1 Background

As part of the Anglesey Distribution Network reinforcement scheme, SP Manweb have installed a 2nd 132/33kV Grid Transformer at Caergeiliog substation (GT2). This additional Grid Transformer helps to maintain supplies for the underlying Amlwch/Caergeiliog group on the isle of Anglesey.

The connection to supply GT2 from the National Grid network for this arrangement differs from typical supply arrangements elsewhere in the SP Manweb Network. The connection is ultimately derived from Wylfa GSP (with National Grid owning and operating the 132kV Busbars at Wylfa). The connection for Caergeiliog GT2 is via a teed connection to a National Grid 132kV owned circuit (EV Line) at tower location EV79 which runs from Wylfa to Penrhos and the south of the island. This Tee point location is some 18km from Wylfa.

A newly constructed SP Manweb 132kV circuit connects this "Interface" point to the SP Manweb Network via a 1.4km circuit into Caergeiliog and GT2 and then onto the 33kV busbars. This is illustrated below.

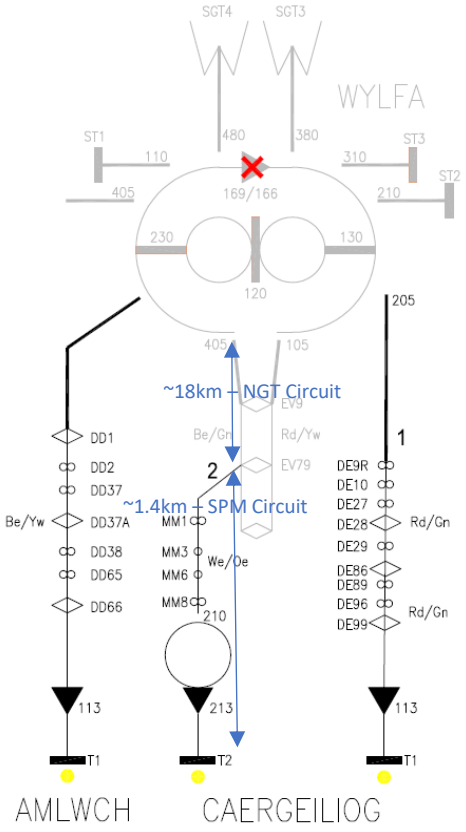


Figure 1 - Outline supply arrangement (Wylfa)

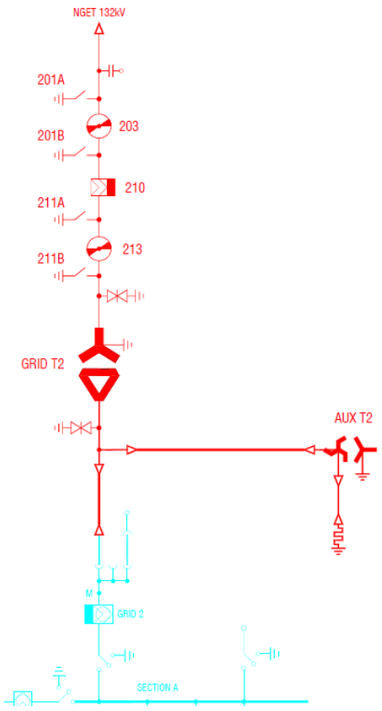


Figure 2 – Operational Diagram - (Caergeiliog GT2)

Due to the remote location and practicalities of locating a meter at the National Grid / SP Manweb interface point and tee off point on tower EV79, a dispensation is required as it is proposed the metered is located at Caergeiliog and at 33kV.

The losses therefore with the SPM network assets from the metering location at Caergeiliog GT2/33kV to the EV79 Tee off point at the 132kV interface needs to be taken into account as these would not be accounted for at the remote metering location as they would be upstream of the meters location and so not be visible.

2 SLD

The diagram below shows a single line diagram representation of the connection from the tower EV79 Tee off to Caergeiliog GT2/33kV.

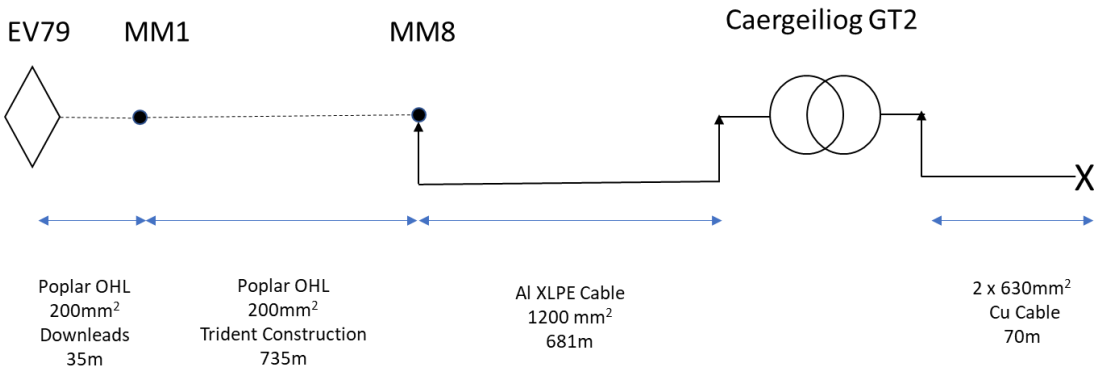


Figure 3 – SLD

3 Impedance data used

3.1 Conductors 132kV

The conductors used are standard supplied equipment. As such, their impedance, reactance and resistance values already exist with the SPM Manweb IPSA Power system model and conductor database. Further information on the installed span lengths are provided in Appendix A.

In summary the base impedance information for the 132kV circuits is illustrated below. Note that a typical modelling system base of 100MVA has been applied as unless otherwise stated.

Base Impedance		R1, pu per km	X1, pu per km	R0, pu per km	X0, pu per km	B, uS pu per km
200mm AAAC Poplar	OHL - Trident	0.0007461	0.002169	0.0015509	0.007504	0.000535
1200mm XLPE AL Cable	Cable - Ducte	0.017219251	0.009090909	0.056684492	0.034224599	0.000143336
Circuit data used		**R1, pu**	**X1, pu**	**R0, pu**	**X0, pu**	**B, uS pu**
200mm AAAC Poplar	OHL - Trident	0.000574146	0.001669111	0.001193464	0.005774553	0.000411699
1200mm XLPE AL Cable	Cable - Ducte	0.01172631	0.006190909	0.038602139	0.023306952	9.76115E-05
	Total	**0.0123005**	**0.0078600**	**0.0397956**	**0.0290815**	**0.0005093**

3.2 Conductors 33kV

The base impedance information for the 33kV circuit (GT2 Tails) is illustrated below.

Base Impedance		R1, pu per km	X1, pu per km	R0, pu per km	X0, pu per km	B, uS pu per km
1 x 630mm CU XLPE		0.003857	0.009231	0.01157	0.009231	0.001163
2 x 630mm CU XLPE		0.0019285	0.0046155	0.005785	0.0046155	0.002326
Circuit data used		**R1, pu**	**X1, pu**	**R0, pu**	**X0, pu**	**B, uS pu**
2 x 630mm CU XLPE		**0.0001350**	**0.0003231**	**0.0004050**	**0.0003231**	**0.0001628**

The IPSA model data tables are also provided in Appendix B for completeness and shows agreement with the data tables here.

3.3 Caergeiliog 132/33kV GT2

The actual Grid transformer name plate Impedance information is provided in Appendix C for completeness. SP Manweb has a standard 60MVA Grid transformer specification and impedance envelope (typically 20% impedance on rating). This is necessary to ensure system fault level infeed compliance and voltage regulation. Transformer X/R ratios of 25 and zero sequence to positive sequence impedance ratios of 85% are typical.

It is important to note that, in this instance, these values are solely for load flow purposes as the Grid Transformer losses are specified and shown in Appendix C on the nameplate. These losses are therefore taken into account in the calculations as they are based on the transformers FAT measurement results (Factory Acceptance Test) and so it is prudent to use these.

4 Modelling

4.1 IPSA V2 Model

An IPSA model was established to calculate the circuit losses. The values used in the IPSA model are shown in Appendix B, and are based on the data previously discussed. This data matches that within the SPM complete network model, but this simple model was created for simplicity. The model is illustrated below.

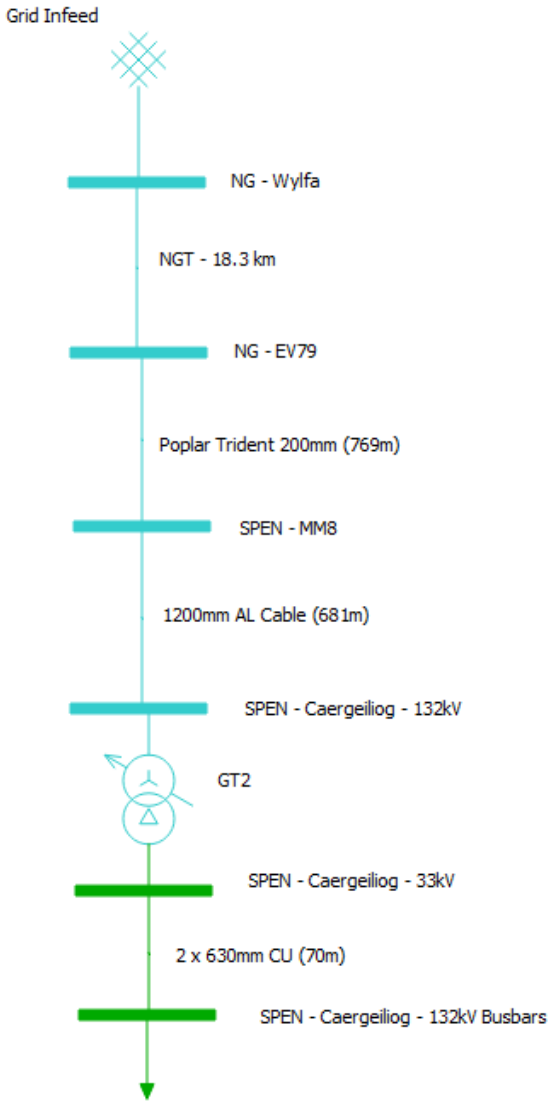


Figure 4 – IPSA Model

4.2 Losses - Circuit

Circuit losses were calculated using IPSA for a range of transformer loadings, up to the rating of the transformer at 60 MVA. This was done for unity power factor and a power factor of 0.95. The diagram below shows the losses for a transformer load factor of 0.3, 0.6 and 1, or 20, 40 and 60MVA.

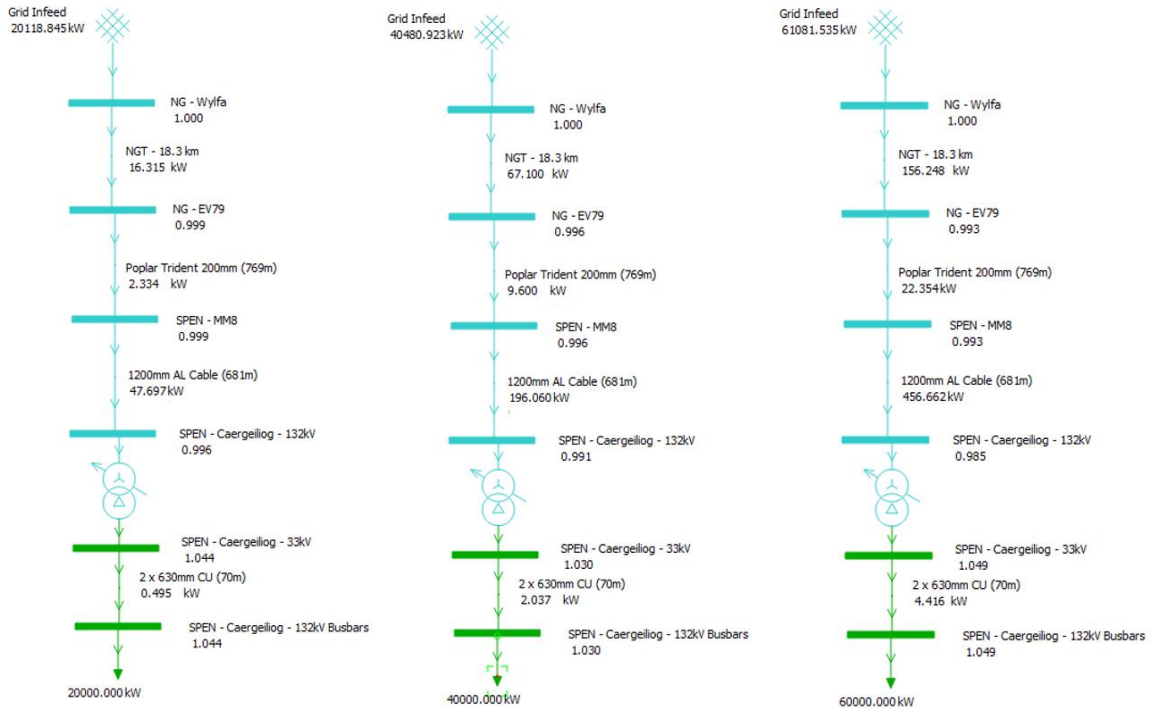


Figure 5 – IPSA Model example circuit losses for transformer load factor of 0.3, 0.6 & 1 at UPF

As mentioned before, we are only concerned with the losses from the NG – EV79 location to Caergeiliog. The losses therefore for the upstream National Grid line is illustrated but has been omitted from the summations. The values for the model for the National Grid EV line was provided to SPEN and is the same as that used within this and the SPEN whole system model.

Circuit ohmic losses are typically proportional to the square of the current, and this can be seen from above.

4.3 Losses - Transformer

As shown in Appendix C, the transformer name plate shows the losses within the 60MVA GT2 as P0=17.08kW and Pk=185.68kW. These have therefore been applied and again have been on a basis they are proportional to the square of the transformer load factor.

4.4 Losses - Adjustment

From the IPSA results, data outlined and shown in the Appendices, an adjustment curve can be derived and applied to the actual observed metered reading. This adjustment takes cognisance of the inferred upstream losses from the 33kV meter location to the EV79 POC as a result of SPM's:

1. 33kV Grid Transformer tails (2 x 630mm^2 CU Cable – 70m)
2. 132/33kV Caergeiliog GT 2 (60MVA – 20.27% on rating)
3. MM 132kV circuit from Caergeiliog to EV79 Tee location
    a. Cable section (1200mm^2 AL Cable – 681m)
    b. OHL Trident section (200mm^2 Poplar OHL – 735m)
    c. Downleads (200mm^2 Poplar OHL –35m)

Note the Figure 6 and the proposed measured kW adjustment has an intercept of 17.08kW, as this takes into account the no load losses for Caergeiliog GT 2 as per nameplate.

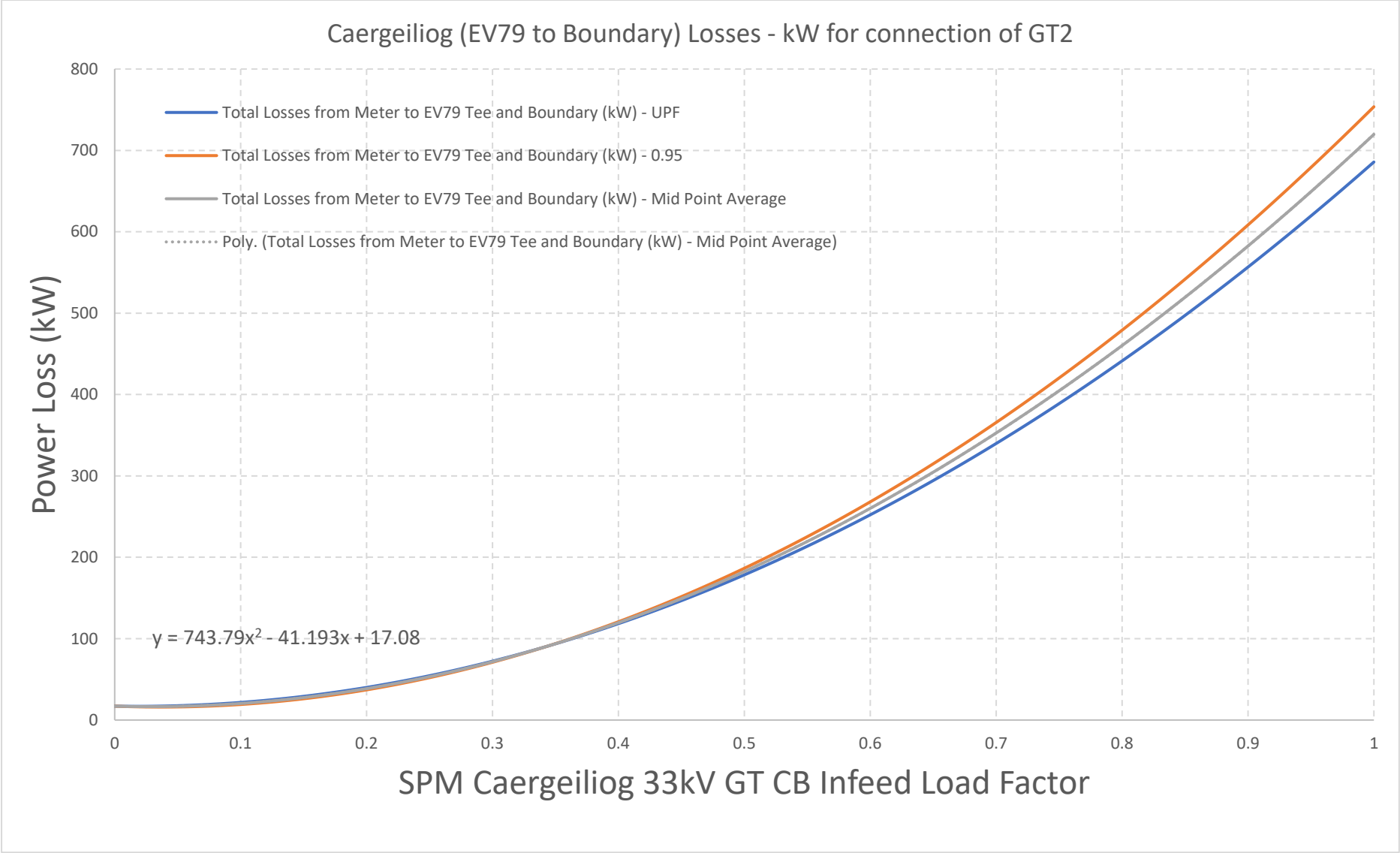


Figure 6 – Caergeiliog (EV79 to Boundary) Losses - kW for connection of GT2

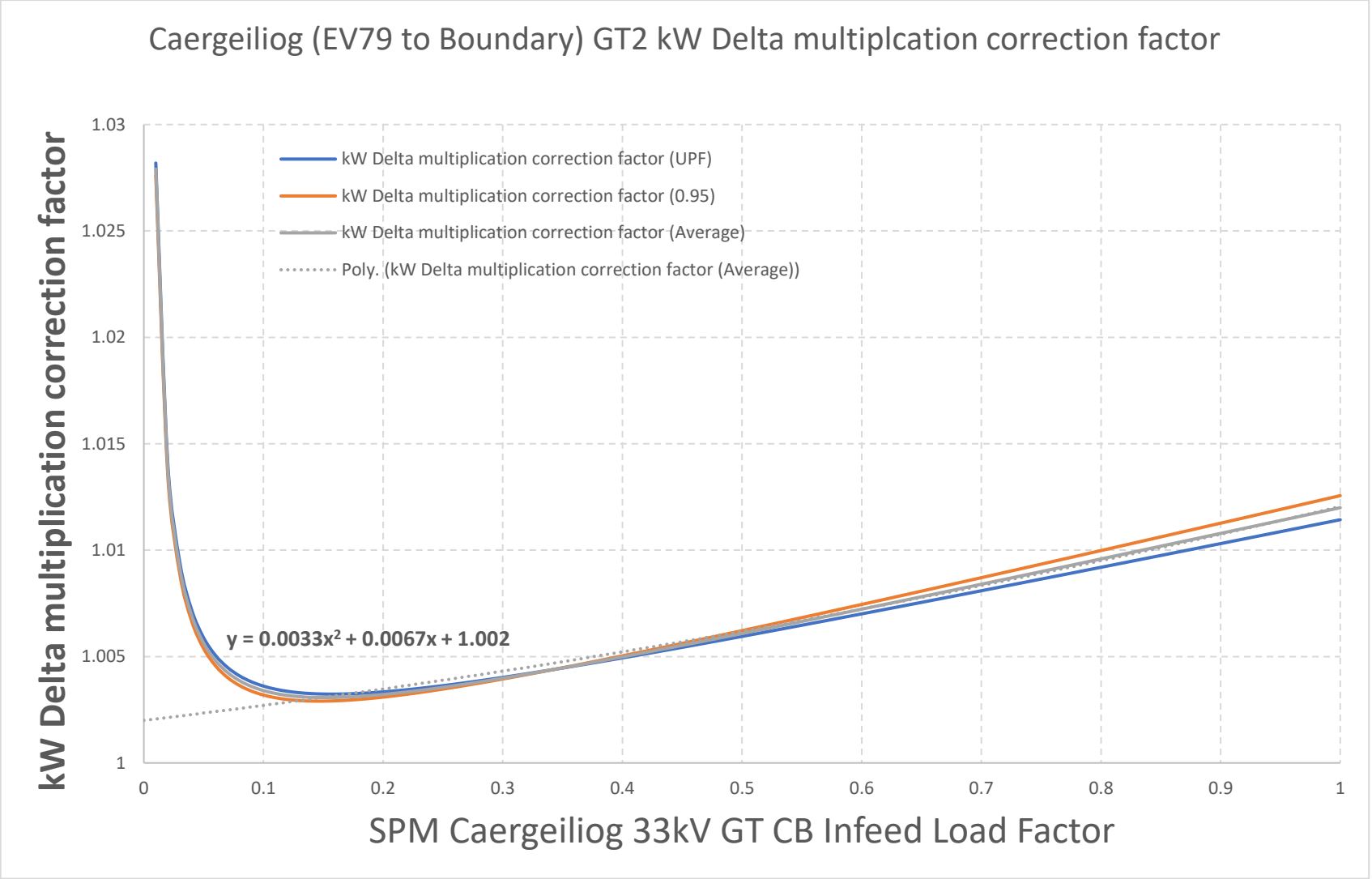


Figure 7 – Caergeiliog (EV79 to Boundary) Losses - kW for connection of GT2

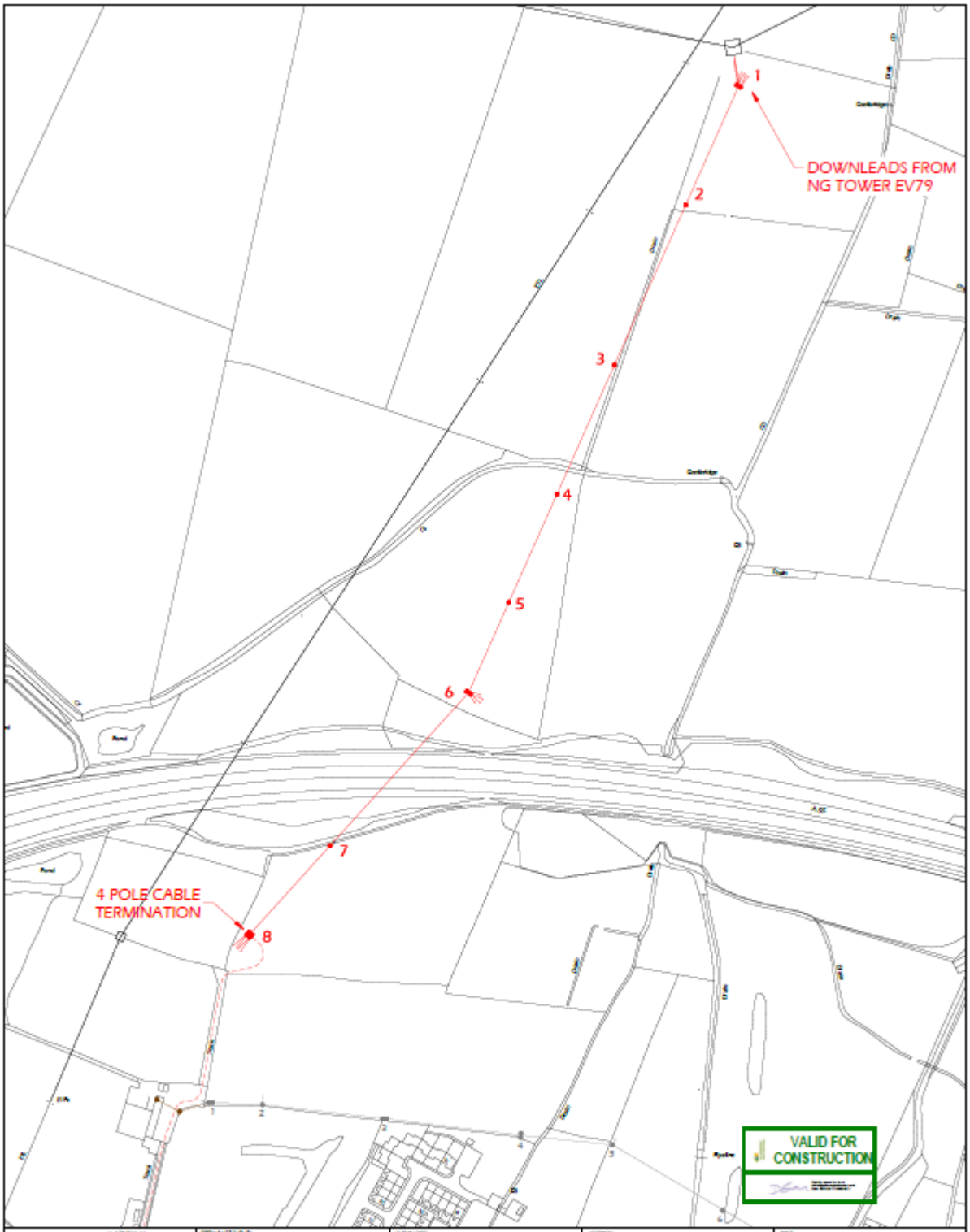
Overhead Line Schedule

Project Title	Anglesey Reinforcement	**Date**	01-08-17	**Status**	Issued
Specification	ENA 43-50 Issue 2	**Route Length**	734m	**Revision**	A
Conductor Details	200mm² AAAC "Poplar" Equivalent OPPC Conductor	**Prepared by**	PWJ	**A.O.D**	3m
Weather Area	Non Severe	**Checked by**	EAJ	**Voltage**	132kV

SP ENERGY NETWORKS

Pole Details						Line Details			Insulators			Stay Details			Drawing Number	Remarks
No.	Type	Length	Butt Dia.	Planting Depth	Class	Span	Section	Angle	Pin	Pilot	Tension	No. Stays	Size	Spread		
1	TERMINAL H-POLE	12	330	2.00	3	0.00		0.0C			3	4	7/4.00	10	435011	Downleads from NG TWR EV79
2	INTER 2.5m ARM	12	350	2.75	F	96.40			3						435007	
3	INTER 2.5m ARM	13	365	3.00	F	129.67			3						435007	
4	INTER 2.5m ARM	15	385	2.75	F	104.65			3						435007	
5	INTER 2.5m ARM	13	365	2.75	F	87.82			3						435007	
6	ANGLE H-POLE	12	320	2.00	2	73.09	491.63	18.1R		3	6	6	7/4.00	10	435010	Failure Containment Structure
7	INTER 2.5m ARM	12	385	2.75	H	152.76									435007	
8	TERMINAL H-POLE	15	370	2.00	2	90.14	242.9				3	4	7/4.00	13	435011	4 Pole Cable Terminal Structure

VALID FOR CONSTRUCTION



LINE DESIGN TECHNOLOGY

SP ENERGY NETWORKS

CAERGEILIOG

PROPOSED 132KV

OVERHEAD LINE

ISSUED

Metres

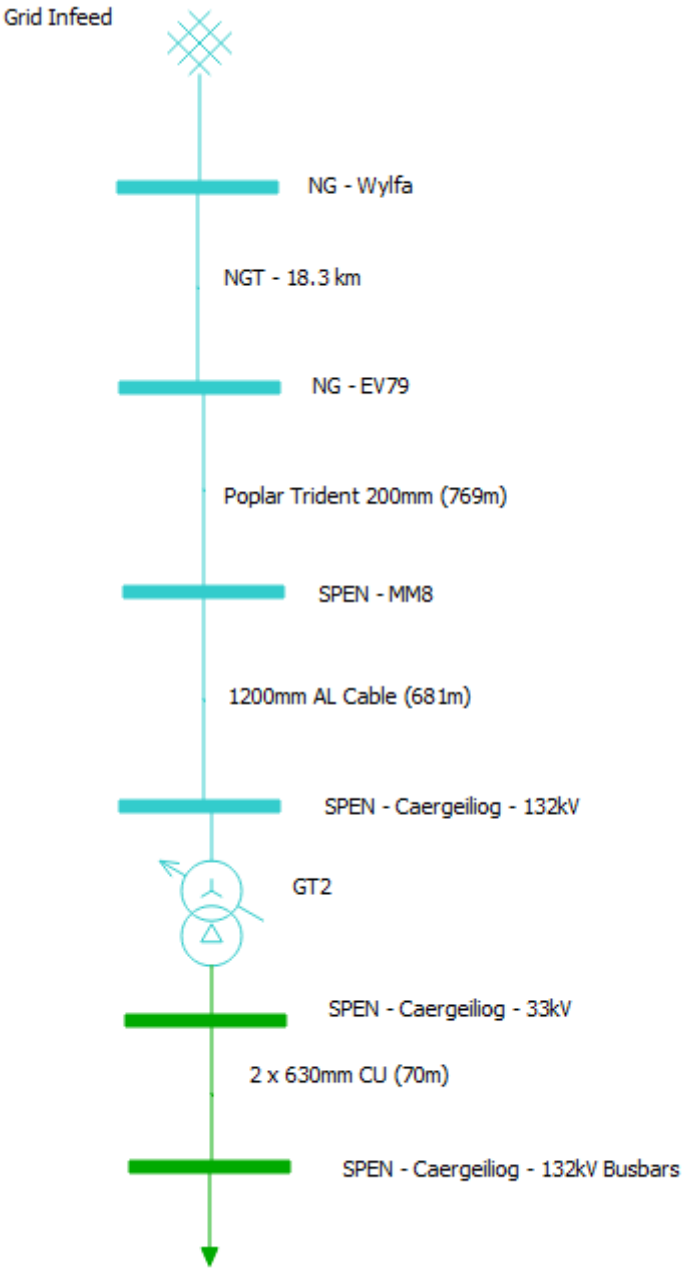
B

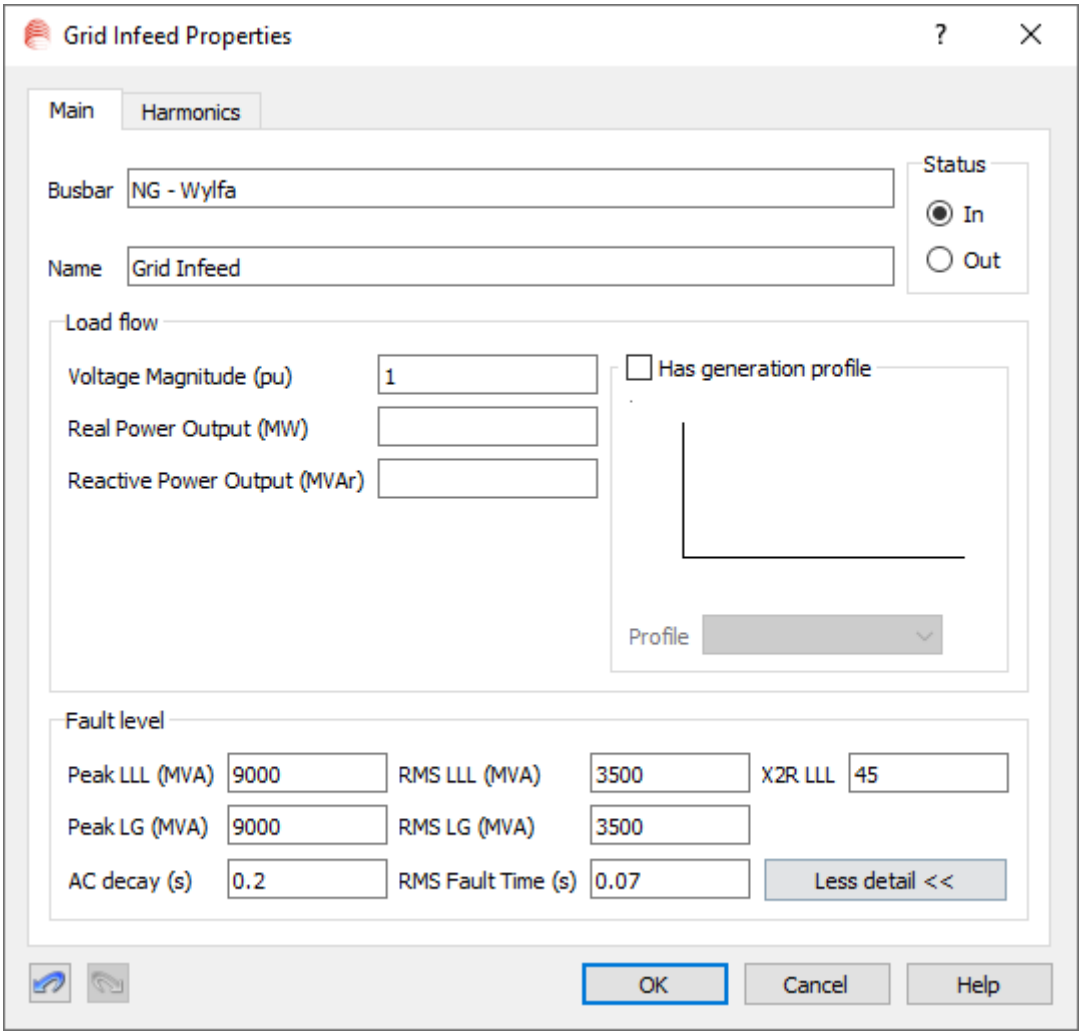
LDT-256-ARF-SRP-006

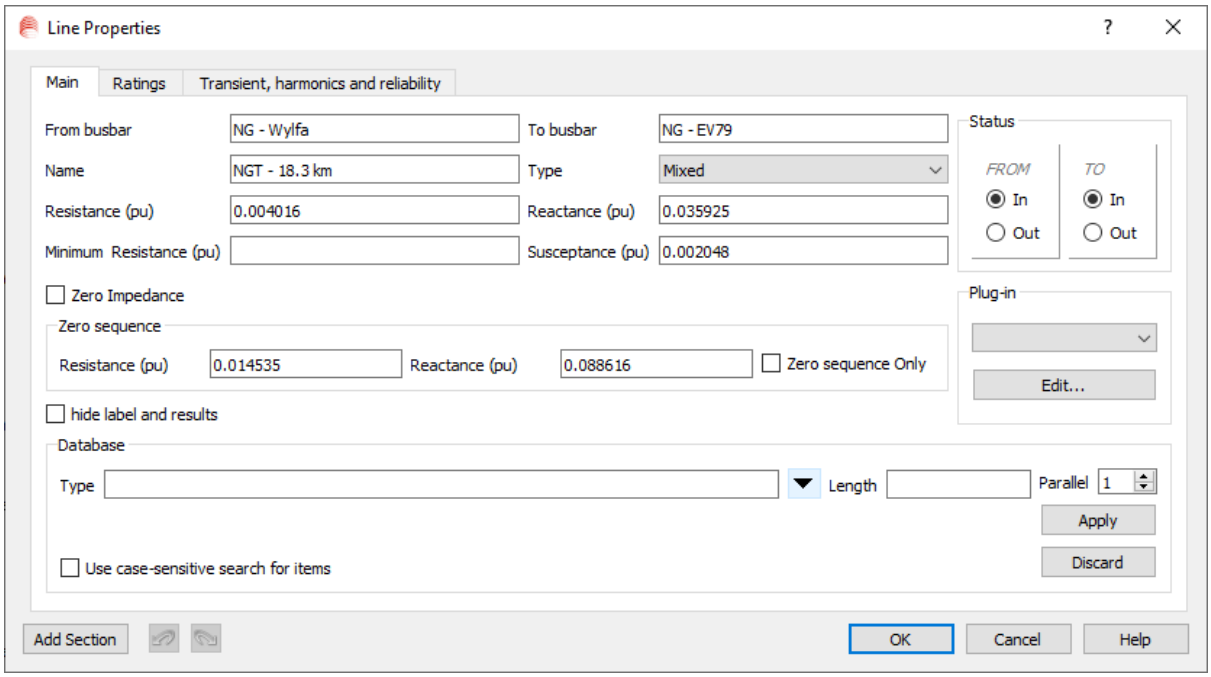
1 of 1

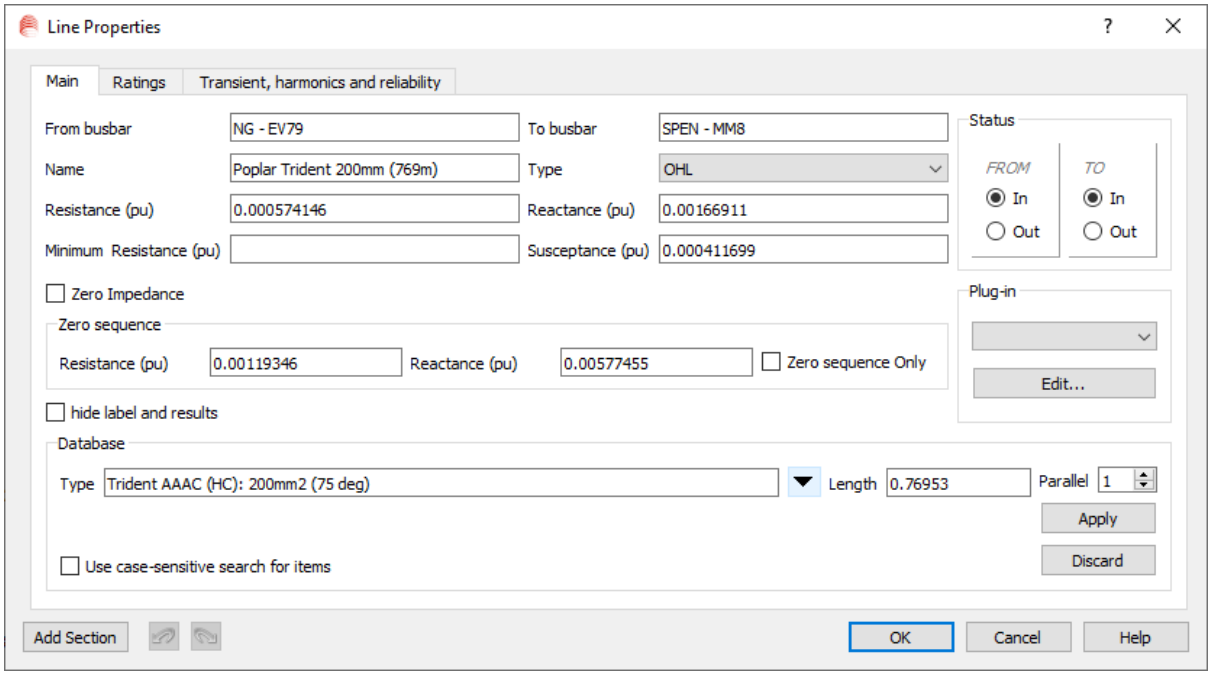
A3

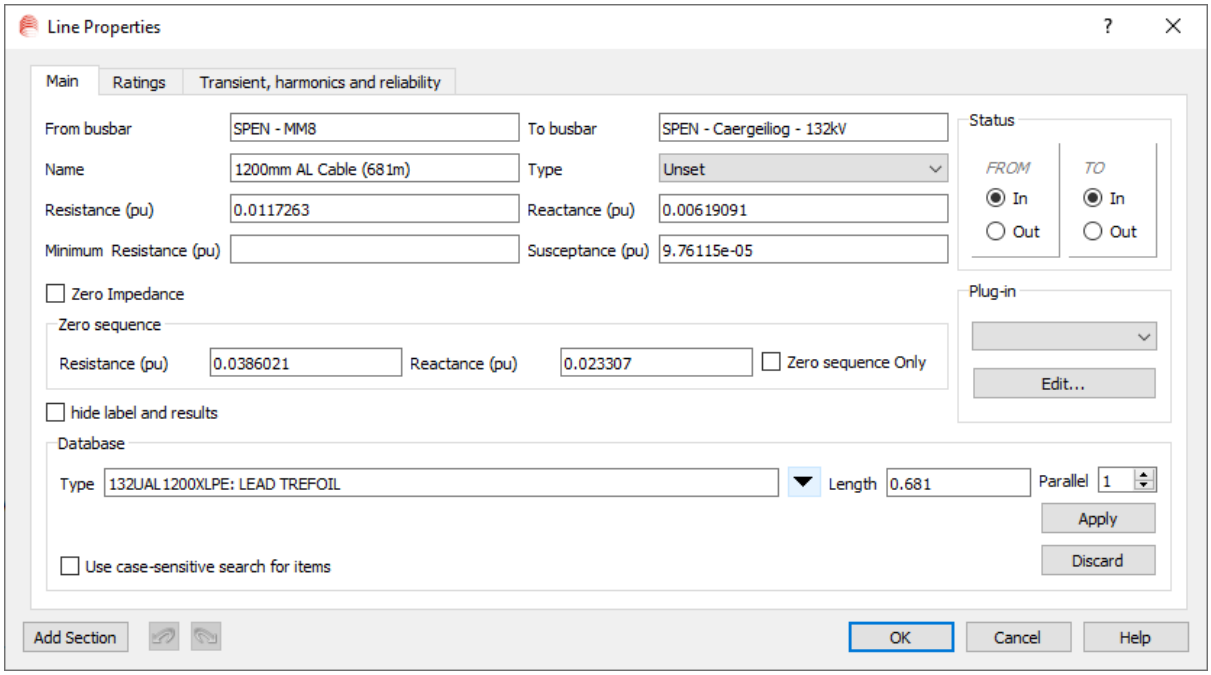
Appendix B – IPSA Model

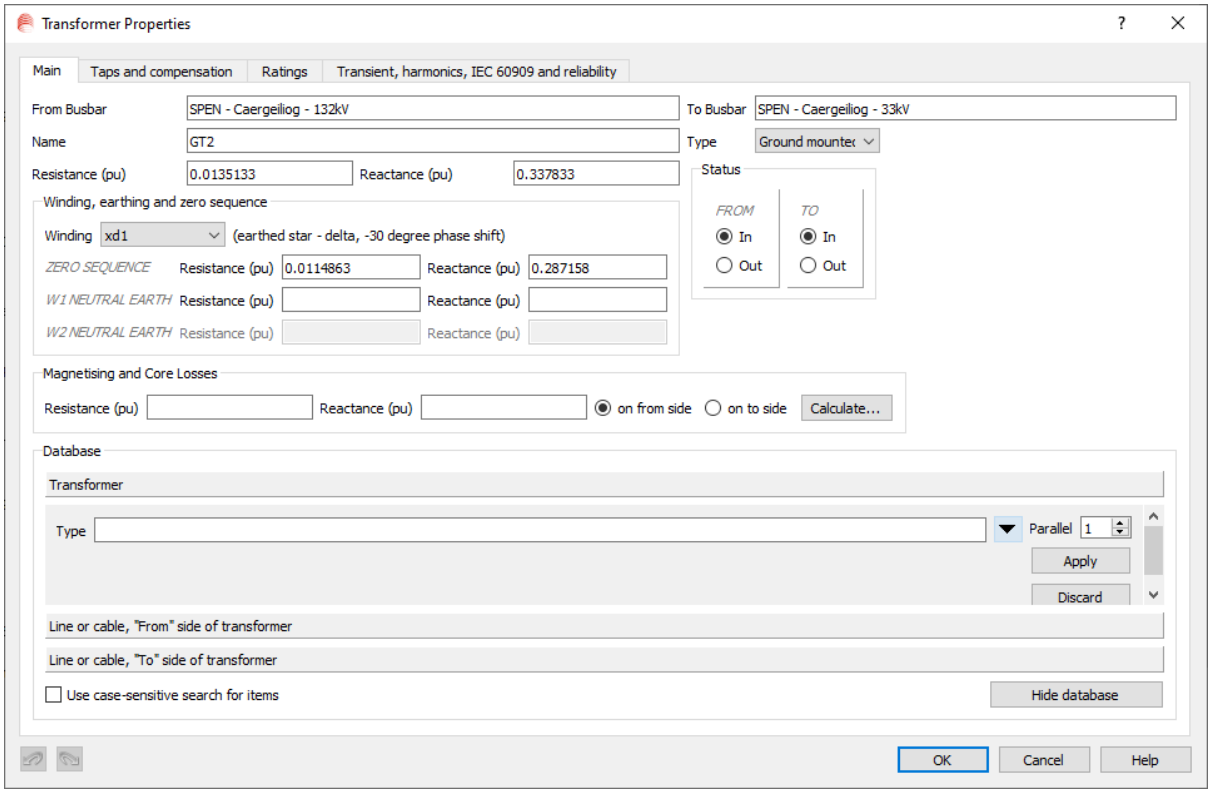


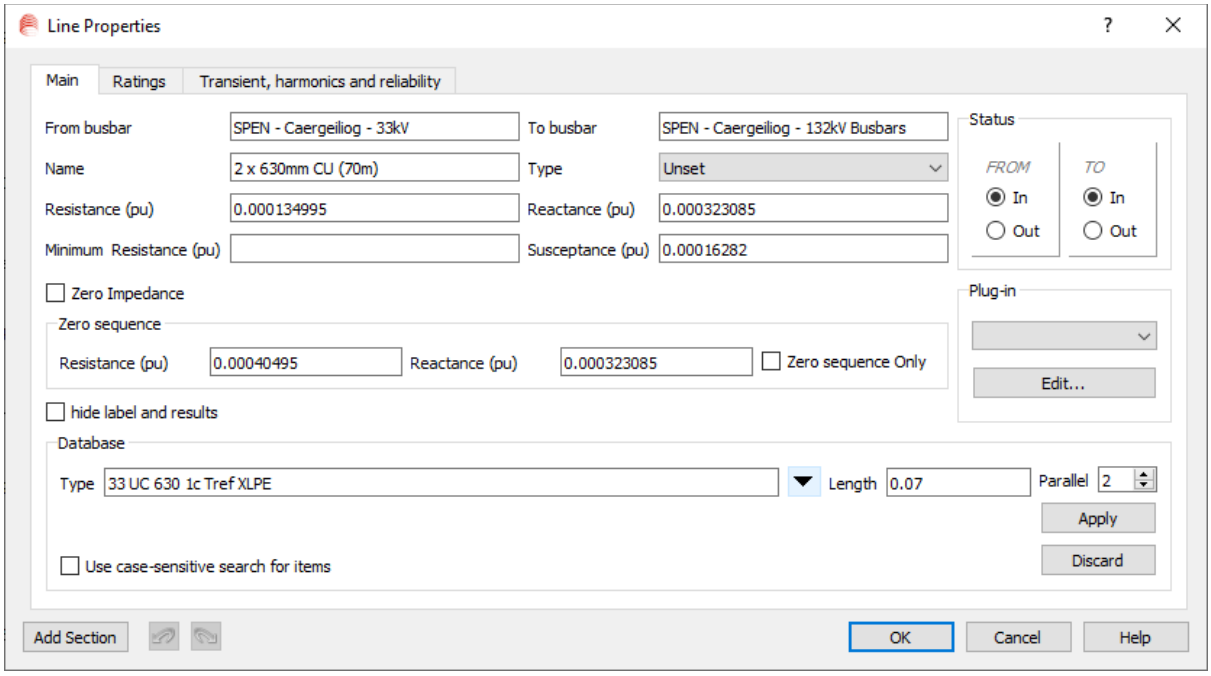

Grid Infeed Properties
Main
Harmonics
Busbar
NG - Wylfa
Name
Grid Infeed
Status
In
Out
Load flow
Voltage Magnitude (pu)
1
Real Power Output (MW)
Reactive Power Output (MVAr)
Has generation profile
Profile
Fault level
Peak LLL (MVA)
9000
RMS LLL (MVA)
3500
X2R LLL
45
Peak LG (MVA)
9000
RMS LG (MVA)
3500
AC decay (s)
0.2
RMS Fault Time (s)
0.07
Less detail <<
OK
Cancel
Help


Line Properties
Main
Ratings
Transient, harmonics and reliability
From busbar
NG - Wylfa
To busbar
NG - EV79
Name
NGT - 18.3 km
Type
Mixed
Resistance (pu)
0.004016
Reactance (pu)
0.035925
Minimum Resistance (pu)
Susceptance (pu)
0.002048
Status
FROM
TO
In
Out
Zero Impedance
Zero sequence
Resistance (pu)
0.014535
Reactance (pu)
0.088616
Zero sequence Only
Plug-in
Edit...
hide label and results
Database
Type
Length
Parallel
1
Apply
Discard
Use case-sensitive search for items
Add Section
OK
Cancel
Help

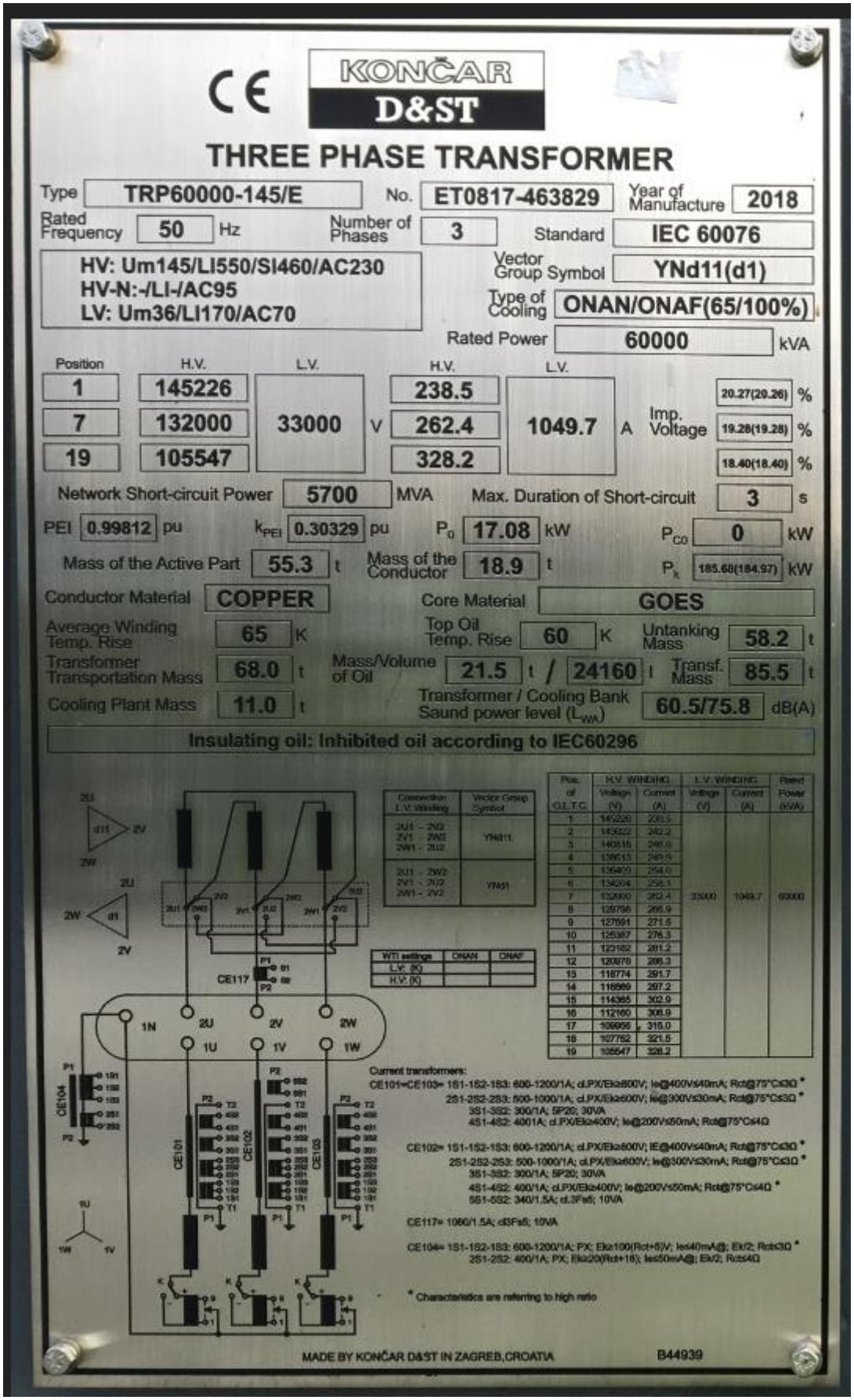

Line Properties
Main
Ratings
Transient, harmonics and reliability
From busbar
NG - EV79
To busbar
SPEN - MM8
Name
Poplar Trident 200mm (769m)
Type
OHL
Resistance (pu)
0.000574146
Reactance (pu)
0.00166911
Minimum Resistance (pu)
Susceptance (pu)
0.000411699
Status
FROM
TO
In
Out
Zero Impedance
Plug-in
Zero sequence
Resistance (pu)
0.00119346
Reactance (pu)
0.00577455
Zero sequence Only
Edit...
hide label and results
Database
Type
Trident AAAC (HC): 200mm2 (75 deg)
Length
0.76953
Parallel
1
Apply
Discard
Use case-sensitive search for items
Add Section
OK
Cancel
Help


Line Properties
Main
Ratings
Transient, harmonics and reliability
From busbar
SPEN - MM8
To busbar
SPEN - Caergeiliog - 132kV
Name
1200mm AL Cable (681m)
Type
Unset
Resistance (pu)
0.0117263
Reactance (pu)
0.00619091
Minimum Resistance (pu)
Susceptance (pu)
9.76115e-05
Status
FROM
TO
In
Out
Zero Impedance
Plug-in
Zero sequence
Resistance (pu)
0.0386021
Reactance (pu)
0.023307
Zero sequence Only
Edit...
hide label and results
Database
Type
132UAL1200XLPE: LEAD TREFOIL
Length
0.681
Parallel
1
Apply
Discard
Use case-sensitive search for items
Add Section
OK
Cancel
Help


Transformer Properties
Main
Taps and compensation
Ratings
Transient, harmonics, IEC 60909 and reliability
From Busbar
SPEN - Caergeiliog - 132kV
To Busbar
SPEN - Caergeiliog - 33kV
Name
GT2
Type
Ground mounte
Resistance (pu)
0.0135133
Reactance (pu)
0.337833
Status
FROM
In
Out
TO
In
Out
Winding, earthing and zero sequence
Winding
xd1
(earthed star - delta, -30 degree phase shift)
ZERO SEQUENCE
Resistance (pu)
0.0114863
Reactance (pu)
0.287158
W1 NEUTRAL EARTH
Resistance (pu)
Reactance (pu)
W2 NEUTRAL EARTH
Resistance (pu)
Reactance (pu)
Magnetising and Core Losses
Resistance (pu)
Reactance (pu)
on from side
on to side
Calculate...
Database
Transformer
Type
Parallel
1
Apply
Discard
Line or cable, "From" side of transformer
Line or cable, "To" side of transformer
Use case-sensitive search for items
Hide database
OK
Cancel
Help


Line Properties
Main
Ratings
Transient, harmonics and reliability
From busbar
SPEN - Caergeiliog - 33kV
To busbar
SPEN - Caergeiliog - 132kV Busbars
Name
2 x 630mm CU (70m)
Type
Unset
Resistance (pu)
0.000134995
Reactance (pu)
0.000323085
Minimum Resistance (pu)
Susceptance (pu)
0.00016282
Status
FROM
In
Out
TO
In
Out
Zero Impedance
Plug-in
Edit...
Zero sequence
Resistance (pu)
0.00040495
Reactance (pu)
0.000323085
Zero sequence Only
hide label and results
Database
Type
33 UC 630 1c Tref XLPE
Length
0.07
Parallel
2
Apply
Discard
Use case-sensitive search for items
Add Section
OK
Cancel
Help

Appendix C – Caergeiliog GT2 Namplate



KONČAR D&ST

THREE PHASE TRANSFORMER

Type	TRP60000-145/E	No.	ET0817-463829	Year of Manufacture	2018		
Rated Frequency	50 Hz	Number of Phases	3	Standard	IEC 60076		
HV: Um145/LI550/SI460/AC230 HV-N:-/LI-/AC95 LV: Um36/LI170/AC70				Vector Group Symbol	YNd11(d1)		
				Type of Cooling	ONAN/ONAF(65/100%)		
				Rated Power	60000 kVA		

Position	H.V.	L.V.	H.V.	L.V.		
1	145226	33000 V	238.5	1049.7 A	Imp. Voltage	20.27(20.26) %
7	132000		262.4			19.28(19.28) %
19	105547		328.2			18.40(18.40) %

Network Short-circuit Power	5700 MVA	Max. Duration of Short-circuit	3 s				
PEI	0.99812 pu	k_{PEI}	0.30329 pu	P_0	17.08 kW	P_{CO}	0 kW
Mass of the Active Part	55.3 t	Mass of the Conductor	18.9 t			P_k	185.68(184.97) kW
Conductor Material	COPPER	Core Material	GOES				
Average Winding Temp. Rise	65 K	Top Oil Temp. Rise	60 K	Untanking Mass	58.2 t		
Transformer Transportation Mass	68.0 t	Mass/Volume of Oil	21.5 t / 24160 l	Transf. Mass	85.5 t		
Cooling Plant Mass	11.0 t	Transformer / Cooling Bank Saund power level (L_{WA})	60.5/75.8 dB(A)				

Insulating oil: Inhibited oil according to IEC60296

Connection L.V. Winding	Vector Group Symbol
2U1 - 2V2 2V1 - 2W2 2W1 - 2U2	YNd11
2U1 - 2W2 2V1 - 2U2 2W1 - 2V2	YNd1

WTI settings	ONAN	ONAF
L.V. (K)		
H.V. (K)		

Pos. of O.L.T.C.	H.V. WINDING Voltage (V)	H.V. WINDING Current (A)	L.V. WINDING Voltage (V)	L.V. WINDING Current (A)	Rated Power (kVA)
1	145226	238.5			
2	143822	242.2			
3	140418	246.0			
4	139015	249.9			
5	136409	254.0			
6	134004	258.1			
7	132000	262.4	33000	1049.7	60000
8	129796	266.9			
9	127591	271.5			
10	125387	276.3			
11	123182	281.2			
12	120978	286.3			
13	118774	291.7			
14	116969	297.2			
15	114365	302.9			
16	112160	308.9			
17	109956	315.0			
18	107752	321.5			
19	105547	328.2			

Current transformers:
CE101÷CE103÷ 1S1-1S2-1S3: 600-1200/1A; cl.PX/Ek≥800V; Ie@400V≤40mA; Rct@75°C≤3Ω *
2S1-2S2-2S3: 500-1000/1A; cl.PX/Ek≥600V; Ie@300V≤30mA; Rct@75°C≤3Ω *
3S1-3S2: 300/1A; 5P20; 30VA
4S1-4S2: 4001A; cl.PX/Ek≥400V; Ie@200V≤50mA; Rct@75°C≤4Ω

CE102÷ 1S1-1S2-1S3: 600-1200/1A; cl.PX/Ek≥800V; IE@400V≤40mA; Rct@75°C≤3Ω *
2S1-2S2-2S3: 500-1000/1A; cl.PX/Ek≥600V; Ie@300V≤30mA; Rct@75°C≤3Ω *
3S1-3S2: 300/1A; 5P20; 30VA
4S1-4S2: 400/1A; cl.PX/Ek≥400V; Ie@200V≤50mA; Rct@75°C≤4Ω *
5S1-5S2: 340/1,5A; cl.3Fs5; 10VA

CE117÷ 1060/1.5A; cl3Fs5; 10VA

CE104÷ 1S1-1S2-1S3: 600-1200/1A; PX; Ek≥100(Rct+5)V; Ie≤40mA@; Ek/2; Rct≤3Ω *
2S1-2S2: 400/1A; PX; Ek≥20(Rct+16); Ie≤50mA@; Ek/2; Rct≤4Ω

* Characteristics are referring to high ratio

MADE BY KONČAR D&ST IN ZAGREB,CROATIA B44939