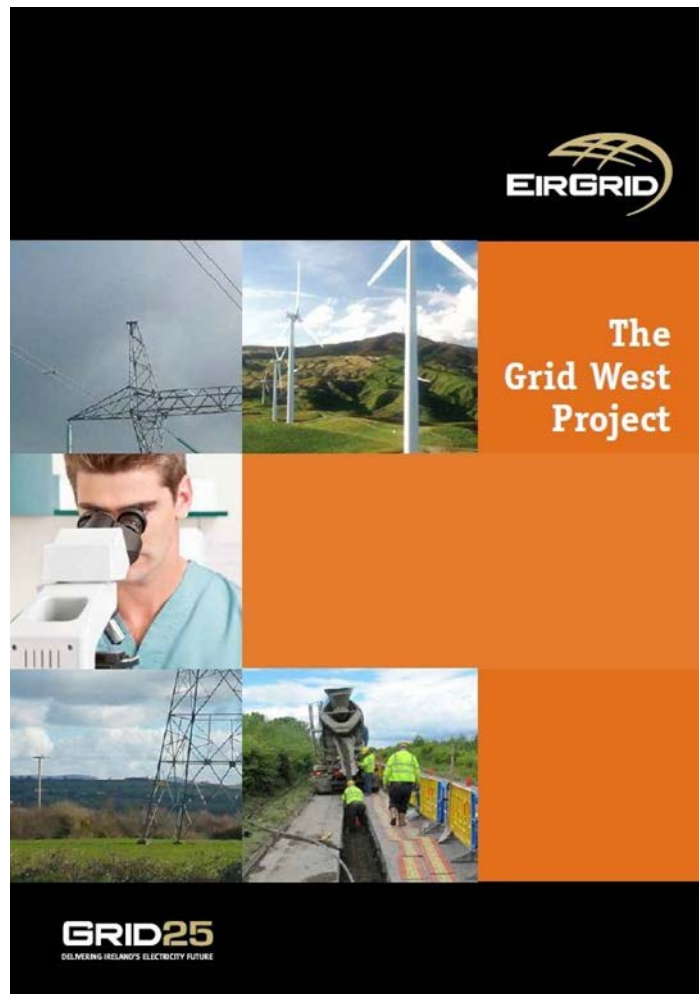


EirGrid

10344 – PSP019 CABLE STUDIES FOR GRID WEST

Partial AC Underground Solution



Appendix A – 400kV Cable Option

17/12/2014

REPORT AUTHORISATION SHEET

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Project: **10344 – PSP019 Cable Studies for Grid west**
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Prepared by:

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

Checked by:

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

Authorised for issue:

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

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1 400 KV PARTIAL CABLE SOLUTIONS

A 400 kV option of overhead line (OHL) and underground cable (UGC) was considered between North Mayo and Flagford substations to verify an existing assumption that a 400 kV cable of significant length would not be feasible on the Grid West circuit.

This appendix will cover the 400 kV overhead line and cable option with the circuit incorporating 90 km OHL and 10 km UGC. This case has failed due to a high resonance point below the 3rd harmonic of above 1000 Ohms and has also failed due to TOVs exceeding the allowable limits.¹

1.1 Network Scenario – 90 km OHL/10 km UGC

A load flow solution for the cable was considered to determine the reactive power requirements for the OHL and UGC configuration.

Reactive power requirements for the 400 kV circuit are detailed in the table below.

Network	Reactive power requirements at Flagford 400 kV station
90 km OHL/10 km UGC	218.7 MVar

The reactive support requirements at each end of the 400 kV partial underground configuration is as follows:

- Flagford – 125 MVar
- North Mayo – 20 MVar – Not consuming in Winter Peak A

These combinations were verified in both the Winter Peak A and the Summer Valley B scenarios.

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.

LOCATION	FLAGFORD		NORTH MAYO	
Scenario	Voltage (pu)	Reactive Power absorbed (MVars)	Voltage (pu)	Reactive Power absorbed (MVars)
Winter Peak A – WPA – 1.05 pu	1.04171	125.0	1.0500	0
Summer Valley A – SVA – 1.0 pu	1.0037	125.9	1.000	20

1.2 Model Verification – Original Model vs. LPA Model

The conclusions of the model verification are detailed below.

Original Grid West 400 kV Model	LPA Grid West 400 kV Model
Cable modelled in 0.566 km sections	Cable modelled in 3.33 km sections
Bergeron models used (Inaccurate, proven by an previous EirGrid study)	PI sections used
Old System network	New system network
No reactors fitted	Reactors fitted
Cable size too small (1400mm ²)	Correct cable modelled (2500mm ²)
<p><u>Conclusion:</u> Update LPA model with shorter subsection PI model to gain accuracy – Carried out in Case 3.</p>	

1.3 Impedance Scan - Length 10 km – Summer Valley B – Case 1

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. Reactors – North Mayo 20 Mvar/Flagford 125 Mvar
4. LPA 400 kV Cable Model used w/ 3.33 km PI Sections

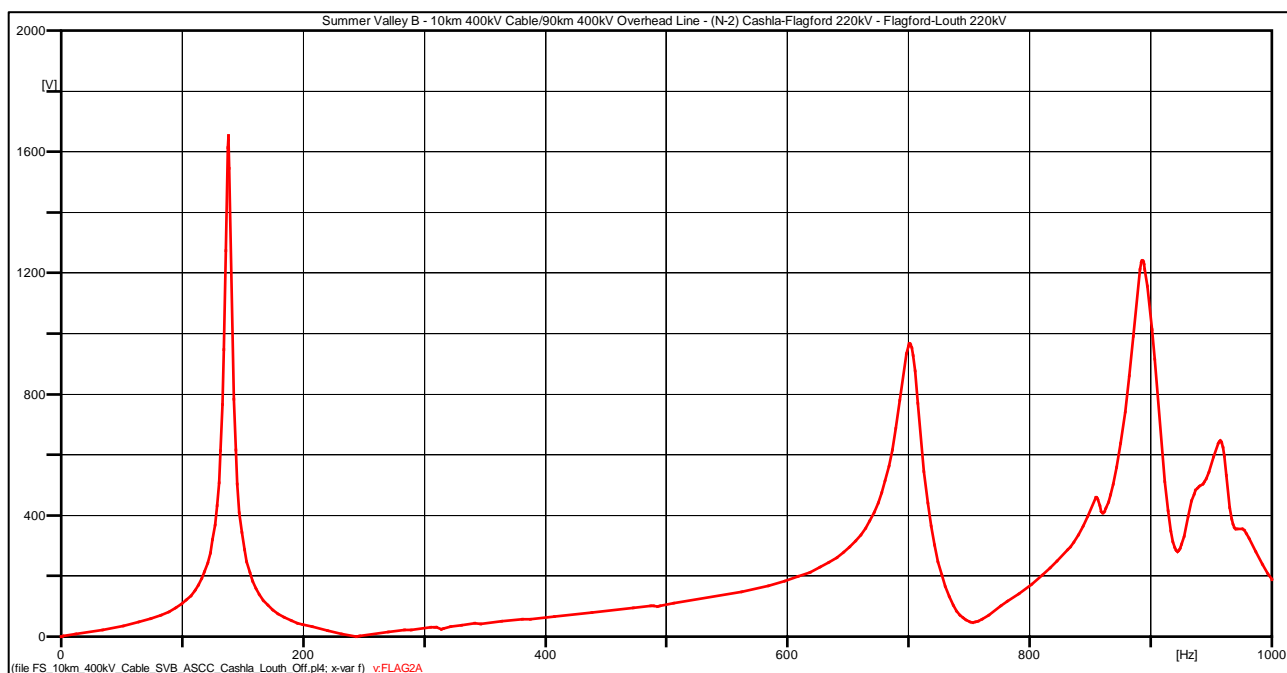


Figure 1: SVB - 90km OHL/10km UGC – Flagford – (N-2) Cashla-Flagford/Flagford-Louth Lines Out

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
138.61	1600.70
700.51	966.35
892.81	1240.40
957.91	644.58

1.4 Time Domain - Length 10km – Summer Valley B – Case 1

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. Reactors – North Mayo 20 Mvar/Flagford 125 Mvar
4. LPA 400 kV Cable Model used w/ 3.33 km PI Sections

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

System Conditions:

1. The Flagford – Louth 220 kV line is on an outage. Fault applied on the Flagford side of Cashla-Flagford line at 0s, removed Fault at 200ms, opened Flagford-Cashla Line breaker at 200ms.

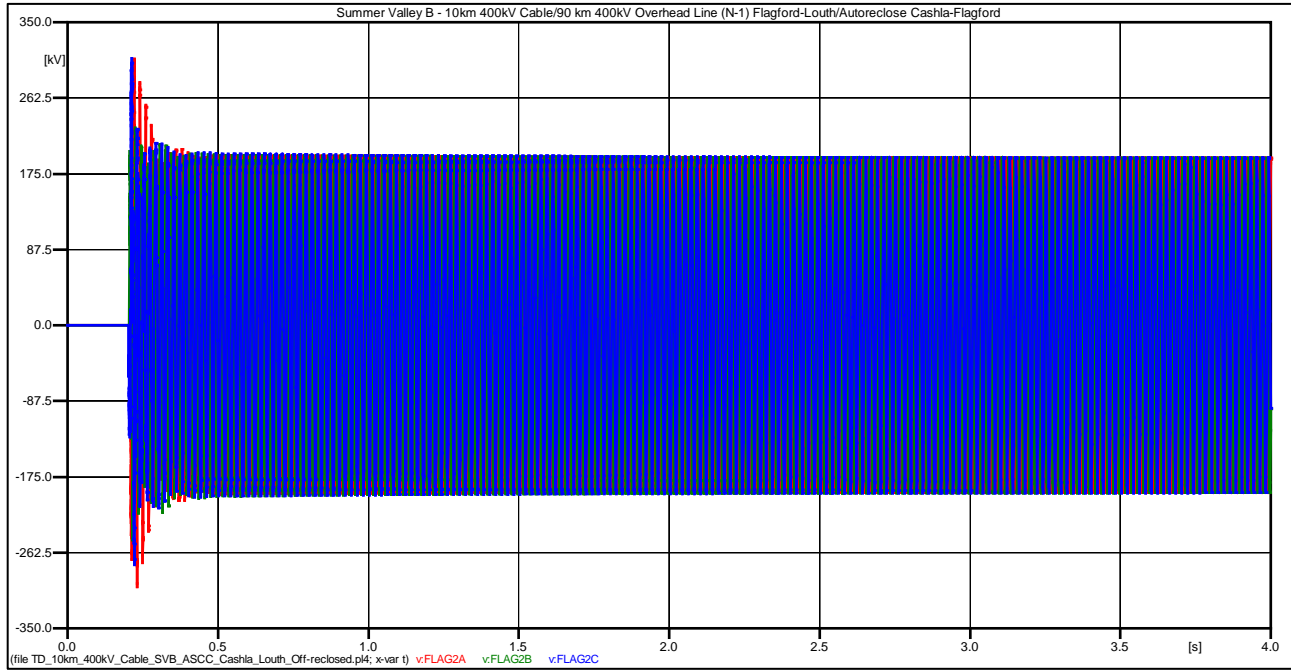


Figure 2: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out (0-4s)

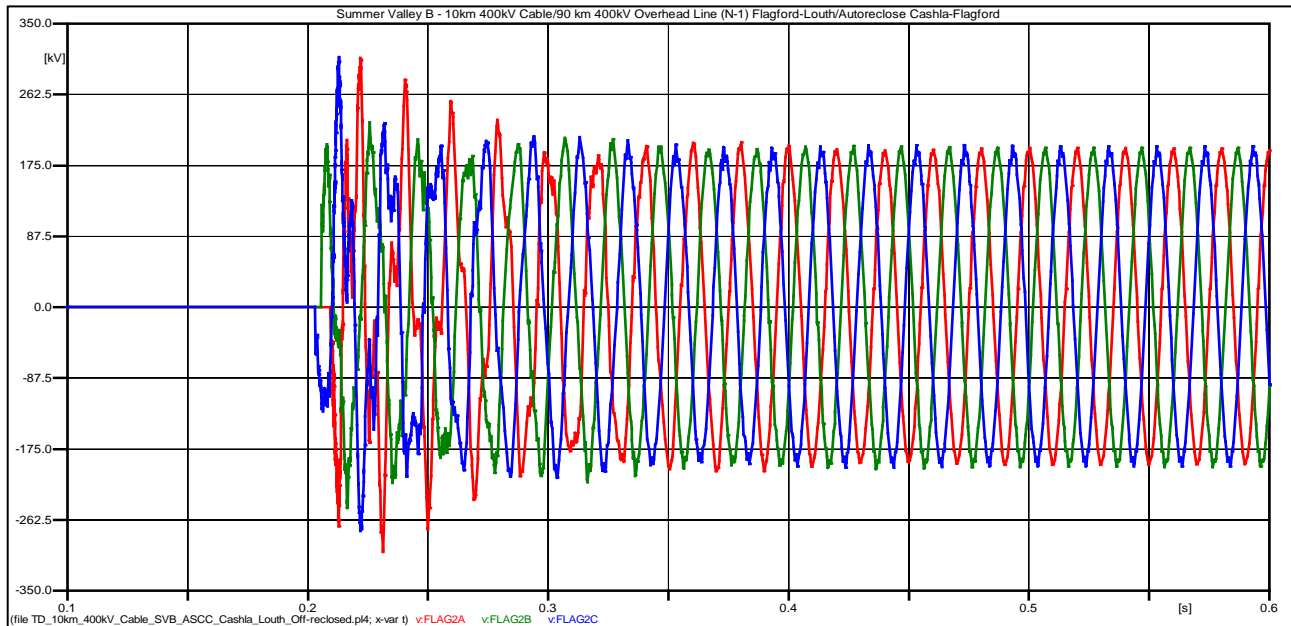


Figure 3: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out (0.1-0.6s)

Condition	Maximum Value	Limit	Result
Switching	326.58 kV (1.8185 pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	281.89 kV (1.5697 pu)	287.32 kV (1.6 pu)	Pass

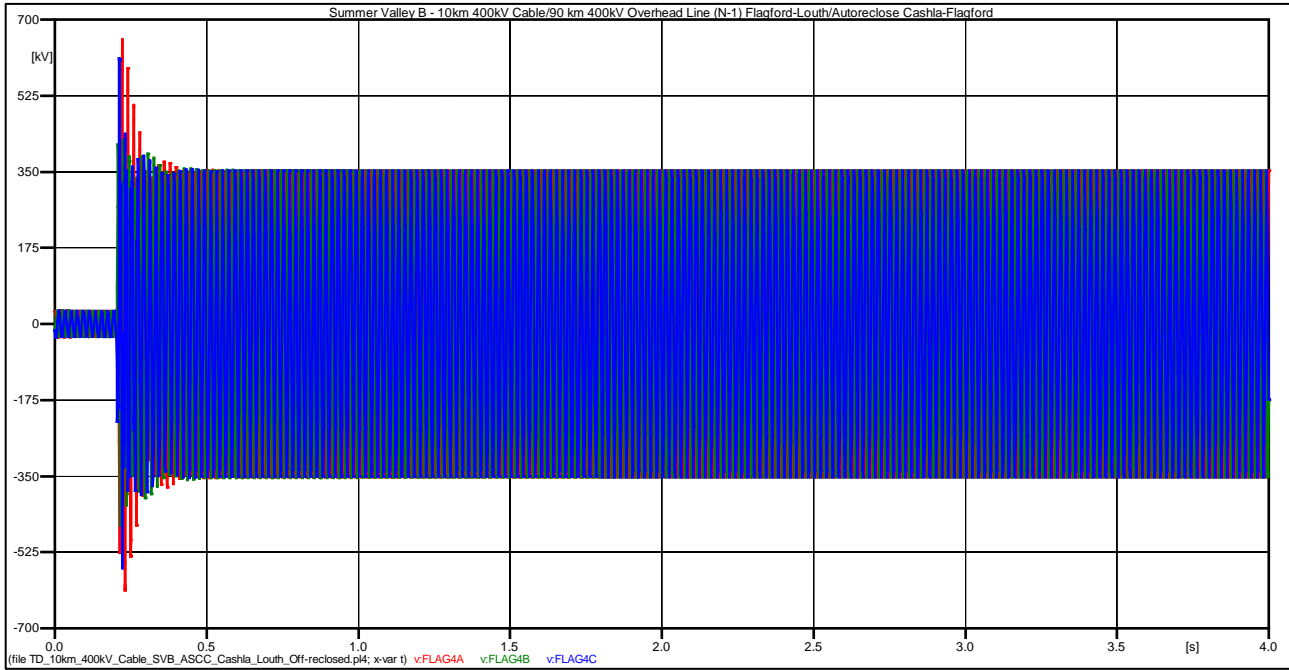


Figure 4: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out (0-4.0s)

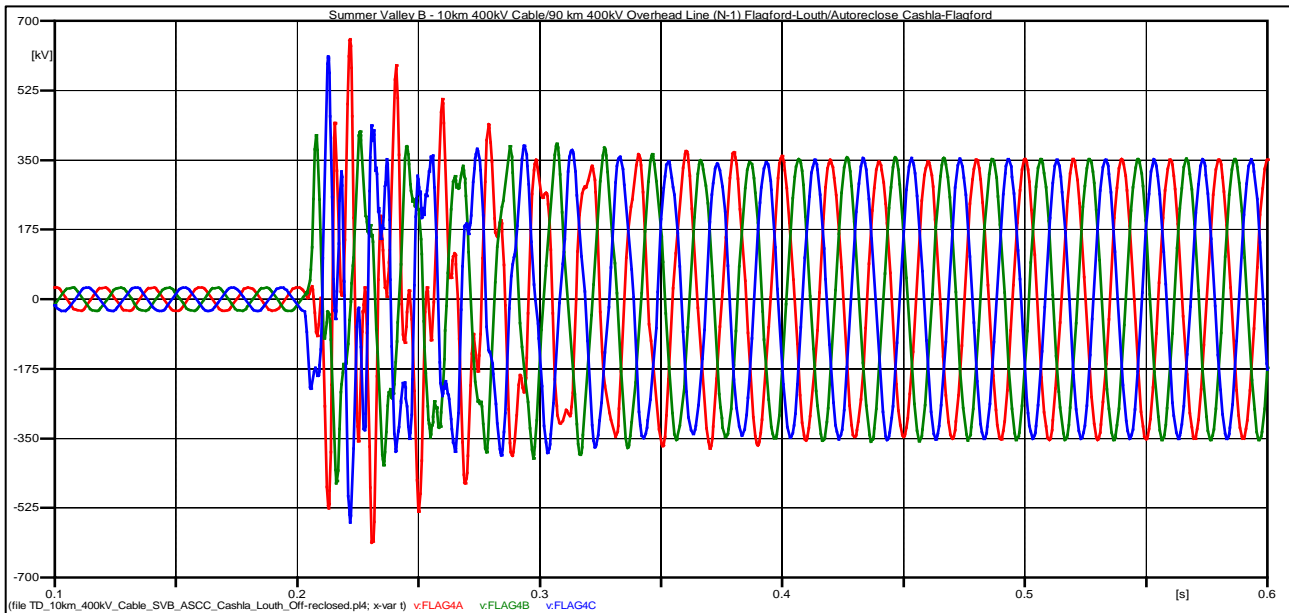


Figure 5: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out (0.1-0.6s)

Condition	Maximum Value	Limit	Result
Switching	600.58 kV (3.3443 pu)	816.49 kV (2.5 pu)	Pass
Temporary Overvoltage	535.69 kV (2.983 pu)	522.55 kV(1.6 pu)	Pass

1.5 Impedance Scan - Length 10 km – Summer Valley B – Case 2

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. No reactors
4. LPA 400 kV Cable Model used w/ 3.33 km PI Sections

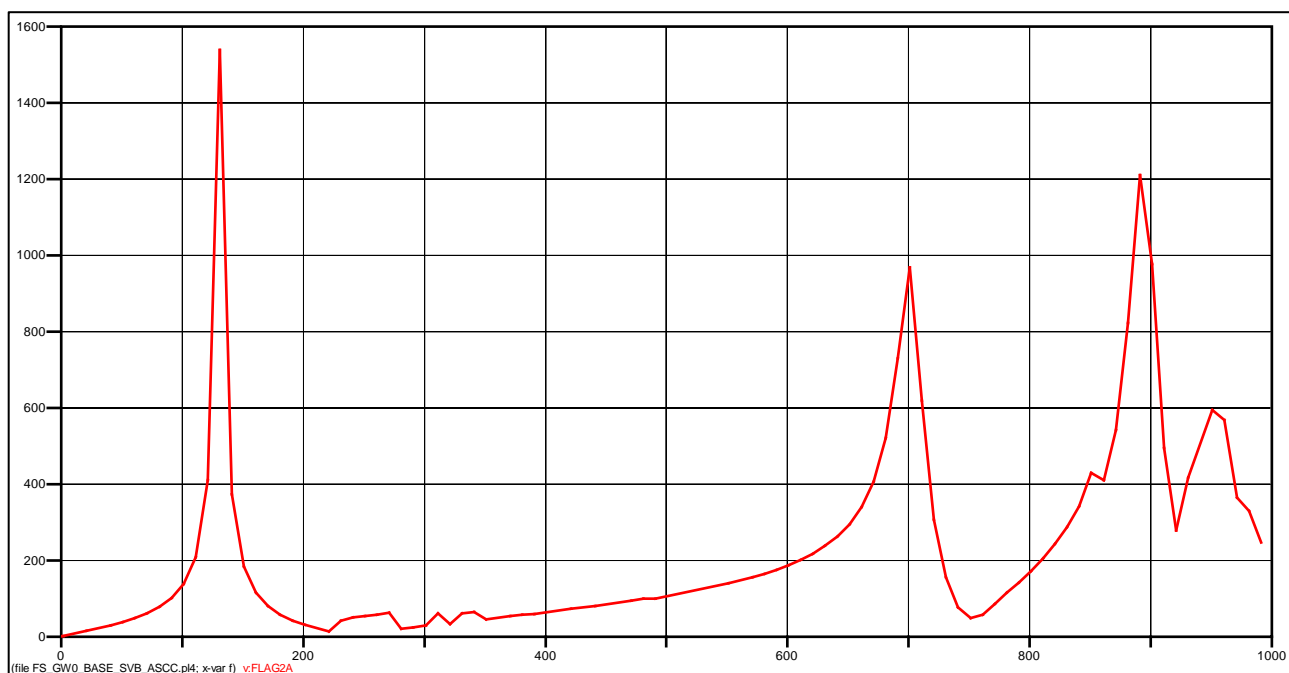


Figure 6: SVB - 90km OHL/10km UGC – Flagford – (N-2) Cashla-Flagford/Flagford-Louth Lines Out Without Reactors

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
131.0	1539.5
701.0	968.03
891.0	1211.3
951.0	594.42

1.6 Time Domain - Length 10km – Summer Valley B – Case 2

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. No reactors
4. LPA 400 kV Cable Model used w/ 3.33 km PI Sections

Case 2: (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out

System Conditions:

1. The Flagford – Louth 220 kV line is on an outage. Fault applied on the Flagford side of Cashla-Flagford line at 0s, removed Fault at 200ms, opened Flagford-Cashla Line breaker at 200ms.

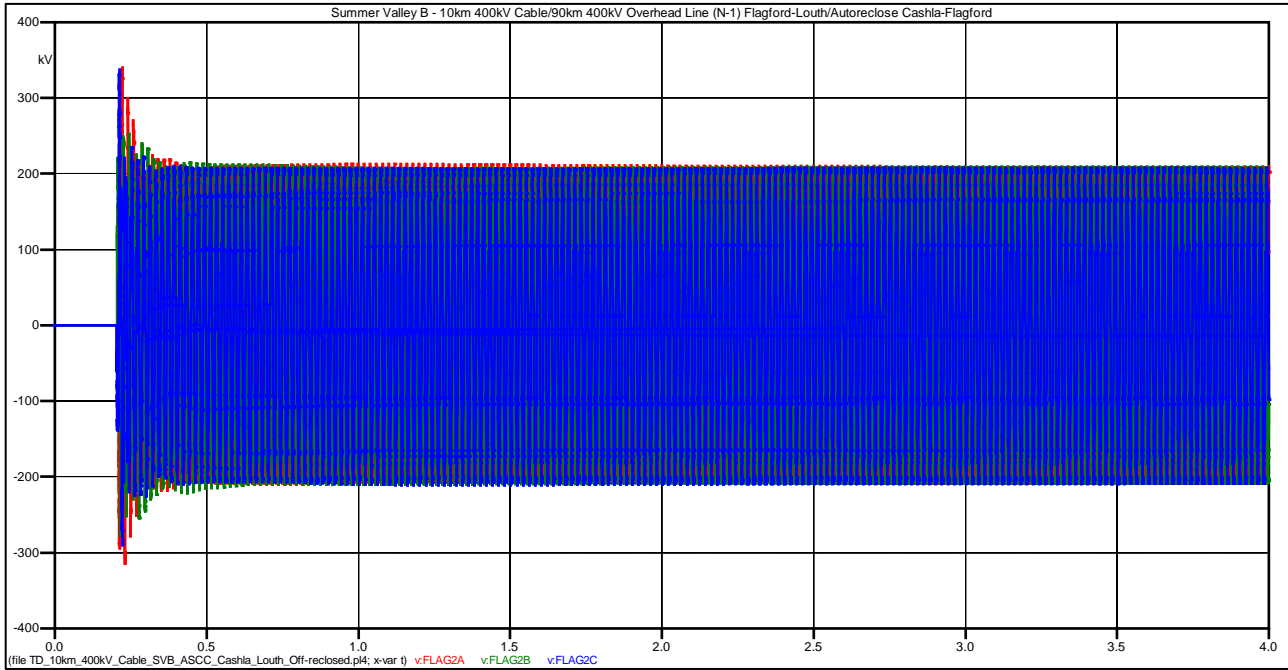


Figure 7: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out Without Reactors (0-4s)

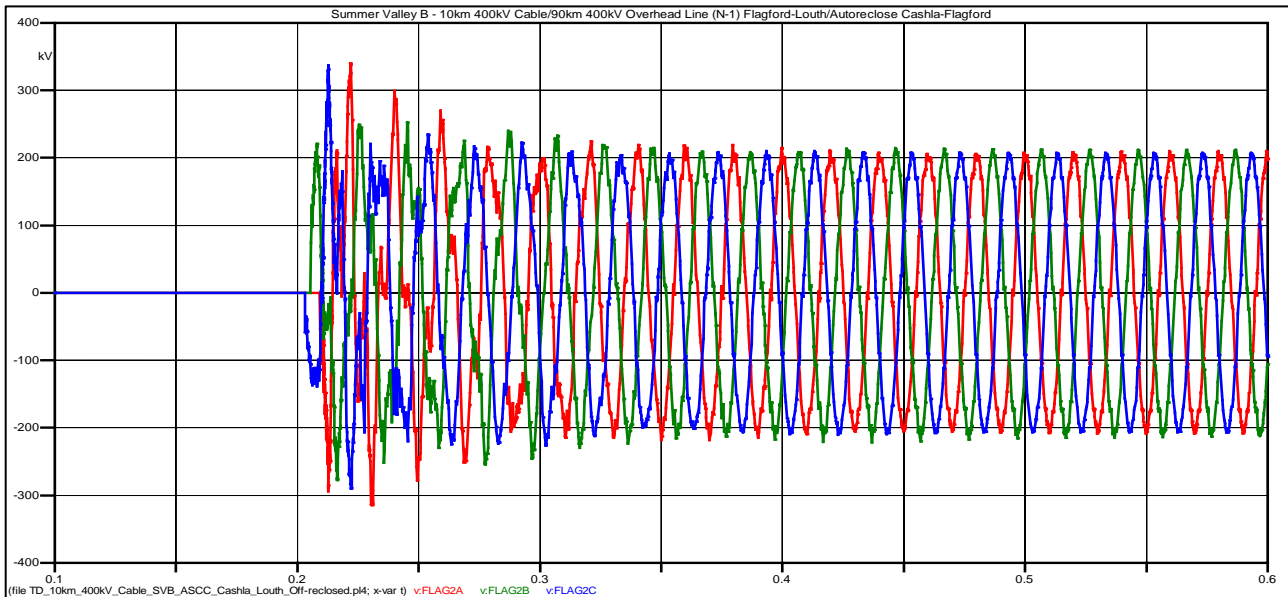


Figure 8: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out Without Reactors (0.1-0.6s)

Condition	Maximum Value	Limit	Result
Switching	341.89 kV (1.9038 pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	301.89 kV (1.6810 pu)	287.32 kV(1.6 pu)	Pass

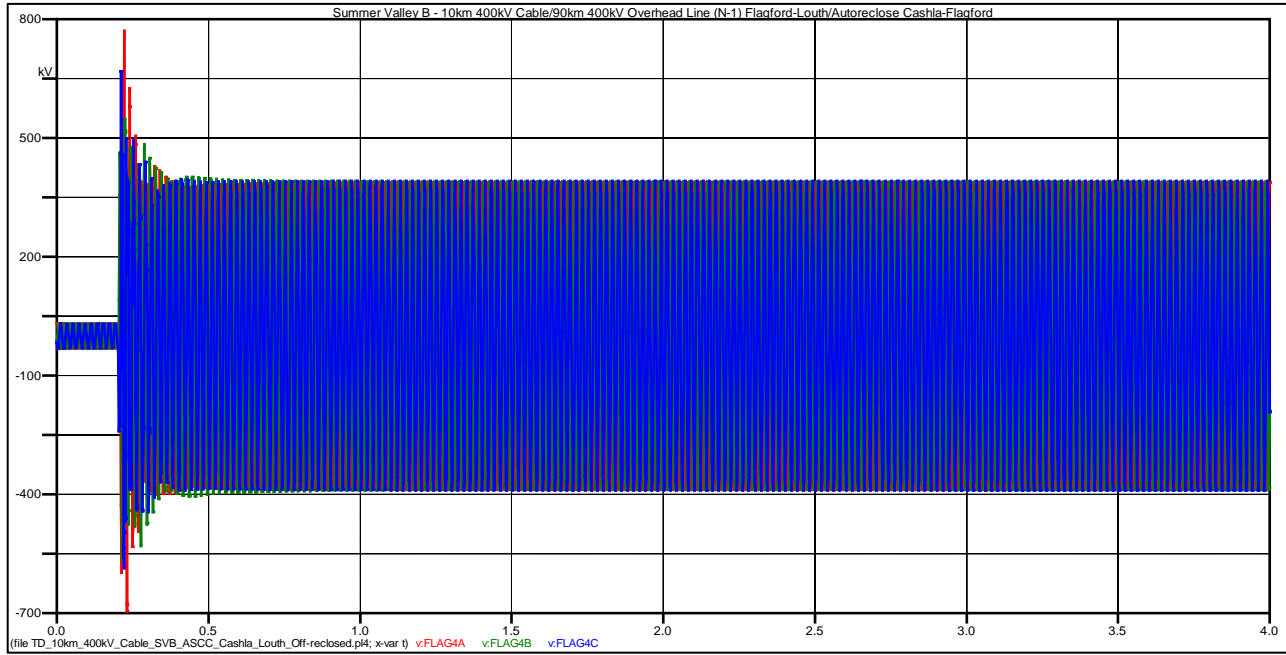


Figure 9: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out Without Reactors (0-4s)

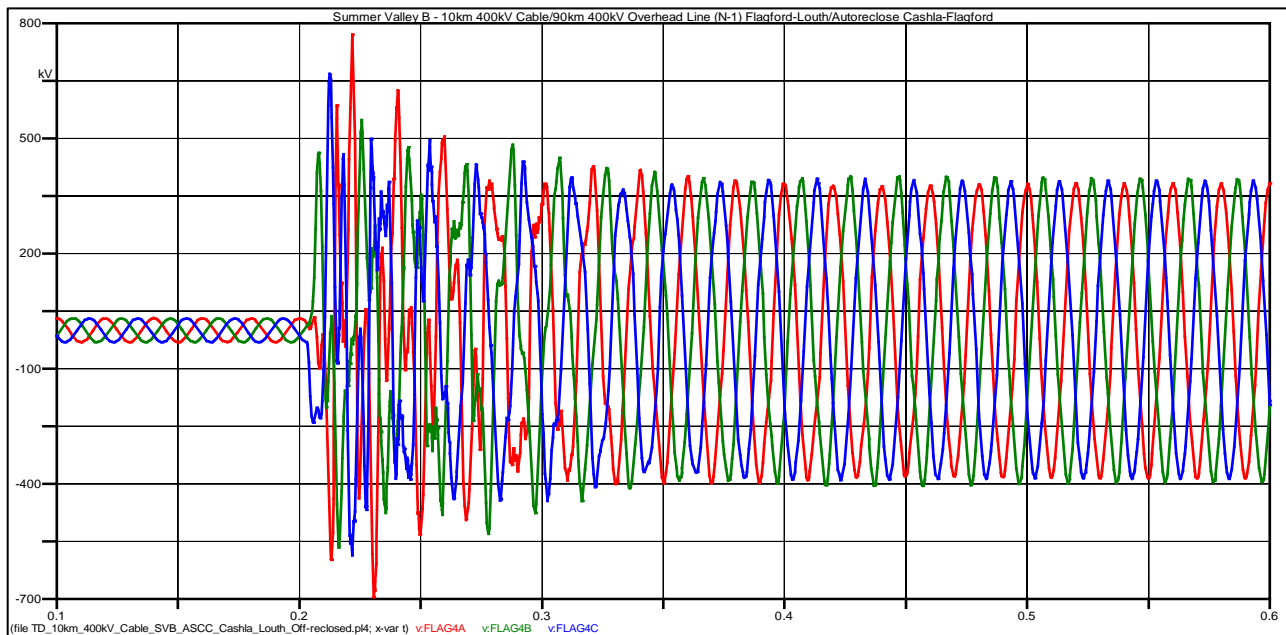


Figure 10: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out Without Reactors (0.1-0.6s)

Condition	Maximum Value	Limit	Result
Switching	786.23 kV (4.378 pu)	449.07 kV (2.5 pu)	Fail*
Temporary Overvoltage	501.23 kV (2.7911 pu)	287.32 kV(1.6 pu)	Fail

*Pass can be achieved with surge arrestors

1.7 Impedance Scan - Length 10km – Summer Valley B – Case 3

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. Reactors – North Mayo 20 Mvar/Flagford 125 Mvar
4. LPA 400 kV Cable Model used w/ 0.566 km PI Sections

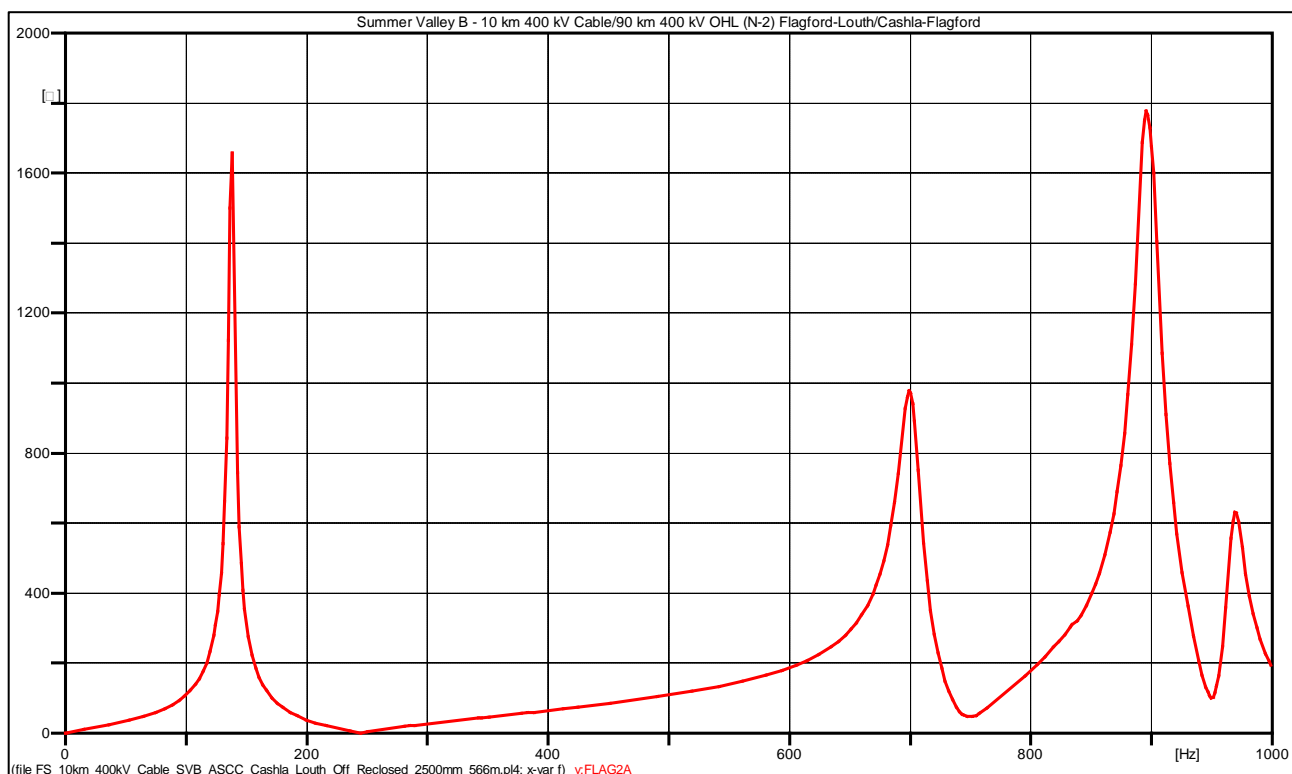


Figure 11: WPA - 90km OHL/10km UGC – Flagford – (N-2) Cashla-Flagford/Flagford-Louth Lines Out/With Reactor

Impedance Scan - Resonance points

Frequency (Hz)	Impedance (Ω)
138.01	1656.6
699.01	977.68
895.51	1777.4
969.01	630.98

1.8 Time Domain - Length 10km – Summer Valley B – Case 3

Conditions for impedance scan:

1. Summer Valley B network
2. North Mayo to Flagford 400 kV Circuit - 10 km Cable/90 km OHL
3. Reactors – North Mayo 20 Mvar/Flagford 125 Mvar
4. LPA 400 kV Cable Model used w/ 0.566 km PI Sections

Case 3: (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out

System Conditions:

1. The Flagford – Louth 220 kV line is on an outage. Fault applied on the Flagford side of Cashla-Flagford line at 10s, removed Fault at 90ms, opened Flagford-Cashla Line breaker at 90ms, reclosed breaker at 110 ms.

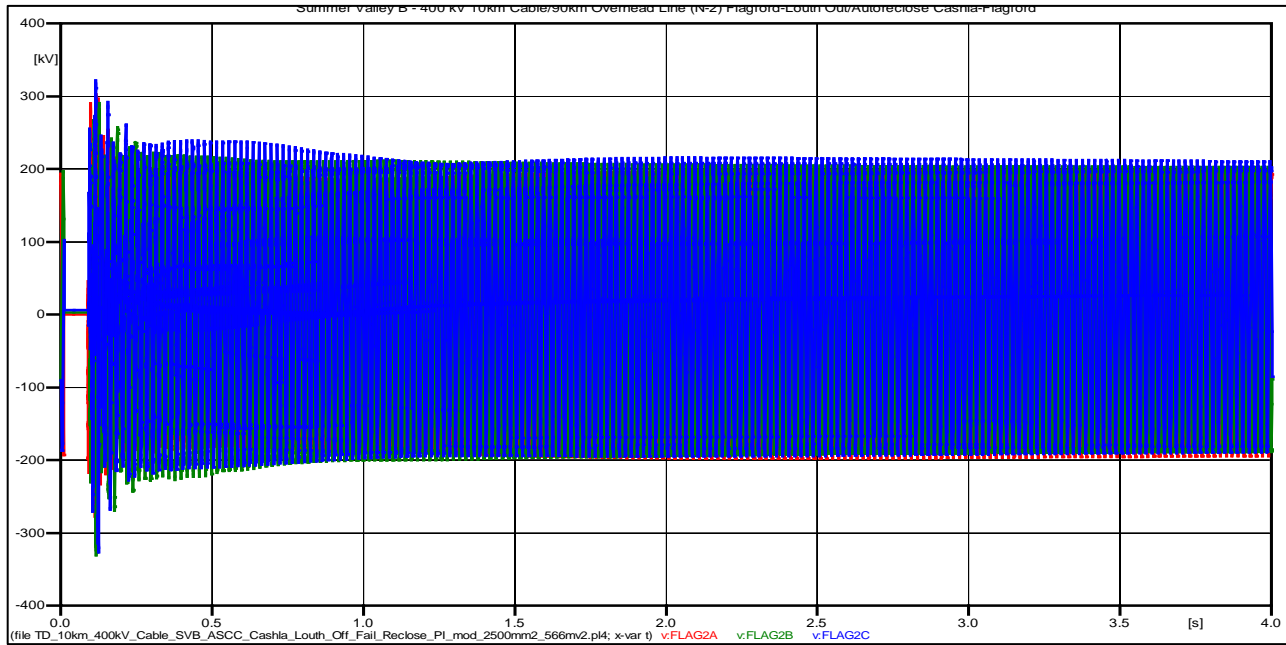


Figure 12: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out/With Reactors (0-4s)

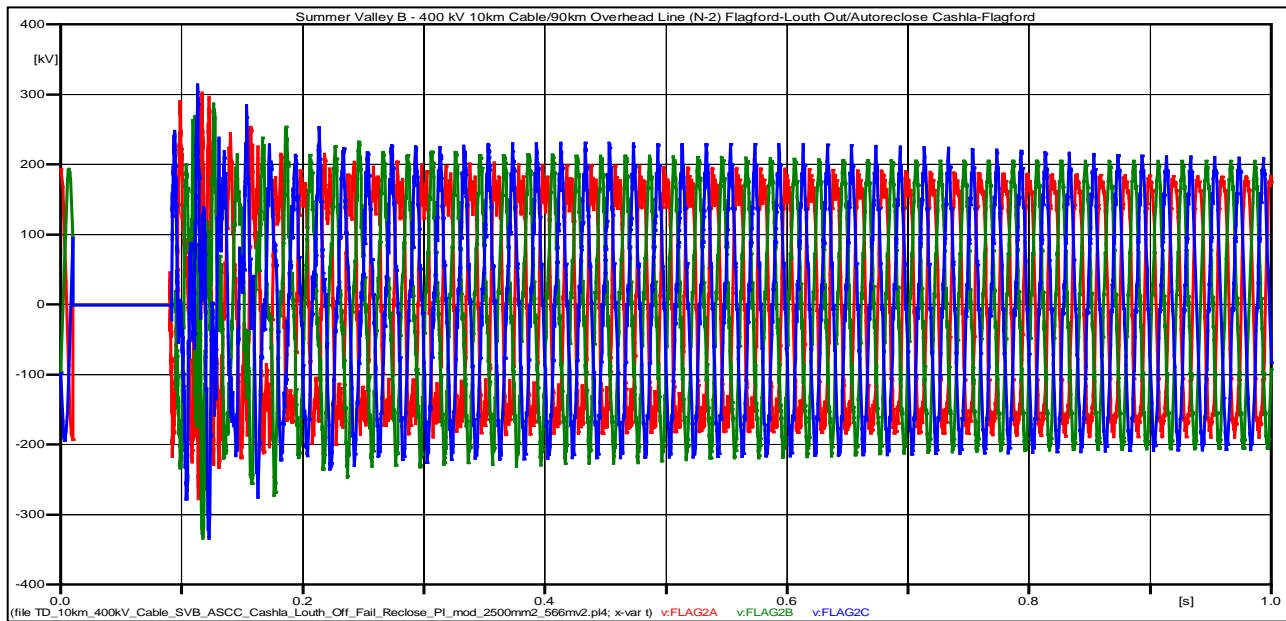


Figure 13: SVB - 90km OHL/10km UGC – Flagford (220kV) – (N-2) Cashla-Flagford Trip/Flagford-Louth Line Out/With Reactors (0-1s)

Condition	Maximum Value	Limit	Result
Switching	315.39 kV (1.755 pu)	449.07 kV (2.5 pu)	Pass
Temporary Overvoltage	272.67 kV (1.5183 pu)	287.32 kV(1.6 pu)	Pass

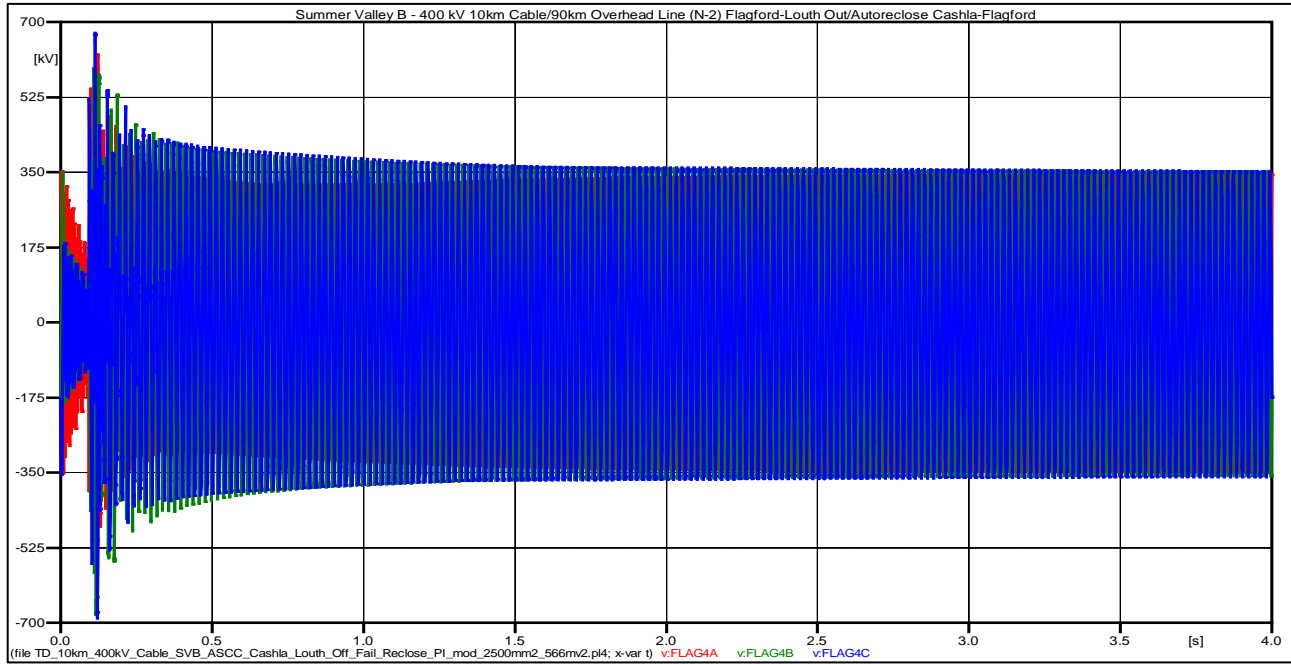


Figure 14: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford/Flagford-Louth Line Out/With Reactors (0-4s)

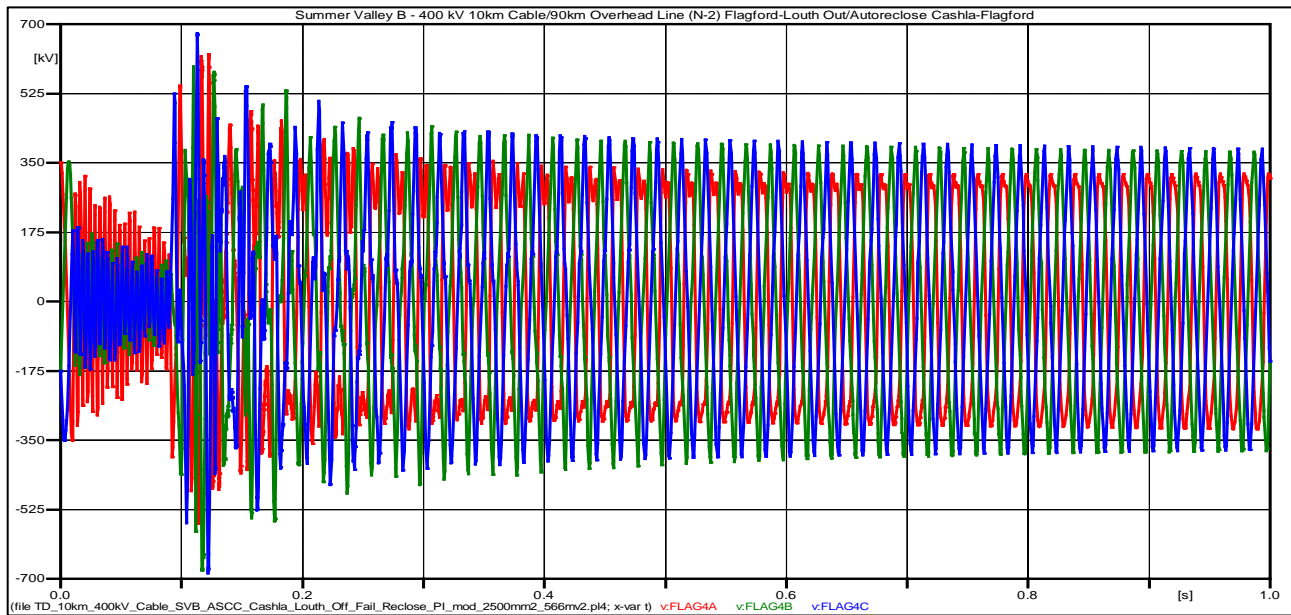


Figure 15: SVB - 90km OHL/10km UGC – Flagford (400kV) – (N-2) Cashla-Flagford/Flagford-Louth Line Out/With Reactors (0-1s)

Condition	Maximum Value	Limit	Result
Switching	676.9 kV (2.0726 pu)	816.49 kV (2.5 pu)	Pass
Temporary Overvoltage	547.2 kV (1.675 pu)	522.55 kV (1.6 pu)	Fail

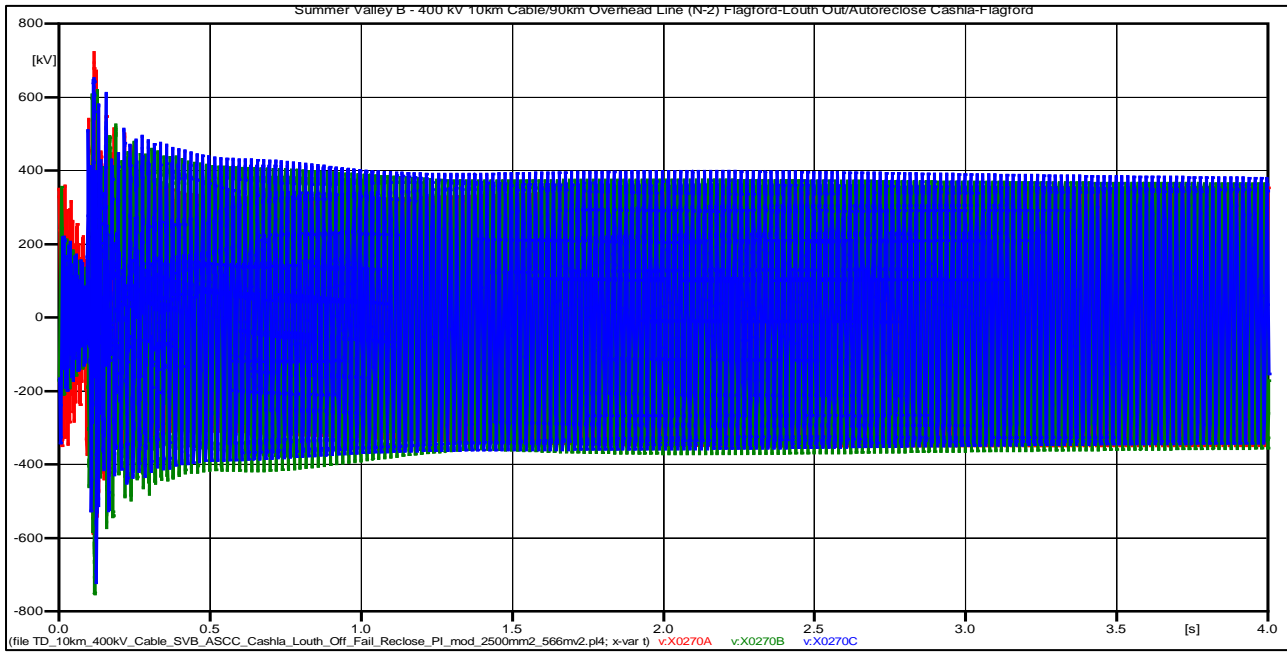


Figure 16: SVB - 90km OHL/10km UGC – North Mayo (400kV) – (N-2) Cashla-Flagford/Flagford-Louth Line Out/With Reactors (0-4s)

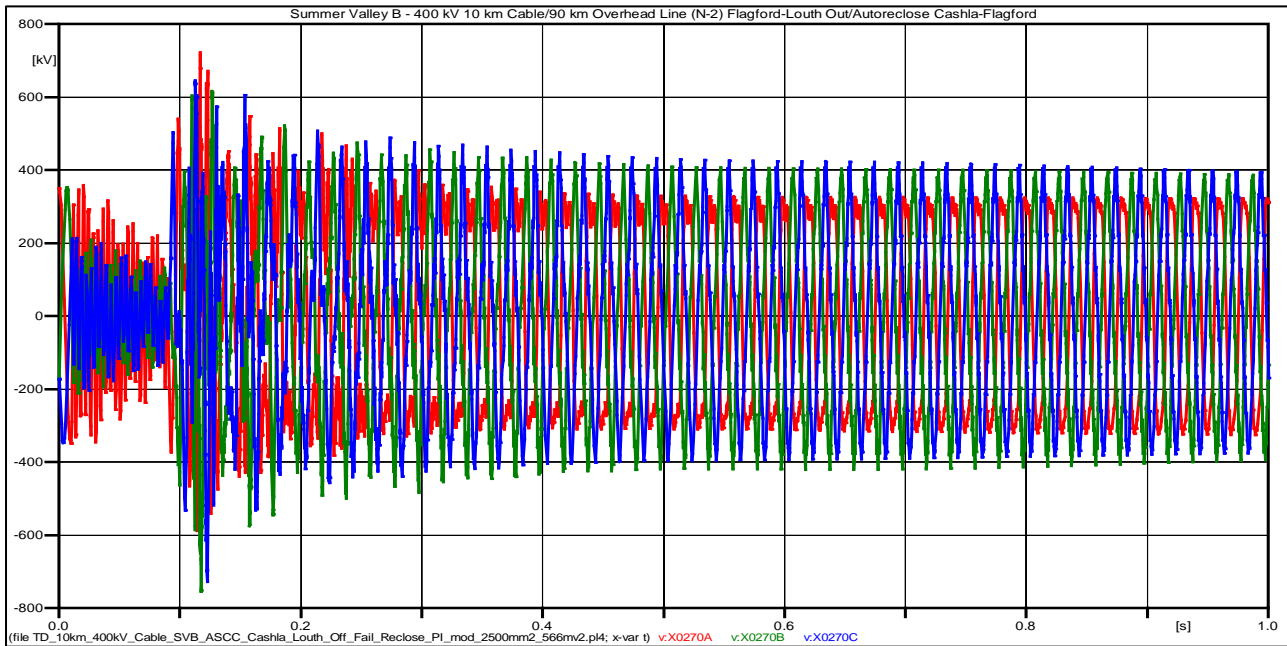


Figure 17: SVB - 90km OHL/10km UGC – North Mayo (400kV) – (N-2) Cashla-Flagford/Flagford-Louth Line Out/With Reactors (0-1s)

Condition	Maximum Value	Limit	Result
Switching	754.72 kV (2.3108 pu)	816.49 kV (2.5 pu)	Pass
Temporary Overvoltage	603.25 kV (1.847 pu)	522.55 kV (1.6 pu)	Fail

It should be noted that these tests were performed without the North Mayo wind farm cables being included. Should these cables be added to the case it would increase the capacitance in the area and further increase TOVs. Additionally, these tests were not performed under the worst case network scenario – an N-2 with Flagford – Louth 220 kV line on outage and an autoreclose onto a permanent fault on Cashla – Flagford 220 kV line. If this test was performed the Switching OverVoltages and TOVs would be exacerbated further.