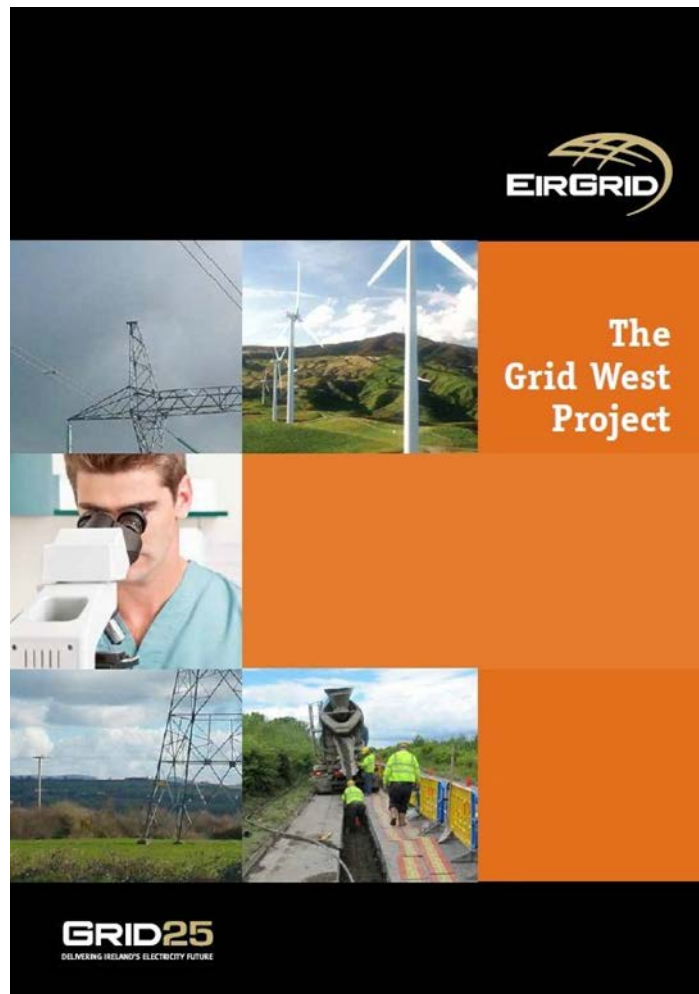


**EirGrid**

**10344 - PSP019 - CABLE STUDIES FOR GRID WEST**

**Partial AC Underground Solution**



**PSP019 - APPENDIX C2 – 99.7 KM, 220 KV CABLE OPTION  
BREAKER OPENING TIMES**

**17th December 2014**

**REPORT AUTHORISATION SHEET**

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Project: **PSP019 - Cable Studies for Grid west**  
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Breaker Opening Times**  
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## **1 RESULTS – SUMMER VALLEY B – BREAKER OPENING TIMES**

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 shows the impact breaker opening time has on the resulting voltage profile for Case 7 (Flagford-Louth out and autoreclose Flagford-Cashla with Flagford Transformer trip) under the Summer Valley B 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.<sup>1</sup>

### **1.1 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Breaker opens at 90°**

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

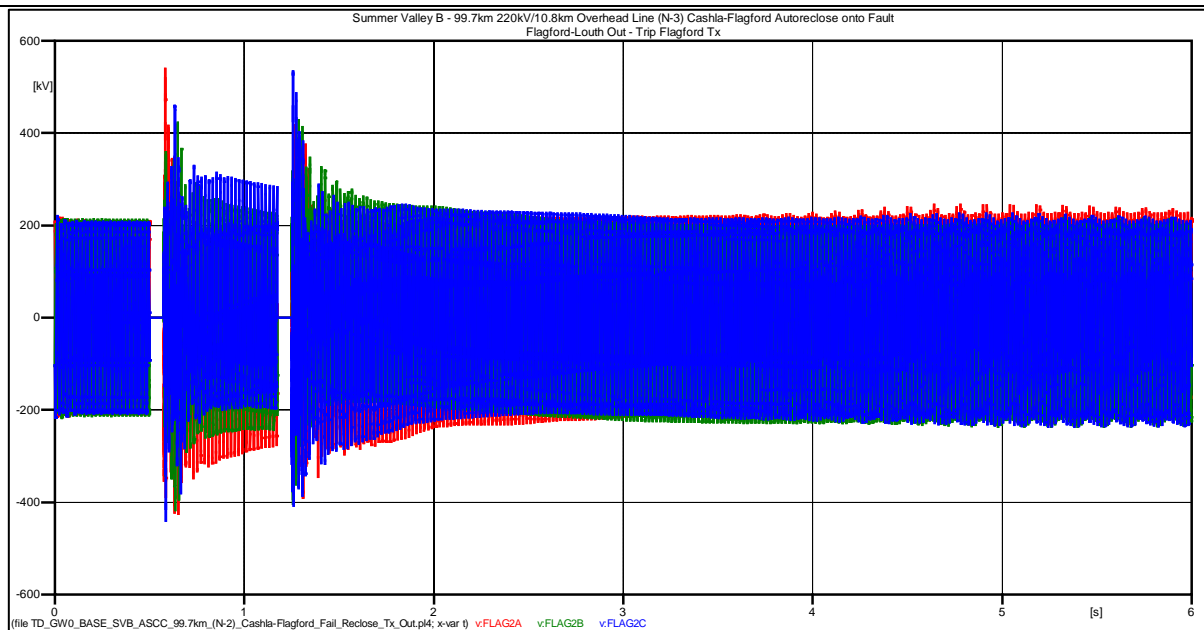
#### **Case 7a: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line**

System Conditions:

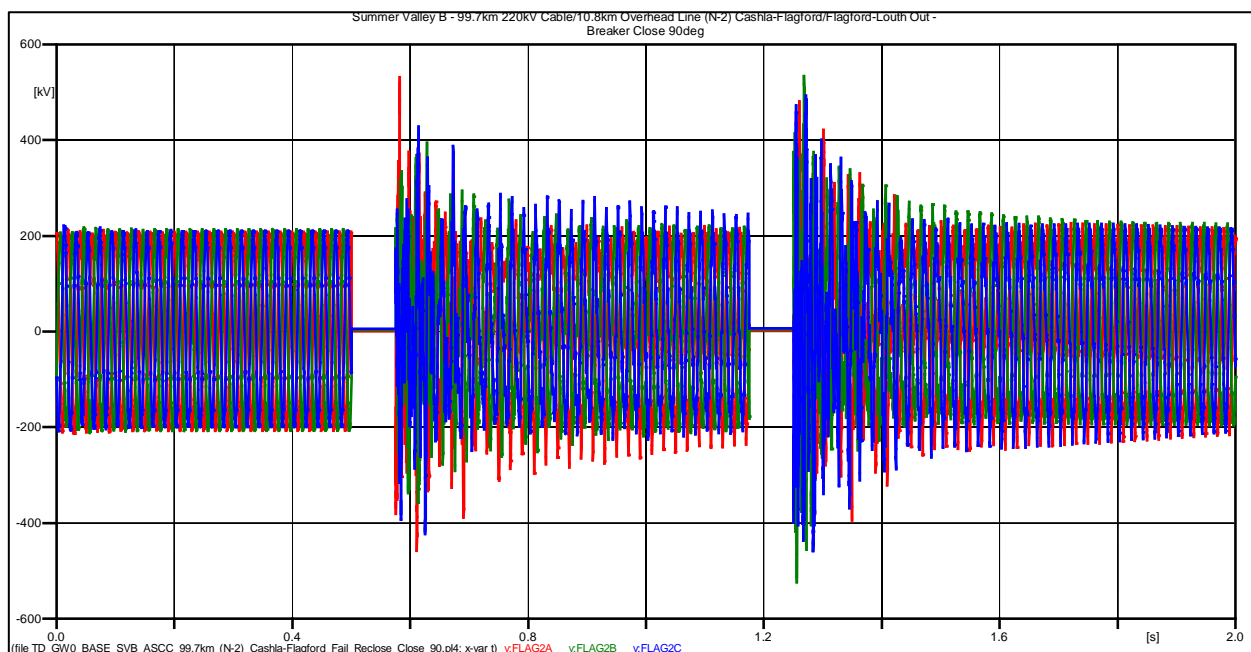
1. Fault on Flagford side of Cashla-Flagford line, applied at 0.5s.
2. Reclose sequence at 0.575s, dead time 0.6s, circuit breaker closes 1.175s.
3. Breaker opens again at 1.25s.

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<sup>1</sup> 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.

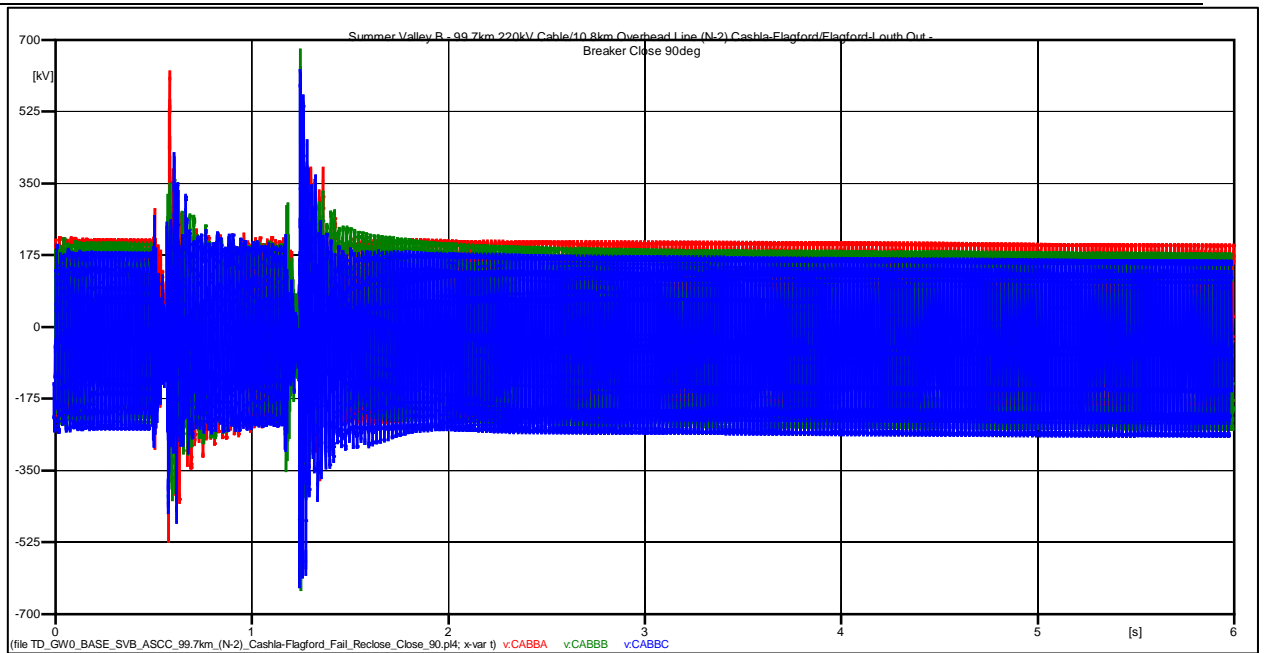


**Figure 1: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-6s)**

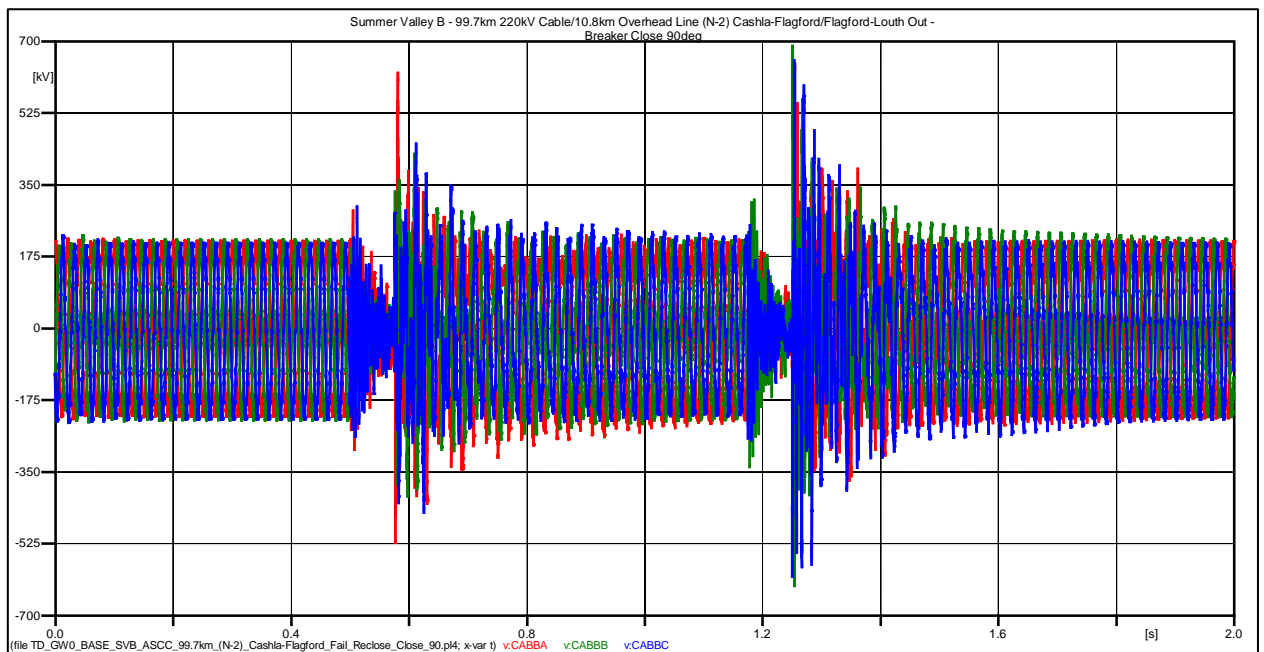


**Figure 2: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	520.23 kV (2.896 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	380.26 kV (2.117 pu)	287.32 kV (1.6pu)	Fail

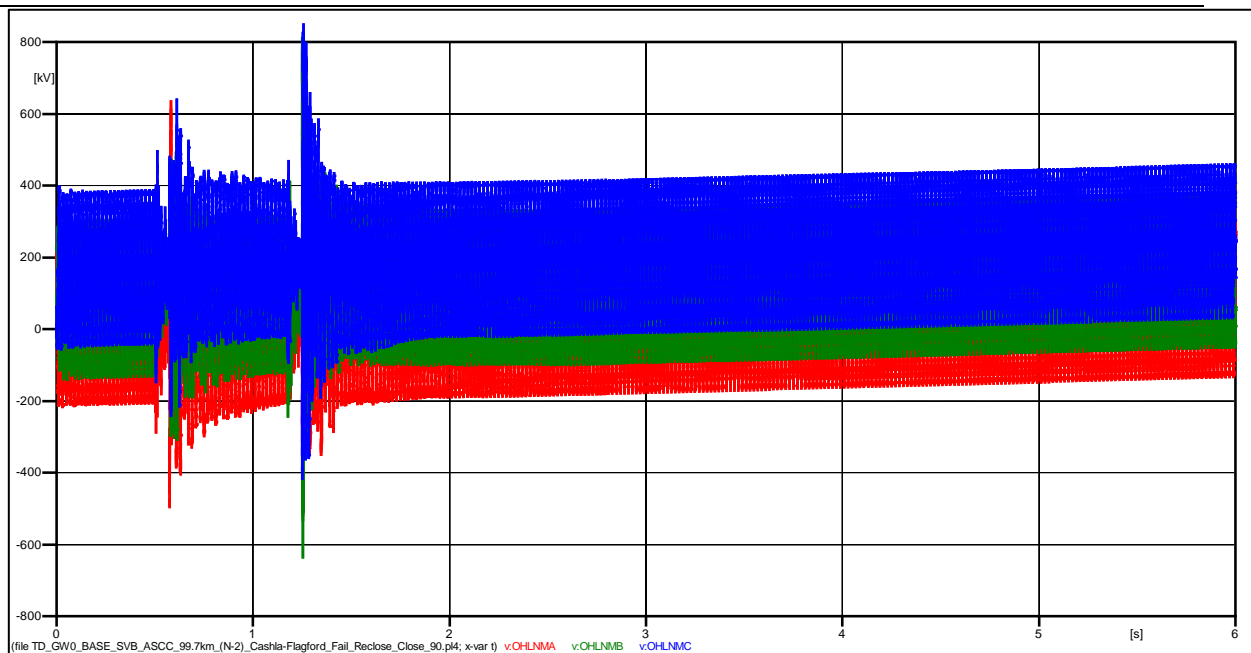


**Figure 3: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-6s)**

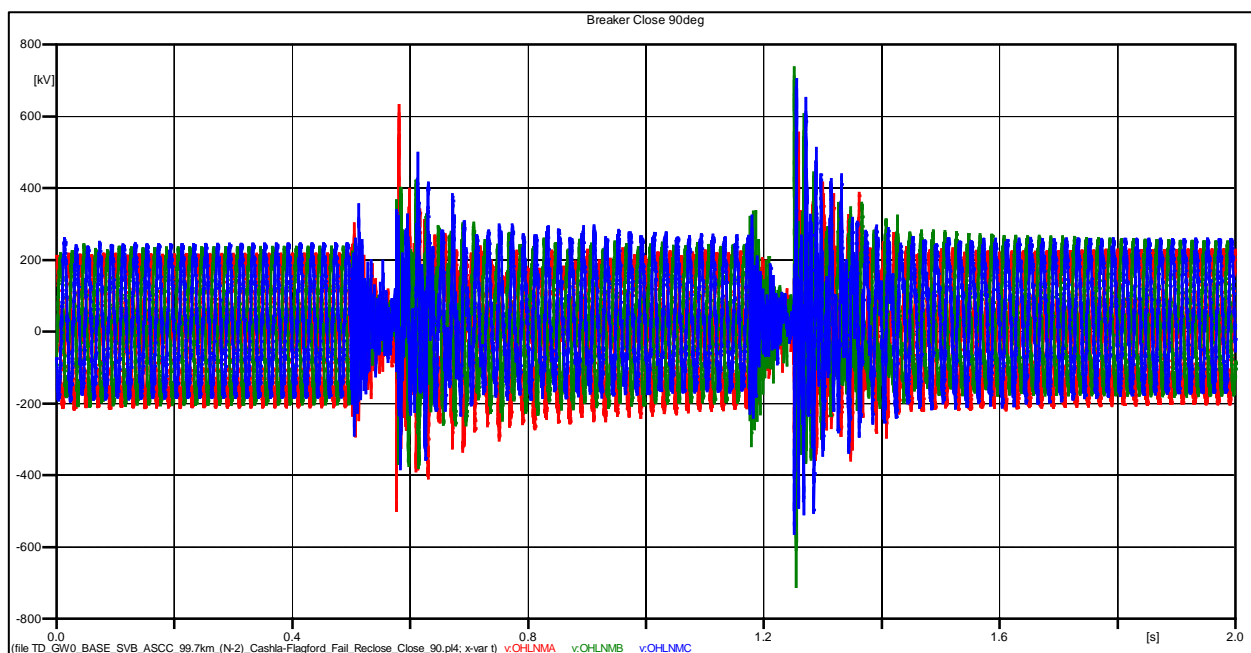


**Figure 4: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	671.56 kV (3.739 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	431.50 kV (2.402 pu)	287.32 kV (1.6pu)	Fail



**Figure 5: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-6s)**



**Figure 6: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 90° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	710.23 kV (3.954pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	451.23 kV (2.512pu)	287.32 kV (1.6pu)	Fail

## **1.2 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Breaker opens at 45°**

Conditions for time domain simulation:

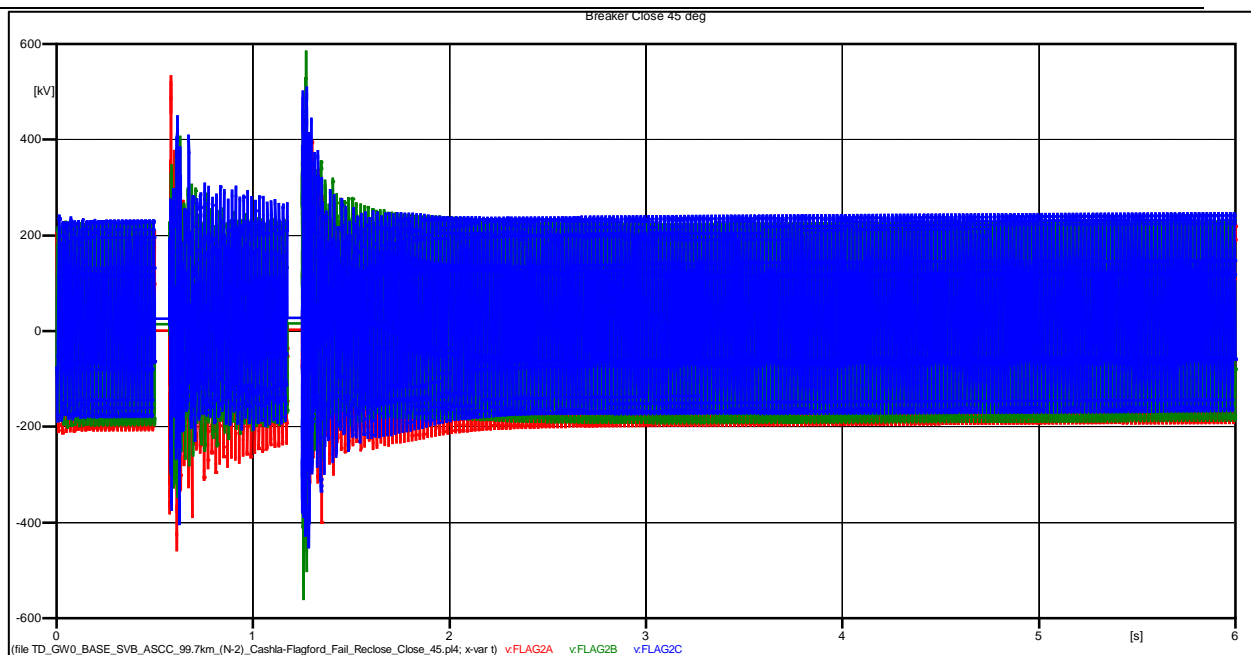
1. Summer Valley B network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

### **Case 7b: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line with breaker opens at 45°**

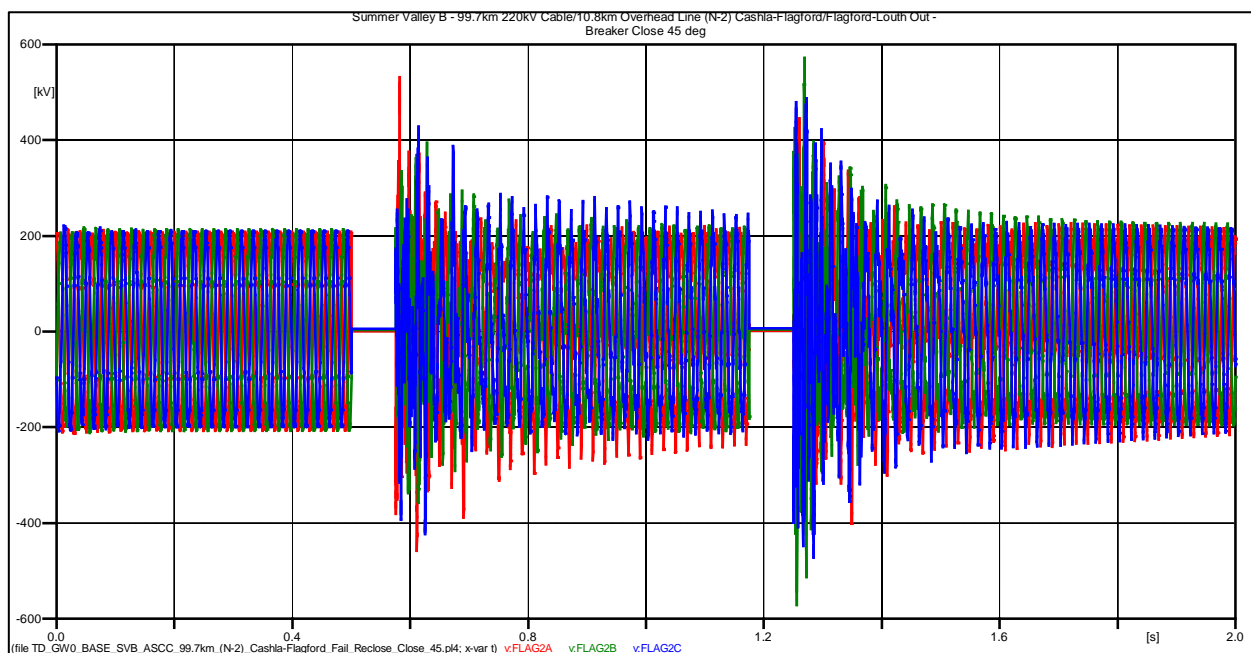
System Conditions:

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.
3. Breaker opens at again at 1.2525s, point on wave opens at 45°.



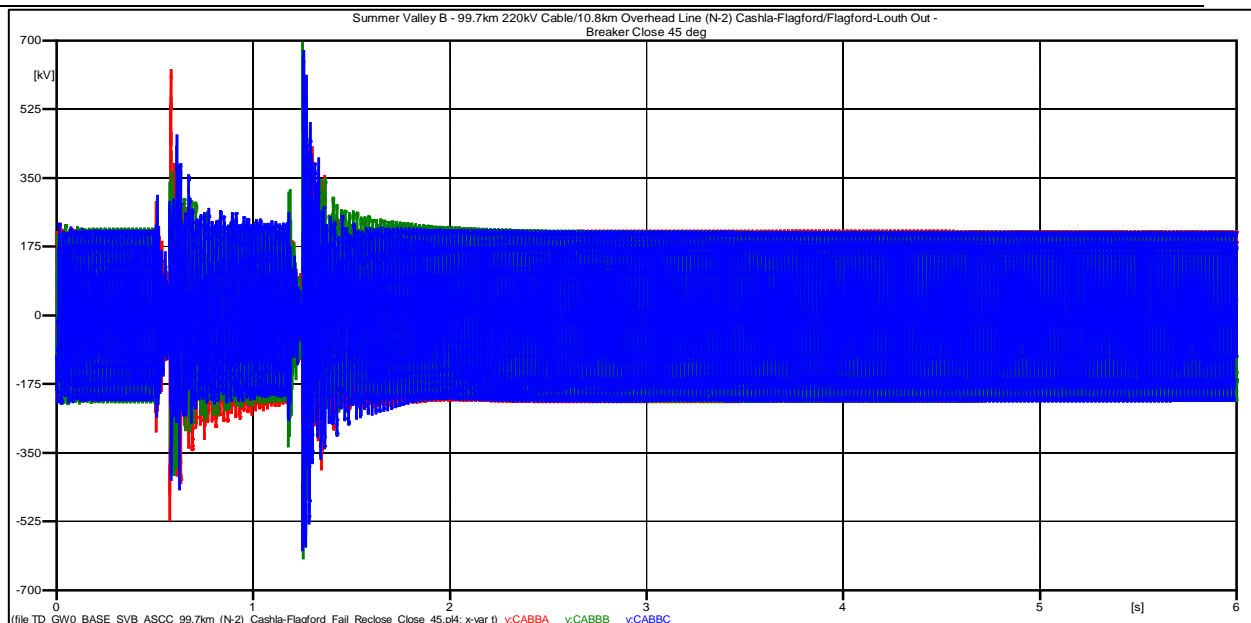


**Figure 7: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-6s)**

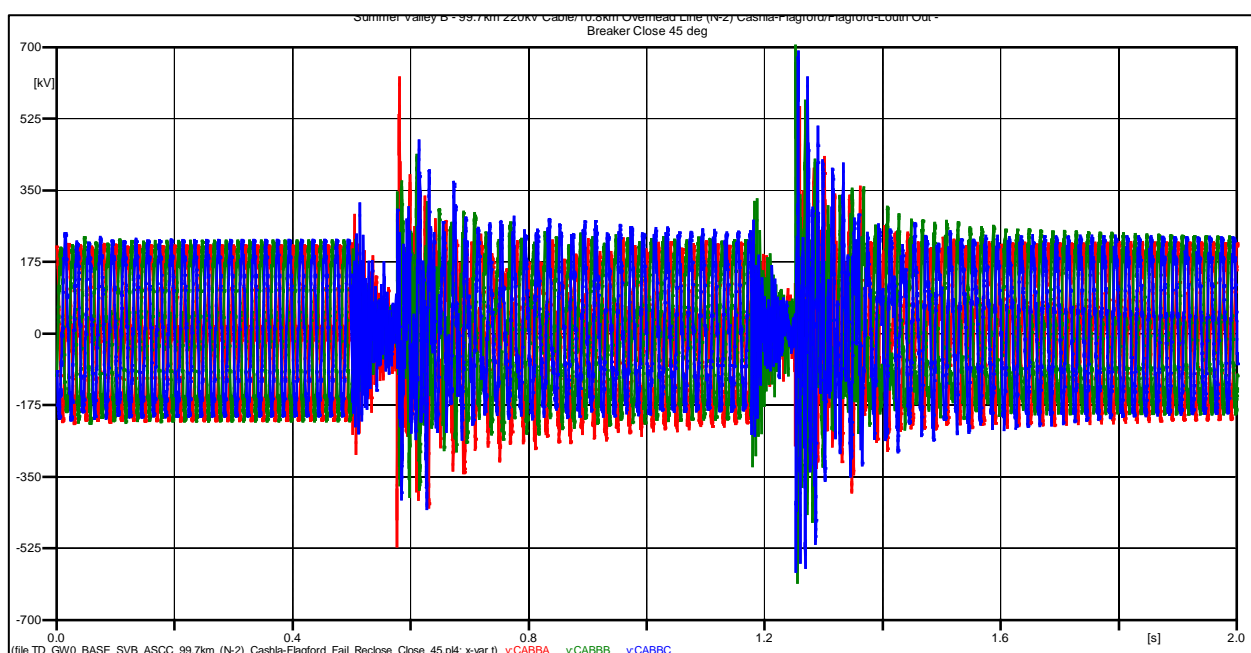


**Figure 8: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	534.35 kV (2.975 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	385.69 kV (2.147 pu)	287.32 kV (1.6pu)	Fail

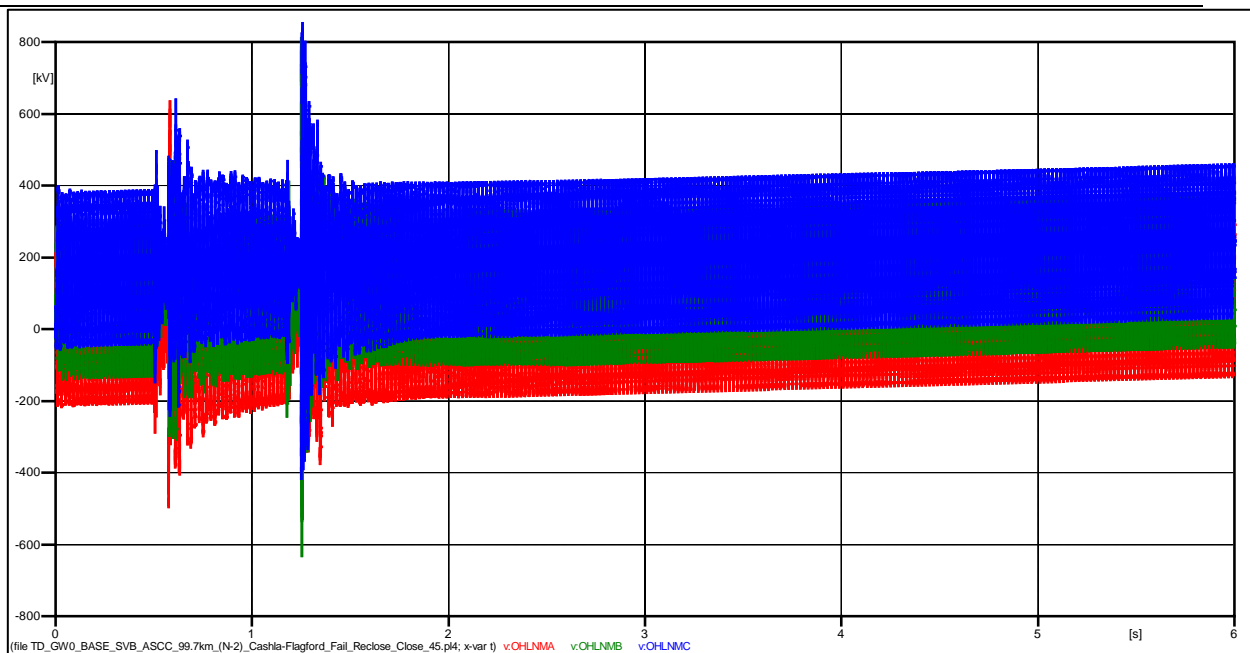


**Figure 9: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-6s)**

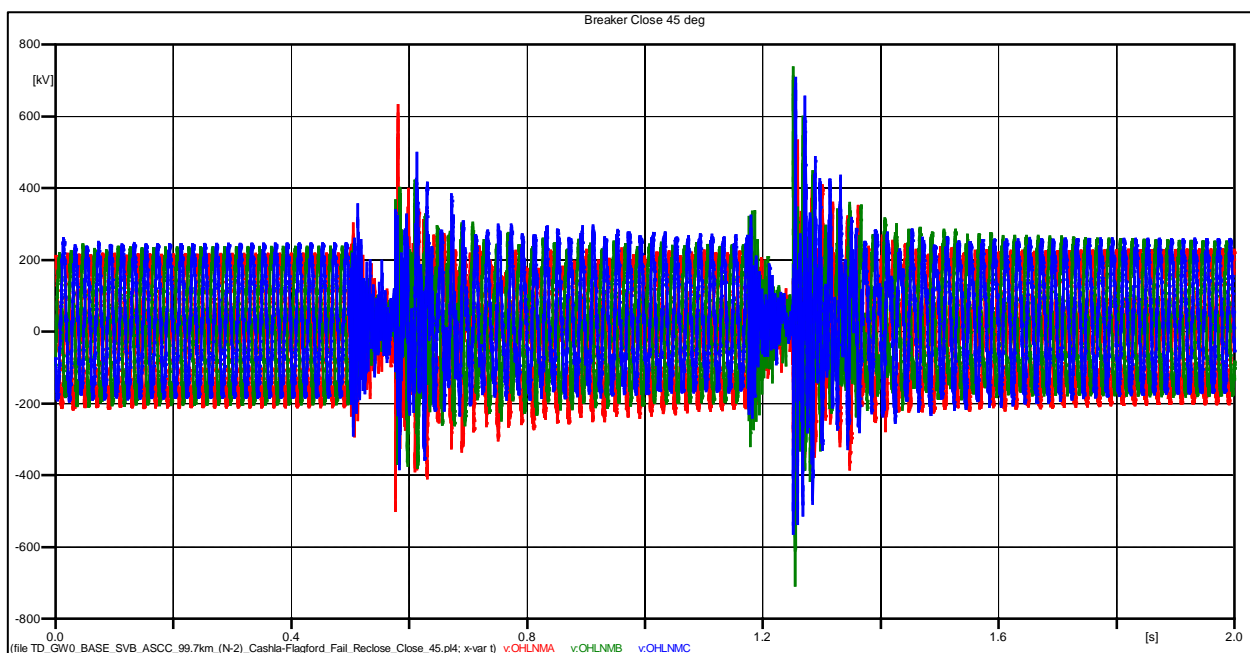


**Figure 10: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	701.23 kV (3.904 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	423.12 kV (2.356 pu)	287.32 kV (1.6pu)	Fail



**Figure 11: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-6s)**



**Figure 12: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 45° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	710.25 kV (3.955 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	441.67 kV (2.459 pu)	287.32 kV (1.6pu)	Fail

### **1.3 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Breaker opens at 135°**

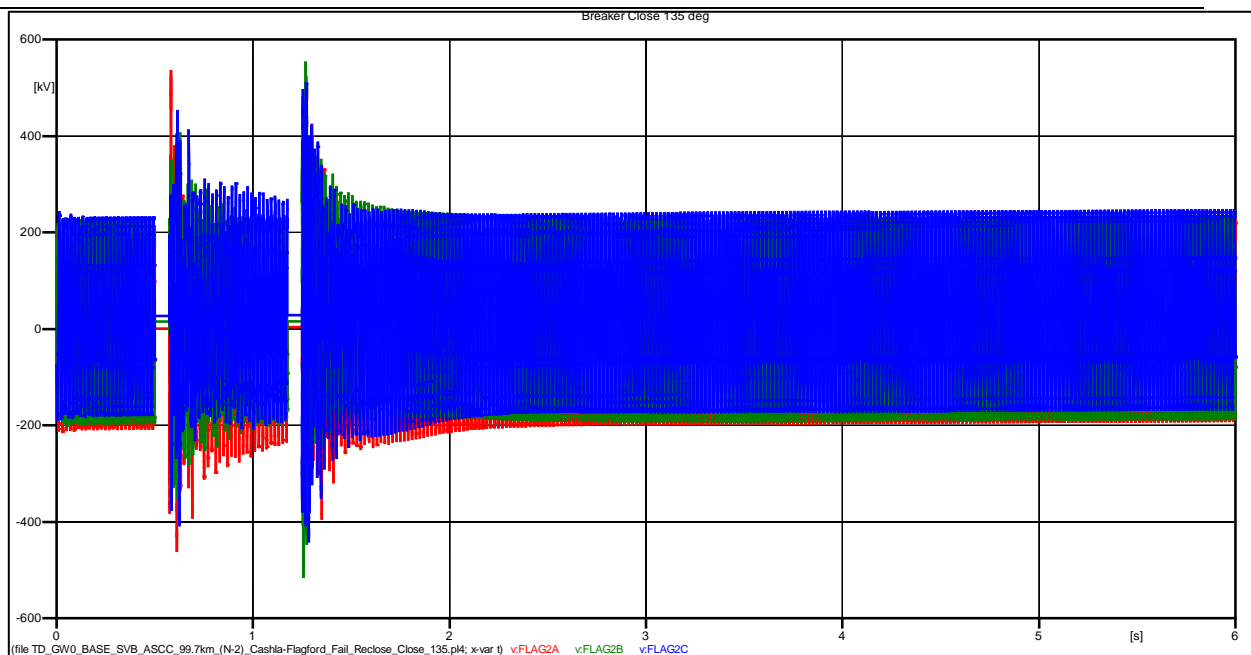
Conditions for time domain simulation:

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

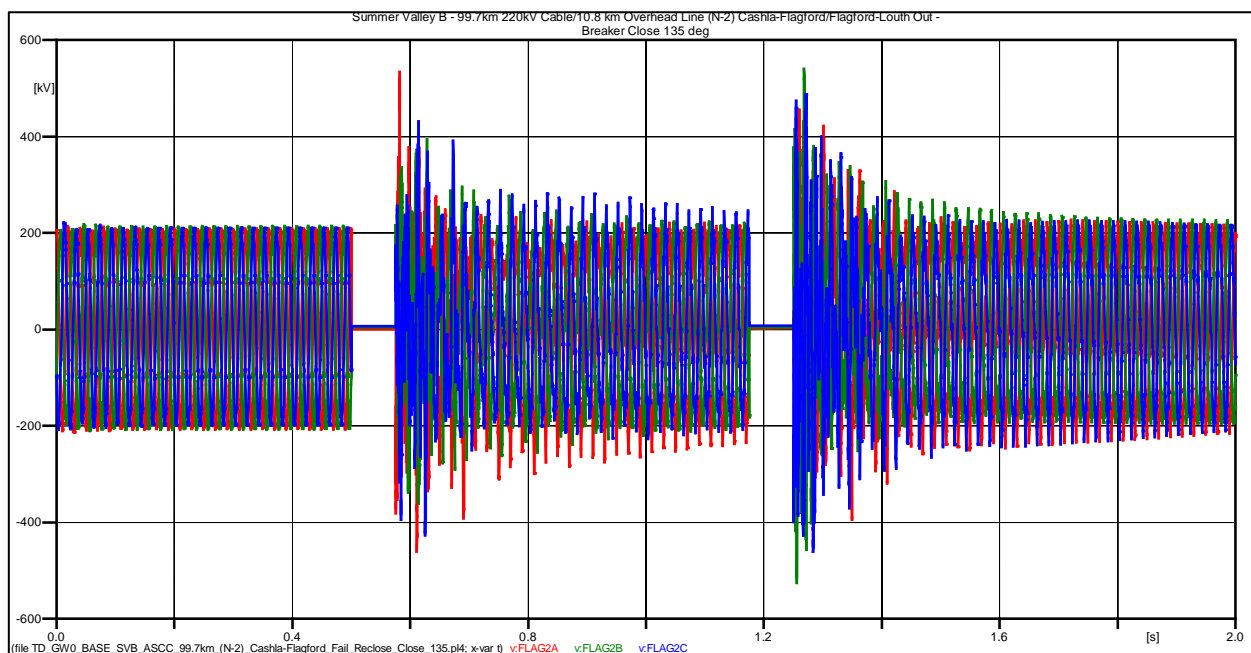
#### **Case 7c (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line with breaker opens at 135°**

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.
3. Breaker opens at again at 1.2575s, point on wave opens at 135°.

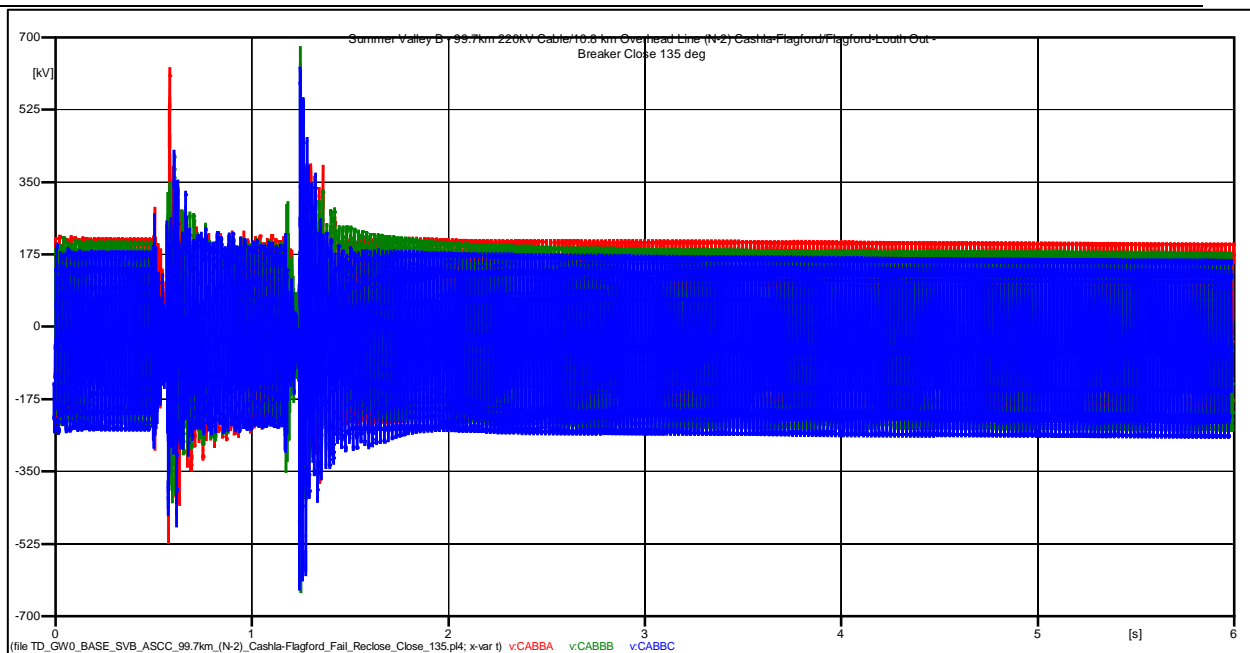


**Figure 13: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-6s)**

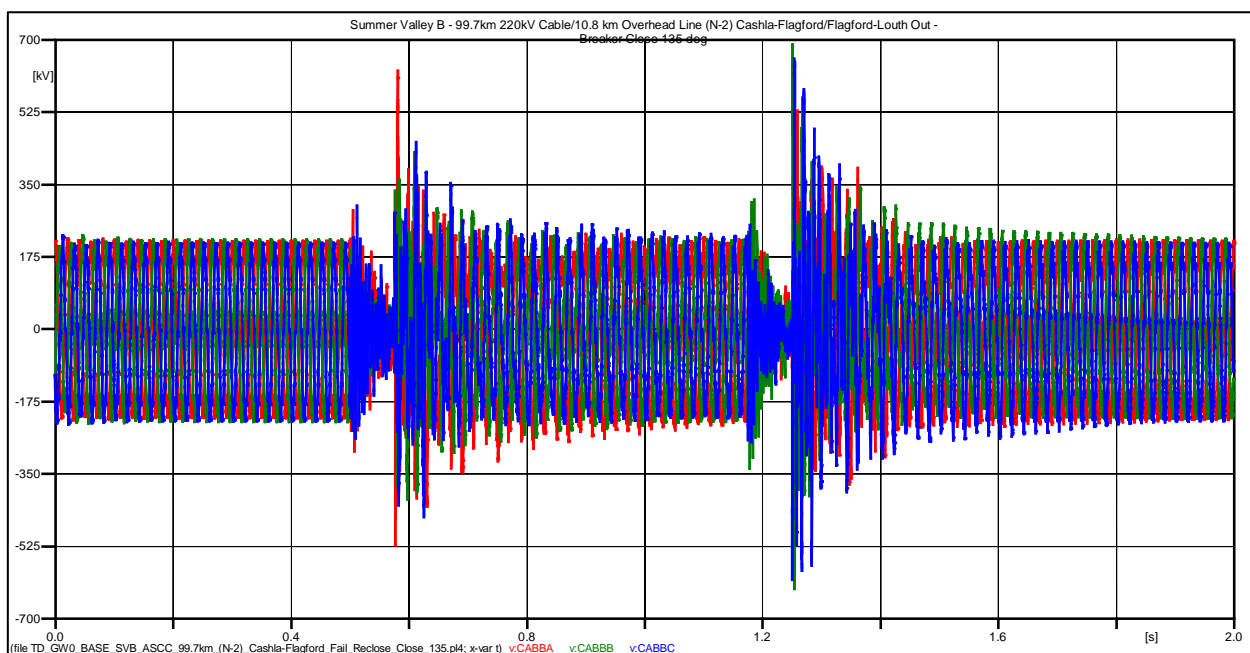


**Figure 14: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	523.65 kV (2.915 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	412.36 kV (2.296 pu)	287.32 kV (1.6 pu)	Fail

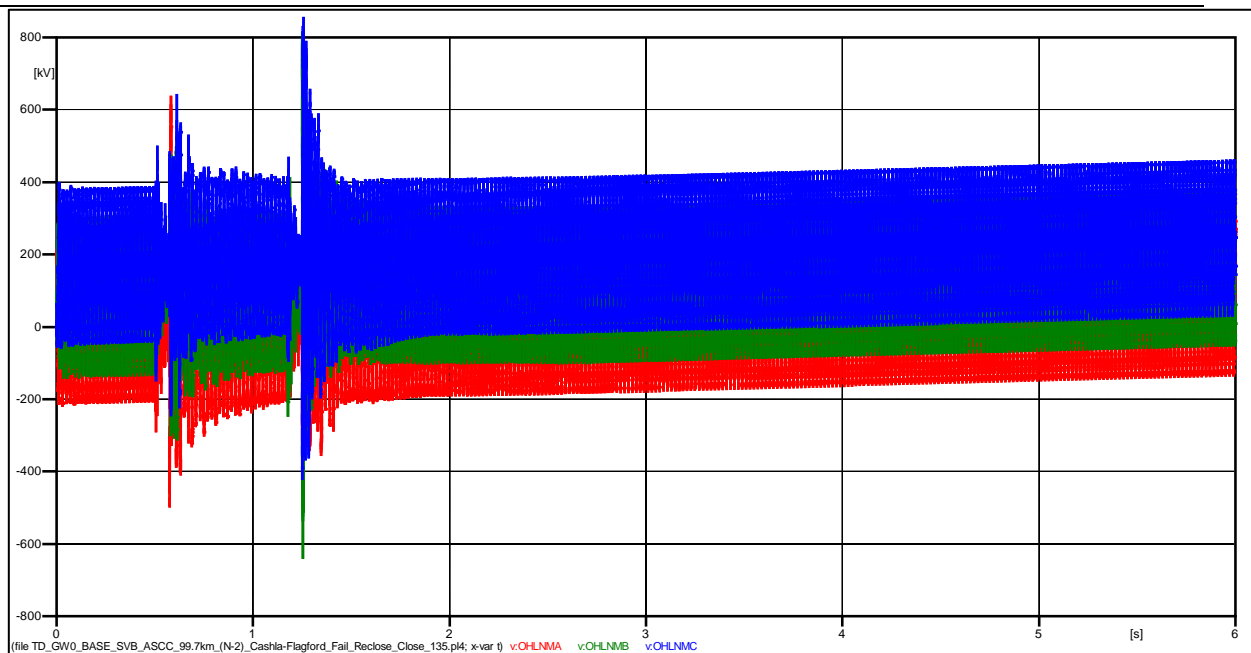


**Figure 15: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-6s)**

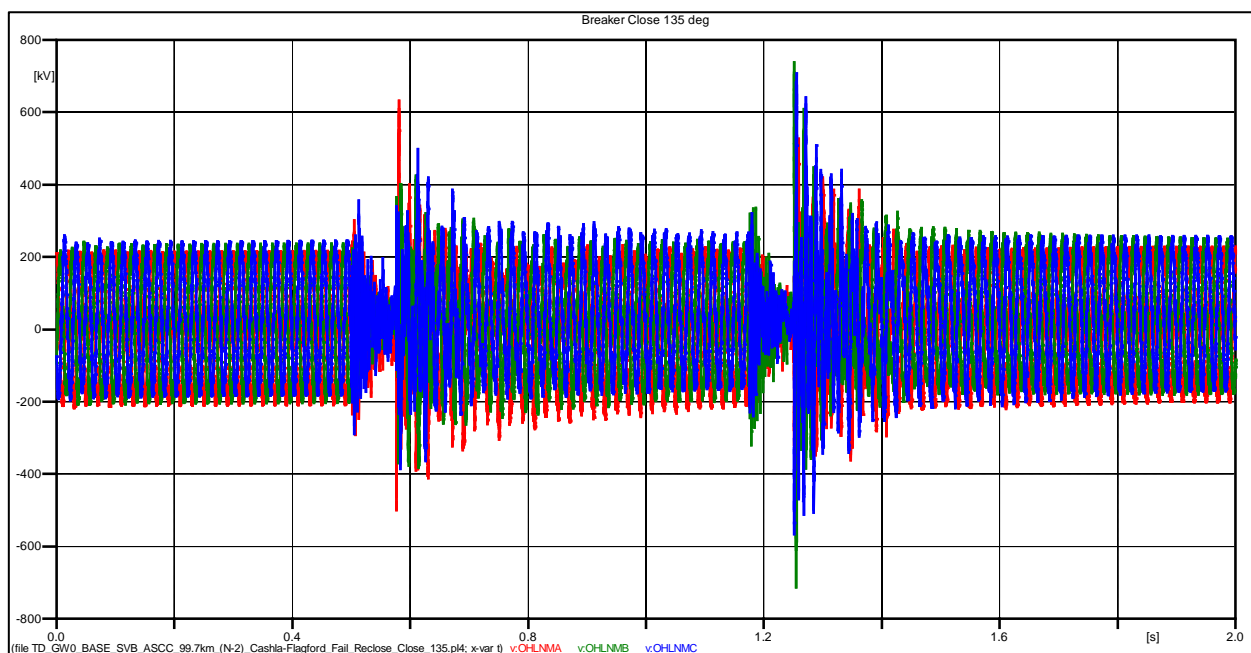


**Figure 16: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	700.01 kV (3.898pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	496.35 kV (2.763 pu)	287.32 kV (1.6pu)	Fail



**Figure 17: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-6s)**



**Figure 18: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 135° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	710.56 kV (3.956 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	580.23 kV (3.231 pu)	287.32 kV (1.6pu)	Fail

#### **1.4 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL - Breaker opens at 210°**

Conditions for time domain simulation:

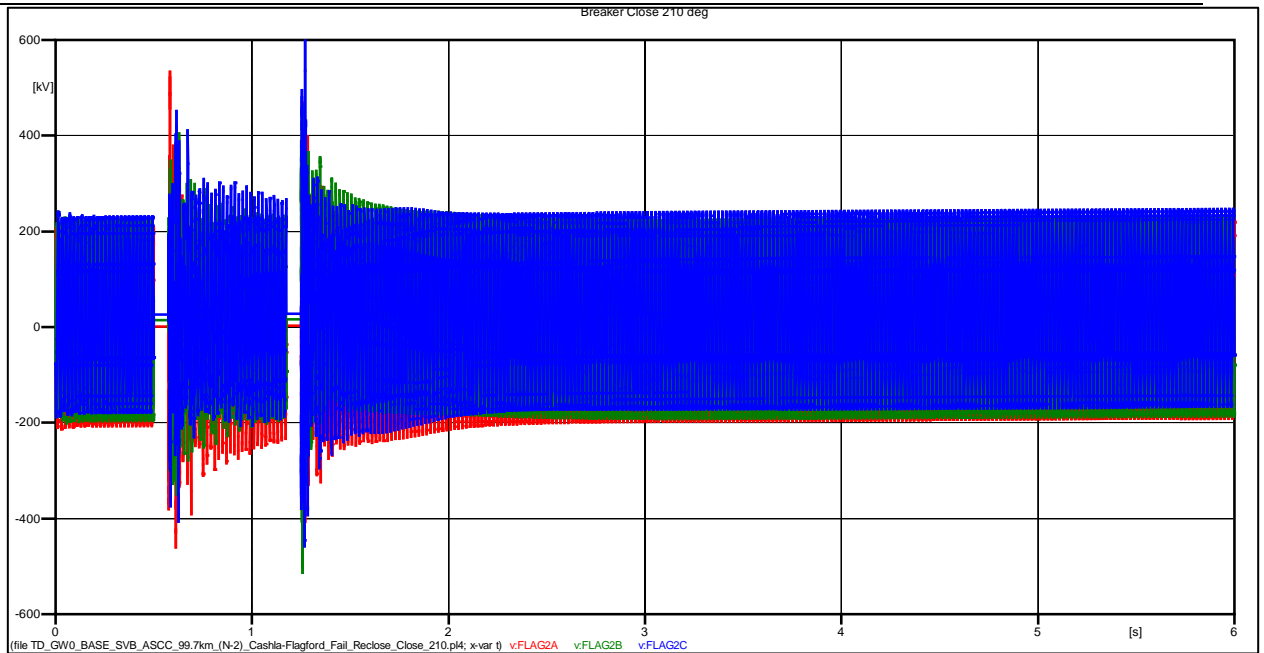
1. Summer Valley B network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

#### **Case 7d: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line with breaker opens at 210°**

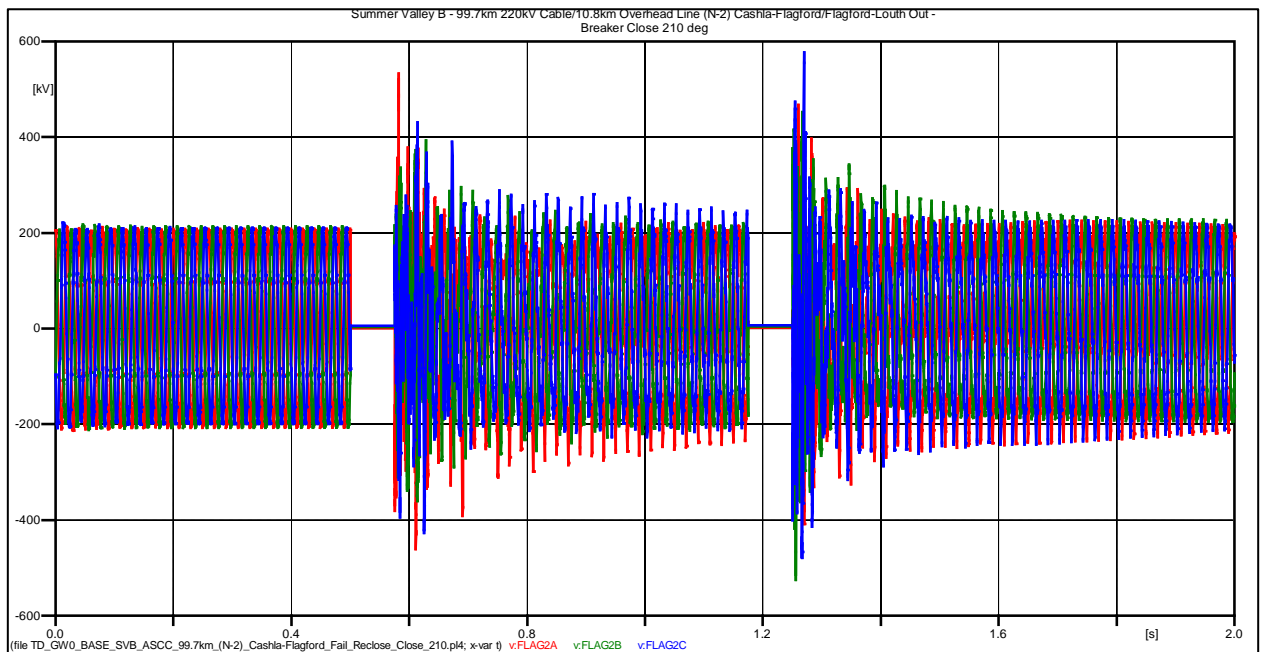
System Conditions:

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.
3. Breaker opens at again at 1.25616s, point on wave opens at 210°.



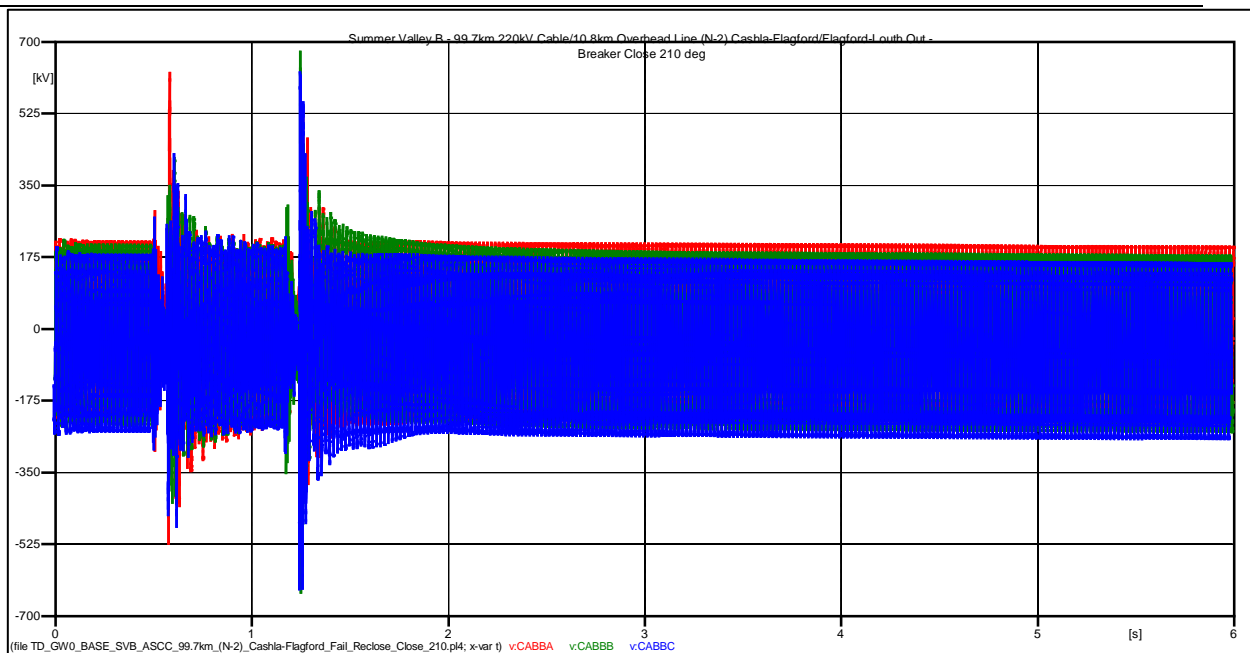


**Figure 19: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-6s)**

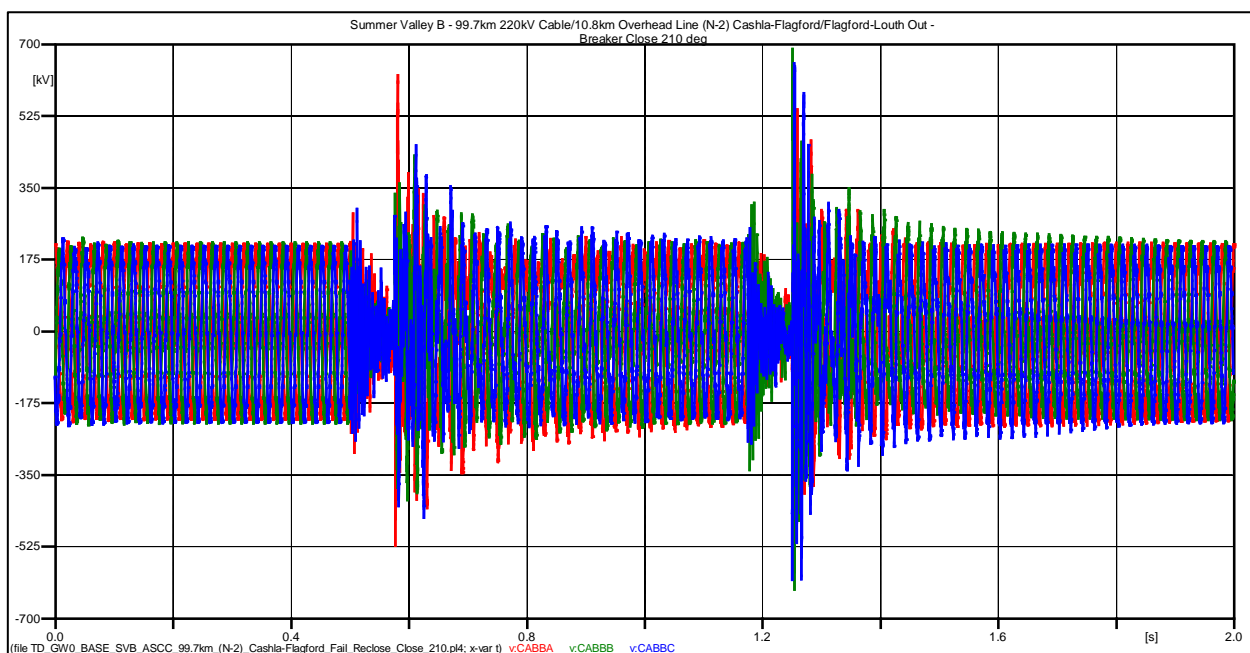


**Figure 20: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	520.36 kV (2.897 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	391.26 kV (2.178 pu)	287.32 kV (1.6pu)	Fail

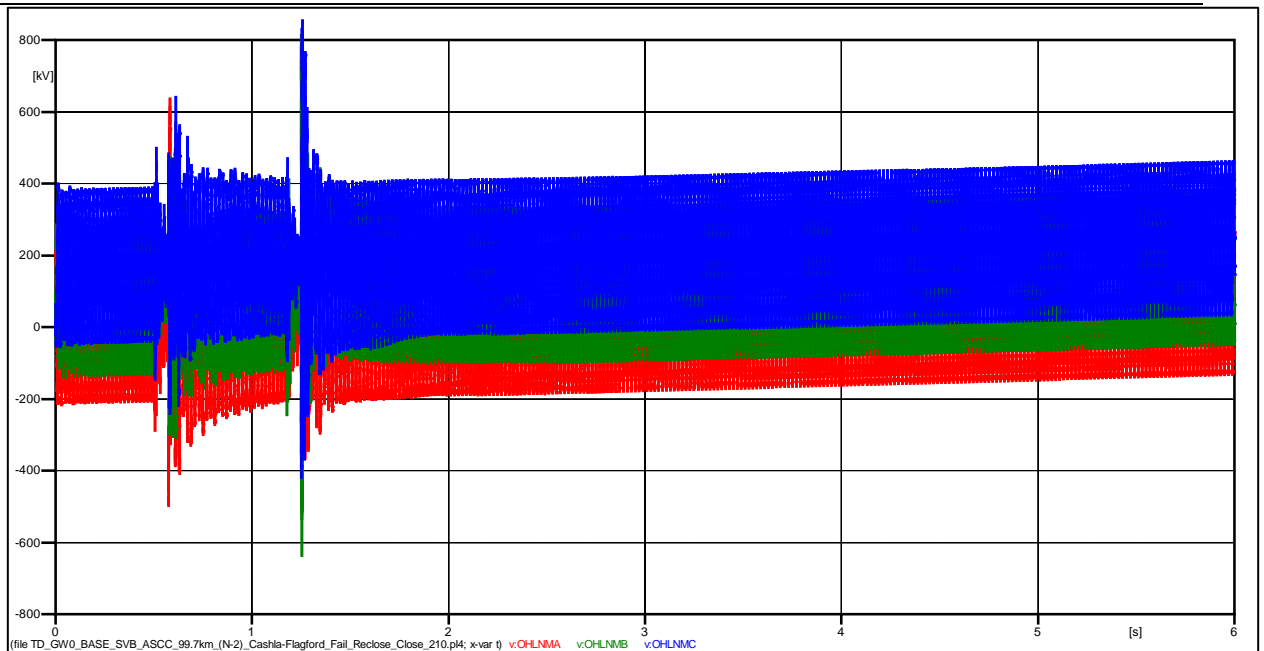


**Figure 21: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-6s)**

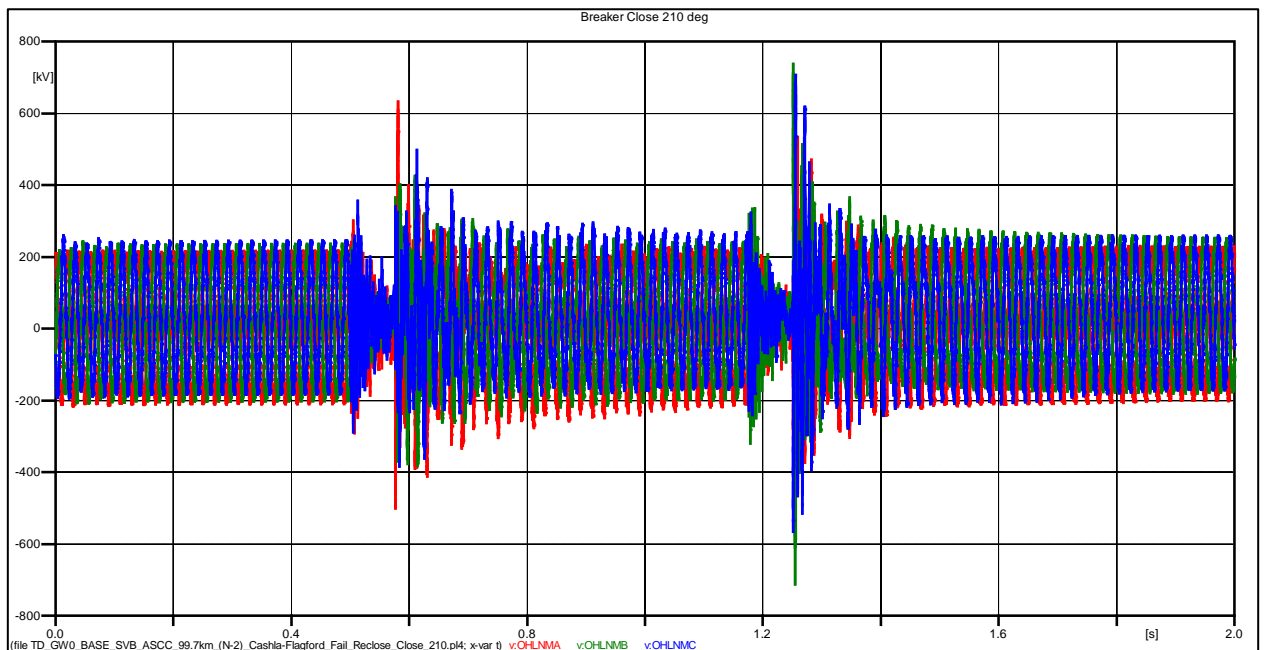


**Figure 22: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	685.89 kV (3.819 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	480.23 kV (2.674 pu)	287.32 kV (1.6pu)	Fail



**Figure 23: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-6s)**



**Figure 24: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 210° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	705.68 kV (3.929 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	432.56 kV (2.408 pu)	287.32 kV (1.6pu)	Fail

## **1.5 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Breaker opens at 330°**

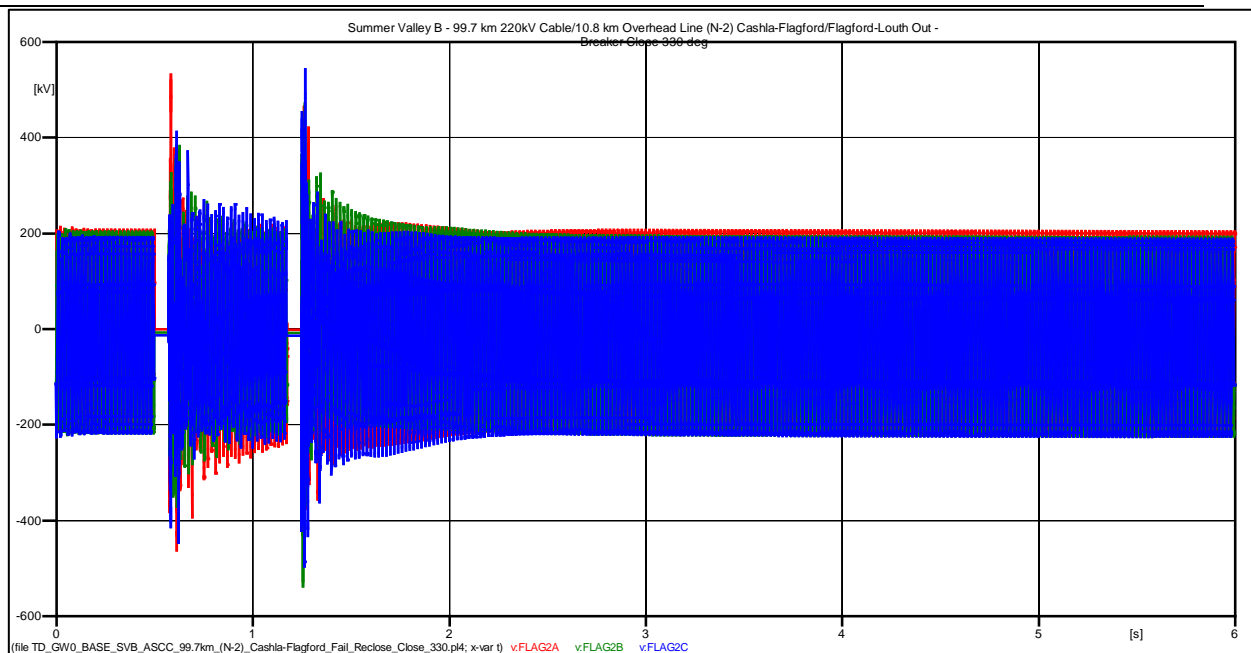
Conditions for time domain simulation:

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

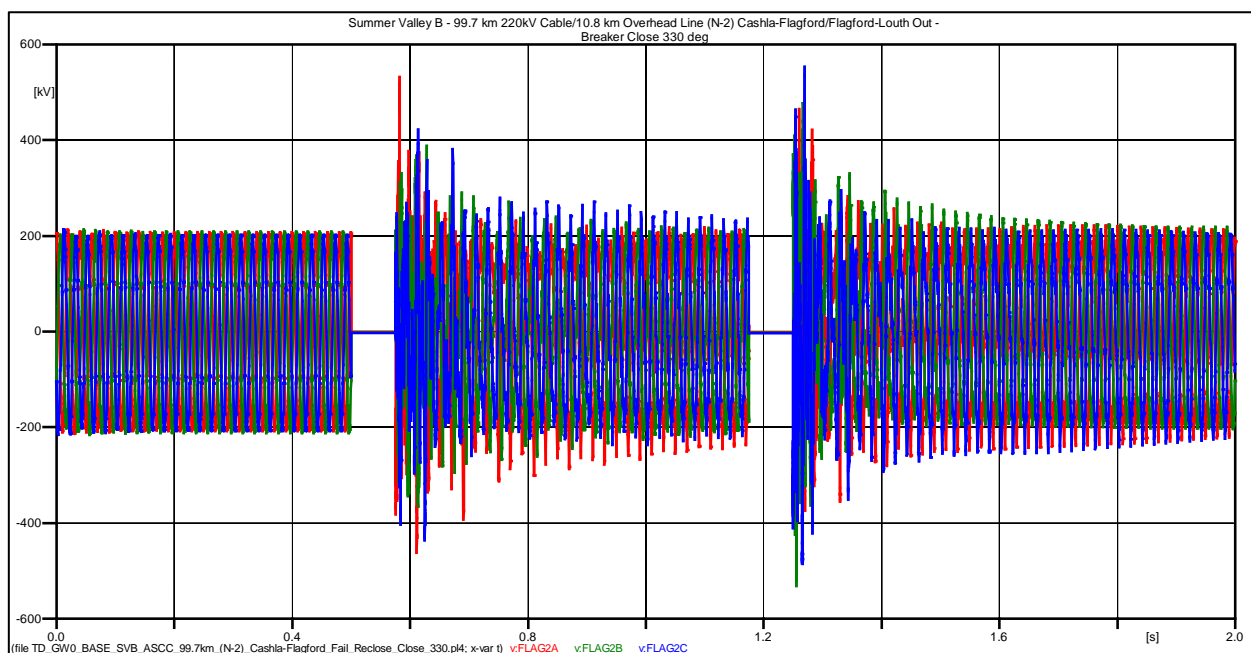
### **Case 7e: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line with breaker opens at 330°**

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.
3. Breaker opens at again at 1.2683s, point on wave opens at 330°.

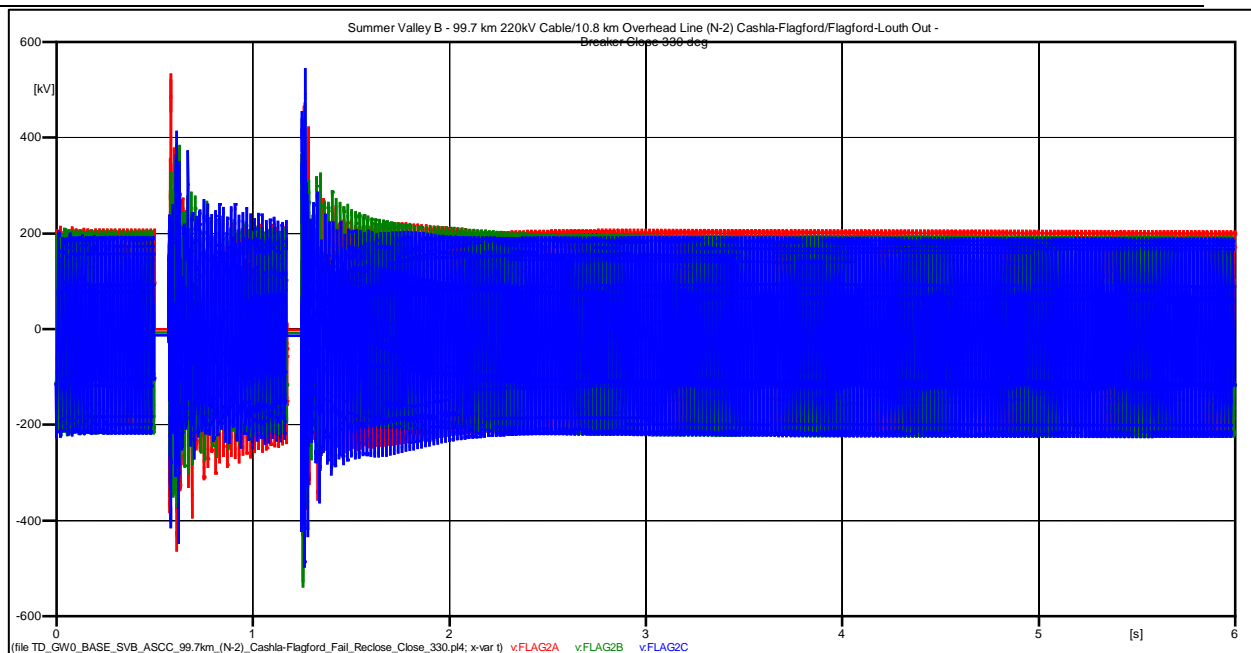


**Figure 25: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-6s)**

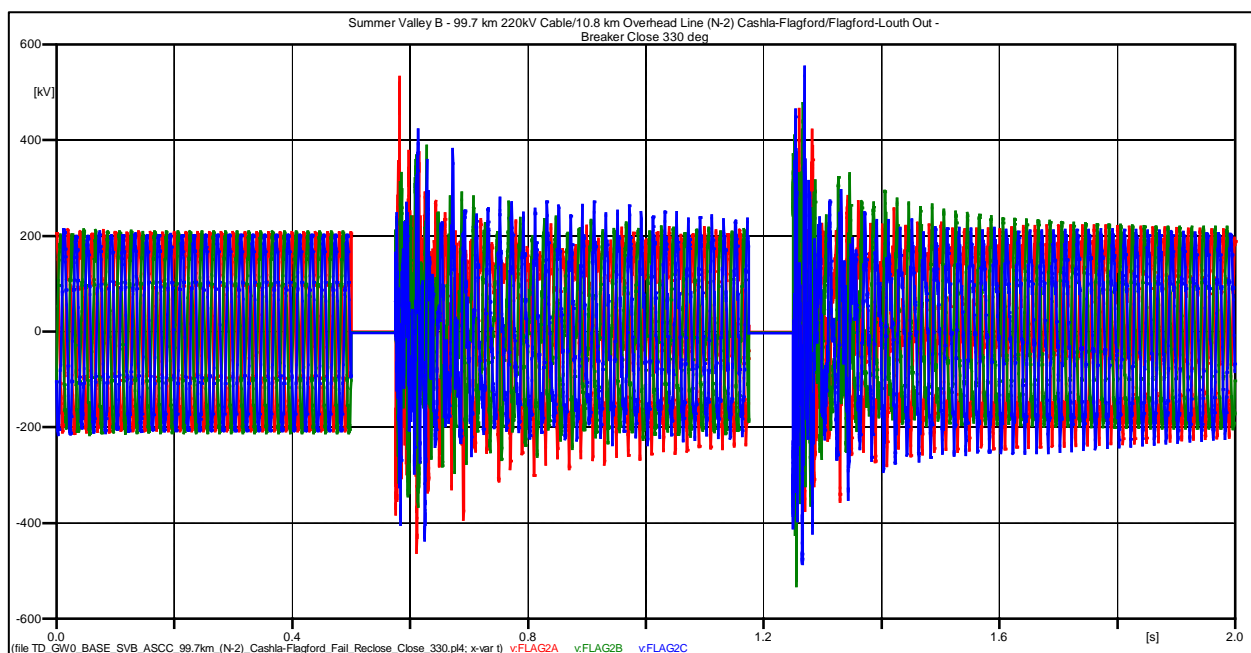


**Figure 26: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	745.89 kV (4.153 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	390.23 kV (2.173 pu)	287.32 kV (1.6pu)	Fail



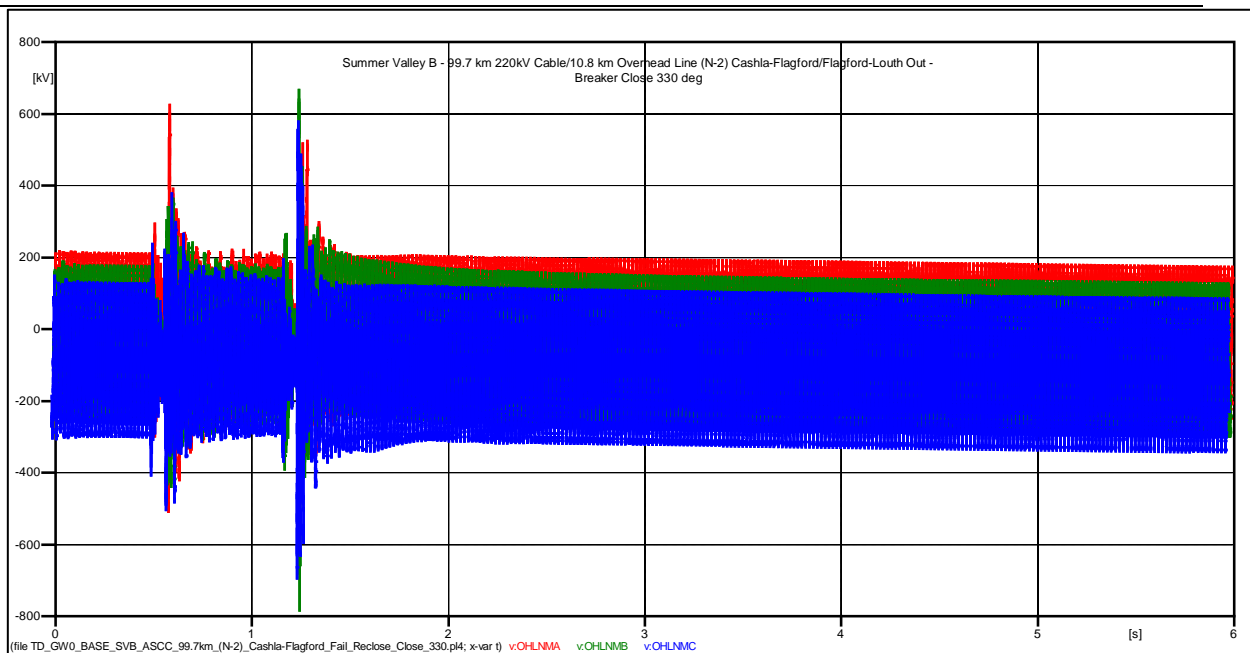
**Figure 27: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-6s)**



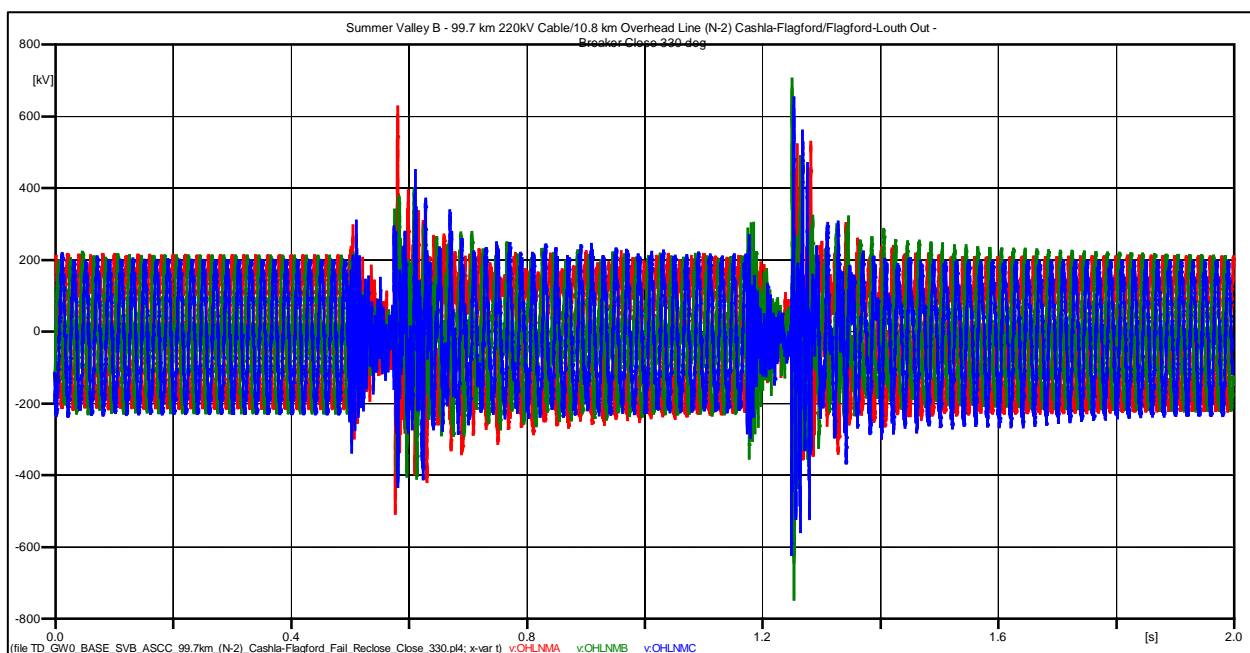
**Figure 28: WPA - Length 99.7 km cable / 10.8 km OHL – Cable End A – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	695.16 kV (3.871 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	391.26 kV (2.1787 pu)	287.32 kV (1.6pu)	Fail

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**Figure 29: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-6s)**



**Figure 30: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 330° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	702.28 kV (3.910 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	431.26 kV (2.401 pu)	287.32 kV (1.6pu)	Fail

## **1.6 Time Domain Simulation – Length 99.7 km cable / 10.8 km OHL – Breaker opens at 0°**

Conditions for time domain simulation:

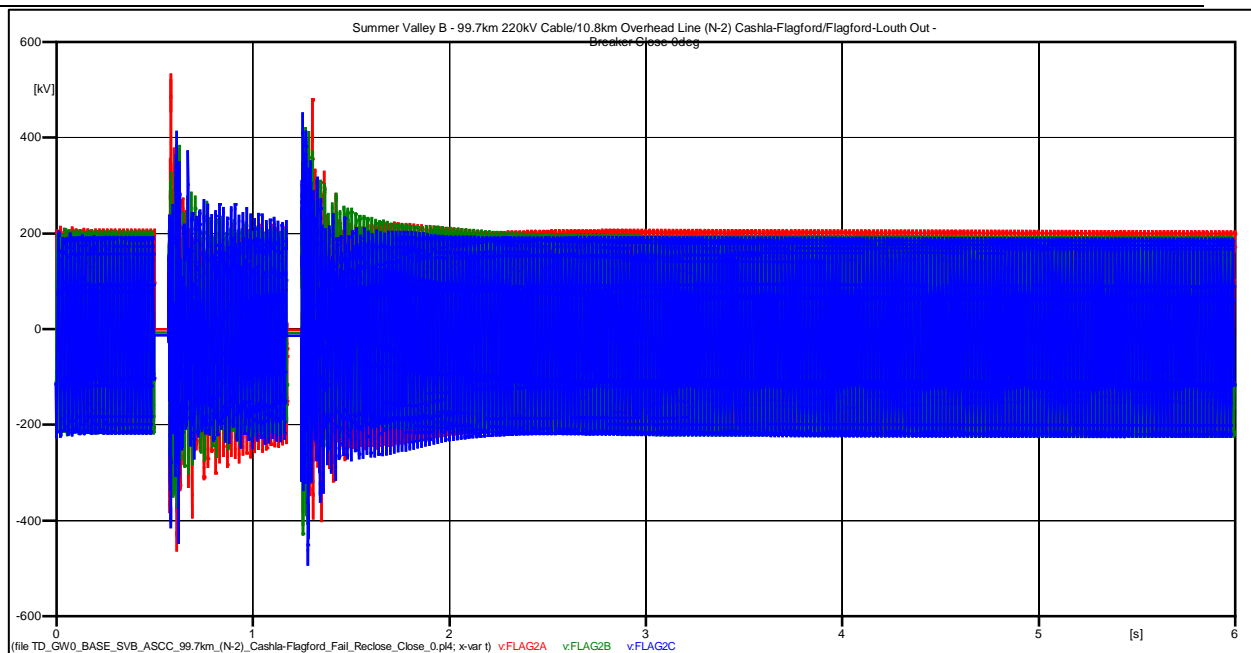
1. Summer Valley B network
2. North Mayo to Flagford Circuit – 99.7 km 220 kV cable, 10.8 km OHL
3. Reactors – North Mayo 75 Mvar / Flagford 225 Mvar

### **Case 7f: (N-2) – Flagford-Louth Disconnected – Autoreclose of the Cashla-Flagford line with breaker opens at 0°**

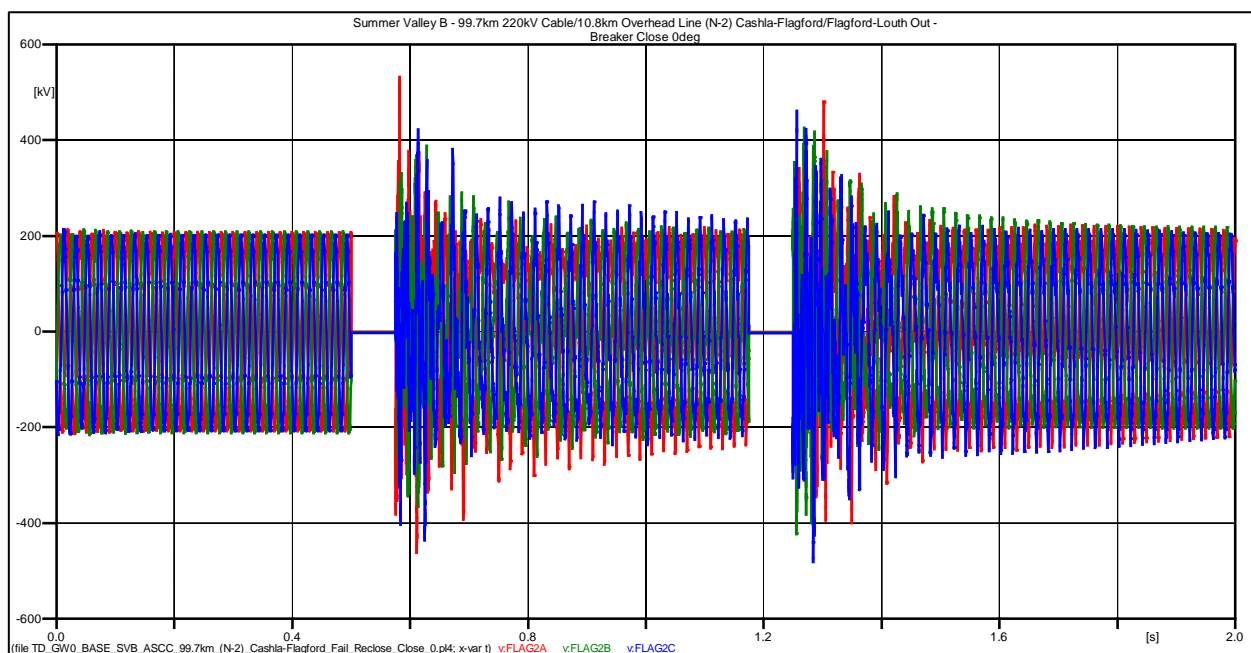
System Conditions:

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 1.25s.
3. Breaker opens at again at 1.27s point on wave opens at 0°.



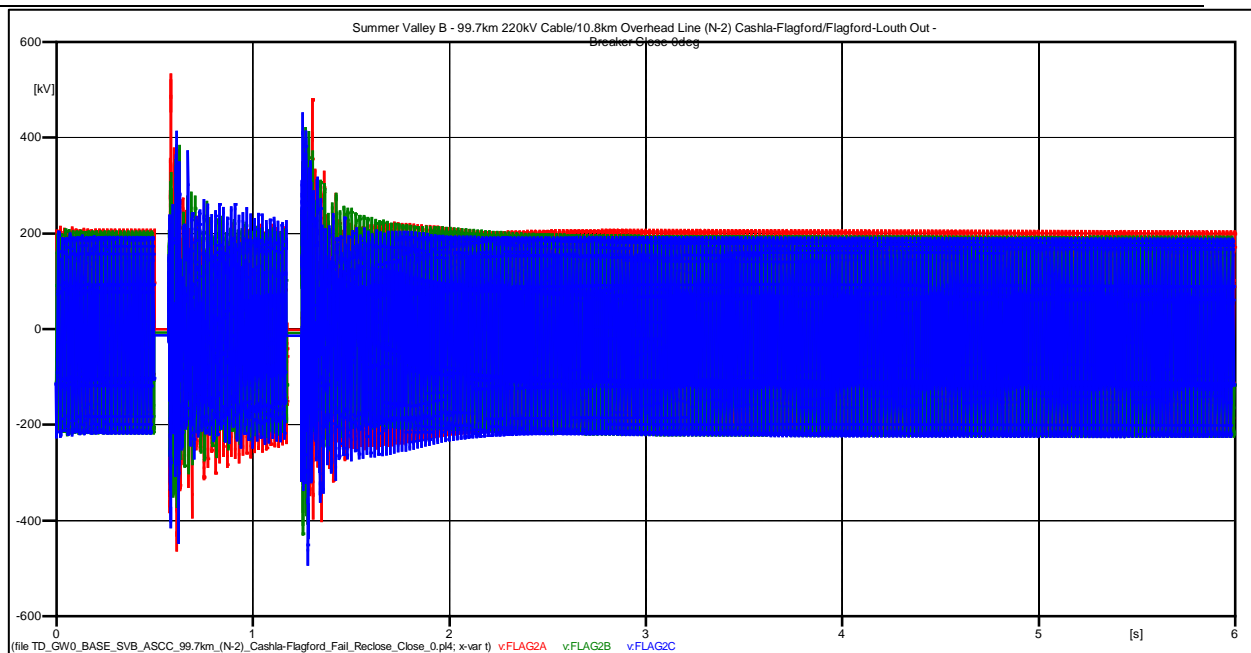


**Figure 31: SVB - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-6s)**

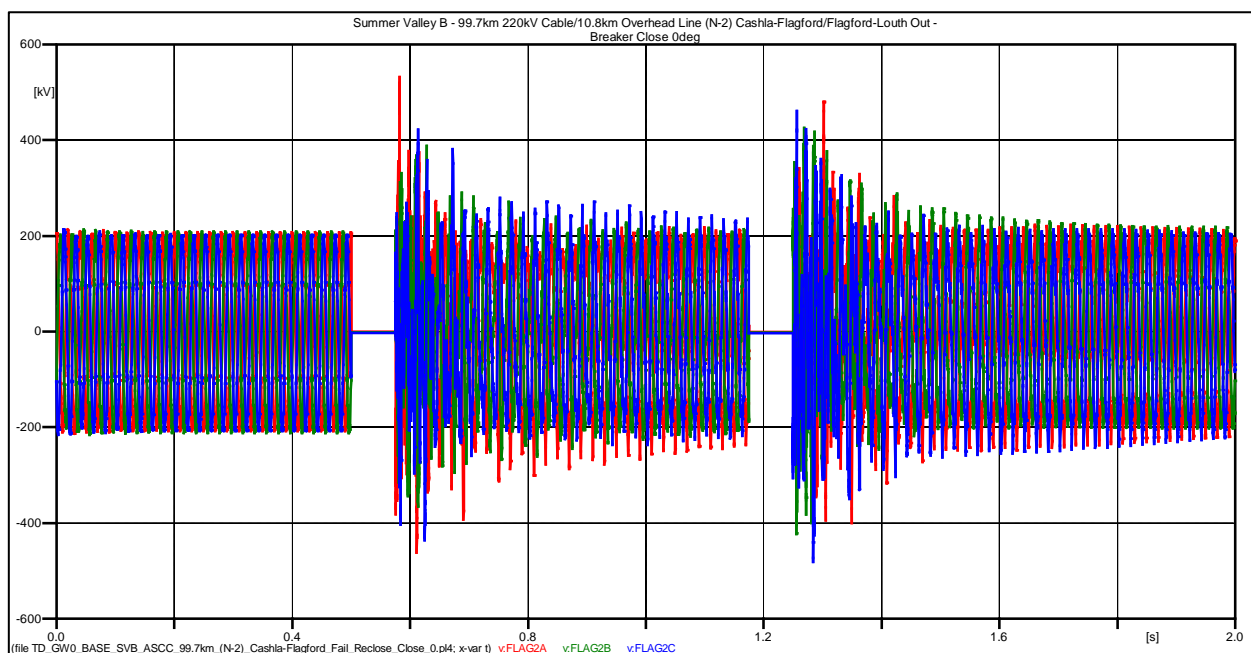


**Figure 32: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	659.13 kV (3.670pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	385.69 kV (2.147 pu)	287.32 kV (1.6pu)	Fail

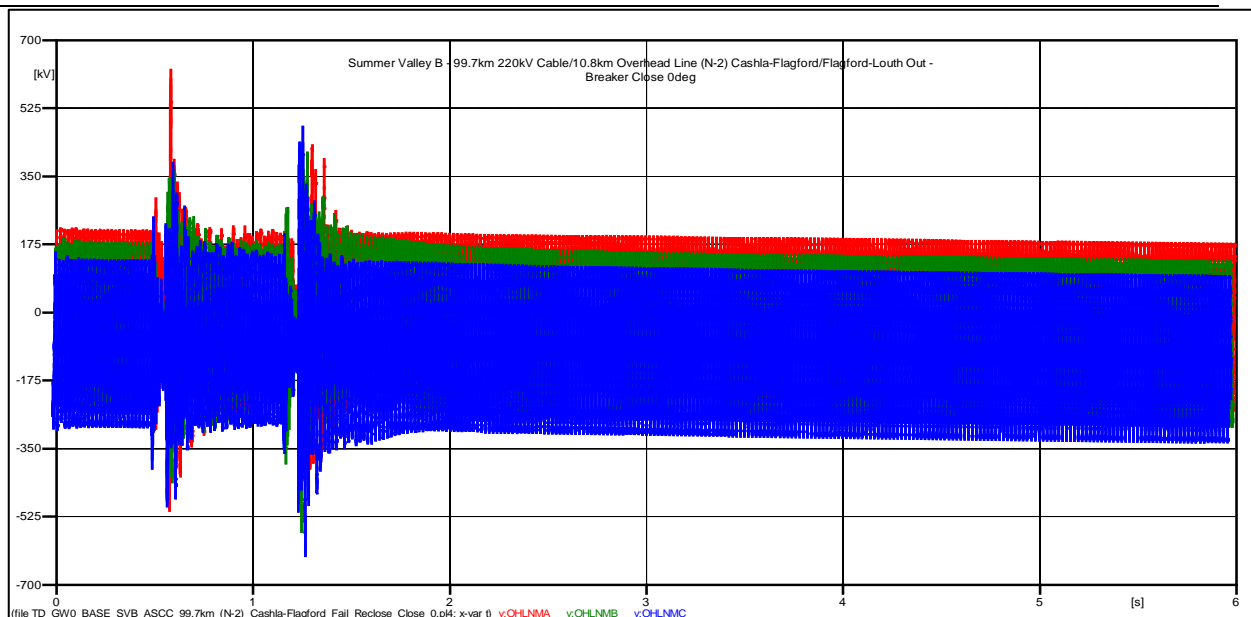


**Figure 33: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-6s)**

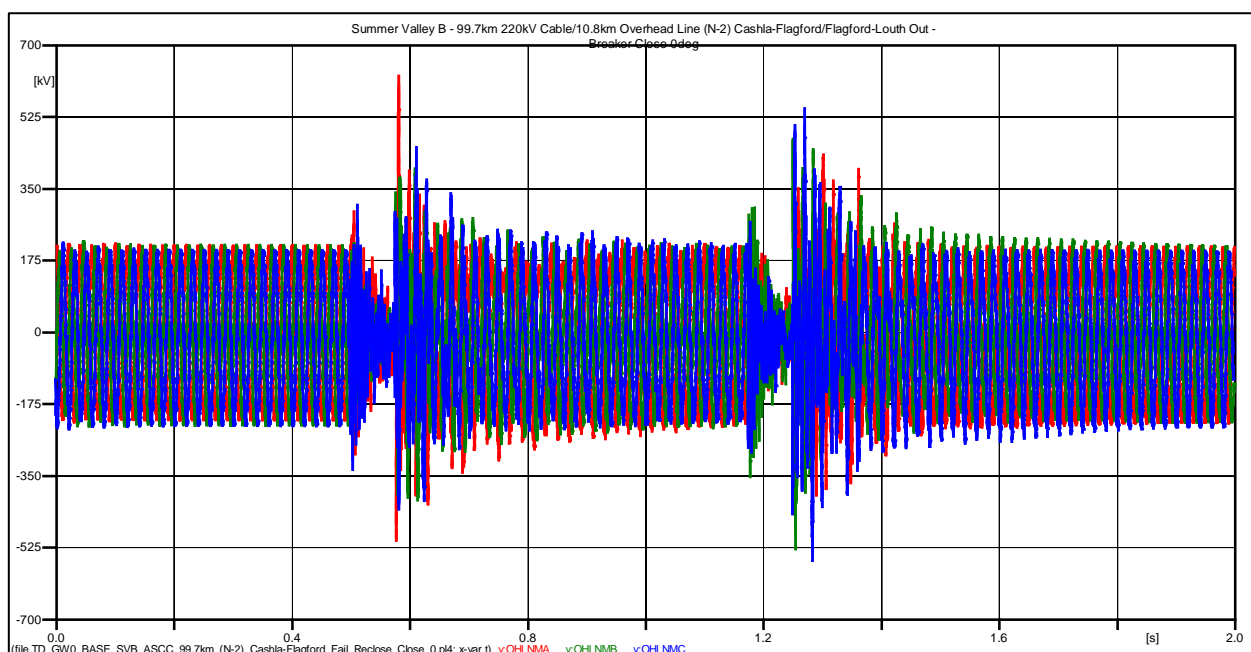


**Figure 34: WPA - Length 99.7 km cable / 10.8 km OHL – Flagford – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	690.22 kV (3.843 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	400.19 kV (2.228 pu)	287.32 kV (1.6pu)	Fail



**Figure 35: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-6s)**



**Figure 36: WPA - Length 99.7 km cable / 10.8 km OHL – North Mayo – (N-2) – Flagford-Louth out – Autoreclose Cashla-Flagford line with breaker close at 0° (0-2s)**

Condition	Maximum Value	Limit	Result
Switching	610.23 kV (3.398 pu)	449.07 kV (2.5 pu)	Fail
Temporary Overvoltage	425.89 kV (2.371 pu)	287.32 kV (1.6pu)	Fail