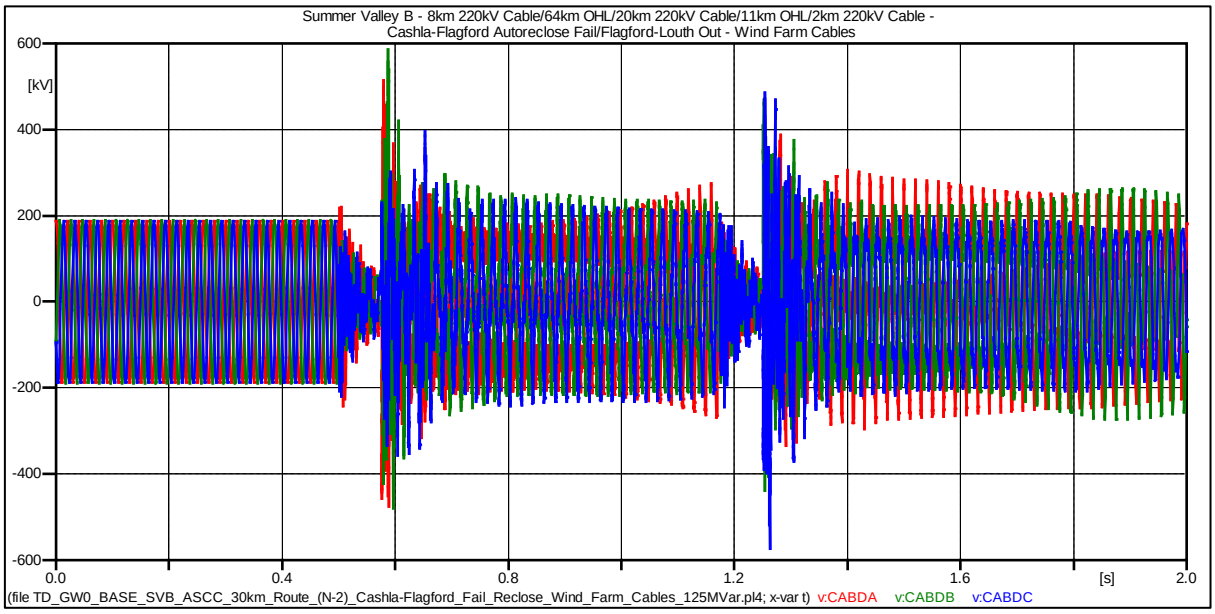

Figure 83: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	590.13 kV (3.286 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	401.25 kV (2.234 pu)	287.32 kV (1.6 pu)	Fail

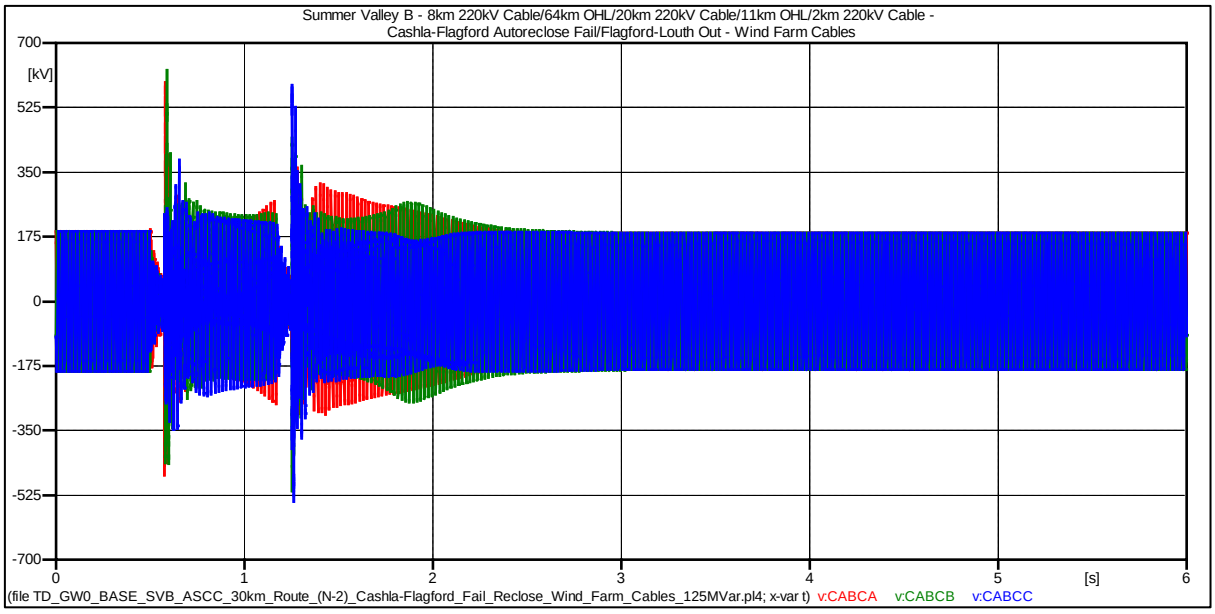

Figure 84: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

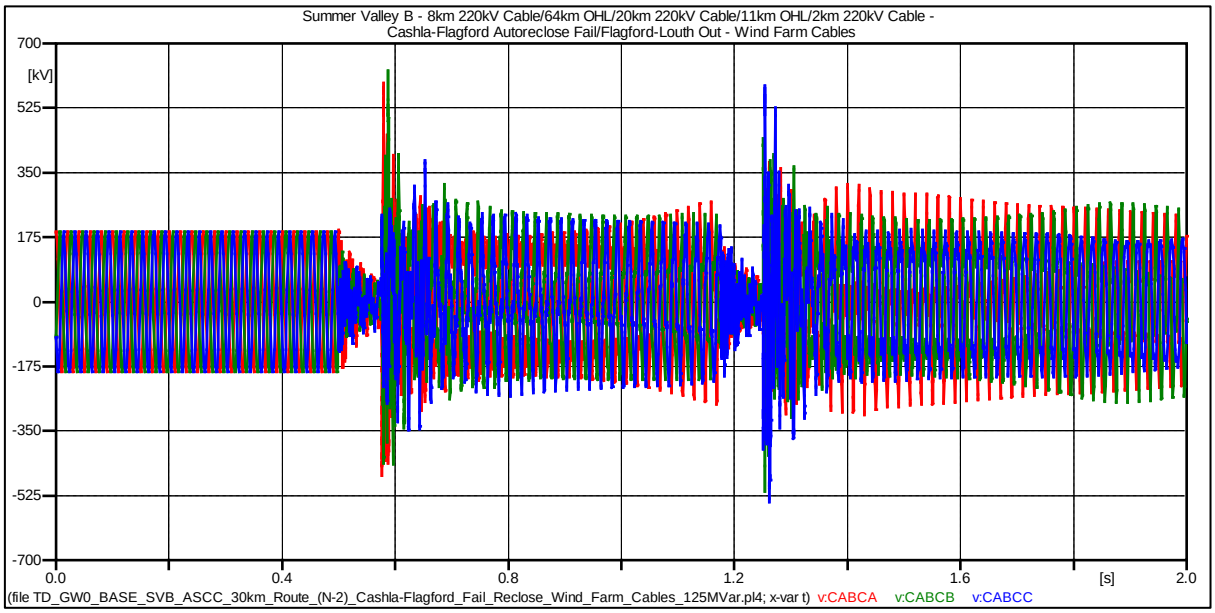

Figure 85: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	620.15 kV (3.453 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	323.12 kV (1.799 pu)	287.32 kV (1.6 pu)	Fail

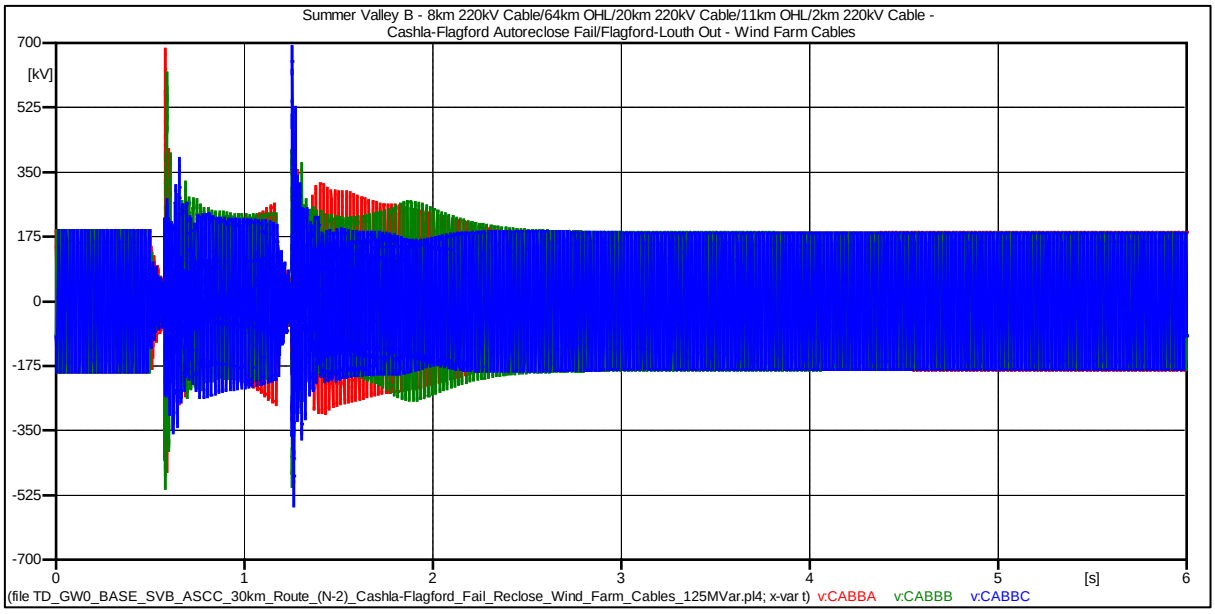

Figure 86: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

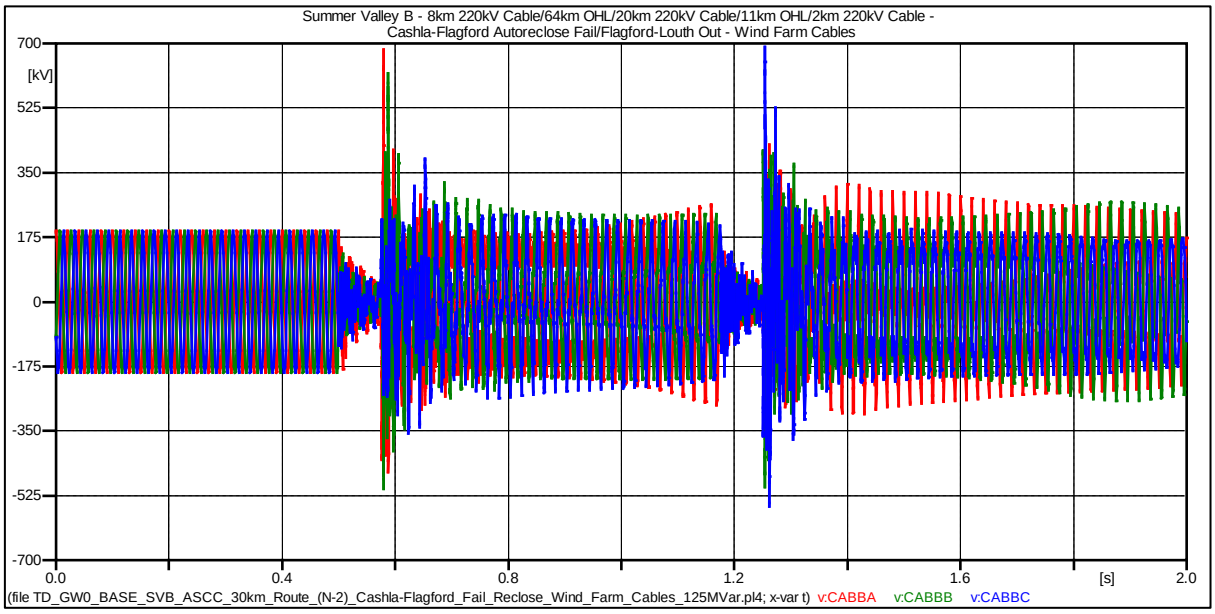

Figure 87: SVB - Length 30km – Cable End - North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	700.12 kV (3.898 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	361.10 kV (2.010 pu)	287.32 kV (1.6 pu)	Fail

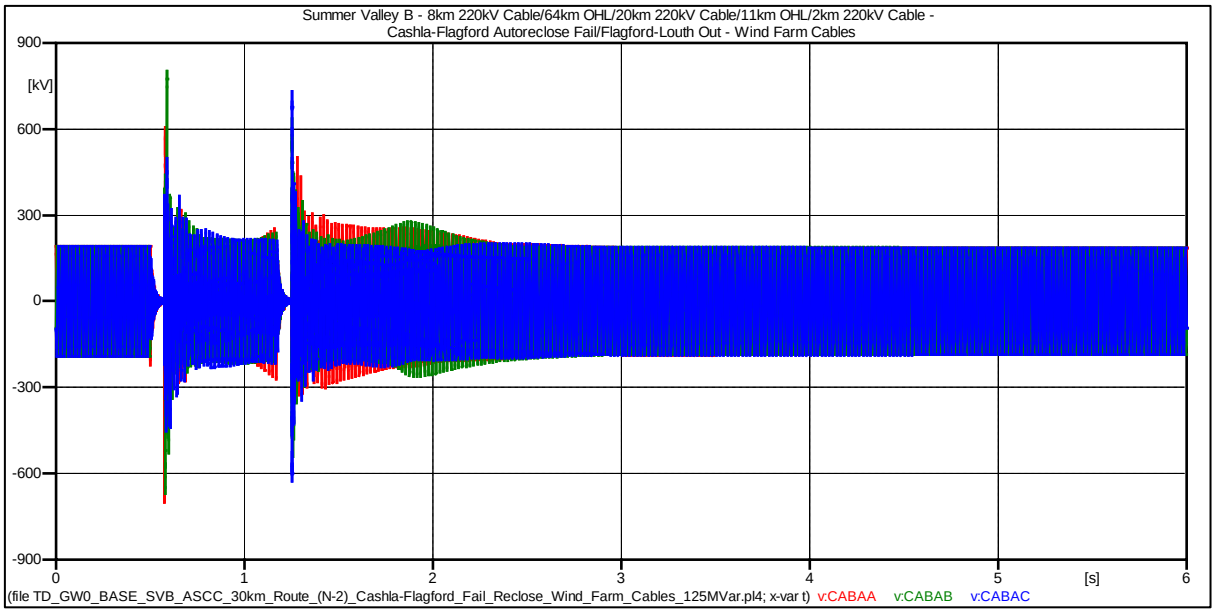

Figure 88: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

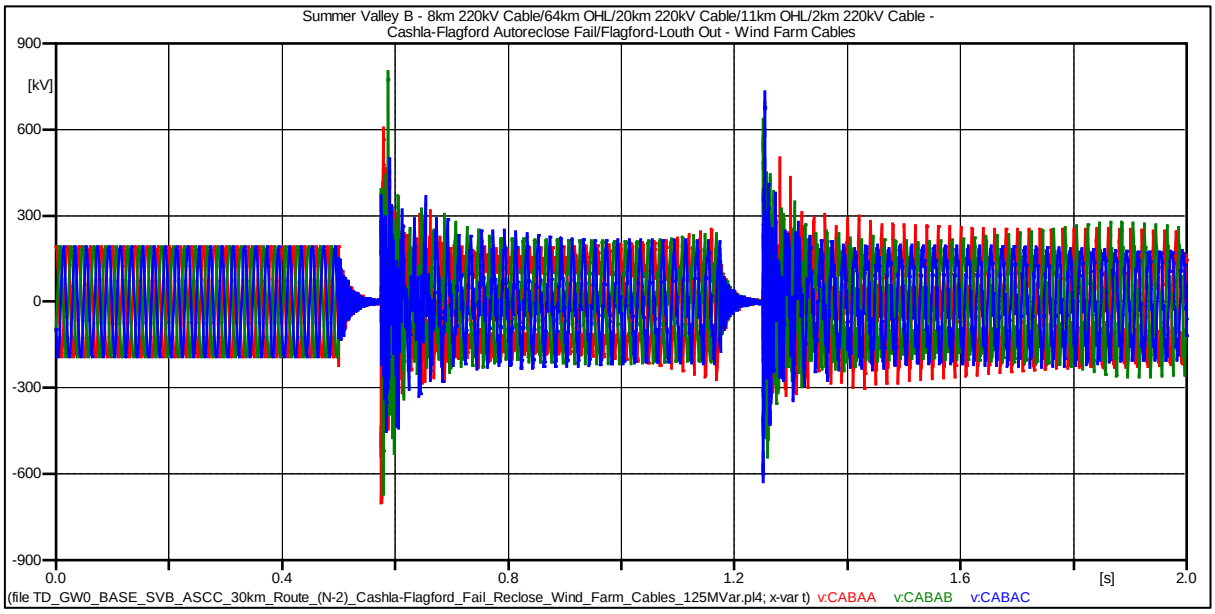

Figure 89: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	810.22 kV (4.511 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	320.15 kV (1.782 pu)	287.32 kV (1.6 pu)	Fail

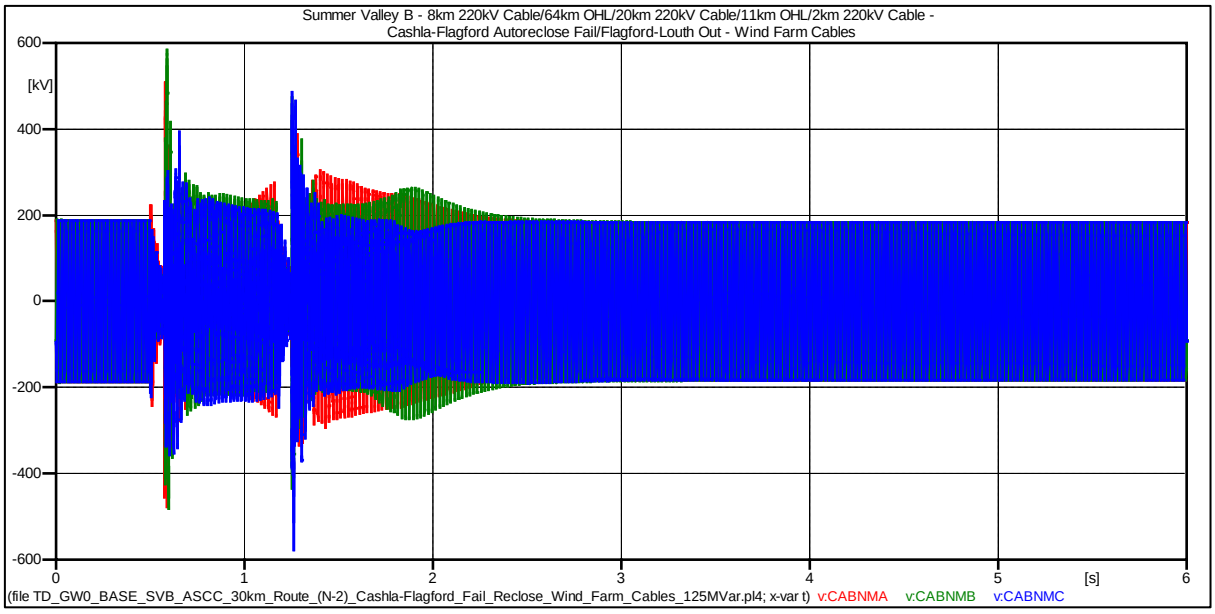

Figure 90: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

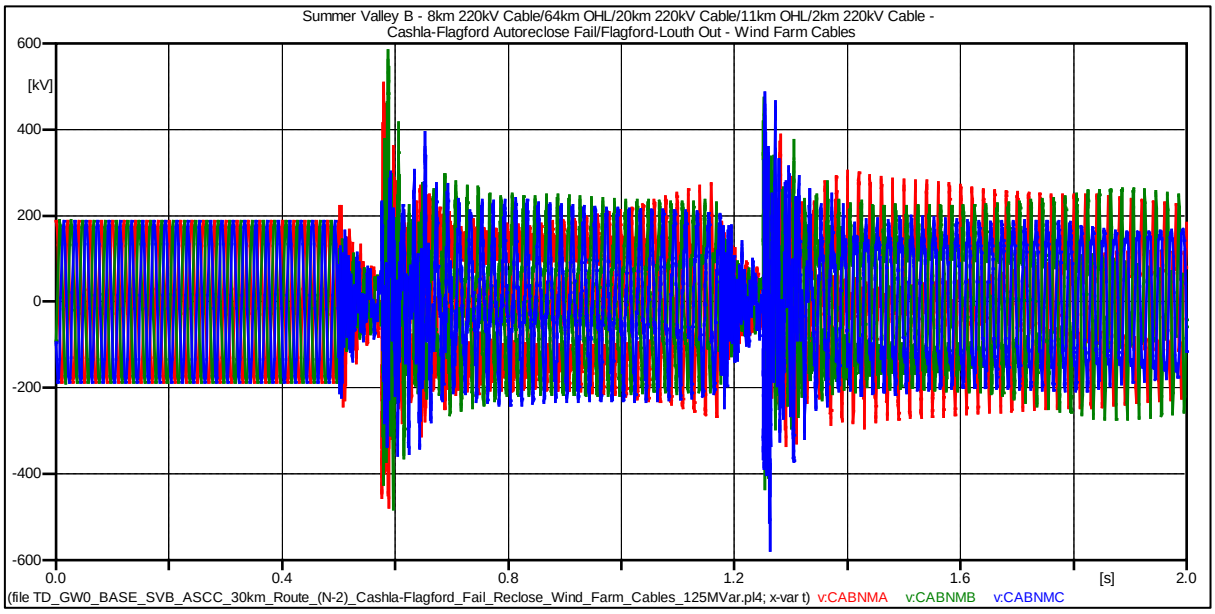

Figure 91: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	590.10 kV (3.286 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	400.15 kV (2.228 pu)	287.32 kV (1.6 pu)	Fail

1.15 Impedance Scans - Length 30km – Summer Valley B – Reduced Size of Reactor – Case 8

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 20MVar
4. Voltages at Steady State - North Mayo 188.5kV, Base = 178.55kV, 5.6% Overvoltage.
5. Voltages at Steady State - Flagford = 194.7kV Base = 178.55kV, 9% Overvoltage.

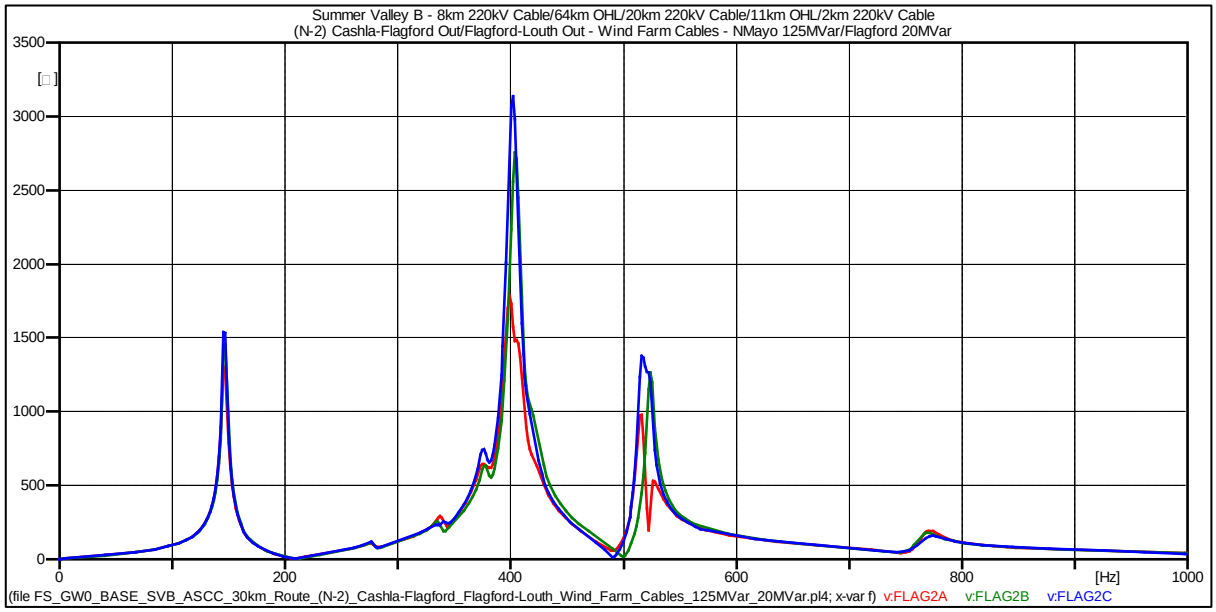

Figure 92: SVB - Length 20km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
145.51	1535.5
402.01	3138
517.51	1367.8

1.16 Time Domain Simulation - Length 30km – Summer Valley B – Reduced Reactor – Case 8

Conditions for time domain simulation:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 20MVar
4. Voltages at Steady State - North Mayo 188.5kV, Base = 178.55kV, 5.6% Overvoltage.
5. Voltages at Steady State - Flagford = 194.7kV Base = 178.55kV, 9% Overvoltage.

Case 8: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

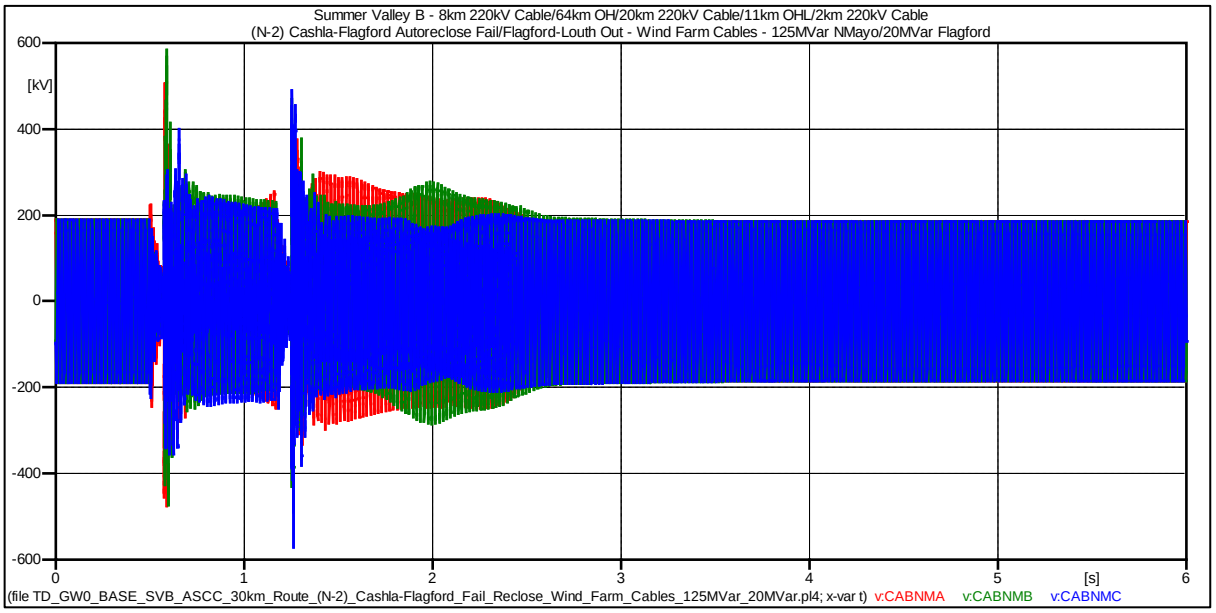

Figure 93: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

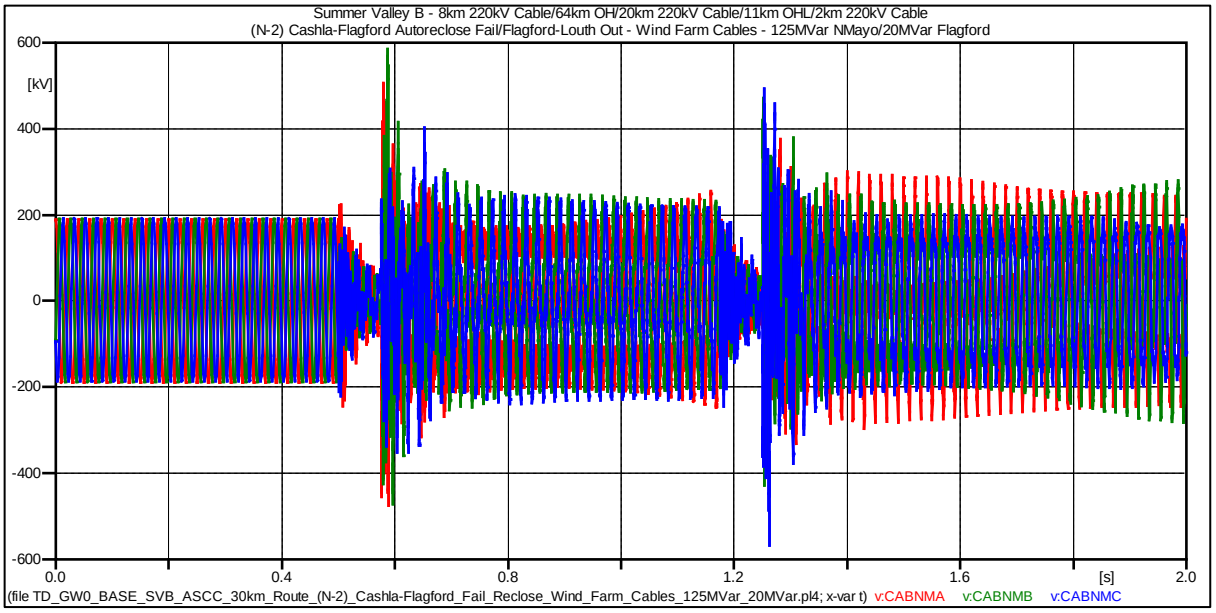

Figure 94: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	580.15 kV (3.230 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	400.56 kV (2.2305 pu)	287.32 kV (1.6 pu)	Fail

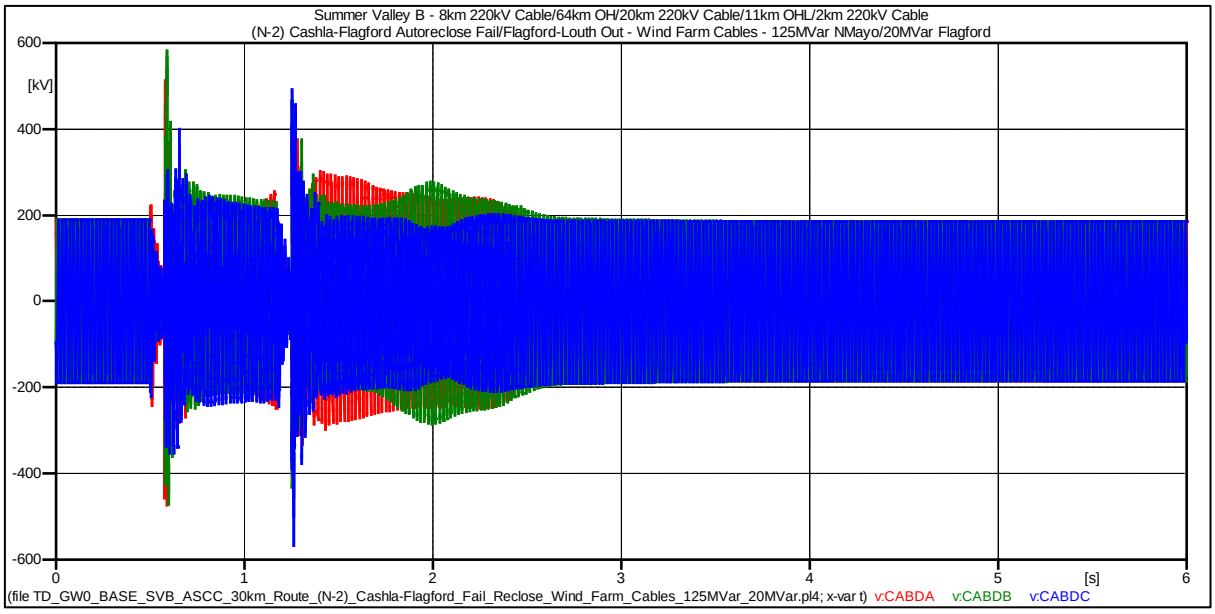

Figure 95: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

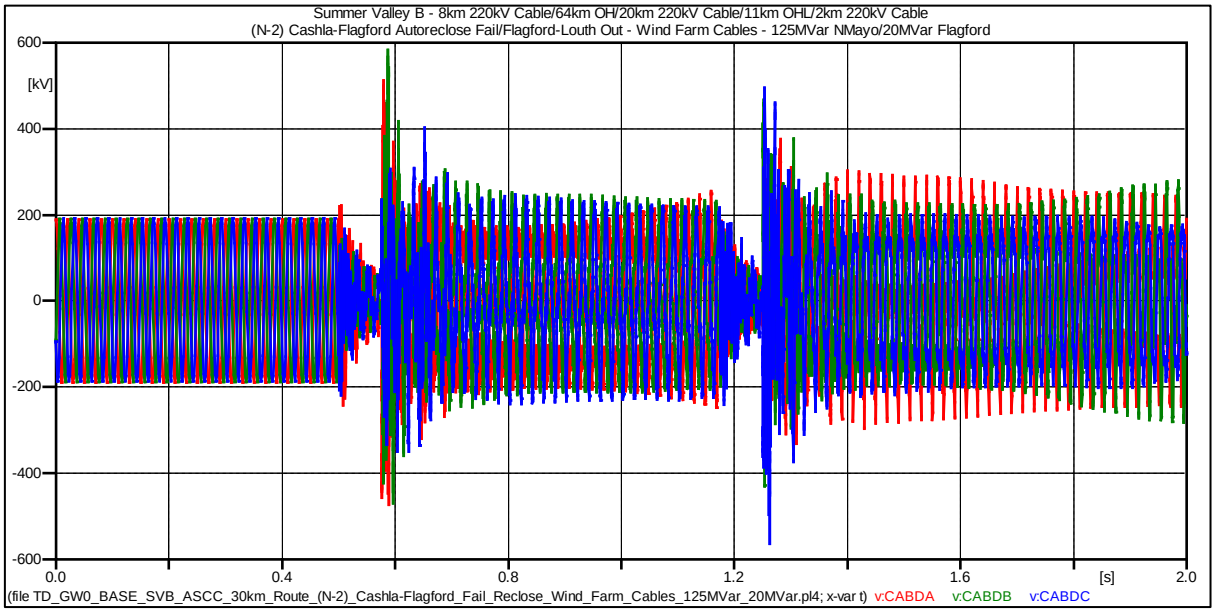

Figure 96: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	580.12 kV (3.230 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	400.99kV (2.2329 pu)	287.32 kV (1.6 pu)	Fail

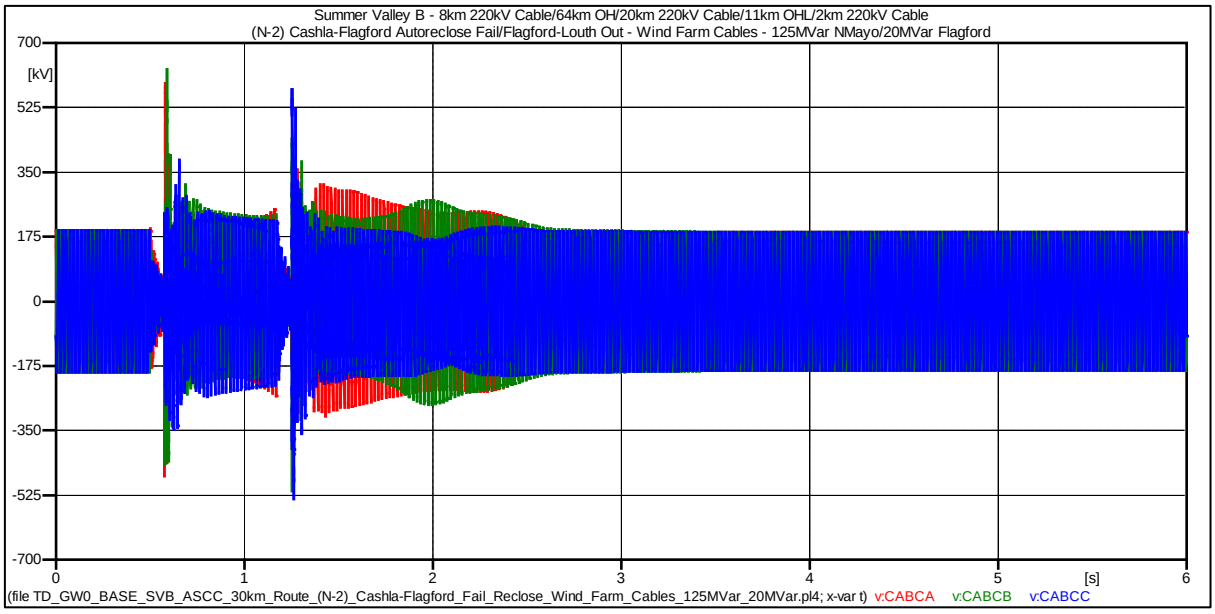

Figure 97: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

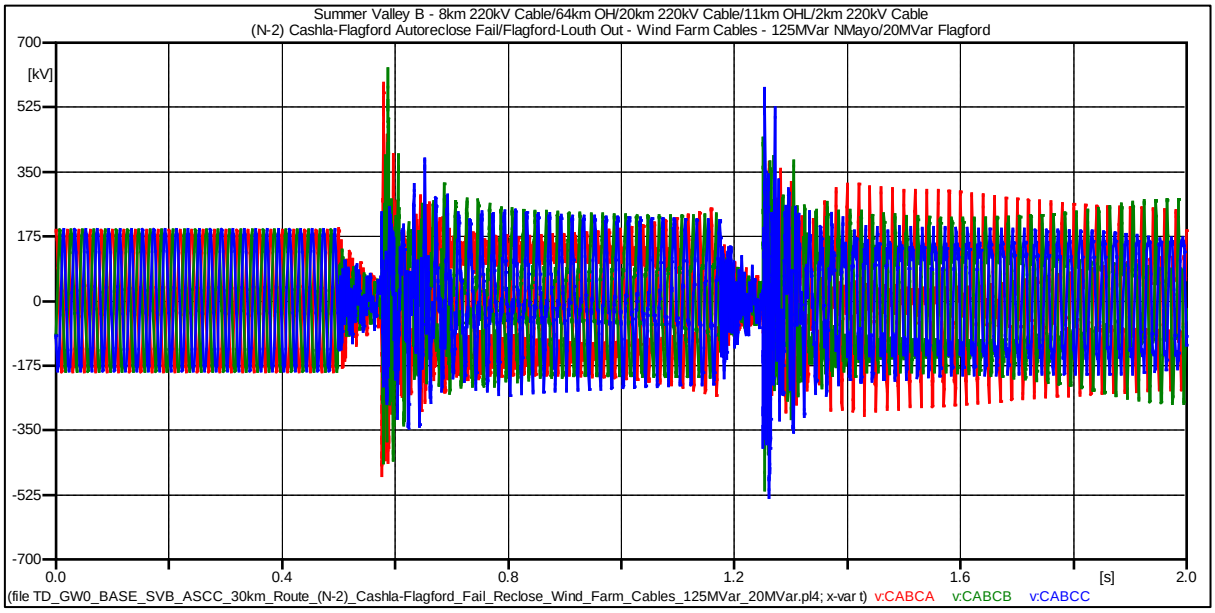

Figure 98: SVB - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	610.54 kV (3.399 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	380.23 kV (2.117 pu)	287.32 kV (1.6 pu)	Fail

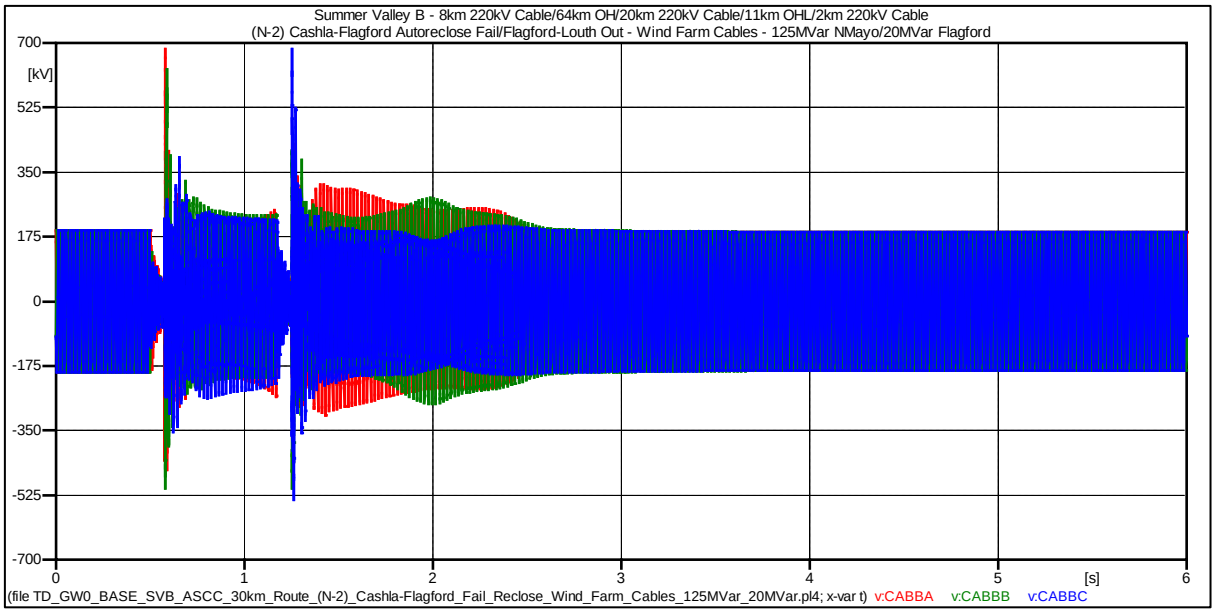

Figure 99: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

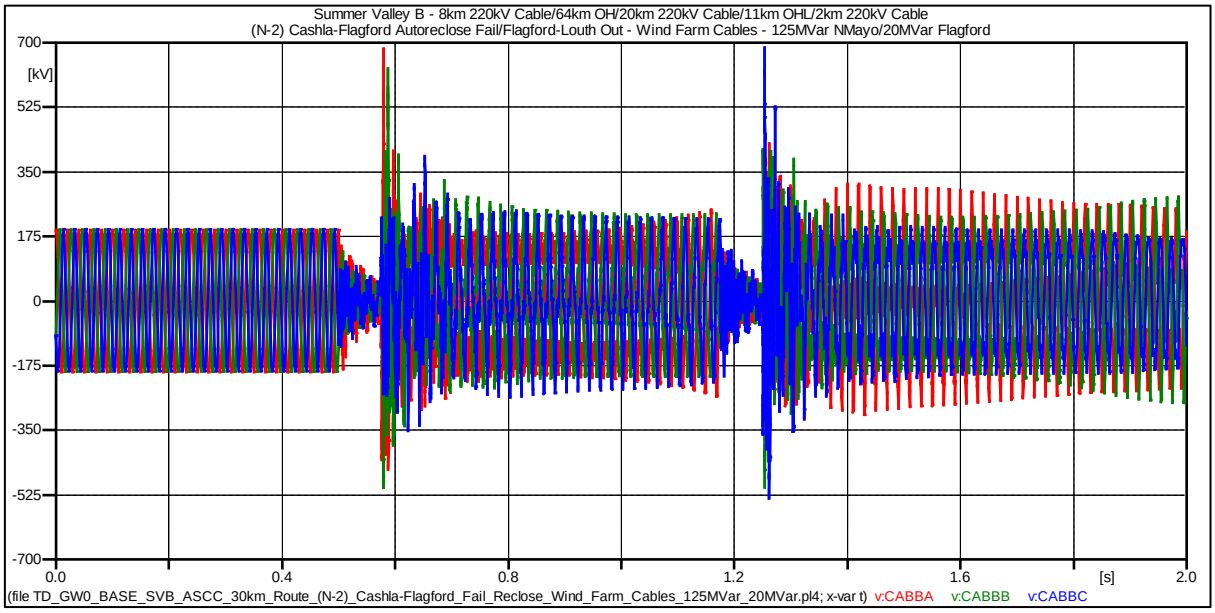

Figure 100: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	680.13 kV (3.787 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	370.65 kV (2.063 pu)	287.32 kV (1.6 pu)	Fail

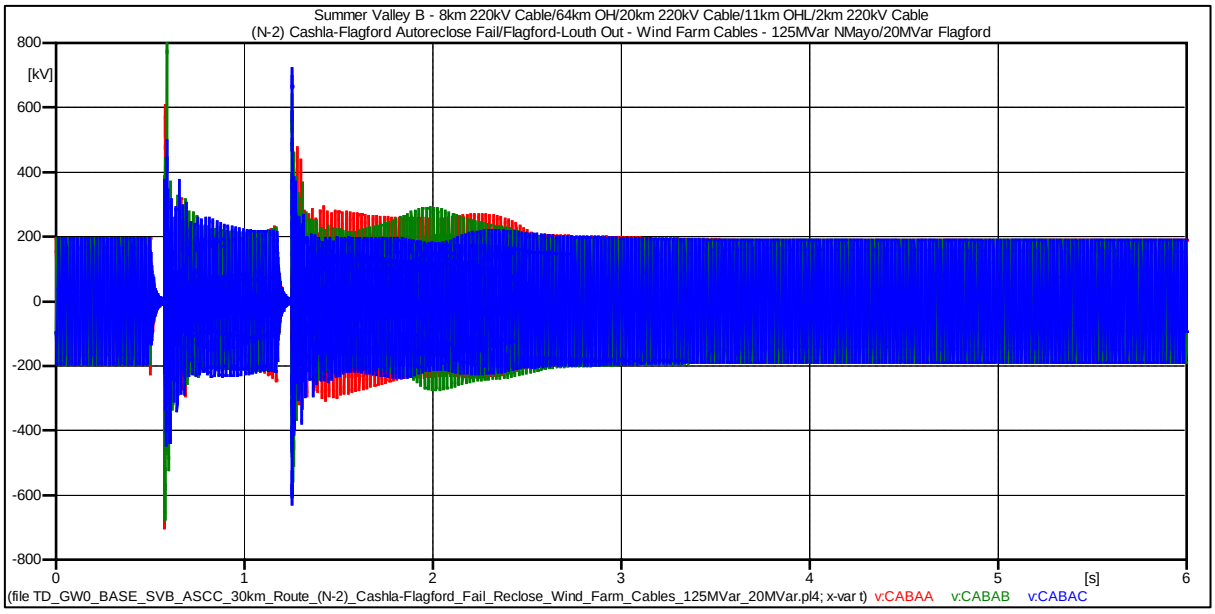

Figure 101: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

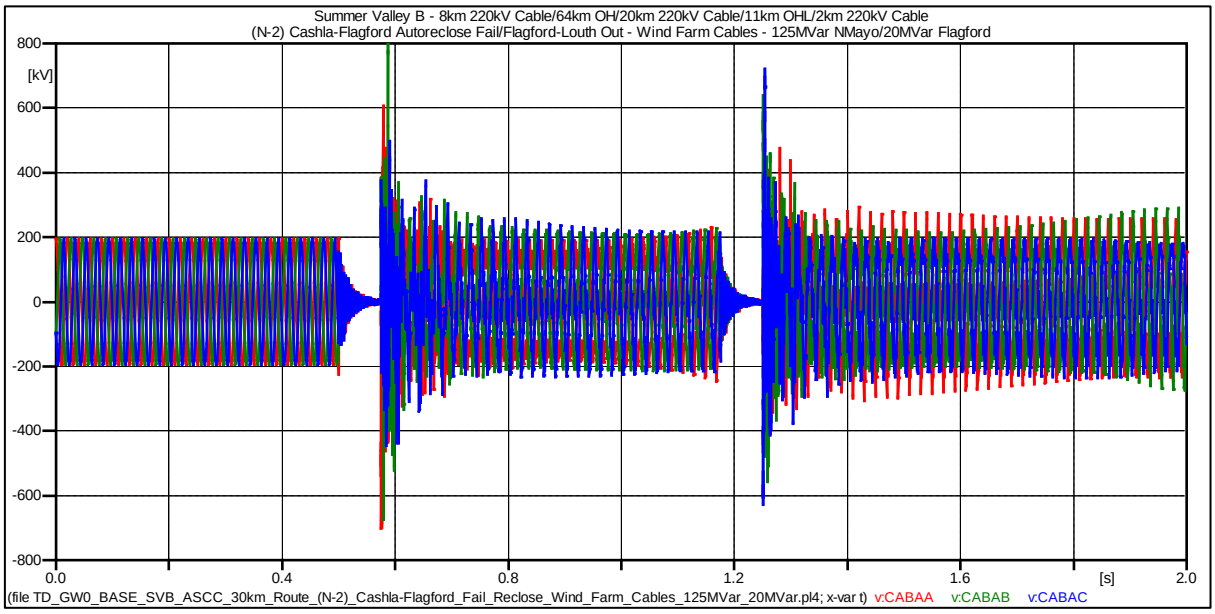

Figure 102: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	801.10 kV (4.4866 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	412.52kV (2.297pu)	287.32 kV (1.6 pu)	Fail

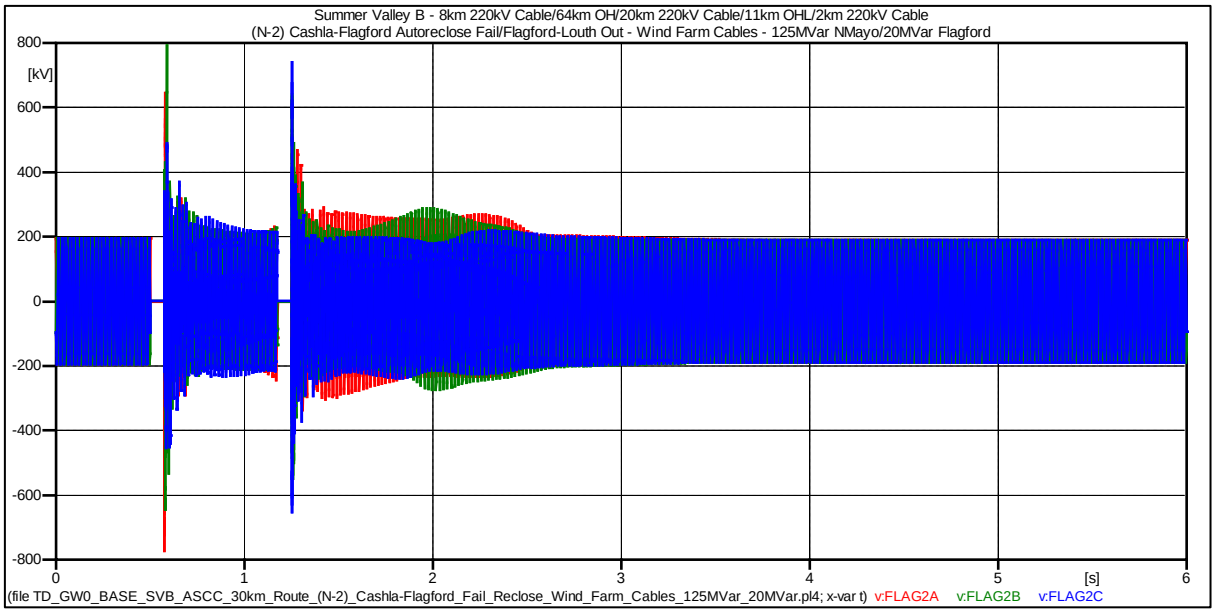

Figure 103: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

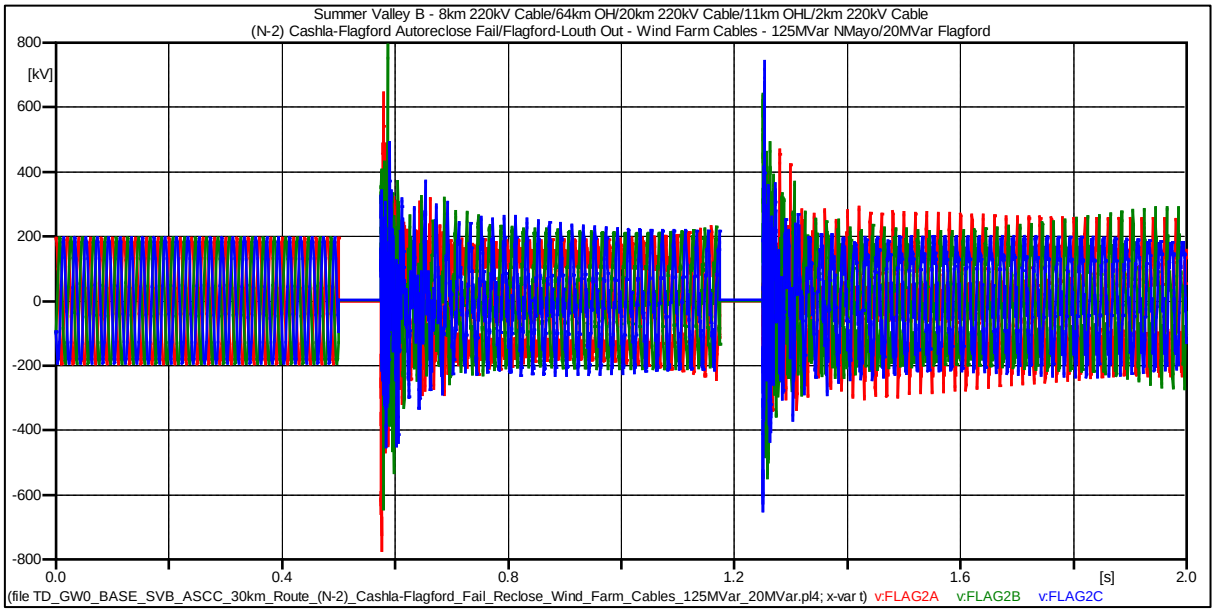

Figure 104: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	801.23 kV (4.461 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	420.54 kV (2.341 pu)	287.32 kV (1.6 pu)	Fail

1.17 Impedance Scans - Length 30km –Summer Valley B – Shunt Filter – Case 8

Conditions for impedance scan:

1. Summer Valley B network.
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 20MVar
4. Shunt Filter (L = 1.2324H, C = 0.9134 uF) connected to the 220 kV busbar at North Mayo to filter the 3rd harmonic

Case 8: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out – Filter Added

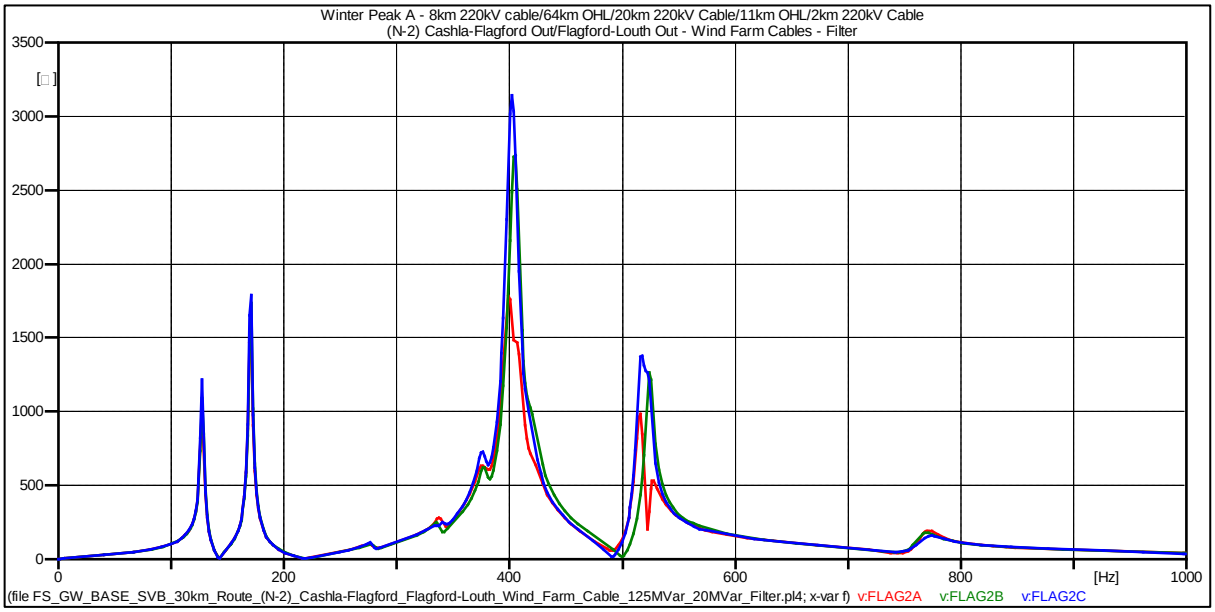

Figure 105: SVB - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out - Filter

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
127.51	1214.2
171.01	1787.6
403.51	3032.2
517.51	1376.1

1.18 Time Domain Simulation - Length 30km – Summer Valley B – Shunt Filter – Case 8

Conditions for time domain simulation:

1. Summer Valley B network
1. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
2. Reactors – North Mayo 125MVar/Flagford 20MVar
3. Shunt Filter (L = 1.2324H, C = 0.9134 uF) connected to the 220 kV busbar at North Mayo to filter the 3rd harmonic

Case 8: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

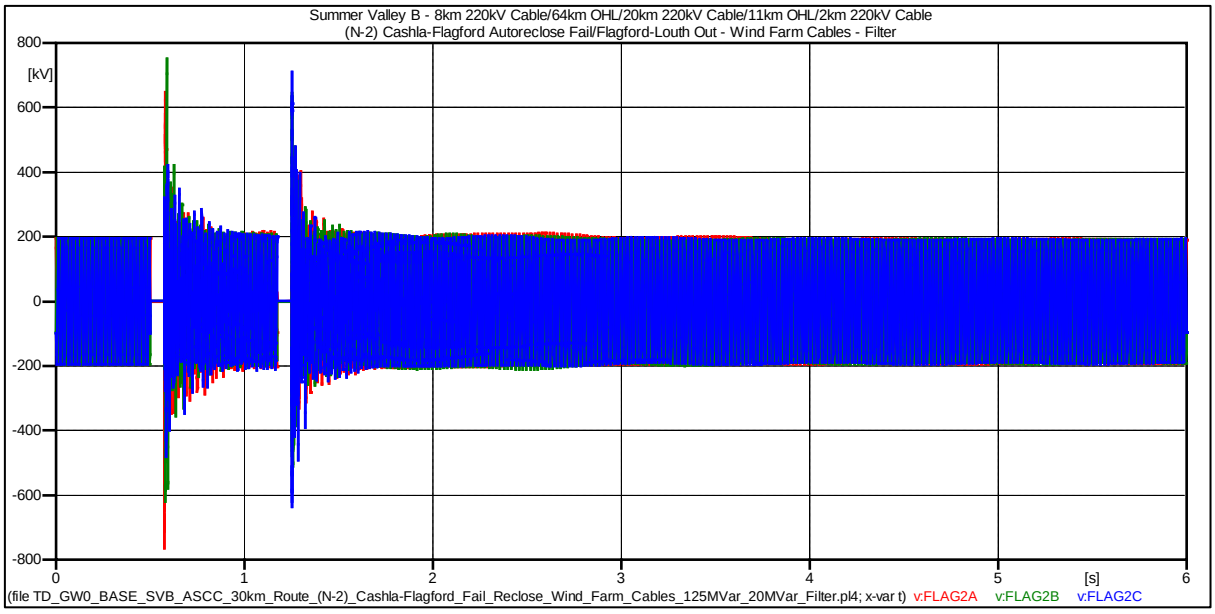

Figure 106: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

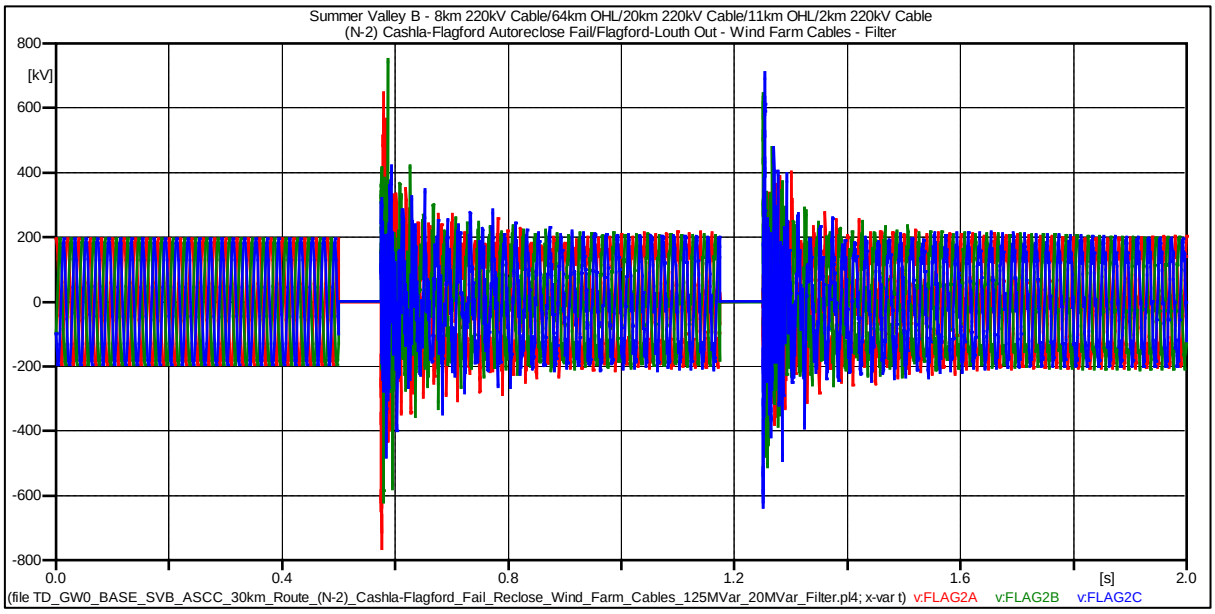

Figure 107: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	775.23 kV (4.316 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	401.89 kV (2.237 pu)	287.32 kV (1.6 pu)	Fail*

*Slight TOV.

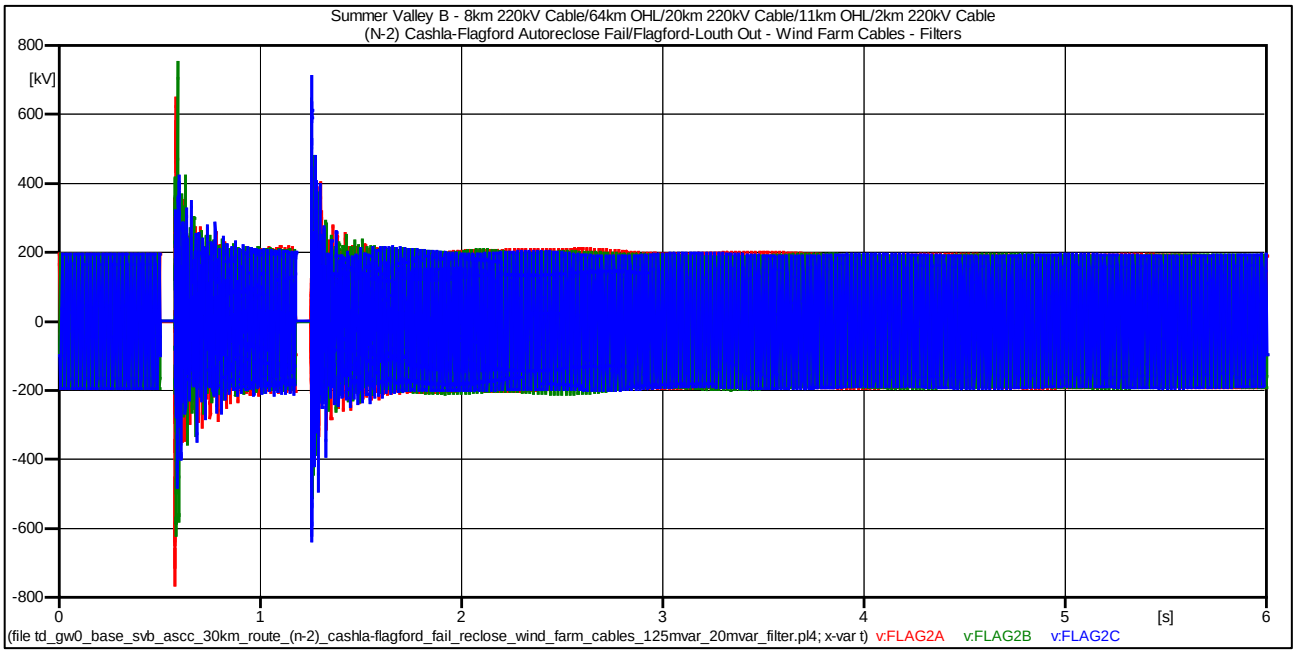

Figure 108: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

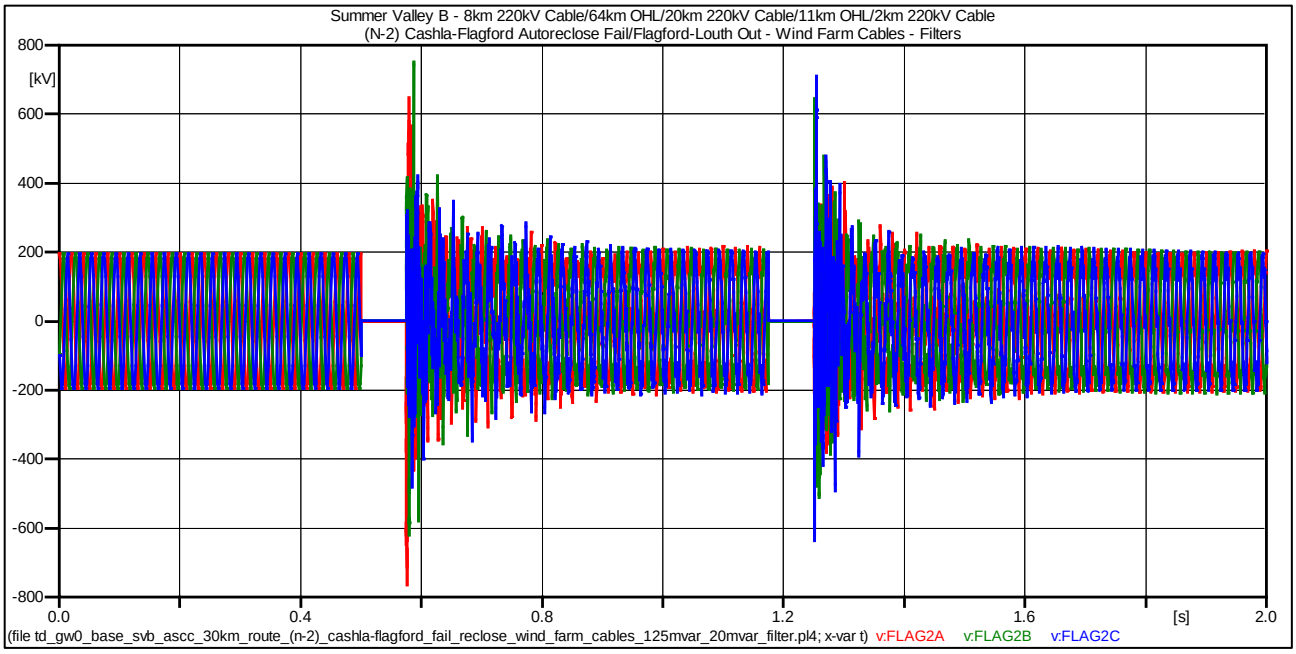

Figure 109: SVB - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	772.13 kV (4.299 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	410.15 kV (2.285 pu)	287.32 kV (1.6 pu)	Fail

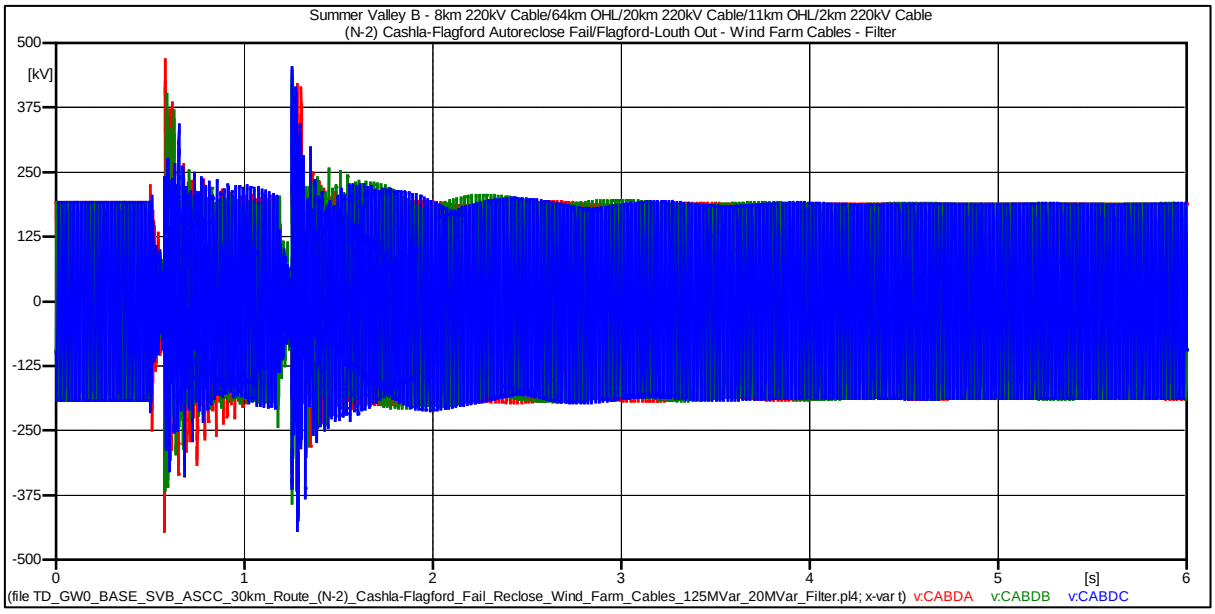

Figure 110: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

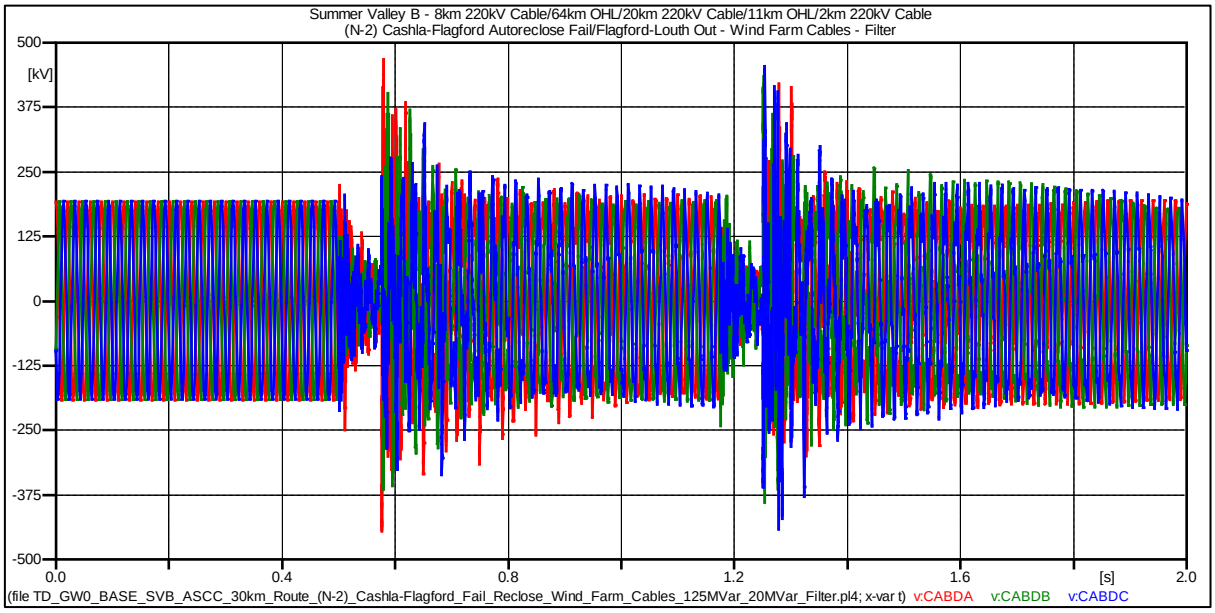

Figure 111: SVB - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	470.23 kV (2.618 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	375.23 kV (2.089 pu)	287.32 kV (1.6 pu)	Fail

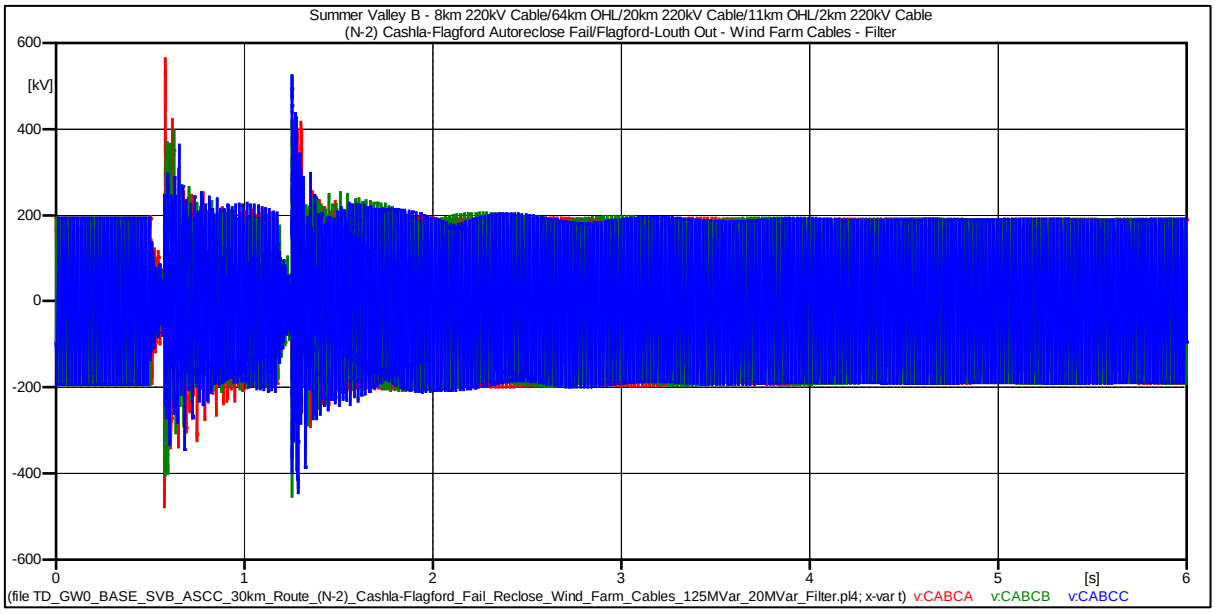

Figure 112: SVB - Length 30km – Cable End C– (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

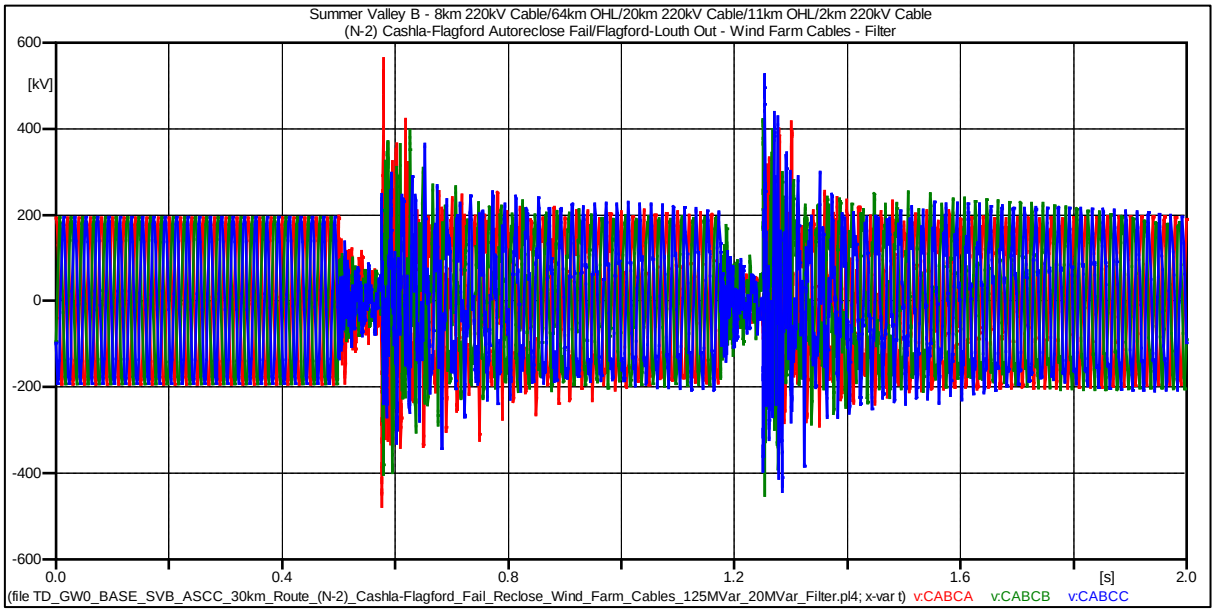

Figure 113: SVB - Length 30km – Cable End C– (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	555.32 kV (3.092 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	441.23 kV (2.457 pu for 40 ms)	287.32 kV (1.6 pu)	Fail

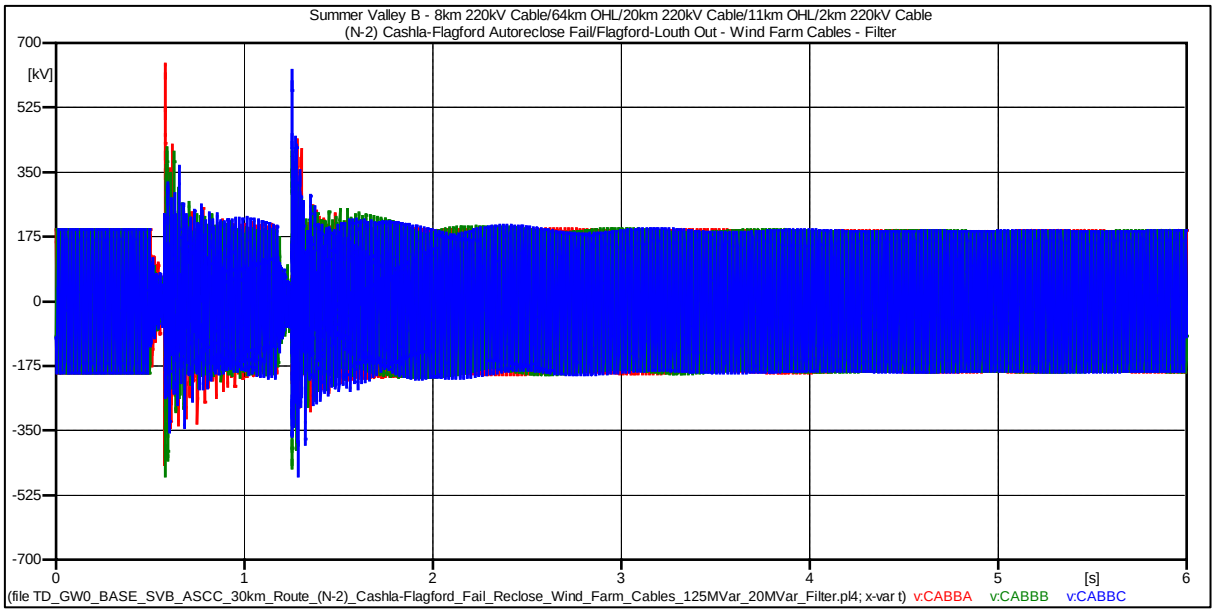

Figure 114: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

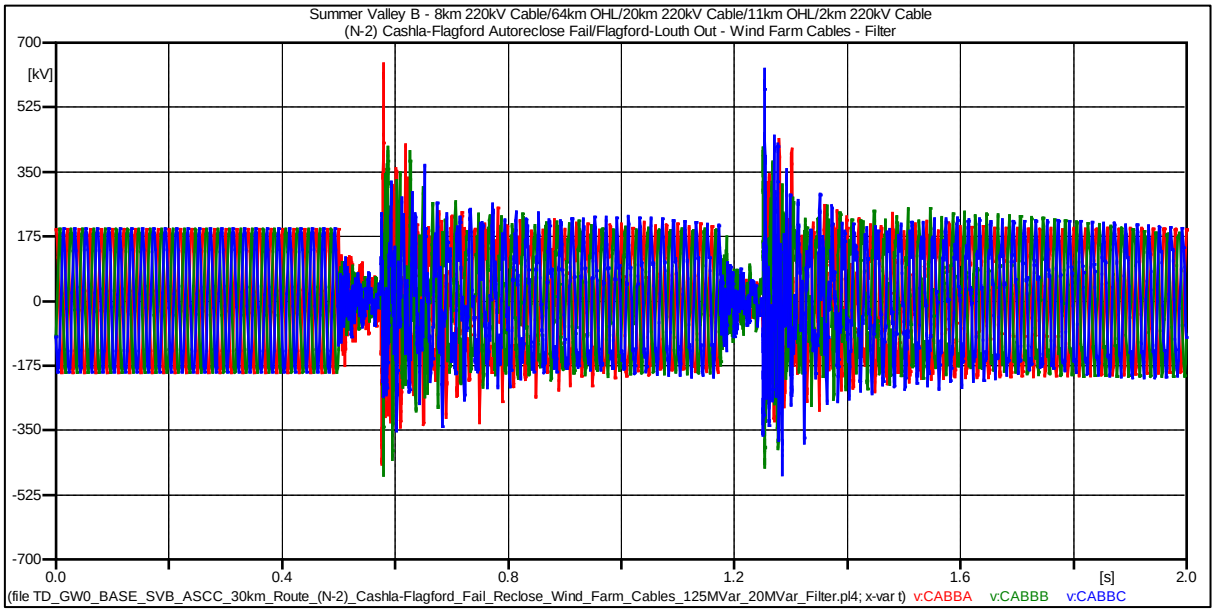

Figure 115: SVB - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	481.12 kV (2.679 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	438.12 kV (2.439 pu)	287.32 kV (1.6 pu)	Fail

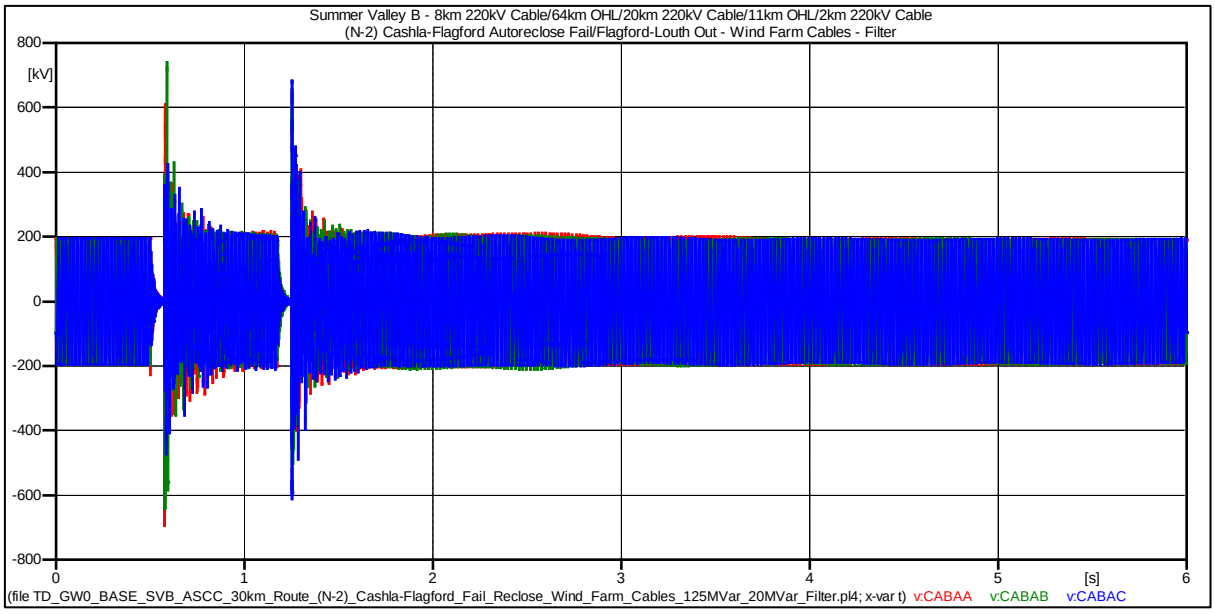

Figure 116: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

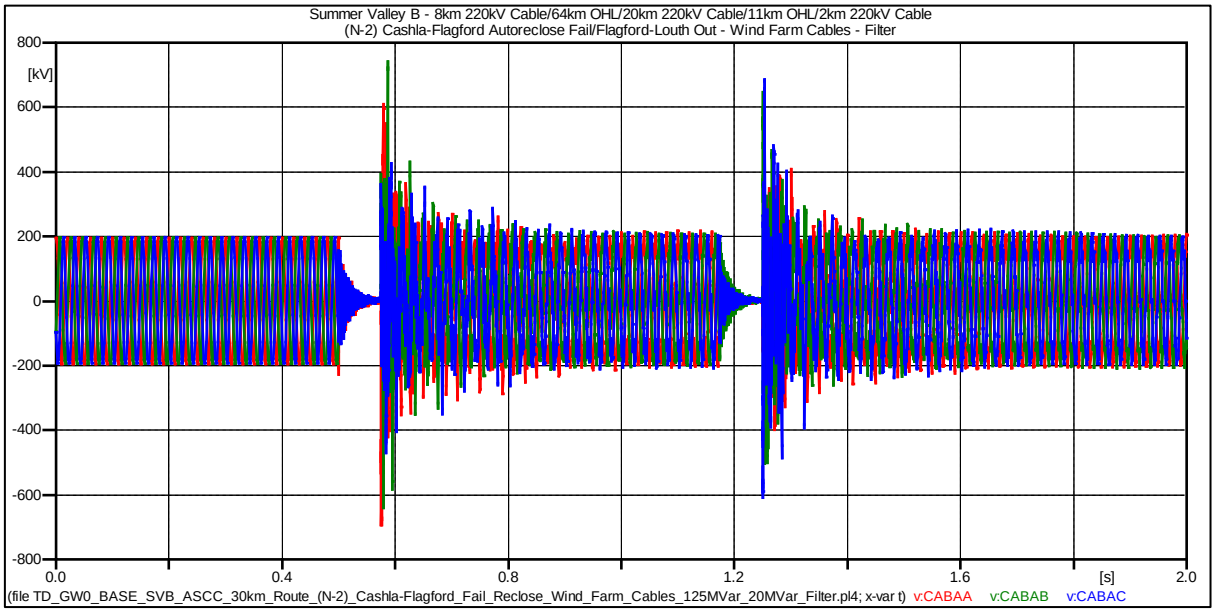

Figure 117: SVB - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	710.23 kV (3.954 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	460.53 kV (2.564 pu)	287.32 kV (1.6 pu)	Fail

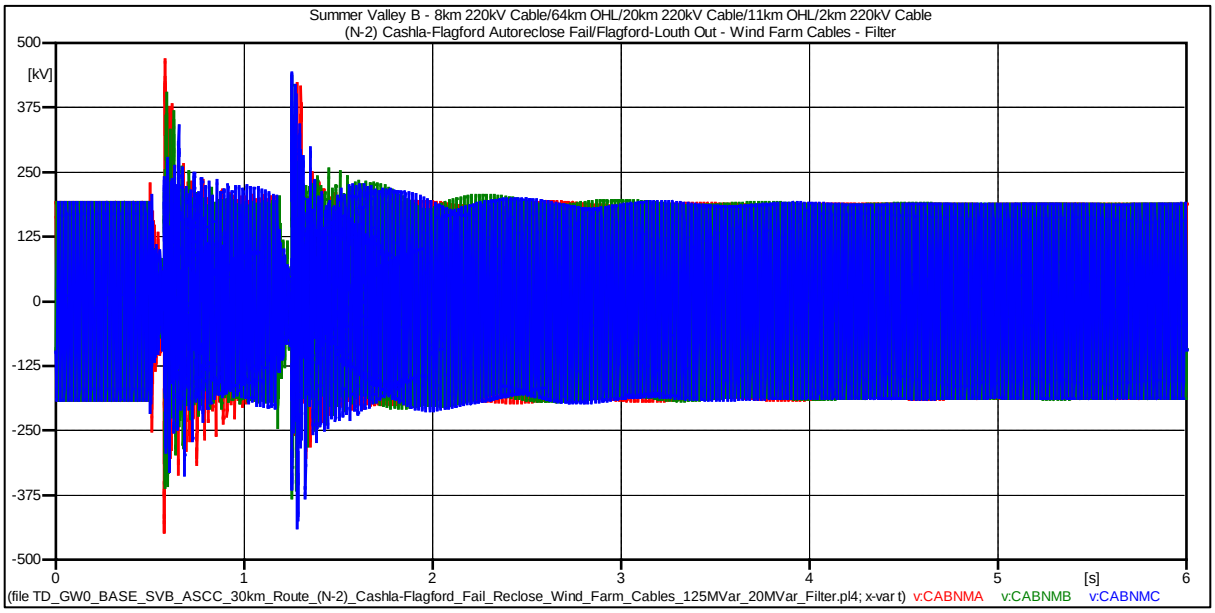

Figure 118: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

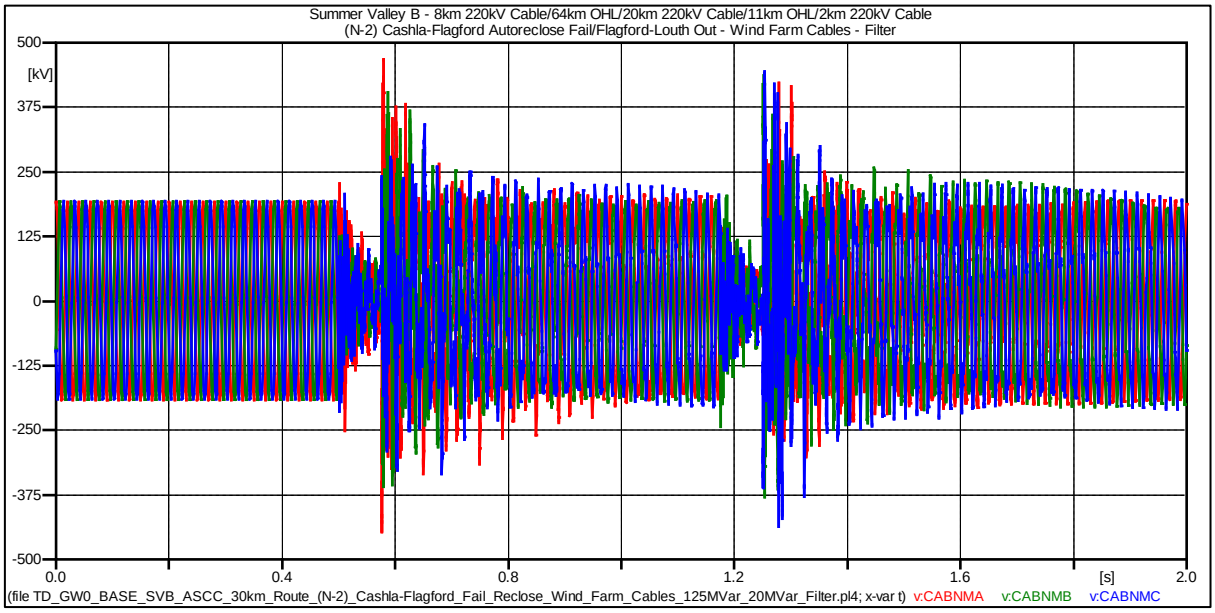

Figure 119: SVB - Length 30km – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	470.53 kV (2.620 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	375.12 kV (2.088 pu)	287.32 kV (1.6 pu)	Fail

1.19 Impedance Scans - Length 30km –Winter Peak A – Shunt Filter – Case 9

Conditions for impedance scan:

1. Winter Peak A network.
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 20MVar
4. Shunt Filter (L = 1.2324H, C = 0.9134 uF) to filter 3rd harmonic connected at 220 kV North Mayo busbar

Case 9: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out – Filter Added

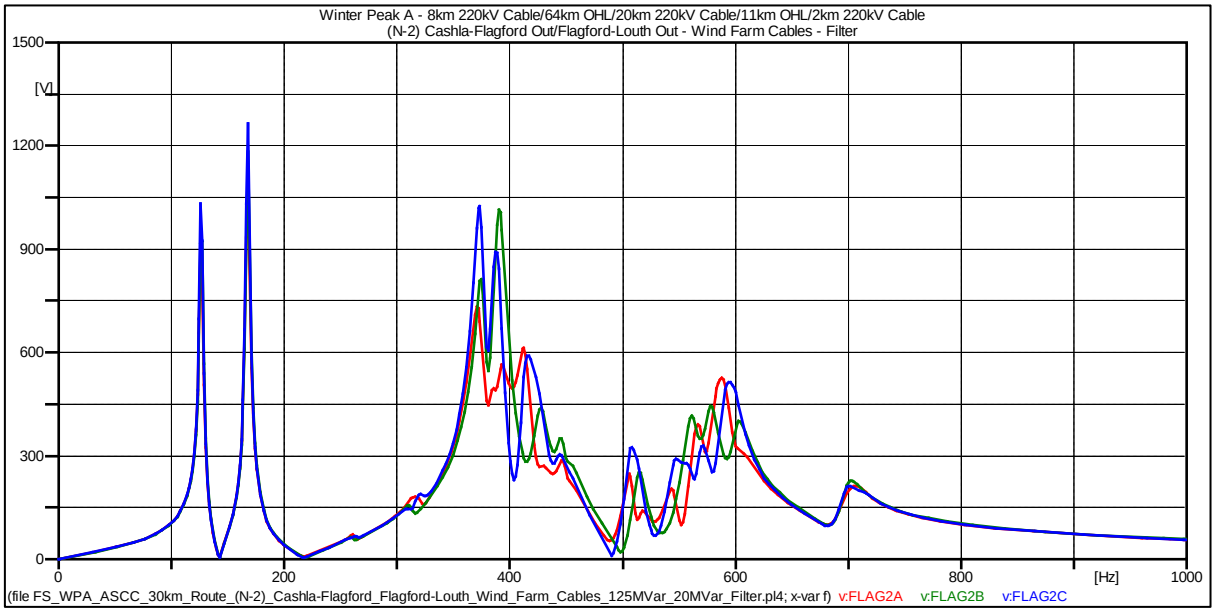

Figure 120: WPA - Length 30km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out - Filter

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
126.01	1032.1
168.01	1264.0
373.51	1025.6
588.01	525.4

1.20 Time Domain Simulation - Length 30km – Winter Peak A – Shunt Filter – Case 9

Conditions for time domain simulation:

1. Winter Peak A network
2. Length - 8km Cable/64km OHL/20km Cable/11km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 20MVar
4. Shunt Filter (L = 1.2324H, C = 0.9134 uF) to filter 3rd harmonic connected at 220 kV North Mayo busbar

Case 9: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

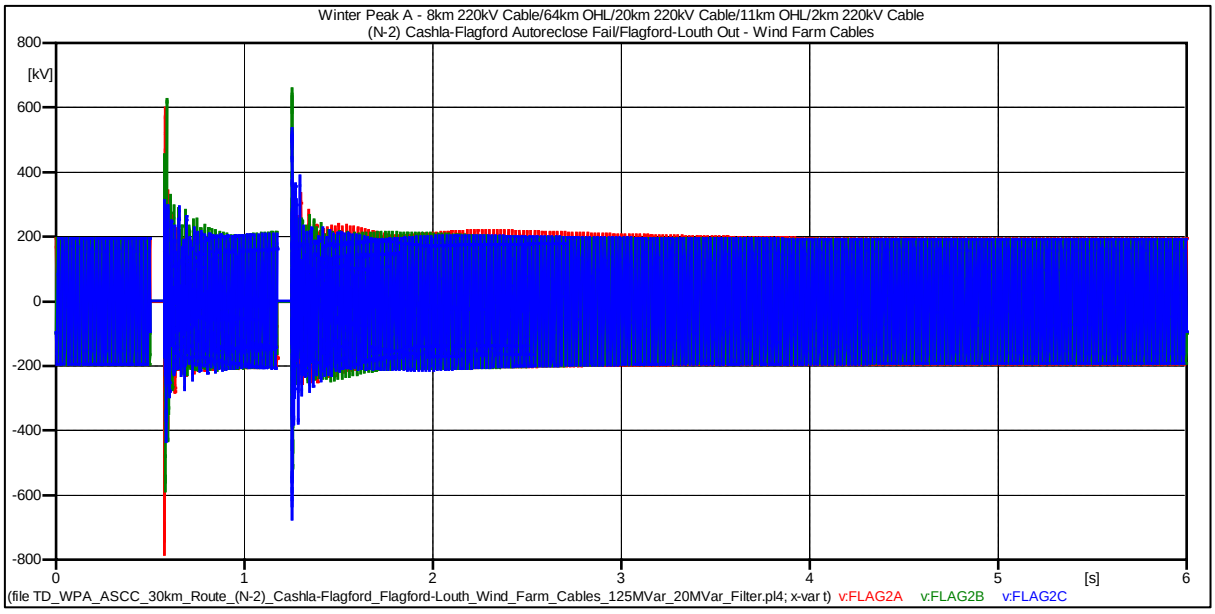

Figure 121: WPA - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

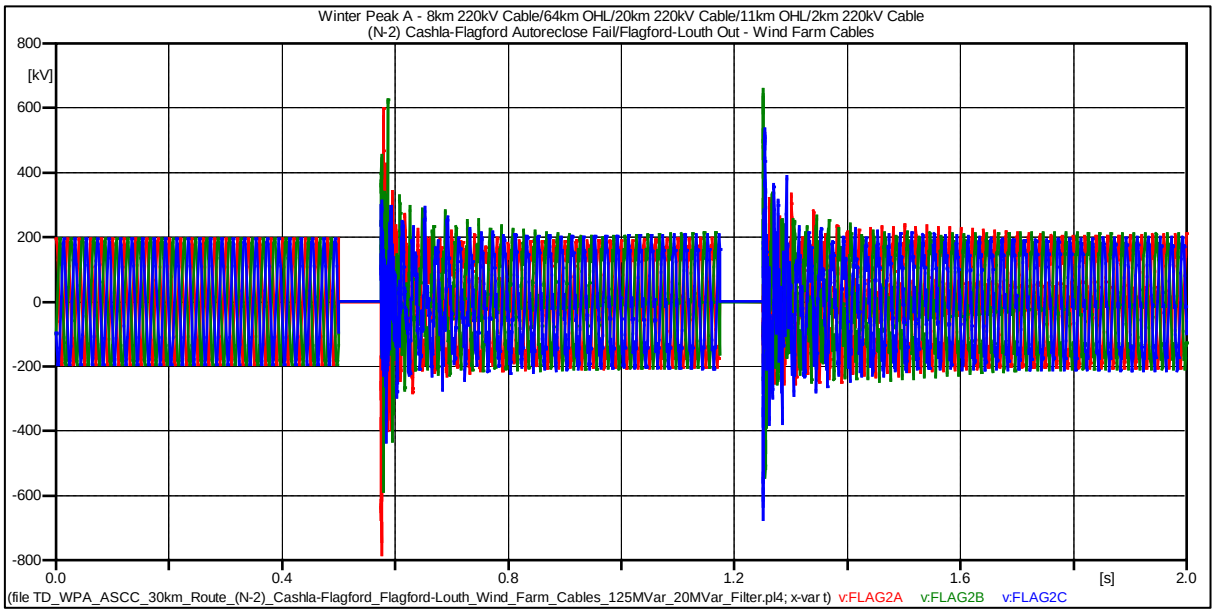

Figure 122: WPA - Length 30km – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	800.15 kV (4.455 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	481.25 kV (2.679 pu)	287.32 kV (1.6 pu)	Fail

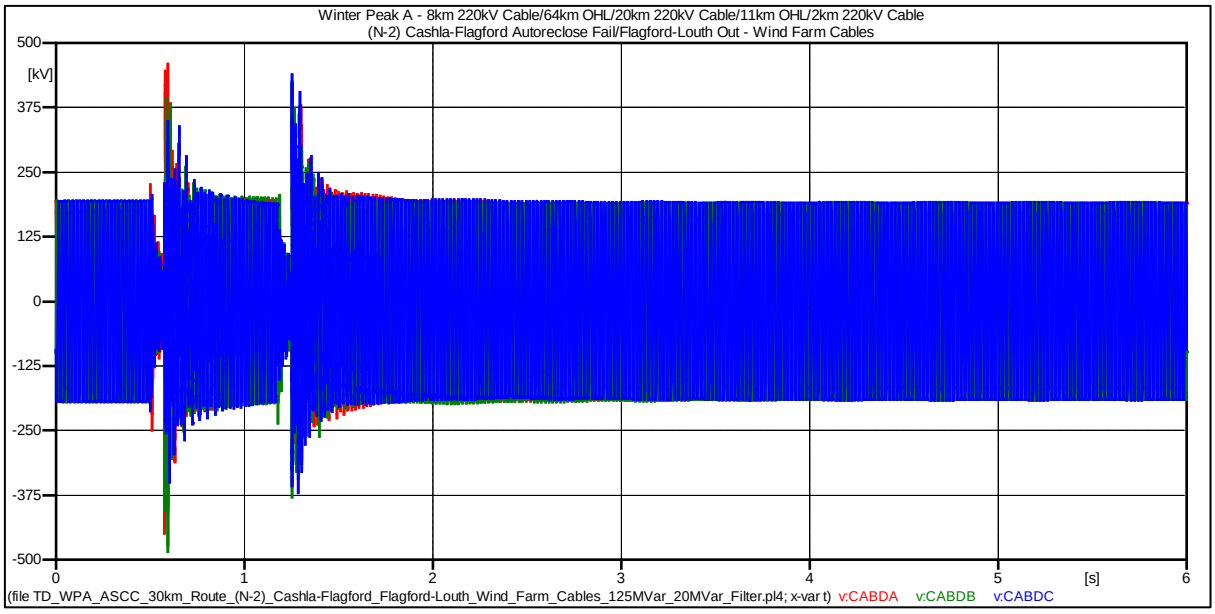

Figure 123: WPA - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

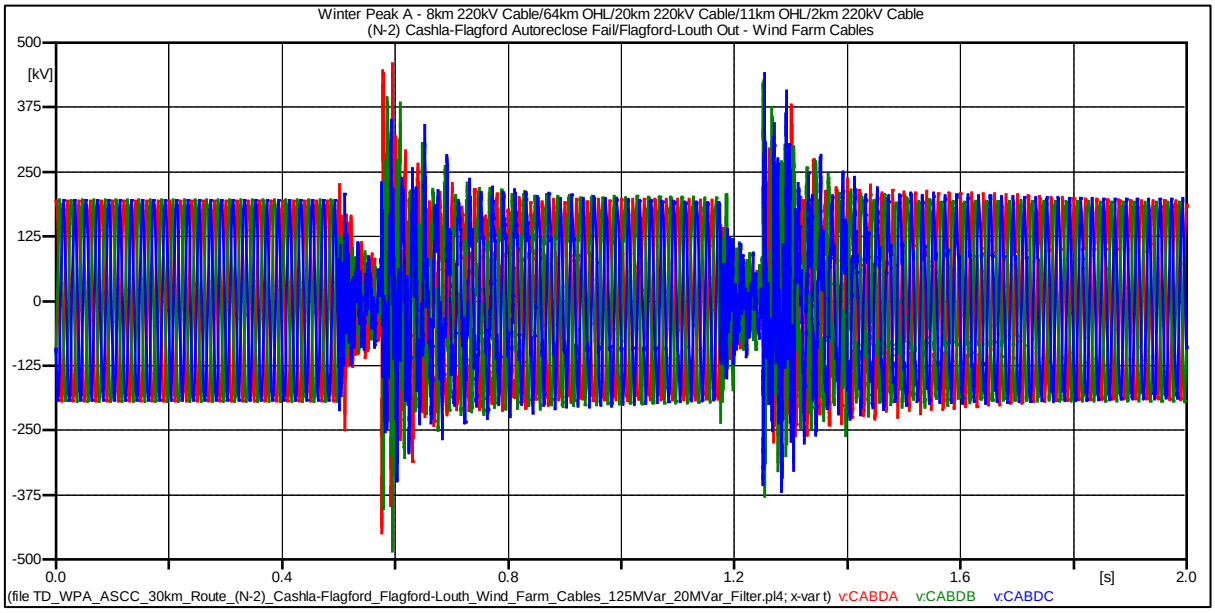

Figure 124: WPA - Length 30km – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	481.51 kV (2.6967 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	325.01 kV (1.809 pu)	287.32 kV (1.6 pu)	Fail

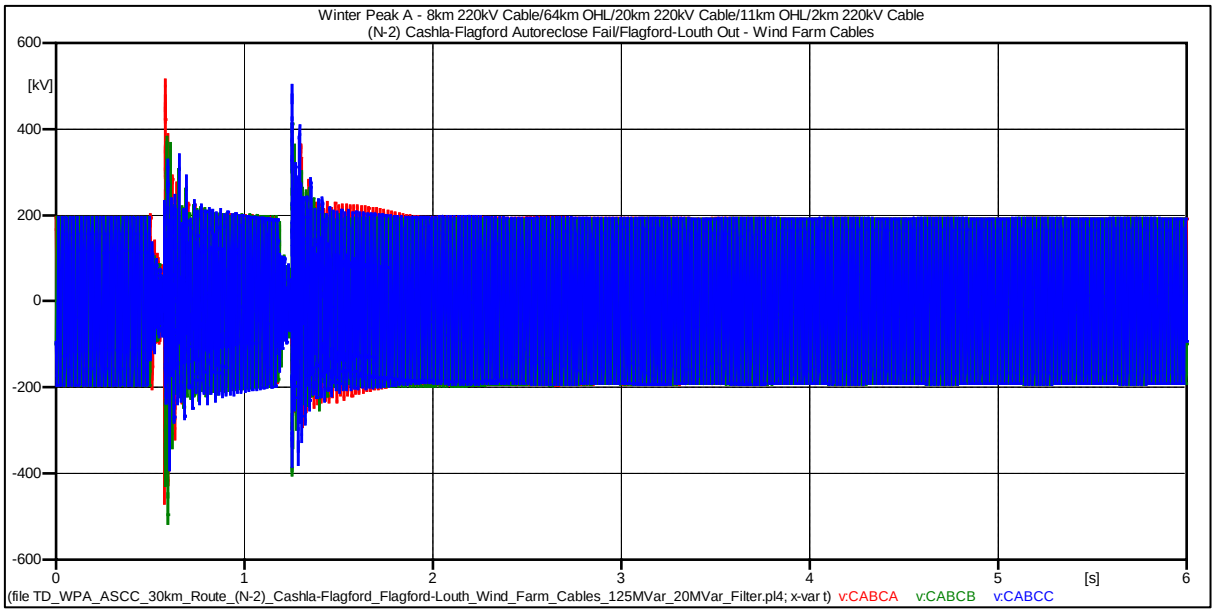

Figure 125: WPA - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

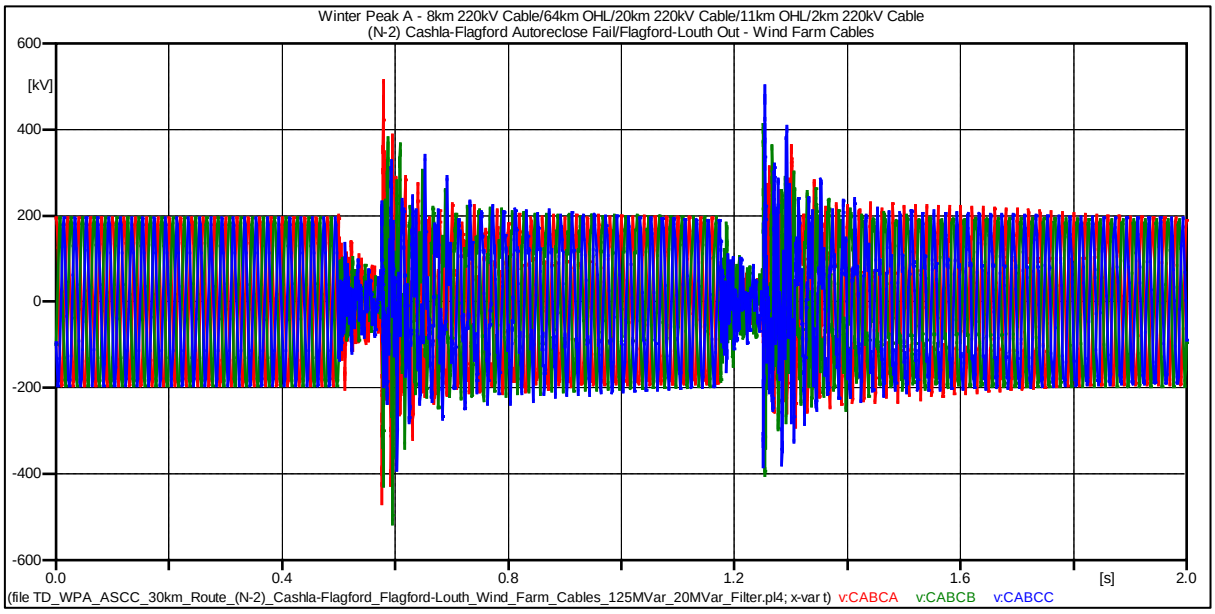

Figure 126: WPA - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	501.23 kV (2.791 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	410.15 kV (2.283 pu)	287.32 kV (1.6 pu)	Fail

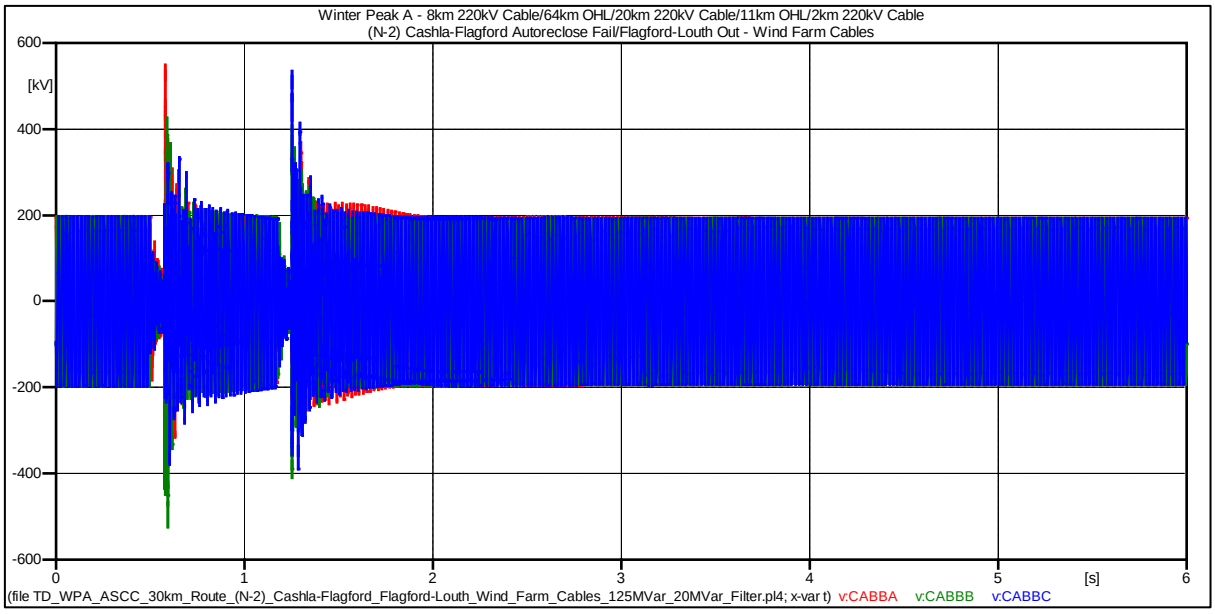

Figure 127: WPA - Length 30km – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

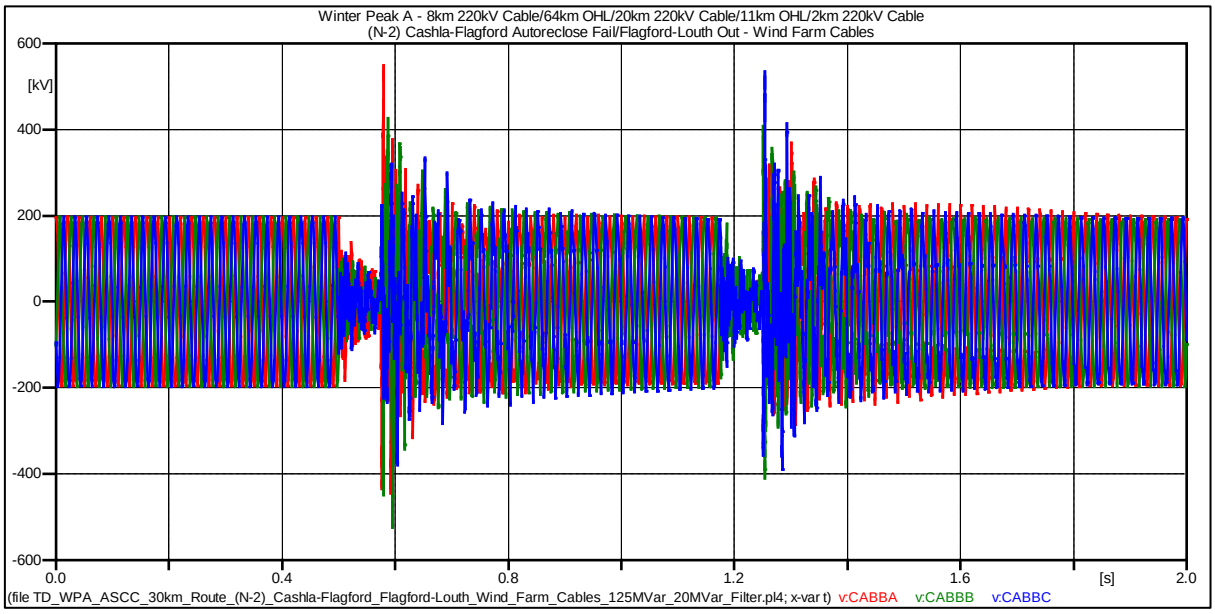

Figure 128: WPA - Length 30km – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	526.81 kV (2.933 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	230.01 kV (1.280 pu)	287.32 kV (1.6 pu)	Pass

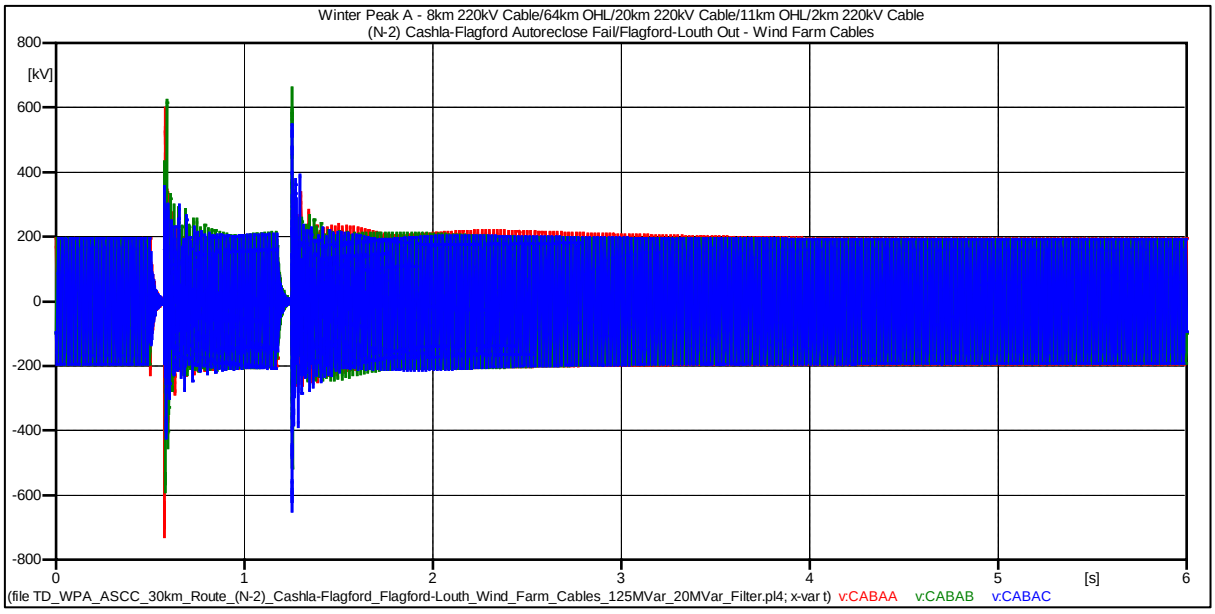

Figure 129: WPA - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

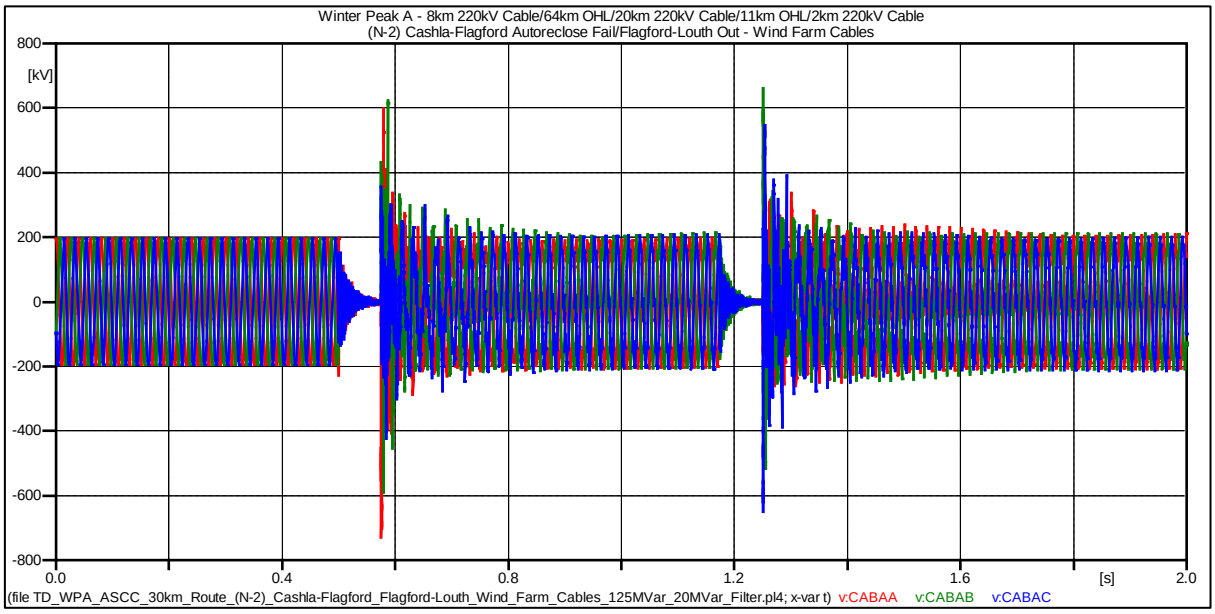

Figure 130: WPA - Length 30km – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	720.56 kV (4.012 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	295.32 kV (1.644 pu)	287.32 kV (1.6 pu)	Fail

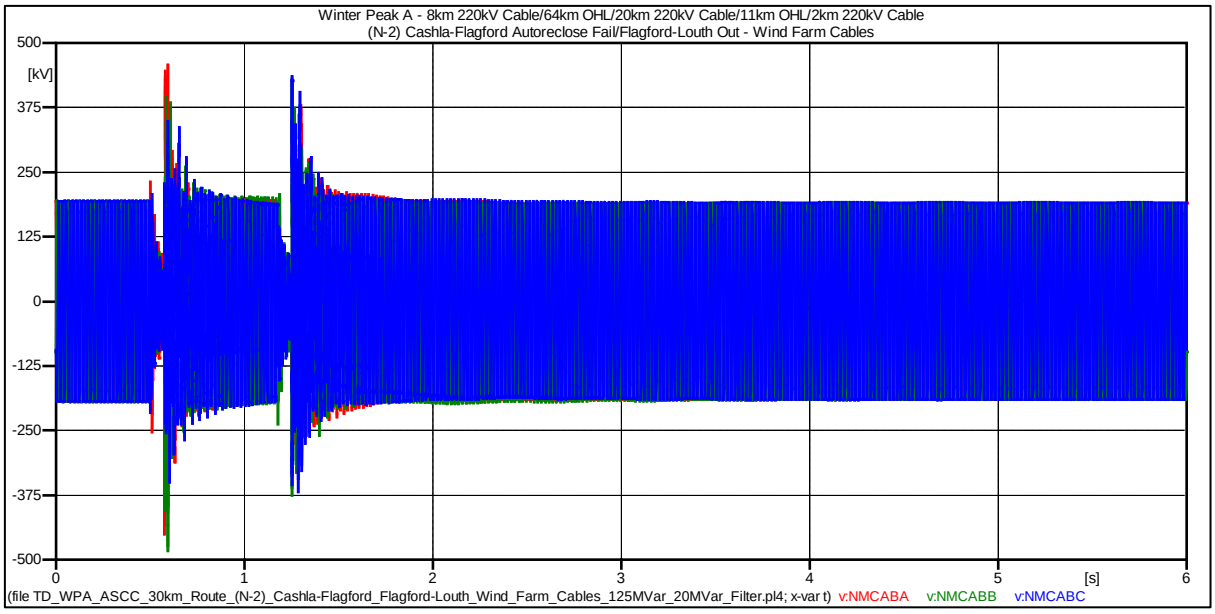

Figure 131: WPA - Length 30km –North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s) – Shunt filter added at North Mayo

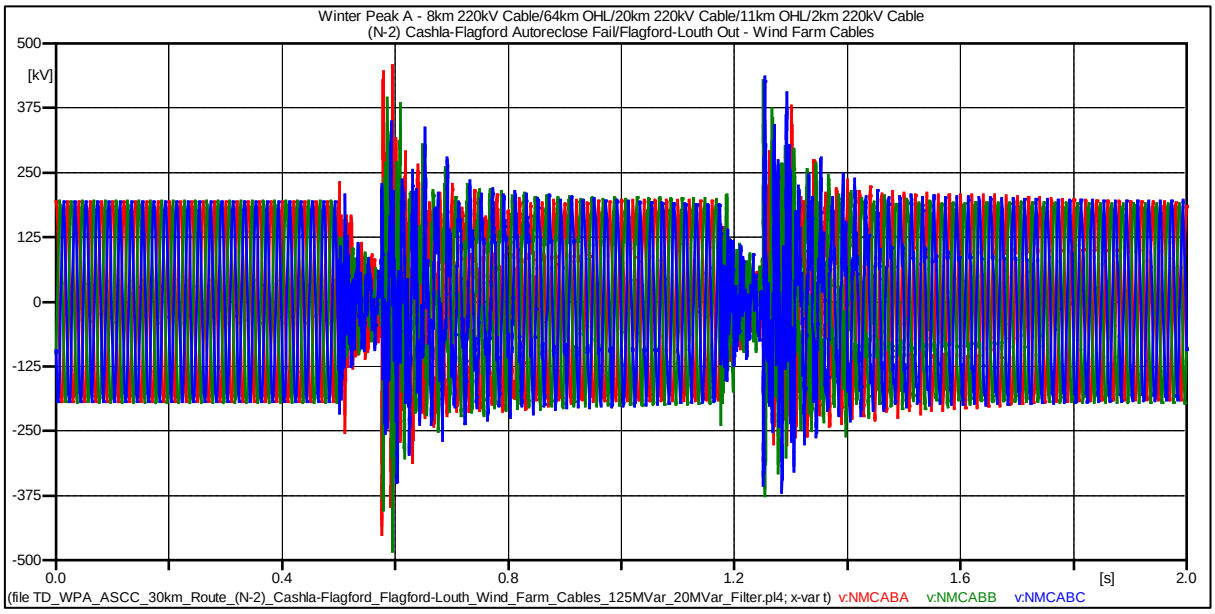

Figure 132: WPA - Length 30km –North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s) – Shunt filter added at North Mayo

Condition	Maximum Value	Limit	Result
Switching	480.25kV (2.674 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	410.25 kV (1.2844 pu)	287.32 kV (1.6 pu)	Fail

1.21 Impedance Scans - Length 23km – Summer Valley B – Case 10

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/13km Cable/18km OHL/2km Cable
3. Reactors – North Mayo 100MVar/Flagford 25MVar

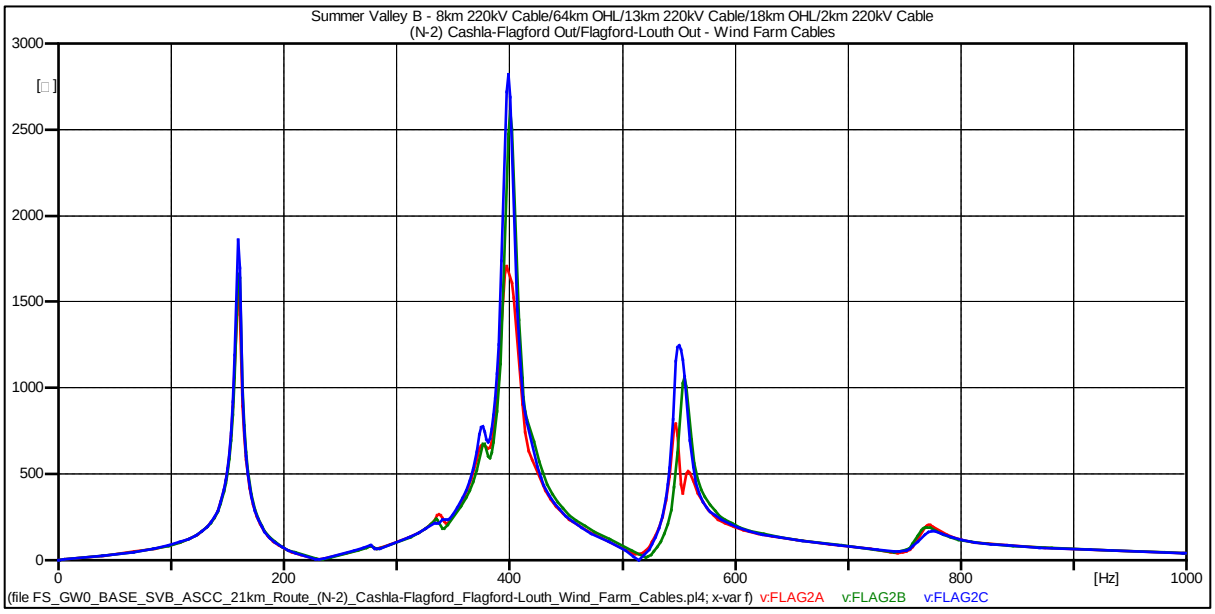

Figure 133: SVB - Length 23km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
160.51	1696.5
399.01	2823.5
550.51	1246.7

1.22 Time Domain Simulation - Length 23km – Summer Valley – Case 10

Conditions for time domain simulation:

1. Summer Valley B network.
2. Length - 8km Cable/64km OHL/13km Cable/18km OHL/2km Cable.
3. Reactors – North Mayo 125 MVar/Flagford 25 MVar.

Case 10: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

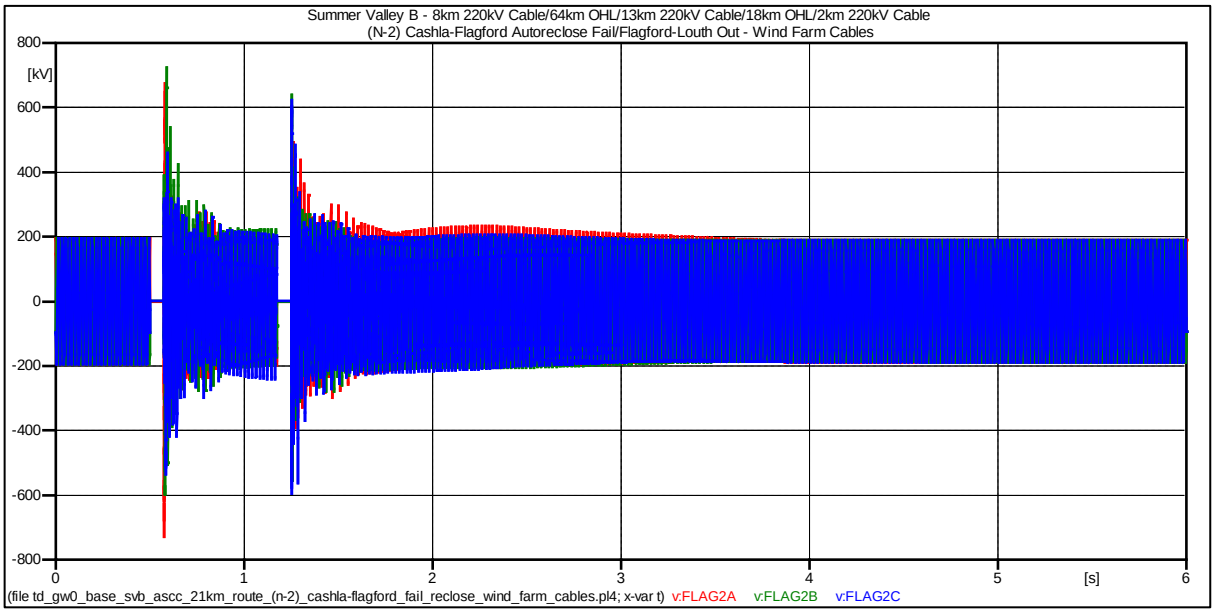

Figure 134: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

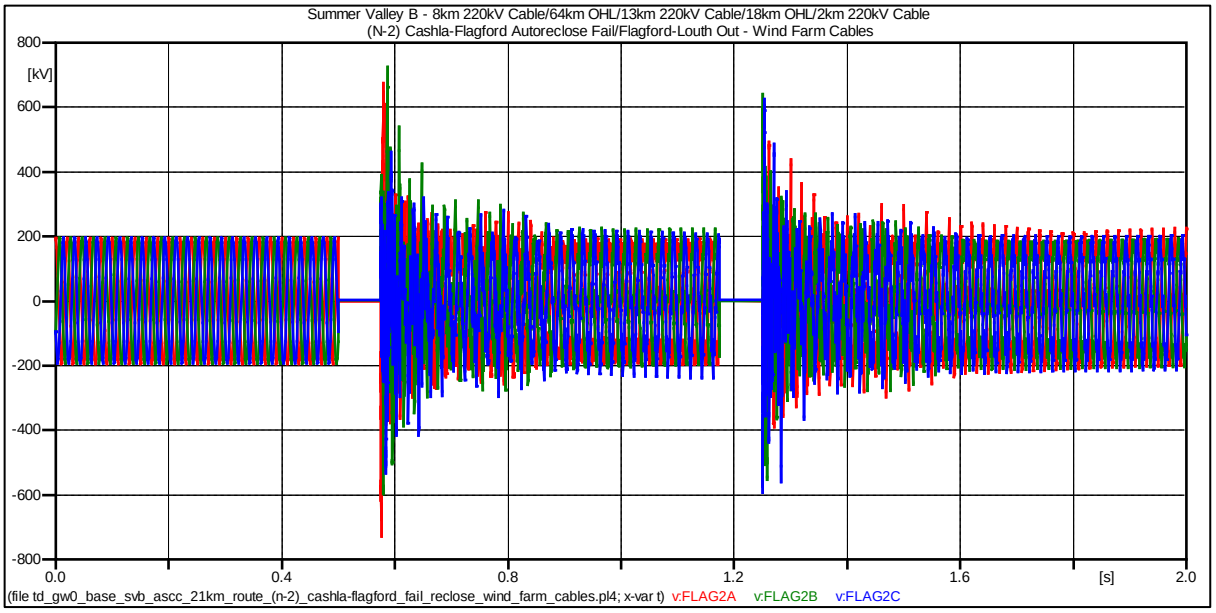

Figure 135: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	723.56 kV (4.029 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	405.25 kV (2.2566 pu)	287.32 kV (1.6 pu)	Fail

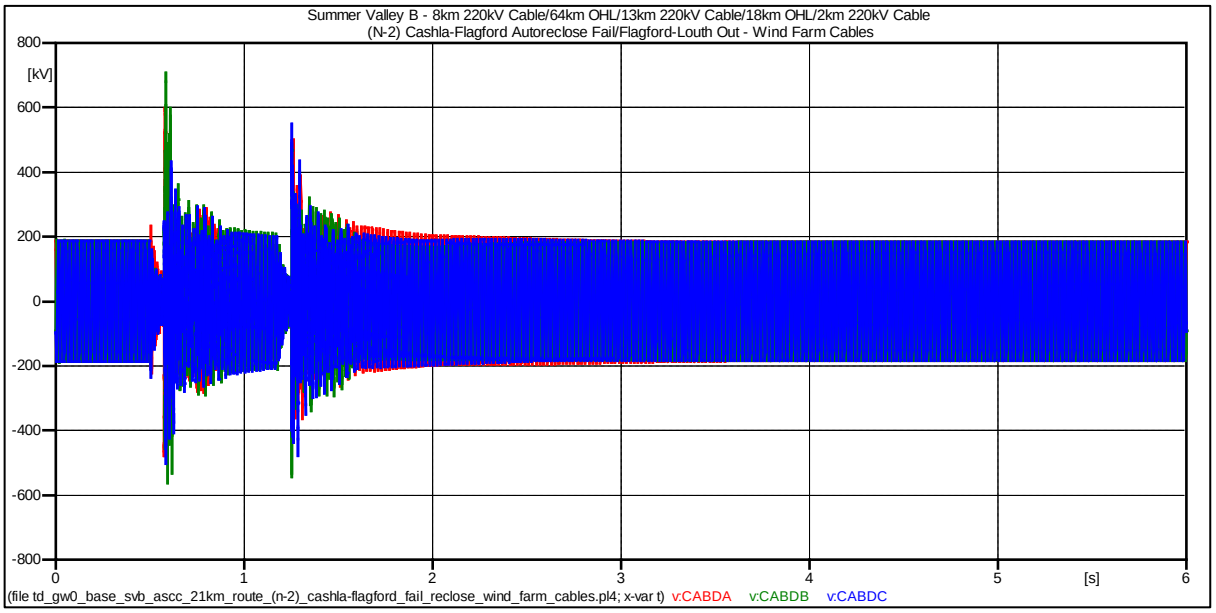

Figure 136: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

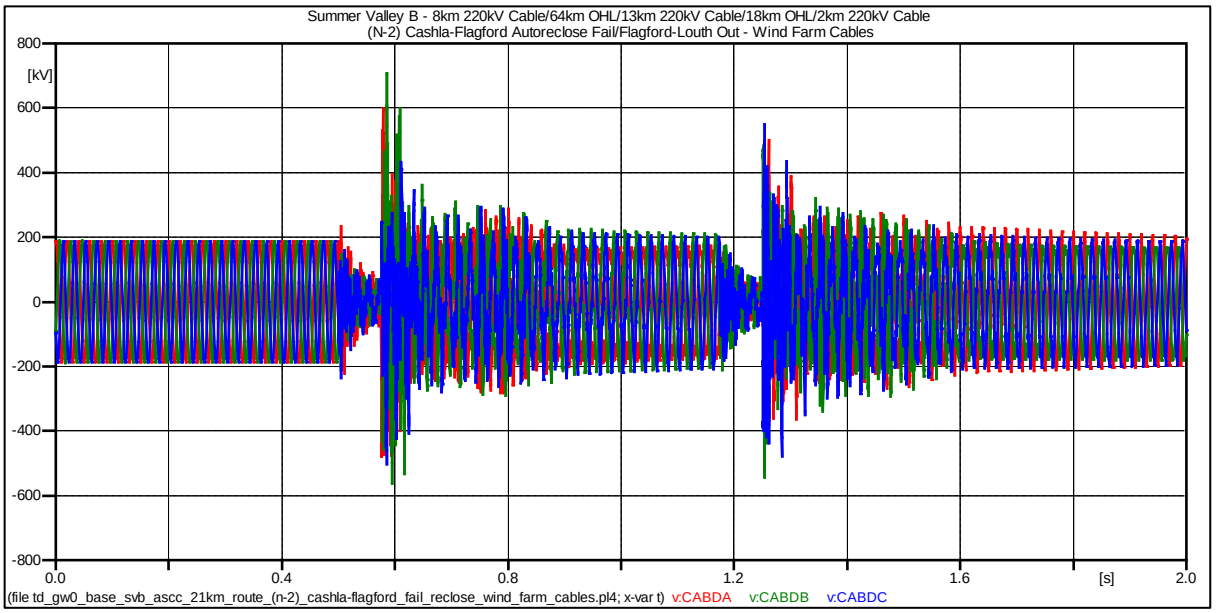

Figure 137: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	723.56 kV (4.029 pu)	449.073 kV (2.5pu)	Fail
Transient Overvoltage	290.23 kV (1.616 pu)	287.32 kV (1.6 pu)	Fail

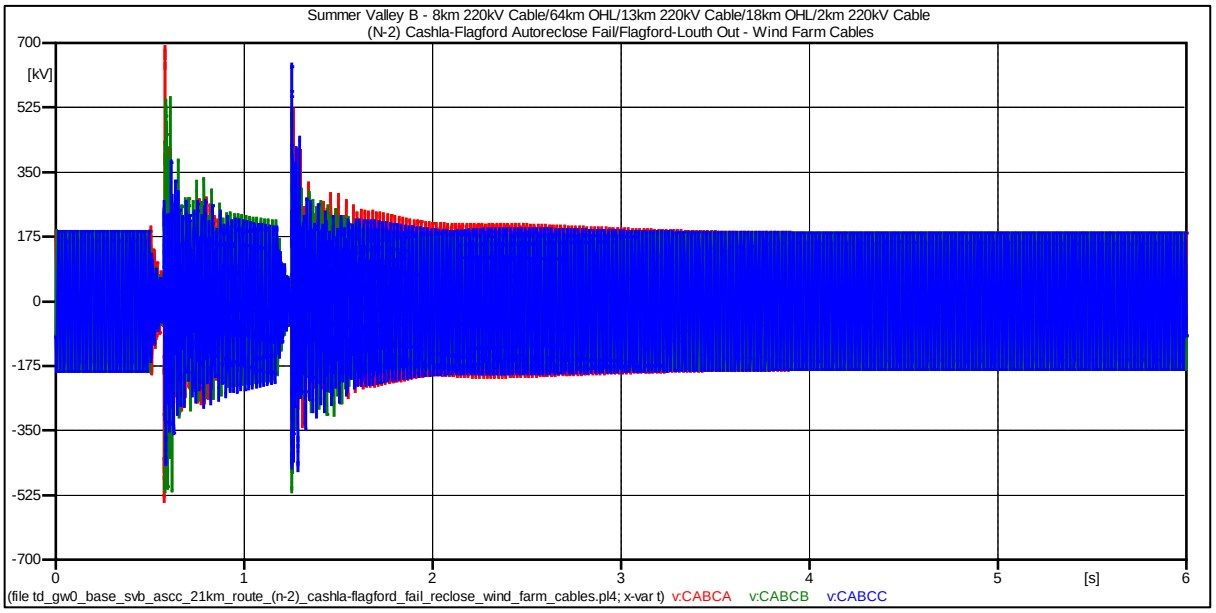

Figure 138: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

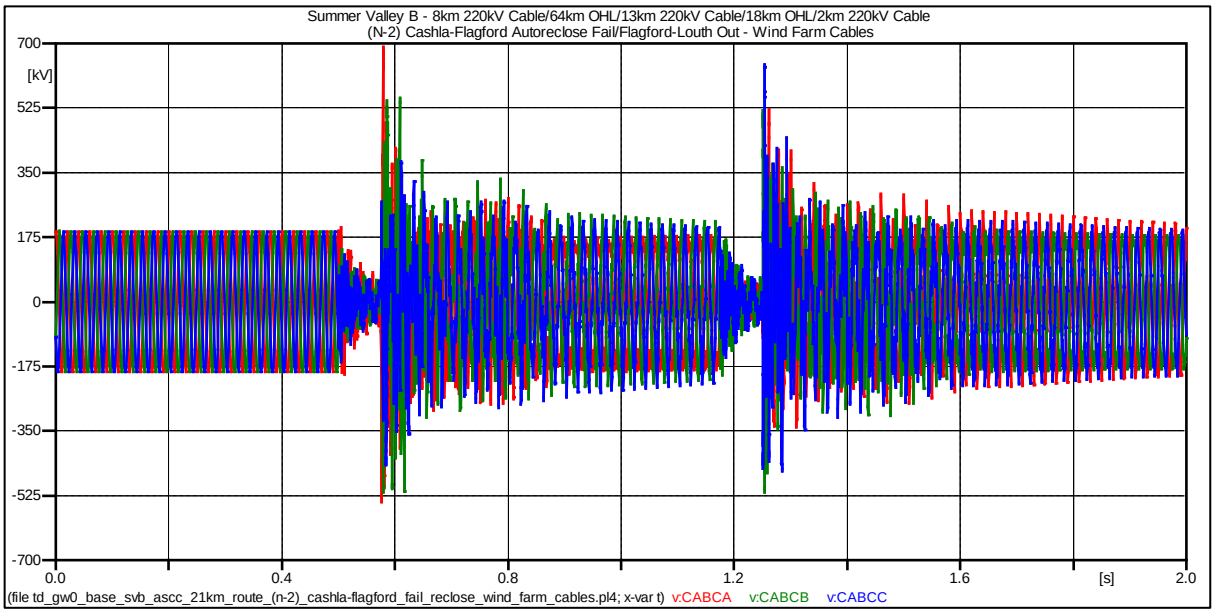

Figure 139: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	700.10 kV (3.898 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	360.56 kV (2.007 pu)	287.32 kV (1.6 pu)	Fail

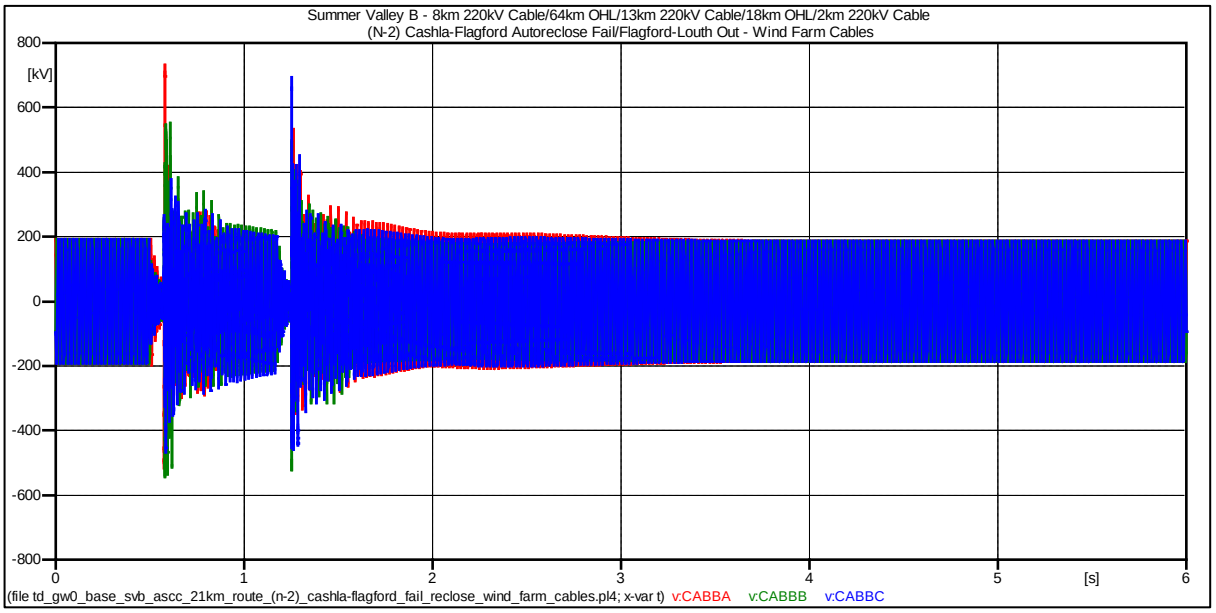

Figure 140: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

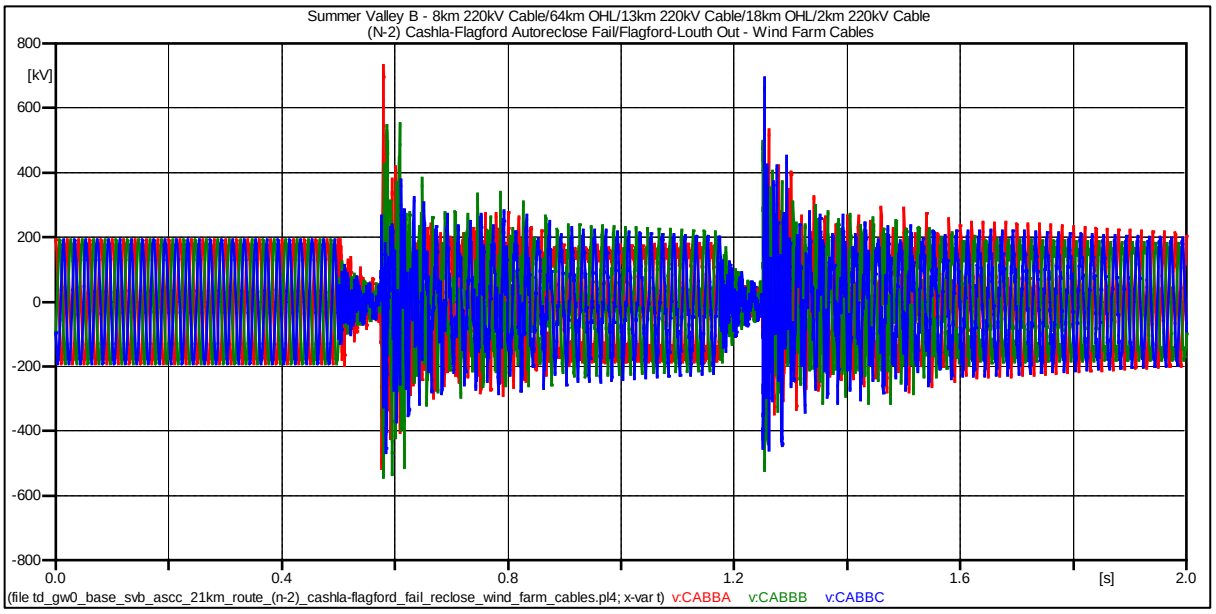

Figure 141: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	710.10 kV (3.954 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	391.68 kV (2.181 pu)	287.32 kV (1.6 pu)	Fail

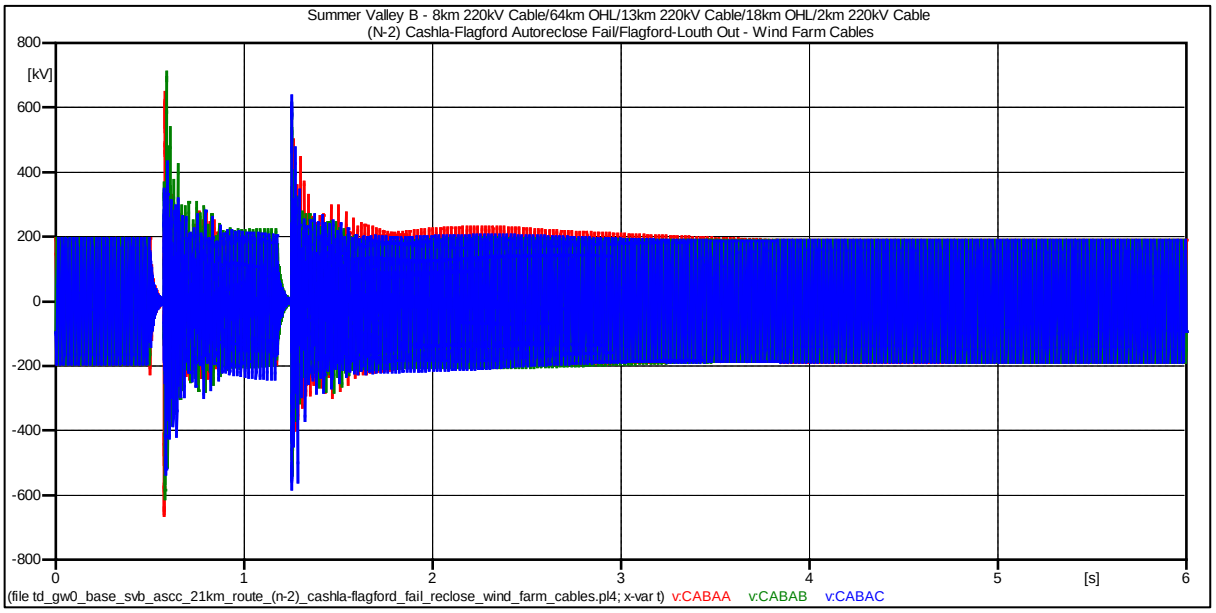

Figure 142: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

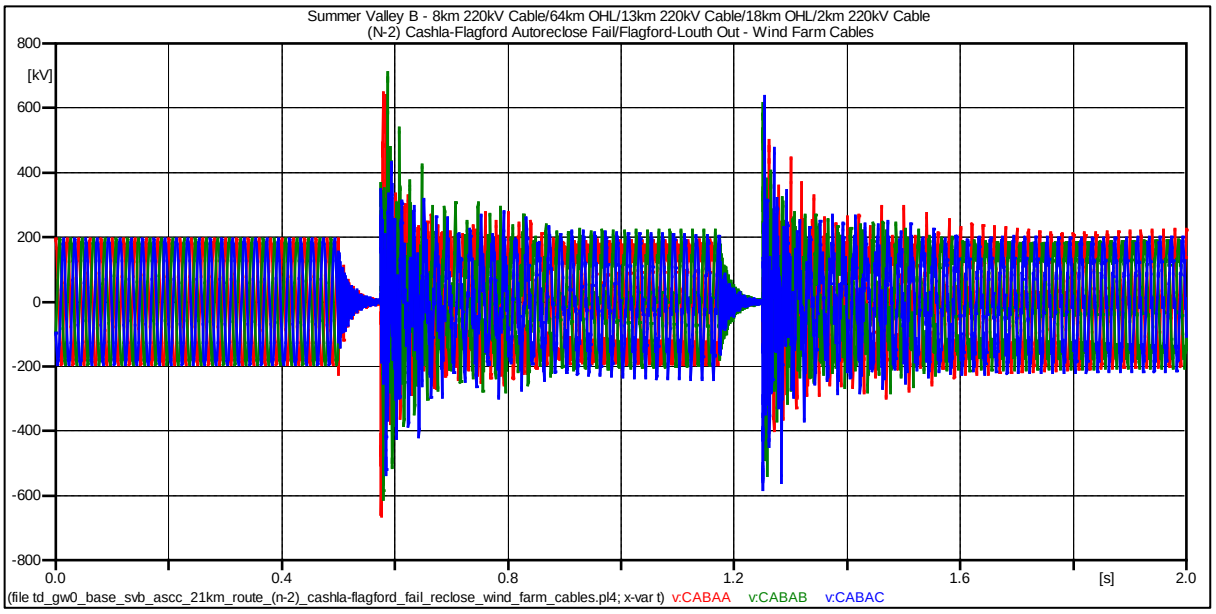

Figure 143: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	690.23 kV (3.843 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	400.12 kV (2.228 pu)	287.32 kV (1.6 pu)	Fail

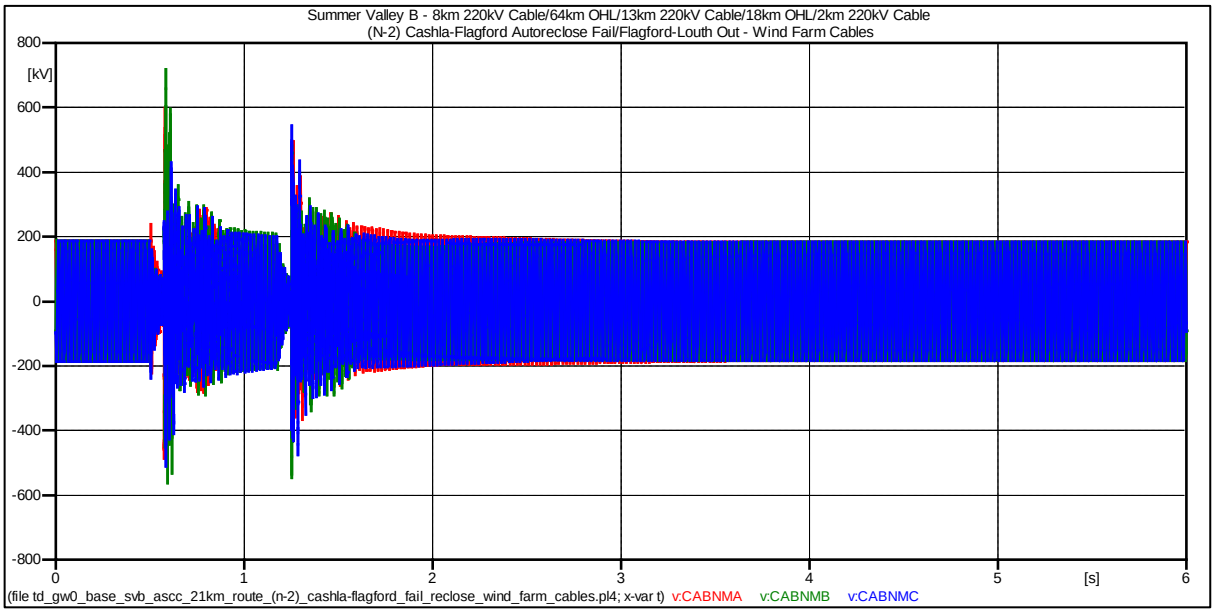

Figure 144: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

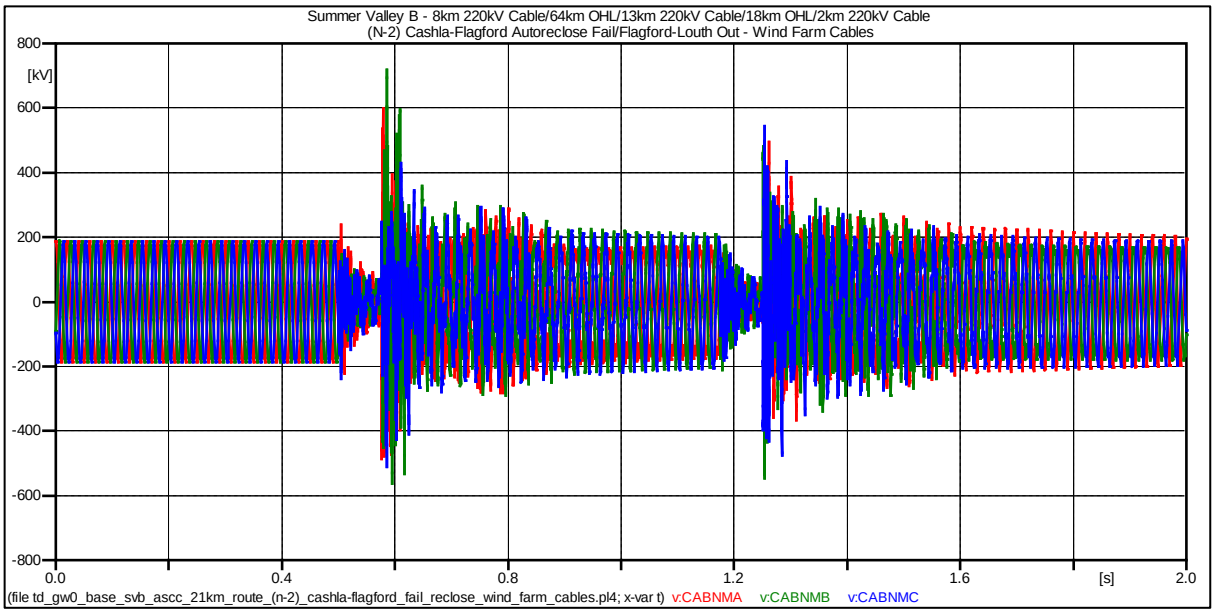

Figure 145: SVB - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	710.23 kV (3.954 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	345.23 kV (1.922 pu)	287.32 kV (1.6 pu)	Fail

1.23 Impedance Scans - Length 23km – Summer Valley B – Case 11

Conditions for impedance scan:

1. Summer Valley B network
2. Length - 8km Cable/64km OHL/13km Cable/18km OHL/2km Cable
3. 400kV Transmission towers used.
4. Reactors – North Mayo 100MVar/Flagford 25MVar

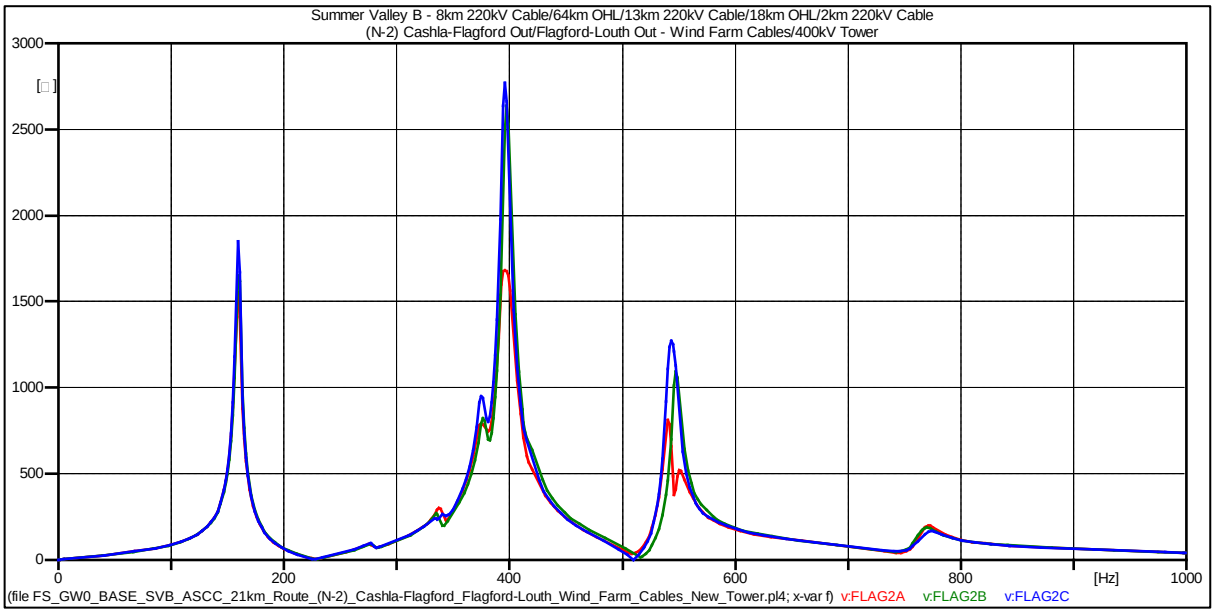

Figure 146: SVB - Length 23km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out – 400 kV Tower

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
160.51	1672.7
396.01	2770.9
544.51	1253.3
772.51	183.09

1.24 Impedance Scans - Length 23km –Winter Peak A – Case 12

Conditions for impedance scan:

1. Winter Peak A network
2. Length - 8km Cable/64km OHL/13km Cable/18km OHL/2km Cable
3. Reactors – North Mayo 100MVar/Flagford 25MVar
4. 400kV Transmission towers used.

Case 12: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out – 400kV Tower

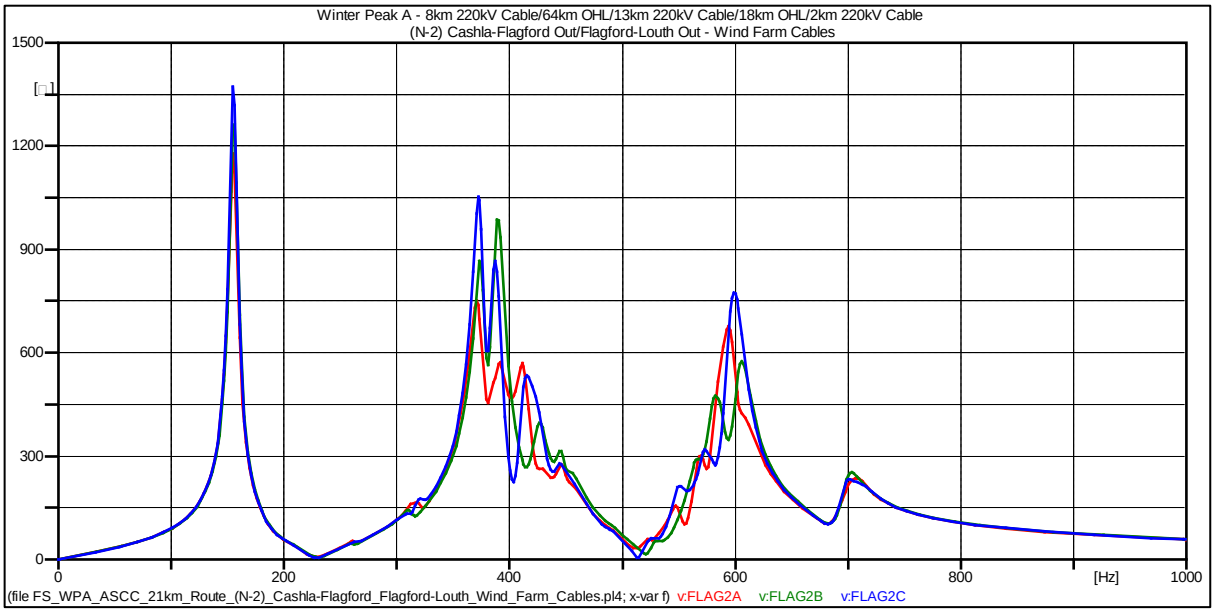

Figure 147: WPA - Length 23km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
156.01	1319.0
373.51	1042.3
598.51	774.14

1.25 Time Domain Simulation - Length 23 km – Winter Peak – Case 12

Conditions for time domain simulation:

1. Winter Peak A network
2. Length - 8km Cable/64km OHL/13km Cable/18km OHL/2km Cable
3. Reactors – North Mayo 125MVar/Flagford 25MVar

Case 12: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

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.

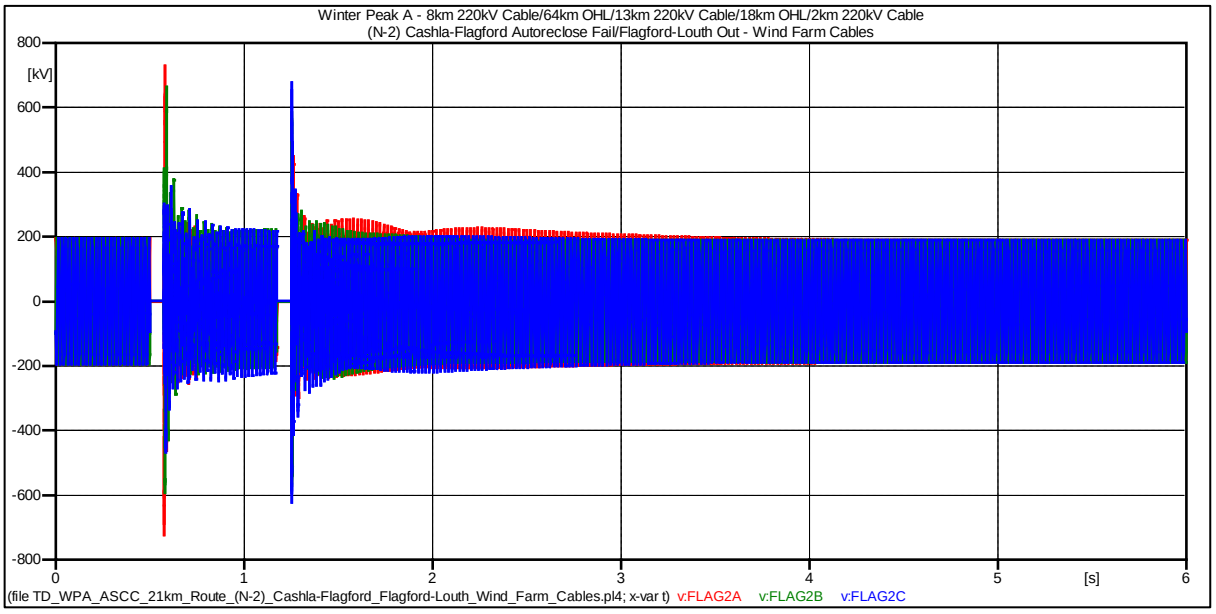

Figure 148: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

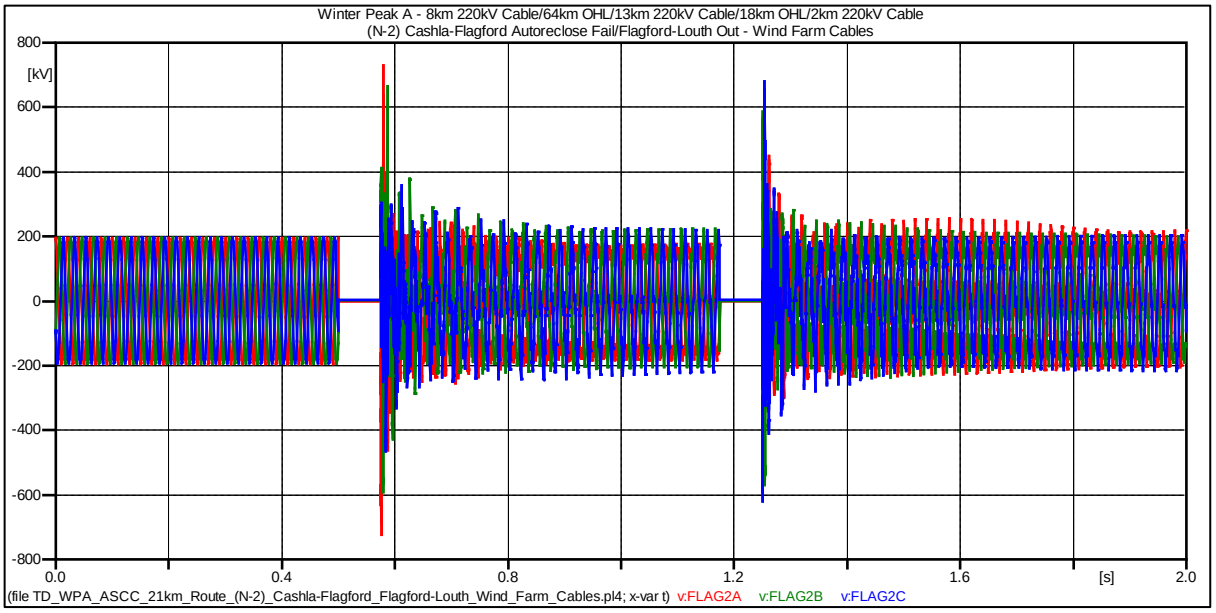

Figure 149: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Flagford – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	725.18 kV (4.038 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	380.26kV (2.117 pu)	287.32 kV (1.6 pu)	Pass

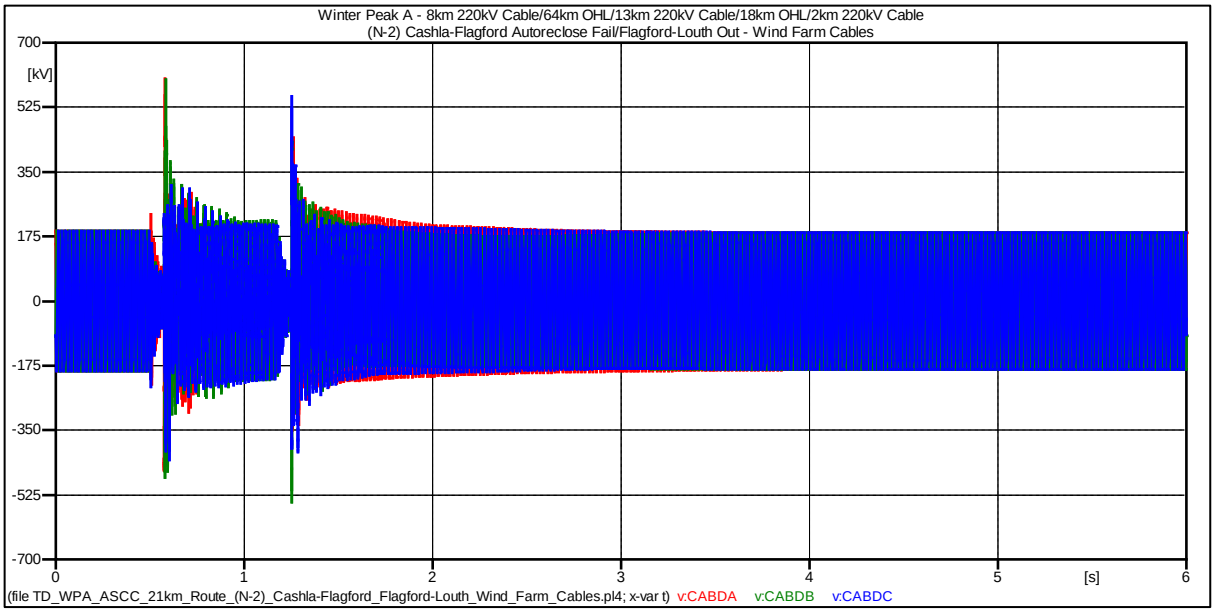

Figure 150: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

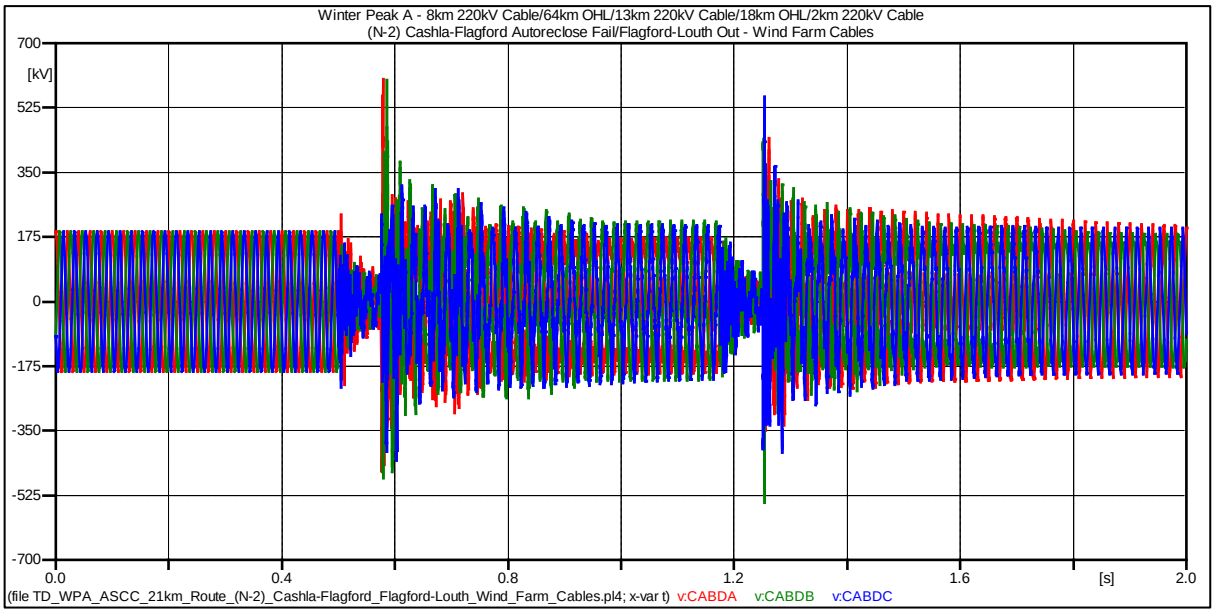

Figure 151: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End D – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	601.25 kV (3.348 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	330.26kV (1.839 pu)	287.32 kV (1.6 pu)	Fail

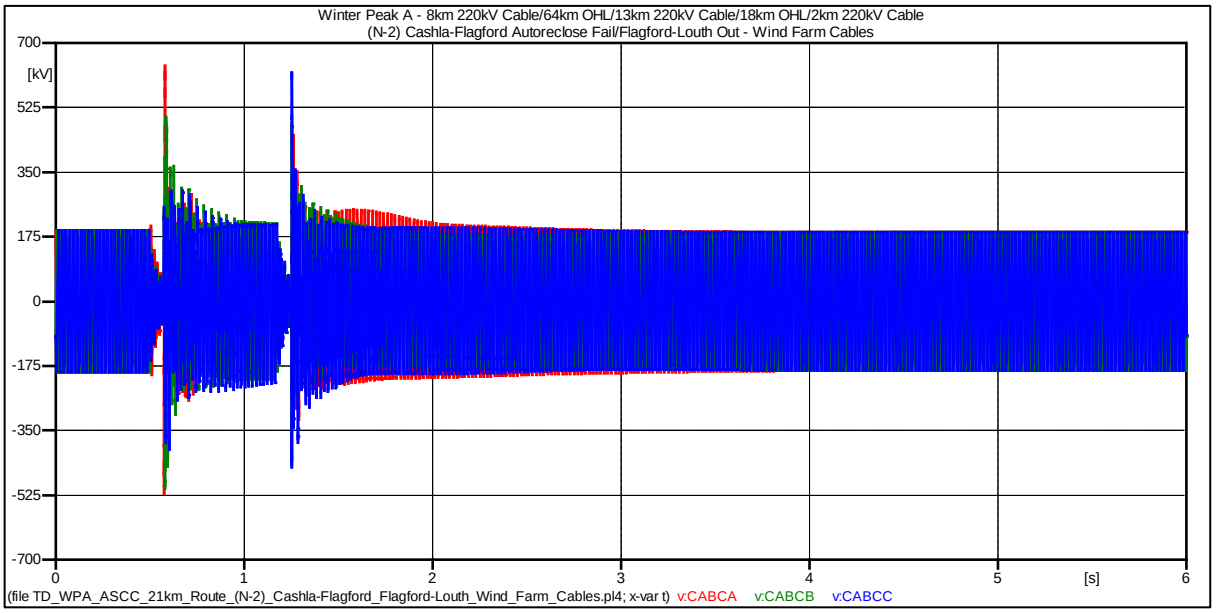

Figure 152: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

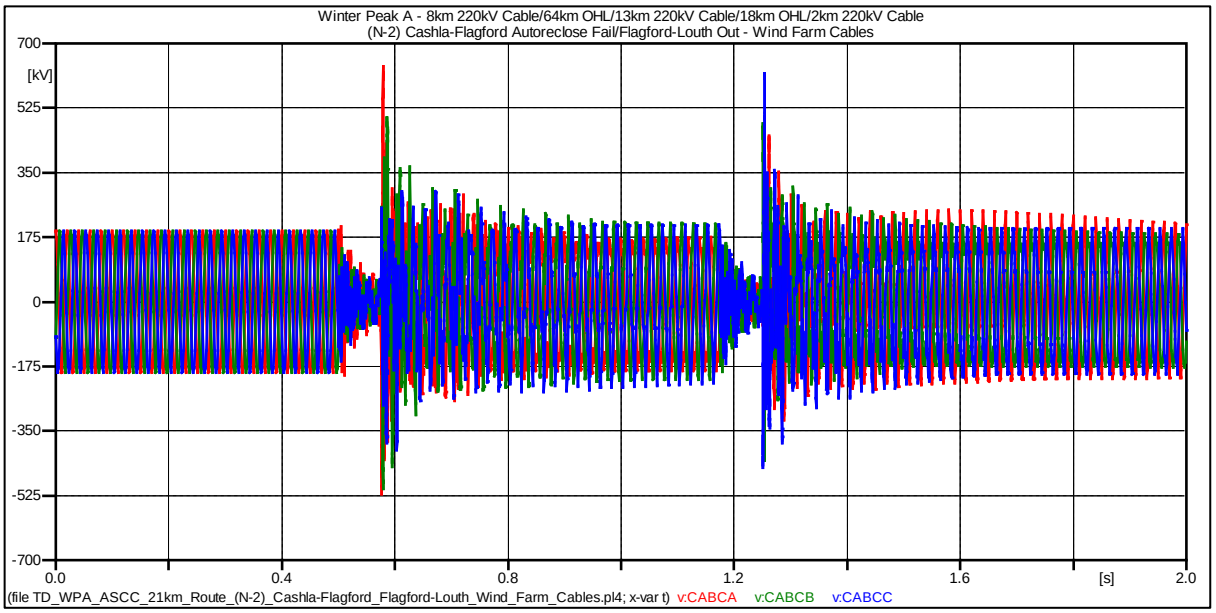

Figure 153: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End C – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	612.37kV (3.410 pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	310.26kV (1.727 pu)	287.32 kV (1.6 pu)	Fail

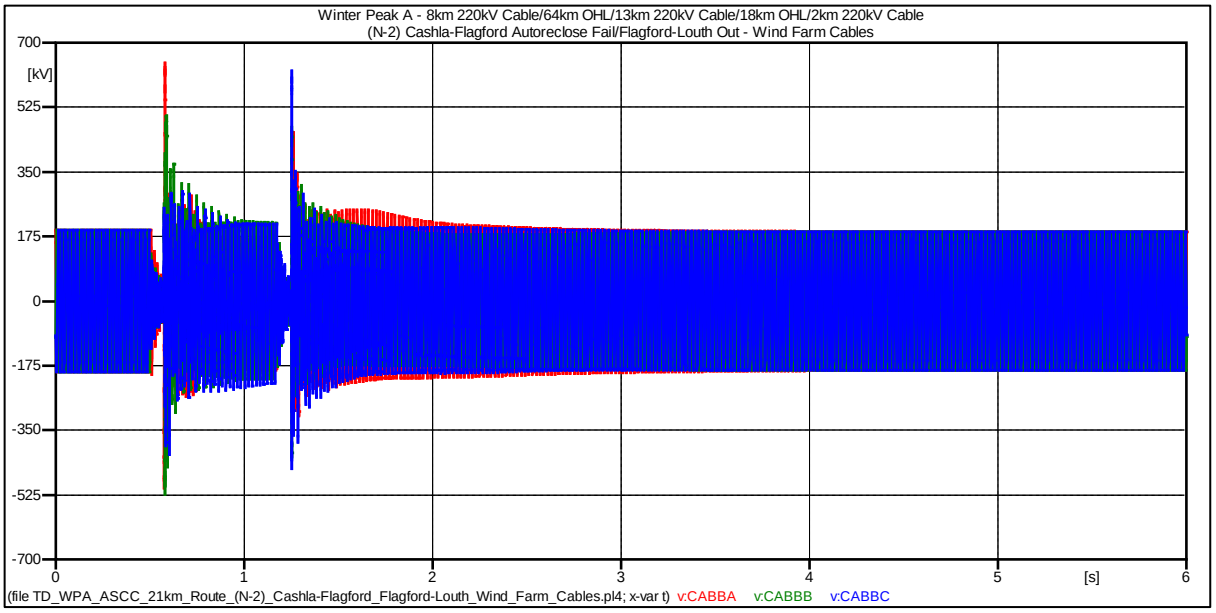

Figure 154: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

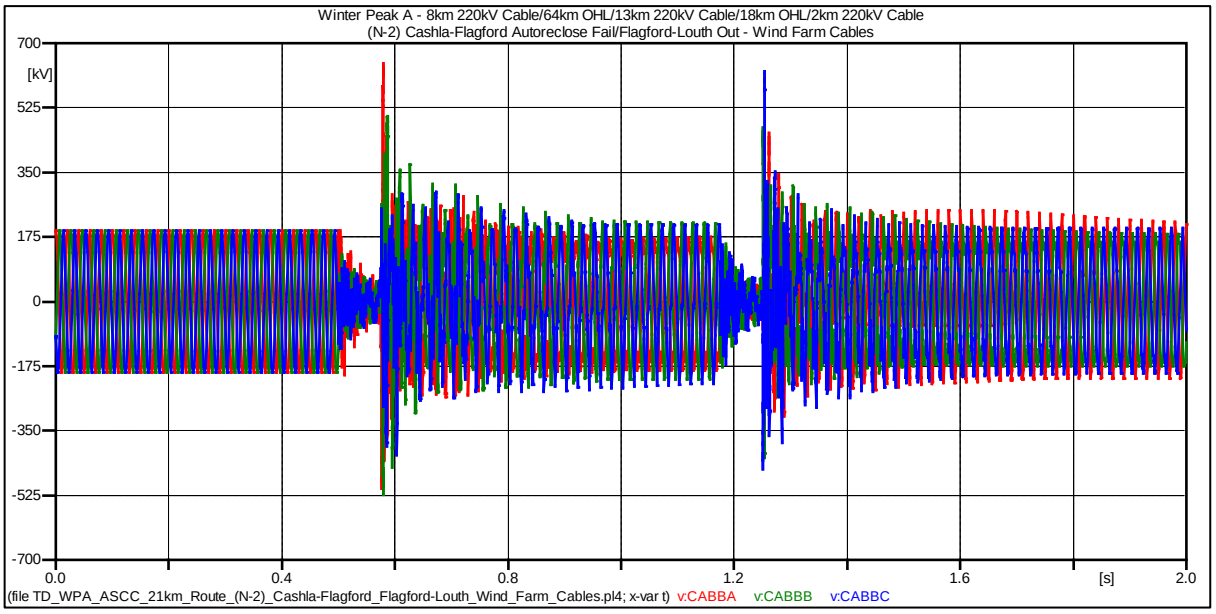

Figure 155: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End B – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	623.58 kV (3.472pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	361.26kV (2.011 pu)	287.32 kV (1.6 pu)	Fail

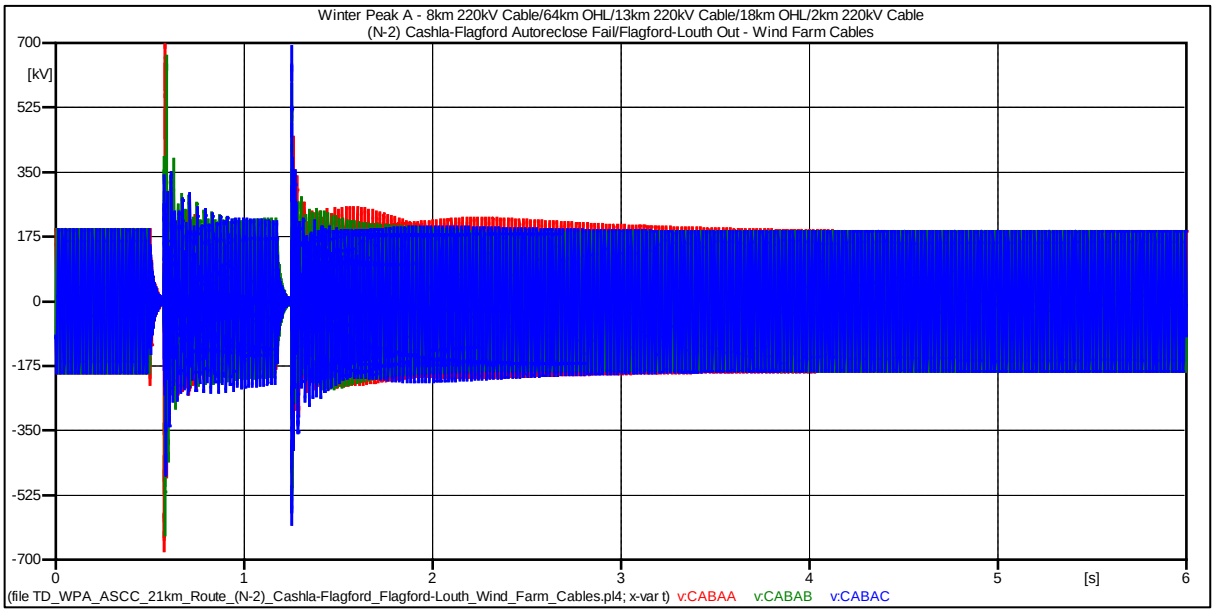

Figure 156: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

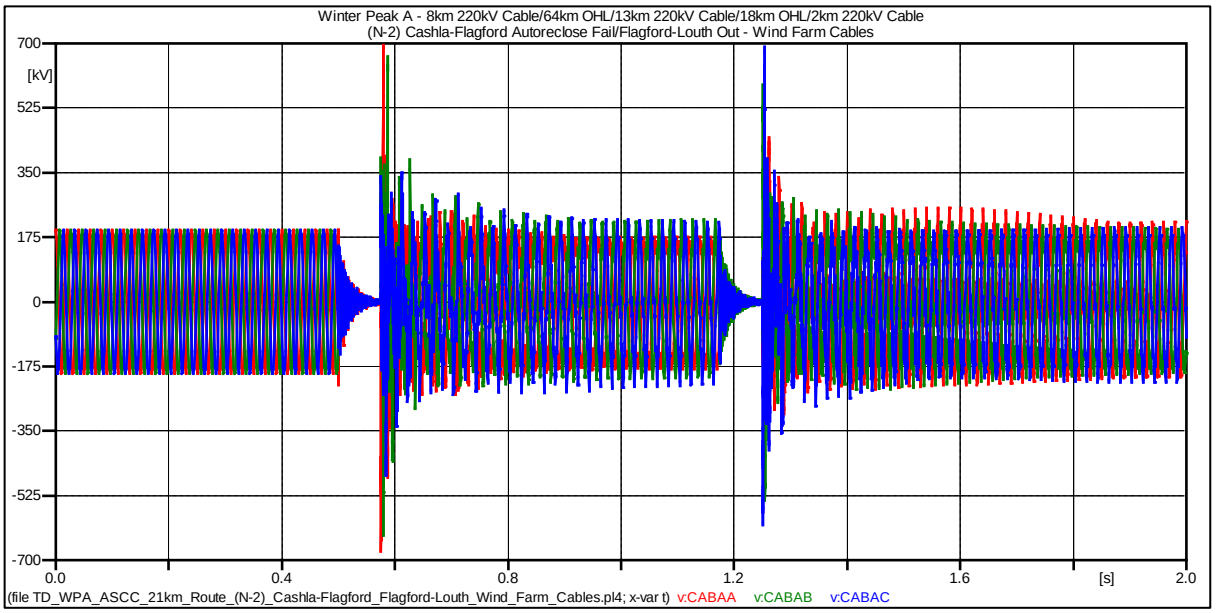

Figure 157: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – Cable End A – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	701.23 kV (3.904pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	361.26kV (2.011 pu)	287.32 kV (1.6 pu)	Fail

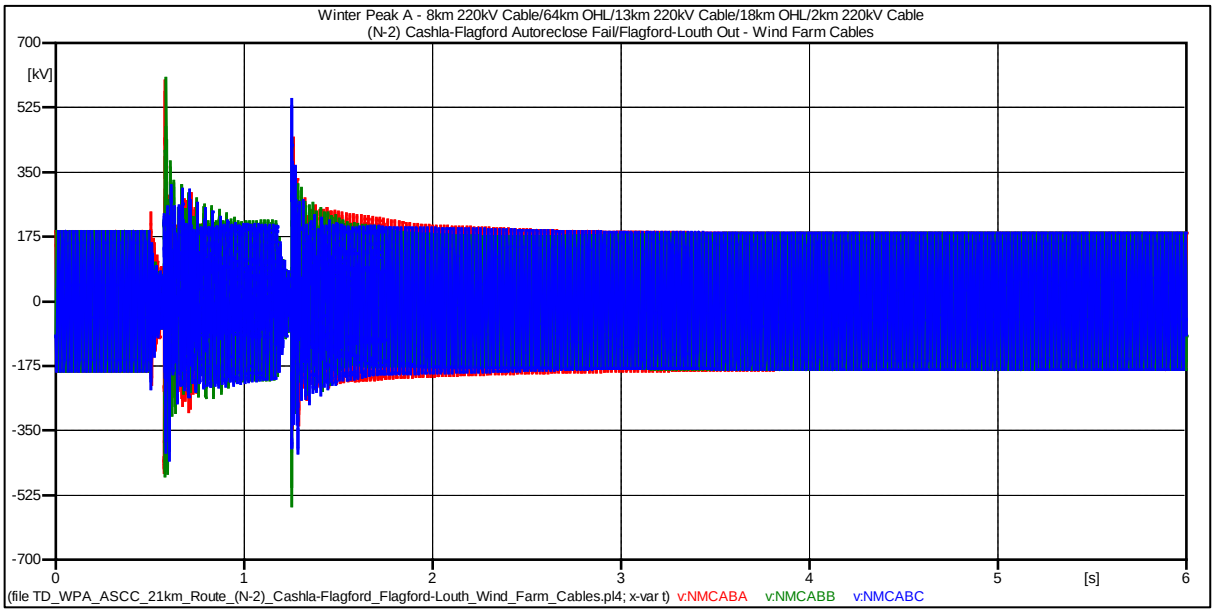

Figure 158: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-6s)

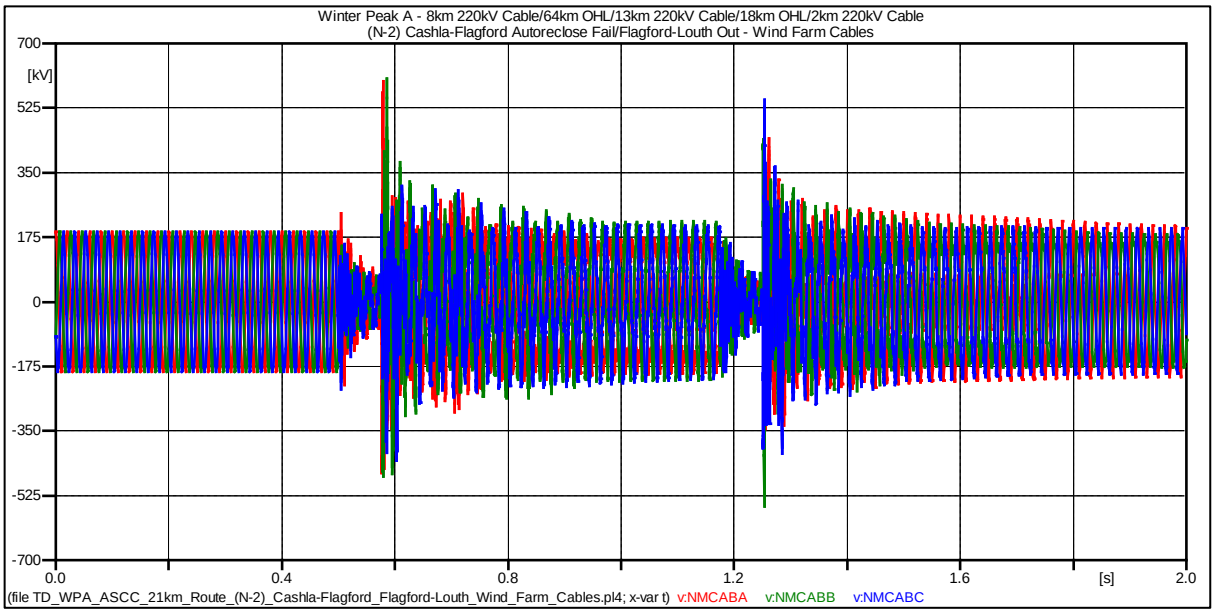

Figure 159: WPA - Length 23 km (8 km+13 km+2 km) cable / 82 km (64 km+18 km) OHL – North Mayo – (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out (0-2s)

Condition	Maximum Value	Limit	Result
Switching	610.23kV (3.398pu)	449.073 kV (2.5pu)	Fail
Temporary Overvoltage	361.26kV (2.011 pu)	287.32 kV (1.6 pu)	Fail

1.26 Impedance Scans - Length 22 km cable + 8km cable at Srananagh –Summer Valley B – Case 13

Conditions for impedance scan:

1. Winter Peak A network
2. Length - 2km OHL/72km OHL/20km Cable/11km OHL/2km Cable + 8 km cable at Srananagh
3. Reactors – North Mayo 100MVar/Flagford 25MVar

Case 13: (N-2) Cashla-Flagford Auto Reclose onto Fault/Flagford-Louth Lines Out

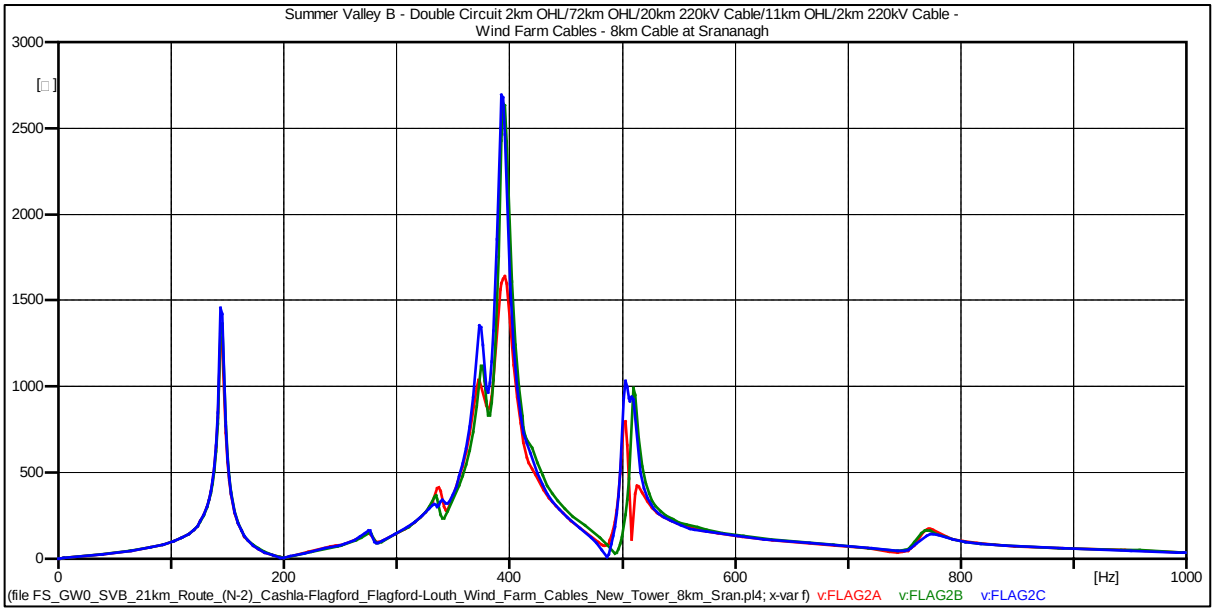

Figure 160: WPA - Length 23km - (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
144.01	1457.7
393.01	2692.3
504.01	994.35