electricity north west

Bringing energy to your door

Code of Practice 204

Issue 4 May 2023

Network Component Impedance Data

Amendment Summary

ISSUE NO. DATE	DESCRIPTION
Issue 4	Updated to new template.
May 2023	Prepared by: Peter Twomey Approved by: Policy Approval Panel and signed on its behalf by Steve Cox, DSO Director

Contents

1 Introduction

To facilitate consistent operation and design of the distribution network (the Network) of Electricity North West Limited, including the application of protection systems, one source of component impedance values must be available. Computer packages that perform fault level and load flow calculations require such data and, similarly, those for the design of the network, either by manual calculation or by the use of a computer package, to ensure that Electricity North West Limited meets their statutory obligations for the provision of electricity networks.

2 Scope

This Code of Practice (CP) is to be the definitive source of network component impedance values used for the Network. The detailed formulae and range of information used in the preparation of this CP are given in CP205 (Network Component Impedance Data - Supporting Document).

This CP provides the network component impedances for network, transformers, cables and overhead lines at all voltage levels from 132kV transformers to LV mains. 132kV circuit impedances are held within the Interactive Power System Analysis (IPSA) model, on a whole-circuit basis.

The impedance values are at the appropriate voltage and, for cables and lines, are per kilometre. The % values are on a 100MVA base.

All manual calculations relating to network design and all computer-based network analysis programmes shall use the data in this CP, unless better information is available in any particular case, e.g. from a transformer nameplate, which, in such circumstances, shall be used in preference.

However, the data must be interpreted before use to ensure that appropriate values are used for the specific situation. The impedance values in the tables are quoted for a defined conductor temperature of 20°C. Voltage drops will be required to be correct at maximum loading and not necessarily at 20°C. Similarly, protection must operate correctly at any loading, but should assume adiabatic conditions during the passage of fault current. Therefore, different impedance values from those provided in these tables may be required for some voltage drop, protection and fusing calculations and recalculation of some of the values may be necessary.

The data sources are included in each table. Where possible, British Standards and Energy Networks Association (ENA) documents have been used as the sources of data. However, in some cases, particularly for the positive sequence impedance values, it has been necessary to use manufacturers' data. In cases where component-specific manufacturer's data differ from those in the tables, the manufacturer's figures can be used in preference. However, this may necessitate recalculating the zero sequence impedances.

3 Network Impedance Values

Voltage /Fault level	R(Ω)	jX(Ω)	R%	jX%
132kV @ 5 000MVA	0	3.485	0	2.000
33kV @ 1 000MVA	0	1.089	0	10.00
11kV @ 250MVA	0	0.484	0	40.00
6.6kV @ 250MVA	0	0.174	0	40.00

The values of maximum design fault level are taken from Electricity Policy Document (EPD) 279.

4 Cable Impedance Values

The impedance values in the tables are quoted at 20ºC for all the cables. For other operating temperatures, use the appropriate temperature coefficient of resistance in CP205 Table 1 'Temperature coefficients of resistance for conductor materials' to calculate the resistance at the required temperature. Note that if a different temperature is selected then the zero sequence resistance will also need to be re-calculated.

Values of capacitance have been obtained from manufacturer's data and interpreted as follows:

- Single-core cable values are the capacitance per cable.
- Screened 3-core cable values are the capacitance per core.
- Belted 3-core 11kV cable values are the equivalent star capacitance.
- LV 3-core and 4-core cable values are the equivalent star capacitance

The capacitance values have been converted to positive sequence susceptance values and quoted as microsiemens per kilometre (µS/km). If zero sequence susceptance values are required, then refer to manufacturer's data. In the absence of manufacturer's data, it is recommended that the zero sequence susceptance be taken to be equal to the positive sequence value.

In the following tables, some of the references to data sources for the positive sequence impedance and cable capacitance values have been abbreviated, using the following codes, followed by the page number or the table number:

- BICC = BICC Cables 'Electric Cables Handbook'. Third Edition. 1997 (Ref. 8.27)
- AEI = AEI Cables Limited. Brochure of Technical Information (Ref. 8.28)
- Elektrim = Elektrim Kable data sheet (Ref. 8.29)

4.1 33kV 3-core Cables ('H' & Polymeric Types)

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV 3-core 'H' cables - Modern Types										
3-core stranded Copper conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured, Hessian served to BS 480/6480 (metric sizes)	185mm²	0.100	0.101	0.540	0.108	72.6	0.918	0.927	4.960	0.992
	240mm²	0.077	0.097	0.473	0.102	72.6	0.707	0.891	4.340	0.937
	300mm²	0.062	0.094	0.422	0.097	72.6	0.569	0.863	3.880	0.891
	400mm²	0.050	0.092	0.385	0.087	72.6	0.450	0.845	3.540	0.799
Data sources:	Cable dimensions: BS 6480: 1988	R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C								
3-core stranded Aluminium conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured, Hessian served to BS 480/6480 (metric sizes)	185mm²	0.166	0.101	0.605	0.117	72.6	1.524	0.927	5.560	1.074
	240mm²	0.127	0.097	0.523	0.112	79.8	1.166	0.891	4.800	1.028
	300mm²	0.102	0.094	0.463	0.107	87.1	0.937	0.863	4.250	0.983
Data sources:	Cable dimensions: BS 6480: 1988	R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C								
33kV 3-core Polymeric cables - Modern Types										
3-core stranded Copper conductor, Triple extruded XLPE insulated, MDPE sheathed, Steel wire armoured, MDPE oversheath to BS 6622 & IEC502	185mm²	0.100	0.110	1.270	0.162	38.1	0.918	1.010	11.70	1.488
	240mm²	0.077	0.106	1.187	0.155	45.4	0.707	0.973	10.90	1.423
	300mm²	0.062	0.102	1.052	0.150	49.0	0.569	0.937	9.660	1.377
Data sources:	Cable dimensions: BS 6622: 1999	R_1, X_1, Capacitance: BICC p1000					R_1 value corrected to 20°C			
	R_o assumes steel wire armour values based on data in BS 6480 using 3.15mm dia steel strands									
33kV 3-core 'H' cables - Historic Types										
3-core stranded Copper conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured and served to BS 480/6480 (Imperial sizes)	0.10in²	0.273	0.124	0.753	0.136	45.7	2.510	1.139	6.910	1.249
	0.15in²	0.186	0.114	0.627	0.130	54.4	1.708	1.047	5.760	1.194
	0.20in²	0.140	0.109	0.545	0.123	59.9	1.286	1.001	5.000	1.129
	0.25in²	0.112	0.105	0.499	0.115	67.1	1.028	0.964	4.580	1.056
	0.30in²	0.091	0.101	0.450	0.113	72.6	0.836	0.927	4.130	1.038
	0.40in²	0.067	0.098	0.377	0.108	79.8	0.615	0.900	3.460	0.992
	0.50in²	0.058	0.094	0.342	0.102	87.1	0.533	0.863	3.140	0.937

Data sources:	Cable dimensions: BS 480: 1966 R_1: BS 6360:1966 X_1, Capacitance: data supplied by Pirelli	R_1 is dc value at 20°C

4.2 33kV Single-core Cables (Close Trefoil Group)

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV single-core cables - Modern Types										
Single-core stranded **Copper** conductor, Paper insulated, Lead alloy sheathed, unarmoured to BS 480/6480 (metric sizes) (Laid in trefoil)	185mm²	0.099	0.114	1.200	0.061	70.7	0.909	1.047	11.02	0.560
	240mm²	0.075	0.110	1.041	0.057	78.0	0.689	1.010	9.56	0.523
	300mm²	0.061	0.106	0.966	0.054	85.3	0.560	0.973	8.87	0.496
	400mm²	0.048	0.103	0.846	0.051	94.3	0.441	0.946	7.77	0.459
	500mm²	0.039	0.098	0.734	0.049	103.4	0.358	0.900	6.74	0.450
	630mm²	0.032	0.097	0.640	0.046	114.3	0.294	0.891	5.88	0.422
	800mm²	0.027	0.092	0.562	0.043	127.0	0.248	0.845	5.16	0.395
	960mm²	0.020	0.089	0.486	0.041	143.3	0.184	0.817	4.46	0.376
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C									
Single-core stranded **Aluminium** conductor, Paper insulated, Lead alloy sheathed, unarmoured to BS 480/6480 (metric sizes) (Laid in trefoil)	185mm²	0.162	0.114	1.264	0.065	70.7	1.488	1.047	11.61	0.597
	240mm²	0.123	0.110	1.089	0.061	78.0	1.129	1.010	10.00	0.560
	300mm²	0.099	0.106	1.004	0.058	85.3	0.909	0.973	9.22	0.533
	400mm²	0.078	0.103	0.875	0.054	94.3	0.716	0.946	8.03	0.496
	500mm²	0.063	0.098	0.757	0.052	103.4	0.579	0.900	6.95	0.478
	630mm²	0.049	0.097	0.658	0.047	114.3	0.450	0.891	6.04	0.432
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C									
Single-core stranded **Copper** conductor, Triple extruded XLPE or extruded EPR insulated, MDPE sheathed, Copper wire screen, MDPE oversheath to ENA TS 09-17 or BS 7870 4 -10 (Laid in trefoil) **Note: Use this table for 33kV Copper Triplex XLPE cables**	95mm²	0.194	0.135	0.571	0.075	53.4	1.781	1.240	5.24	0.689
	150mm²	0.125	0.126	0.502	0.073	62.8	1.148	1.157	4.61	0.670
	185mm²	0.100	0.122	0.477	0.069	66.0	0.918	1.120	4.38	0.634
	240mm²	0.077	0.117	0.454	0.064	75.4	0.707	1.074	4.17	0.588
	300mm²	0.062	0.113	0.438	0.060	81.7	0.569	1.038	4.02	0.551
	400mm²	0.049	0.108	0.426	0.056	88.0	0.450	0.992	3.91	0.514
	500mm²	0.039	0.104	0.416	0.051	97.4	0.358	0.955	3.82	0.468
Data sources:	Cable dimensions: ENA TS 09-17 R_1, X_1, Capacitance: AEI p31 R_1 value corrected to 20°C R_0 assumes copper wire screen is 50mm² CSA as used in the Network									

33kV single-core cables - Historic Types										
Single-core stranded **Copper** conductor, Paper insulated, Lead alloy sheathed, unarmoured to BS 480/6480 (Imperial sizes) (Laid in trefoil)	0.10in²	0.263	0.130	1.660	0.095	41.7	2.415	1.194	15.24	0.872
	0.15in²	0.189	0.124	1.404	0.081	54.4	1.736	1.139	12.89	0.744
	0.20in²	0.151	0.118	1.313	0.076	58.1	1.387	1.084	12.06	0.698
	0.25in²	0.123	0.114	1.188	0.070	65.3	1.129	1.047	10.91	0.643
	0.30in²	0.099	0.114	1.127	0.065	70.7	0.909	1.047	10.35	0.597
	0.40in²	0.075	0.110	0.970	0.062	78.0	0.689	1.010	8.91	0.569
	0.50in²	0.061	0.106	0.902	0.058	85.3	0.560	0.973	8.28	0.533
	0.60in²	0.048	0.103	0.799	0.054	94.3	0.441	0.944	7.34	0.496
	0.75in²	0.039	0.098	0.709	0.051	103.4	0.358	0.900	6.51	0.468
	1.00in²	0.032	0.097	0.605	0.049	114.3	0.294	0.891	5.56	0.450
Data sources:	Cable dimensions: BS 480: 1966 R_1: BS 6360: 1966 R_1 is dc value at 20 °C X_1, Capacitance: BICC p954 (assumes metric equiv.)									

4.3 33kV 3-core 'HSL' Cables

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV 3-core 'HSL' cables - Modern Types										
3-core stranded **Copper** conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (metric sizes)	185mm²	0.100	0.101	0.553	0.117	72.6	0.918	0.927	5.08	1.074
	240mm²	0.077	0.097	0.489	0.112	79.8	0.707	0.891	4.49	1.028
	300mm²	0.062	0.094	0.451	0.108	87.1	0.569	0.863	4.14	0.992
	400mm²	0.049	0.092	0.442	0.104	96.1	0.450	0.845	4.05	0.955
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C									
3-core stranded **Aluminium** conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (metric sizes)	185mm²	0.166	0.101	0.619	0.127	72.6	1.524	0.927	5.68	1.166
	240mm²	0.127	0.097	0.539	0.122	79.8	1.166	0.891	4.95	1.120
	300mm²	0.102	0.094	0.491	0.118	87.1	0.937	0.863	4.51	1.084
	400mm²	0.079	0.092	0.472	0.113	96.1	0.725	0.845	4.33	1.038
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance: BICC p954 R_1 value corrected to 20°C									
33kV 3-core 'HSL' cables - Historic Types										
3-core stranded **Copper** conductor, Paper insulated, Lead alloy sheathed, Steel wire armoured and served to BS 480/6480 (Imperial sizes)	0.10in²	0.271	0.138	0.895	0.178	61.7	2.489	1.267	8.22	1.635
	0.15in²	0.185	0.128	0.696	0.138	79.8	1.699	1.175	6.39	1.267
	0.20in²	0.139	0.122	0.570	0.132	87.1	1.276	1.120	5.24	1.212
	0.25in²	0.112	0.115	0.486	0.125	94.3	1.028	1.056	4.46	1.148
	0.30in²	0.091	0.112	0.397	0.123	103.4	0.836	1.028	3.64	1.129
	0.40in²	0.068	0.108	0.324	0.117	116.1	0.624	0.992	2.98	1.074
	0.50in²	0.056	0.105	0.288	0.115	127.0	0.514	0.964	2.65	1.056
Data sources:	Cable dimensions: BS 480: 1966 R_1: BS 6360: 1966 R_1 is dc value at 20°C X_1, Capacitance: data supplied by Pirelli									

4.4 33kV Pressure Assisted Cables

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV Fluid-filled cables - Modern Types										
3-core stranded **Copper** compacted **circular** conductor, Paper insulated, Lead alloy sheathed, **Fluid** filled to ENA TS 09-3	240mm²	0.077	0.083	1.345	0.100	119.7	0.707	0.762	12.35	0.920
	400mm²	0.050	0.079	1.002	0.095	146.9	0.459	0.725	9.20	0.870
	630mm²	0.034	0.075	0.749	0.088	183.2	0.312	0.689	6.88	0.810
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
3-core stranded **Aluminium** compacted **circular** conductor, Paper insulated, Lead alloy sheathed, **Fluid** filled to ENA TS 09-3	400mm²	0.080	0.079	1.072	0.108	146.9	0.735	0.725	9.84	0.990
	630mm²	0.051	0.075	0.810	0.100	183.2	0.468	0.689	7.44	0.920
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
3-core stranded **Copper** compacted **oval** conductor, Paper insulated, Corrugated aluminium sheathed, **Fluid** filled to ENA TS 09-3	240mm²	0.077	0.081	0.241	0.113	125.2	0.707	0.744	2.21	1.040
	400mm²	0.049	0.079	0.189	0.110	152.4	0.450	0.725	1.740	1.010
	630mm²	0.033	0.075	0.139	0.105	190.5	0.303	0.689	1.280	0.960
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
3-core stranded **Aluminium** compacted **oval** conductor, Paper insulated, Corrugated aluminium sheathed, **Fluid** filled to ENA TS 09-3	400mm²	0.080	0.079	0.226	0.107	152.4	0.735	0.725	2.08	0.980
	630mm²	0.050	0.075	0.163	0.099	190.5	0.459	0.689	1.500	0.910
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
33kV Gas Assisted cables - Modern Types										
3-core stranded **copper** compacted **oval** conductor, Paper insulated, Smooth aluminium sheathed, **Gas** filled to ENA TS 09-3	300mm²	0.062	0.081	0.208	0.084	134.2	0.569	0.744	1.910	0.771
	400mm²	0.050	0.079	0.175	0.081	148.8	0.459	0.725	1.607	0.744
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
3-core stranded **Aluminium** compacted **oval** conductor, Paper insulated, Smooth	300mm²	0.104	0.081	0.250	0.084	134.2	0.955	0.744	2.30	0.771
	400mm²	0.080	0.079	0.206	0.081	148.8	0.735	0.725	1.892	0.774

aluminium sheathed, **Gas** filled to ENA TS 09-3										
Data sources:	Cable dimensions: ENA TS 09-3 R_1, X_1, Capacitance values: ENA TS 09-3 R_1 value corrected to 20°C									
33kV Fluid-filled cables - Historic Types										
3-core stranded **Copper** compacted **oval** conductor, Paper insulated & screened without fillings or oil ducts, Corrugated aluminium sheathed, **Fluid** filled to BEBS C4 (1966) Schedule 5	0.20in²	0.142	0.086	0.768	0.112	91.2	1.304	0.790	7.05	1.030
	0.25in²	0.114	0.084	0.655	0.110	99.2	1.047	0.771	6.01	1.010
	0.30in²	0.093	0.082	0.603	0.105	109.0	0.854	0.753	5.54	0.960
	0.35in²	0.080	0.080	0.534	0.102	115.0	0.735	0.735	4.90	0.940
	0.40in²	0.071	0.079	0.505	0.102	123.0	0.652	0.725	4.64	0.940
	0.45in²	0.064	0.078	0.457	0.097	129.0	0.588	0.716	4.20	0.890
	0.50in²	0.058	0.077	0.442	0.095	135.0	0.533	0.707	4.06	0.870
	0.55in²	0.054	0.075	0.403	0.094	140.8	0.496	0.689	3.70	0.860
	0.60in²	0.049	0.074	0.382	0.091	146.8	0.450	0.680	3.51	0.840
Data sources:	Cable dimensions: BEBS C4 R_1, X_1, Capacitance values: BEBS C4 R_1 value corrected to 20°C									

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV Fluid-filled cables - Historic Types (continued)										
3-core stranded **Aluminium** compacted **oval** conductor, Paper insulated & screened without fillings or oil ducts, Corrugated aluminium sheathed, **Fluid** filled BEBS C4 (1966) Schedule 5	0.30in²	0.152	0.082	0.662	0.105	109.0	1.396	0.753	6.08	0.960
	0.40in²	0.118	0.079	0.552	0.102	123.0	1.084	0.725	5.07	0.940
	0.50in²	0.096	0.077	0.480	0.096	135.0	0.882	0.707	4.41	0.880
	0.60in²	0.078	0.074	0.412	0.092	146.8	0.716	0.680	3.78	0.840
Data sources:	Cable dimensions: BEBS C4 R_1, X_1, Capacitance values: BEBS C4 R_1 value corrected to 20°C									
3-core stranded **Copper** compacted **circular** conductor, Paper insulated & screened, Lead alloy sheathed, **Fluid** filled to BEBS C4 (1966) Schedule 5	0.20in²	0.142	0.086	1.861	0.114	89.3	1.304	0.790	17.09	1.050
	0.25in²	0.114	0.084	1.726	0.109	97.2	1.047	0.771	15.85	1.000
	0.30in²	0.093	0.082	1.525	0.106	105.2	0.854	0.753	14.00	0.970
	0.35in²	0.080	0.080	1.416	0.104	113.0	0.735	0.735	13.00	0.960
	0.40in²	0.071	0.079	1.263	0.104	121.0	0.652	0.725	11.60	0.960
	0.50in²	0.058	0.077	1.203	0.098	133.0	0.533	0.707	11.05	0.900

	0.55in²	0.054	0.075	1.105	0.096	137.0	0.496	0.689	10.15	0880
	0.60in²	0.049	0.074	1.063	0.092	144.8	0.450	0.680	9.76	0.840
Data sources:	Cable dimensions: BEBS C4			R_1, X_1, Capacitance values: BEBS C4				R_1 value corrected to 20°C		
3-core stranded **Aluminium** compacted **circular** conductor, Paper insulated & screened, Lead alloy sheathed, **Fluid** filled to BEBS C4 (1966) Schedule 5	0.30in²	0.152	0.082	1.584	0.106	105.2	1.396	0.753	14.55	0.970
	0.40in²	0.118	0.079	1.342	0.104	121.0	1.084	0.725	12.32	0.960
	0.50in²	0.096	0.077	1.240	0.099	133.0	0.882	0.707	11.39	0.910
	0.60in²	0.078	0.074	1.092	0.092	144.8	0.716	0.680	10.03	0.840
Data sources:	Cable dimensions: BEBS C4			R_1, X_1, Capacitance values: BEBS C4				R_1 value corrected to 20°C		
3-core stranded **Copper** compacted **shaped or oval** conductor, Paper insulated & screened, Lead alloy sheathed, **Fluid** filled to BEBS C4 (1966) Schedule 7	0.20in²	0.142	0.086	2.240	0.087	91.2	1.304	0.790	20.6	0.800
	0.25in²	0.114	0.084	2.060	0.085	99.2	1.047	0.771	18.93	0.780
	0.30in²	0.093	0.082	1.804	0.082	109.0	0.854	0.753	16.57	0.750
	0.35in²	0.080	0.080	1.699	0.080	115.0	0.735	0.735	15.60	0.730
	0.40in²	0.071	0.079	1.630	0.078	123.0	0.652	0.725	14.97	0.720
	0.50in²	0.058	0.077	1.428	0.075	135.0	0.533	0.707	13.11	0.690
	0.55in²	0.054	0.075	1.390	0.070	140.8	0.496	0.689	12.76	0.640
Data sources:	Cable dimensions: BEBS C4			R_1, X_1, Capacitance values: BEBS C4				R_1 value corrected to 20°C		
3-core stranded **Aluminium** compacted **shaped or oval** conductor, Paper insulated & screened, Lead alloy sheathed, **Fluid** filled to BEBS C4 (1966) Schedule 7	0.30in²	0.152	0.082	1.863	0.082	109.0	1.396	0.753	17.11	0.750
	0.40in²	0.118	0.079	1.677	0.078	123.0	1.084	0.725	15.40	0.720
	0.50in²	0.096	0.077	1.466	0.075	135.0	0.882	0.707	13.46	0.690
Data sources:	Cable dimensions: BEBS C4			R_1, X_1, Capacitance values: BEBS C4				R_1 value corrected to 20°C		
33kV Gas Assisted cables - Historic Types										
3-core stranded **copper** compacted oval conductor, Paper insulated, Lead alloy sheathed, **Gas** filled to BEBS C4 (1966) Schedule 7	0.20in²	0.142	0.086	2.239	0.087	91.2	1.304	0.790	20.56	0.800
	0.25in²	0.114	0.084	2.062	0.085	99.2	1.047	0.771	18.93	0.780
	0.30in²	0.093	0.082	1.804	0.082	109.0	0.854	0.753	16.57	0.753
	0.40in²	0.071	0.079	1.630	0.078	123.0	0.652	0.725	14.97	0.716
	0.45in²	0.064	0.078	1.489	0.073	129.0	0.588	0.716	13.67	0.670
	0.50in²	0.058	0.077	1.440	0.073	135.0	0.533	0.707	13.2	0.670
	0.55in²	0.054	0.075	1.390	0.070	140.8	0.496	0.689	12.76	0.643

	0.60in^2	0.049	0.074	1.342	0.066	148.8	0.450	0.680	12.32	0.606
Data sources:	Cable dimensions: BEBS C4			R_1, X_1, Capacitance values: BEBS C4				R_1 value corrected to 20°C		

4.5 11kV / 6.6kV 3-core Cables

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV 3-core cables - Modern Types										
3-core stranded shaped **Aluminium** conductor, Belted, Paper insulated, Corrugated aluminium sheathed to Table 1 ENA TS 09-12 (PICAS & ACAS)	95mm²	0.322	0.087	0.954	0.116	81.6	26.6	7.19	78.8	9.59
	185mm²	0.166	0.081	0.550	0.107	105.2	13.72	6.69	45.5	8.84
	300mm²	0.102	0.077	0.361	0.096	128.8	8.43	6.36	29.8	7.93
Data sources:	Cable dimensions: ENA TS 09-12 (CAS dimensions - data supplied by Pirelli) R_1, X_1, Capacitance values: BICC p950 R_1 value corrected to 20°C									
3-core stranded **Copper** conductor, Triple extruded polymeric (3.4mm) insulated, Copper wire screened, unarmoured, PVC oversheath to BS 6622 & IEC 502	70mm²	0.268	0.107	1.840	0.158	91.1	22.1	8.84	152.1	13.06
	95mm²	0.194	0.101	1.766	0.149	103.7	16.03	8.35	145.9	12.31
	120mm²	0.154	0.097	1.726	0.144	116.3	12.73	8.02	142.6	11.90
	150mm²	0.125	0.095	1.697	0.137	122.5	10.33	7.85	140.2	11.32
	185mm²	0.100	0.092	1.672	0.133	132.0	8.26	7.60	138.2	10.99
	240mm²	0.078	0.089	1.650	0.126	147.7	6.45	7.36	136.4	10.41
	300mm²	0.064	0.086	1.636	0.121	163.4	5.29	7.11	135.2	10.00
Data sources:	Cable dimensions: BS 6622: 1999 R_1, X_1, Capacitance values: AEI p17 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per BS 6622 - For other screen sizes recalculate R_o									
3-core stranded **Aluminium** conductor, Triple extruded polymeric (3.4mm) insulated, Copper wire screened, unarmoured, PVC oversheath to BS 6622 & IEC 502	70mm²	0.445	0.106	2.02	0.158	94.3	36.8	8.76	166.7	13.06
	95mm²	0.322	0.101	1.894	0.149	106.8	26.6	8.35	156.5	12.31
	120mm²	0.255	0.097	1.827	0.144	116.3	21.1	8.02	151.0	11.90
	150mm²	0.208	0.095	1.780	0.137	122.5	17.19	7.85	147.1	11.32
	185mm²	0.165	0.092	1.737	0.133	132.0	13.64	7.60	143.6	10.99
	240mm²	0.128	0.089	1.700	0.126	150.8	10.58	7.36	140.5	10.41
	300mm²	0.103	0.086	1.675	0.121	166.5	8.51	7.11	138.4	10.00
Data sources:	Cable dimensions: BS 6622: 1999 R_1, X_1, Capacitance values: AEI p49 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per BS 6622 - For other screen sizes recalculate R_o									
11kV / 6.6kV 3-core cables - Historic Types										
3-core stranded **Aluminium** conductor,	0.0225in²	2.08	0.114	4.04	0.168	43.5	171.8	9.42	333	13.88

Belted, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (Imperial sizes)	0.04in^2	1.162	0.102	2.91	0.146	50.8	96.0	8.43	240	12.07
	0.06in^2	0.767	0.096	2.37	0.134	56.2	63.4	7.93	196.0	11.07
	0.10in^2	0.456	0.090	1.674	0.116	70.7	37.7	7.44	138.0	9.59
	0.15in^2	0.312	0.084	1.342	0.112	79.8	25.8	6.94	111.0	9.26
	0.20in^2	0.234	0.082	1.119	0.107	87.1	19.34	6.78	92.5	8.84
	0.30in^2	0.152	0.078	0.843	0.100	103.4	12.56	6.45	69.7	8.26
	0.50in^2	0.092	0.074	0.593	0.090	127.0	7.60	6.12	49.0	7.19
Data sources:	Cable dimensions: BS 480: 1966 R_1: BS 6360: 1966 R_1 is dc value at 20°C X_1, Capacitance values: BICC p948 (assumes metric equiv.)									
3-core stranded **Aluminium** conductor, Belted, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (metric sizes)	95mm^2	0.321	0.086	1.421	0.113	79.8	26.5	7.11	117.4	9.34
	185mm^2	0.166	0.080	0.977	0.101	103.4	13.72	6.61	80.7	8.35
	240mm^2	0.127	0.078	0.801	0.098	116.1	10.50	6.45	66.2	8.10
	300mm^2	0.102	0.076	0.700	0.093	127.0	8.43	6.28	57.9	7.69
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance values: BICC p948 R_1 value corrected to 20°C									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV 3-core cables - Historic Types (continued)										
3-core stranded **Copper** conductor, Belted, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (Imperial sizes)	0.016in² *	1.910	0.124	4.02	0.182	39.9	157.9	10.25	332	15.04
	0.0225in²	1.257	0.114	3.21	0.168	43.5	103.9	9.42	266	13.88
	0.04in²	0.703	0.102	2.45	0.146	50.8	58.1	8.43	202	12.07
	0.06in²	0.464	0.096	2.07	0.134	56.2	38.3	7.93	170.7	11.07
	0.075in² *	0.387	0.093	1.867	0.131	63.5	32.0	7.69	154.3	10.83
	0.10in²	0.276	0.090	1.493	0.116	70.7	22.8	7.44	123.4	9.59
	0.15in²	0.188	0.084	1.219	0.112	79.8	15.50	6.94	100.7	9.26
	0.20in²	0.142	0.082	1.026	0.108	87.1	11.74	6.78	84.8	8.93
	0.25in²	0.113	0.080	0.892	0.102	94.3	9.34	6.61	73.7	8.43
	0.30in²	0.092	0.078	0.783	0.100	103.4	7.60	6.45	64.7	8.26
	0.40in²	0.068	0.077	0.664	0.099	116.1	5.62	6.36	54.9	8.26
	0.50in²	0.056	0.074	0.556	0.094	127.0	4.63	6.12	46.0	7.77
Data sources:	Cable dimensions: BS 480: 1966 R_1: BS 6360: 1966 R_1 is dc value at 20 °C X_1, Capacitance: data supplied by Pirelli * 0.016 & 0.075in² not BS imperial sizes – dimensions estimated using nearest metric equivalent									
3-core stranded **Copper** conductor, Belted, Paper insulated, Lead alloy sheathed, Steel wire armoured to BS 480/6480 (metric sizes)	95mm²	0.194	0.086	1.296	0.110	79.8	16.03	7.11	107.1	9.09
	185mm²	0.100	0.080	0.912	0.097	103.4	8.26	6.61	75.4	8.02
	240mm²	0.077	0.078	0.752	0.095	116.1	6.36	6.45	62.1	7.85
	300mm²	0.062	0.076	0.660	0.090	127.0	5.12	6.28	54.5	7.44
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance values: BICC p948 R_1 value corrected to 20°C									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

4.6 11kV / 6.6kV Single-core Cables (Close Trefoil Group)

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV single-core cables - Modern Types										
Single-core solid **Aluminium** conductor, Polymeric insulated, Copper screened, MDPE sheathed overall and laid in **Triplex** formation to BS 7870 - 4.10	95mm²	0.322	0.110	0.844	0.065	91.1	26.6	9.09	69.8	5.37
	185mm²	0.168	0.086	0.692	0.055	116.3	13.88	7.11	57.2	4.55
	300mm²	0.104	0.071	0.628	0.048	141.4	8.59	5.87	51.9	3.97
Data sources:	Cable dimensions: Elektrim R_1, X_1, Capacitance values: Elektrim R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA - For other screen sizes recalculate R_o									
Single-core stranded **Copper** compacted conductor, Triple extruded Polymeric insulated, unarmoured, Copper wire screened, to ENA TS 09-17 (Laid in trefoil)	300mm²	0.062	0.095	0.586	0.048	94.3	5.12	7.81	48.4	3.97
	400mm²	0.049	0.092	0.573	0.045	107.0	4.05	7.59	47.4	3.72
Data sources:	Cable dimensions: ENA TS 09-17 R_1, X_1, Capacitance values: AEI p13 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per ENA TS 09-17- For other screen sizes recalculate R_o									
Single-core stranded **Aluminium** compacted conductor, Triple extruded Polymeric insulated, unarmoured, copper wire screened to ENA TS 09-17 (Laid in trefoil)	400mm²	0.080	0.094	0.624	0.045	107.0	6.61	7.74	51.6	3.72
	500mm²	0.063	0.091	0.605	0.043	117.9	5.21	7.53	50.0	3.55
Data sources:	Cable dimensions: ENA TS 09-17 R_1, X_1, Capacitance values: AEI p45 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per ENA TS 09-17- For other screen sizes recalculate R_o									
Single-core stranded **Copper** conductor, Triple extruded Polymeric insulated, unarmoured, Copper wire screened, PVC oversheath to BS 6622 & IEC 502 (Laid in trefoil)	70mm²	0.267	0.122	0.790	0.071	52.6	22.1	10.08	65.3	5.87
	95mm²	0.193	0.116	0.716	0.065	59.9	15.95	9.59	59.2	5.37
	150mm²	0.124	0.108	0.648	0.056	70.7	10.25	8.93	53.6	4.63
	185mm²	0.100	0.105	0.624	0.053	76.2	8.26	8.68	51.6	4.38
	240mm²	0.077	0.101	0.600	0.049	85.3	6.36	8.35	49.6	4.05
	300mm²	0.062	0.098	0.586	0.046	94.3	5.12	8.07	48.4	3.80
	400mm²	0.049	0.094	0.573	0.043	107.0	4.05	7.77	47.4	3.55
	500mm²	0.040	0.091	0.564	0.031	117.9	3.31	7.53	46.6	2.56

	630mm²	0.032	0.088	0.557	0.028	130.6	2.64	7.31	46.0	2.31
Data sources:	Cable dimensions: BS 6622: 1999 R_1, X_1, Capacitance values: AEI p12 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per BS 6622 - For other screen sizes recalculate R_o									
Single-core stranded **Aluminium** conductor, Triple extruded Polymeric insulated, unarmoured, Copper wire screened, PVC oversheath to BS 6622 & IEC 502 (Laid in trefoil)	70mm²	0.443	0.121	0.967	0.081	54.4	36.6	10.00	79.9	6.69
	95mm²	0.321	0.115	0.844	0.075	61.7	26.5	9.50	69.8	6.20
	150mm²	0.207	0.108	0.730	0.067	70.7	17.11	8.93	60.3	5.54
	185mm²	0.165	0.104	0.688	0.063	78.0	13.64	8.59	56.9	5.21
	240mm²	0.126	0.100	0.649	0.059	87.1	10.41	8.26	53.6	4.88
	300mm²	0.101	0.097	0.625	0.055	96.1	8.35	7.99	51.7	4.55
	400mm²	0.080	0.094	0.603	0.047	107.0	6.61	7.74	49.8	3.88
	500mm²	0.063	0.091	0.587	0.044	117.9	5.21	7.53	48.5	3.64
	630mm²	0.050	0.088	0.574	0.039	130.6	4.13	7.31	47.4	3.22
Data sources:	Cable dimensions: BS 6622: 1999 R_1, X_1, Capacitance values: AEI p45 R_1 value corrected to 20°C R_o assumes copper wire screen is 35mm² CSA as per BS 6622 - For other screen sizes recalculate R_o									
11kV / 6.6kV single-core cables - Historic Types										
Single-core stranded **copper** conductor, Paper insulated, Lead sheathed, unarmoured to BS 480/6480 (metric sizes) (Laid in trefoil)	400mm²	0.051	0.085	0.938	0.036	157.8	4.21	7.02	77.5	2.98
	630mm²	0.033	0.083	0.738	0.034	181.4	2.73	6.86	61.0	2.81
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance values: BICC p 948 R_1 value corrected to 20°C									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

4.7 LV Mains 3-core & 4-core Cables

4.7.1 3-core Cables

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
LV Mains 3-core Cables - Modern Types										
3 –core Polymeric insulated, CNE cables with solid **Aluminium** phase conductors and concentric Copper wire **Waveform** neutral/earth conductor to BS 7870-3.40	95mm²	0.322	0.074	1.282	0.125	-	18 700	4 300	74 400	7 260
	185mm²	0.166	0.074	0.658	0.112	-	9 640	4 300	38 200	6 500
	240mm²	0.127	0.073	0.619	0.109	-	7 370	4 240	35 900	6 330
	300mm²	0.102	0.073	0.594	0.105	-	5 920	4 240	34 500	6 100
Data sources:	Cable dimensions: BS 7870-3.40: 2001 R_1, X_1 values: BS 7870-3.40: 2001 R_1 value corrected to 20°C Capacitance values: no data source located									
LV Mains 3-core Cables - Historic Types										
3-core solid **Aluminium** conductor, Paper insulated, Aluminium sheath / neutral (**CONSAC**) to ENA TS 09-8	95mm²	0.322	0.069	1.201	0.097	192.3	18 700	4 010	69 700	5 630
	185mm²	0.166	0.069	0.625	0.088	219.5	9 640	4 010	36 300	5 110
	240mm²	0.127	0.068	0.469	0.087	223.1	7 370	3 950	27 200	5 050
	300mm²	0.102	0.068	0.384	0.085	248.5	5 920	3 950	22 300	4 940
Data sources:	Cable dimensions: ENA TS 09-8 R_1, X_1 values: ENA TS 09-8 R_1 value corrected to 20°C Capacitance values: BICC p945									

[1] % values quoted at 415V.

4.7.2 4-Core Cables

As discussed in CP205, two tables of impedance values are provided for the 4-core cables to take account of the effect of the neutral-earth bonding arrangements on the 4-core network on the zero sequence resistance and reactance values of the 4-core cable.

The two tables are calculated to take account of the situation:

(a) The 4-core cable operating as SNE, i.e. with no CNE branch, extension or insert and with earth return via the sheath only. It is assumed that for armoured cables the armour is bonded to its sheath at all joints (plumbed joints); and

(b) The 4-core cable has been jointed to a CNE cable with earth return via the neutral core in parallel with the sheath. In this case it is assumed that the armour will not have been bonded to the sheath (resin joints).
(It is recognised that this ignores the reality that early Consac jointing systems used plumbed joints.)

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
LV Mains 4-core Cables - Modern Types										
4 –core Polymeric insulated cables with solid **Aluminium** phase conductors and concentric Copper wire Waveform neutral/earth conductor to BS 7870-3.40 **Assumes earth return via the sheath only**	95mm²	0.322	0.074	1.282	0.114	-	18 700	4 300	74 400	6 620
	185mm²	0.166	0.073	0.658	0.112	-	9 640	4 240	38 200	6 500
	240mm²	0.127	0.072	0.619	0.106	-	7 370	4 180	35 900	6 150
	300mm²	0.102	0.072	0.594	0.102	-	5 920	4 180	34 300	5 920
Data sources:	Cable dimensions: BS 7870 -3.40: 2001 R_1values: BS 7870 R_1 is dc value at 20°C Capacitance values: no data source located X_1 values: calculated									
4 –core Polymeric insulated cables with solid Aluminium phase conductors and concentric Copper wire **Waveform** neutral/earth conductor to BS 7870-3.40 **Assumes earth return via the neutral core in parallel with the sheath**	95mm²	0.322	0.074	0.804	0.093	-	18 700	4 300	46 700	5 400
	185mm²	0.166	0.073	0.413	0.093	-	9 640	4 240	24 000	5 400
	240mm²	0.127	0.072	0.342	0.089	-	7 370	4 180	19 860	5 170
	300mm²	0.102	0.072	0.291	0.087	-	5 920	4 180	16 900	5 050
Data sources:	Cable dimensions: BS 7870 -3.40: 2001 R_1values: BS 7870 R_1 is dc value at 20°C Capacitance values: no data source located X_1 values: calculated									

[1] % values quoted at 415V.

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
LV Mains 4-core Cables - Historic Types										
4-core solid **Aluminium** conductor, Paper insulated, Lead sheathed, Steel tape armoured to BS 480/6480 (metric sizes) **Assumes earth return via the sheath only (including armouring)**	70mm²	0.446	0.071	2.540	0.091	168.7	25 900	4 120	147 200	5 290
	120mm²	0.255	0.068	1.721	0.086	217.7	14 810	3 950	99 900	4 980
	185mm²	0.166	0.068	1.179	0.084	219.5	9 640	3 950	68 500	4 860
	300mm²	0.102	0.067	0.804	0.082	248.5	5 920	3 890	46 700	4 740
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance values: BICC p945 R_1 value corrected to 20°C Assumes neutral core same size as phase core									
4-core solid **Aluminium** conductor, Paper insulated, Lead sheathed, Steel tape armoured to BS 480/6480 (metric sizes) **Assumes earth return via the neutral core in parallel with the sheath (excluding armouring)**	70mm²	0.446	0.071	1.505	0.083	168.7	25 900	4 120	87 400	4 820
	120mm²	0.255	0.068	0.884	0.079	217.7	14 810	3 950	51 300	4 590
	185mm²	0.166	0.068	0.580	0.078	219.5	9 640	3 950	33 700	4 530
	300mm²	0.102	0.067	0.361	0.076	248.5	5 920	3 890	20 960	4 410
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1, Capacitance values: BICC p945 R_1 value corrected to 20°C Assumes neutral core same size as phase core									
4-core solid **Aluminium** conductor, Paper insulated, Lead sheathed, Steel tape armoured to BS 480/6480 (Imperial sizes) **Assumes earth return via the sheath only (including armouring)**	0.10in²	0.451	0.073	2.280	0.105	141.5	26 200	4 240	132 500	6 100
	0.20in²	0.230	0.069	1.363	0.094	188.7	13 350	4 010	79 100	5 460
	0.30in²	0.150	0.068	0.996	0.091	230.4	8 710	3 950	57 800	5 280
	0.50in²	0.097	0.067	0.643	0.089	250.3	5 630	3 890	37 300	5 160
Data sources:	Cable dimensions: see note R_1 value corrected to 20°C			R_1, X_1 , Capacitance values: Supplied by Pirelli Assumes neutral core same size as phase core						
4-core solid **Aluminium** conductor, Paper insulated, Lead sheathed, Steel tape armoured to BS 480/6480 (Imperial sizes) **Assumes earth return via the neutral core in parallel with the sheath (excluding armouring)**	0.10in²	0.451	0.073	1.490	0.092	141.5	26 200	4 240	86 500	5 340
	0.20in²	0.230	0.069	0.782	0.085	188.7	13 350	4 010	45 400	4 940
	0.30in²	0.150	0.068	0.521	0.083	230.4	8 710	3 950	30 300	4 820
	0.50in²	0.097	0.067	0.337	0.082	250.3	5 630	3 890	19 570	4 760
Data sources:	Cable dimensions: see note R_1 value corrected to 20°C			R_1, X_1, Capacitance values: Supplied by Pirelli Assumes neutral core same size as phase core						

	Note: Cable dimensions are estimated from BS 480 using comparison with BS 6480. (BS 480 refers only to stranded conductors at these sizes and does not include solid conductors. BS 6480 contains both stranded and solid aluminium conductors.)

[1] % values quoted at 415V.

Cable type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
LV mains 4-core Cables - Historic Types (continued)										
4-core stranded **Copper** conductor, paper insulated Lead sheathed, Steel tape armoured cable to BS 480/6480 (Imperial sizes) **Assumes earth return via the sheath only (including armouring)**	0.0225in²	1.257	0.086	4.610	0.114	94.3	73 000	4 990	267 000	6 620
	0.04in²	0.708	0.079	3.450	0.103	112.5	41 100	4 530	200 000	5 980
	0.05in² *	0.589	0.077	3.050	0.102	118.8	34 200	4 440	177 100	5 920
	0.06in²	0.469	0.075	2.650	0.101	125.2	27 200	4 350	153 900	5 860
	0.075in² **	0.396	0.074	2.387	0.093	141.5	23 000	4 310	138 600	5 410
	0.10in²	0.274	0.073	1.946	0.083	168.7	15 910	4 240	113 000	4 820
	0.12in² ***	0.242	0.072	1.780	0.083	181.4	14 050	4 180	103 400	4 820
	0.15in²	0.195	0.070	1.531	0.083	192.3	11 320	4 060	88 900	4 820
	0.20in²	0.150	0.069	1.187	0.082	217.7	8 710	4 010	68 900	4 760
	0.25in²	0.124	0.069	1.013	0.081	197.7	7 200	4 010	58 800	4 700
	0.30in²	0.106	0.068	0.878	0.078	219.5	6 150	3 950	51 000	4 530
	0.40in²	0.072	0.067	0.673	0.077	223.1	4 180	3 890	39 100	4 470
	0.50in²	0.059	0.067	0.560	0.076	248.5	3 430	3 890	32 500	4 410
Data sources:	Cable dimensions: BS 480: 1966 R_1, X_1 values: Supplied by Pirelli R_1 value corrected to 20°C Capacitance values: BICC p945 (nearest metric equivalent) Assumes neutral core same size as phase core * 0.05in² not a British Standard size – values interpolated from 0.04in² & 0.06in² values ** 0.075in² not a British Standard size – values interpolated from 0.06in² & 0.10in² values ** 0.12in² not a British Standard size – values interpolated from 0.10in² & 0.15in² values									
4-core stranded **Copper** conductor, paper insulated Lead sheathed, Steel tape armoured cable to BS 480/6480 (Imperial sizes)	0.0225in²	1.257	0.086	3.830	0.102	94.3	73 000	4 990	222 600	5 920
	0.04in²	0.708	0.079	2.320	0.093	112.5	41 100	4 530	134 600	5 400
	0.05in² *	0.589	0.077	1.950	0.092	118.8	34 200	4 440	113 200	5 340
	0.06in²	0.469	0.075	1.581	0.091	125.2	27 200	4 350	91 800	5 280

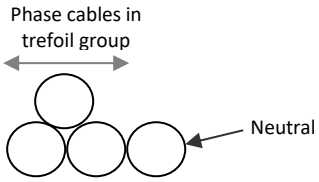
Assumes earth return via the neutral core in parallel with the sheath (excluding armouring)	0.075in² **	0.396	0.074	1.348	0.086	141.5	23 000	4 310	78 300	4 990
	0.10in²	0.274	0.073	0.959	0.079	168.7	15 910	4 240	55 700	4 590
	0.12in² ***	0.242	0.072	0.851	0.079	181.4	14 050	4 180	49 400	4 590
	0.15in²	0.195	0.070	0.690	0.078	192.3	11 320	4 060	40 100	4 530
	0.20in²	0.150	0.069	0.533	0.078	217.7	8 710	4 010	30 900	4 530
	0.25in²	0.124	0.069	0.441	0.077	197.7	7 200	4 010	25 600	4 470
	0.30in²	0.106	0.068	0.379	0.076	219.5	6 150	3 950	22 000	4 410
	0.40in²	0.072	0.067	0.259	0.076	223.1	4 180	3 890	15 040	4 410
	0.50in²	0.059	0.067	0.215	0.074	248.5	3 430	3 890	12 480	4 300
Data sources:	Cable dimensions: BS 480: 1966 R_1, X_1 values: Supplied by Pirelli R_1 value corrected to 20°C Capacitance values: BICC p945 (nearest metric equivalent) Assumes neutral core same size as phase core * 0.05in² not a British Standard size – values interpolated from 0.04in² & 0.06in² values ** 0.075in² not a British Standard size – values interpolated from 0.06in² & 0.10in² values *** 0.12in² not a British Standard size – values interpolated from 0.10in² & 0.15in² values									

[1] % values quoted at 415V.

4.8 LV Single-core Cables

The data in the following tables are for both trefoil and flat formation configurations of 3-phase LV single-core cable installations (3-phase and neutral). For unarmoured cable types, the zero sequence impedance has been calculated based on the earth current returning via the neutral cable only. For armoured cable types, two values of zero sequence impedance are provided (i) earth current returning via the neutral cable only and (ii) fault current returning via the phase cable sheaths only. Reliable data were not found for cable capacitance and so have not been provided.

4.8.1 Phase cables installed in a loose trefoil group with the neutral adjacent and in contact with the trefoil



Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0[2]	X_0[2]	R_1%	X_1%	R_0%	X_0%
LV Mains single-core cables, in trefoil group - Modern Types									
Single-core solid **Aluminium** 4 x 90° sector shaped conductor, PVC insulated, PVC sheathed, Aluminium strip armoured to BS 6346: 1989 (In trefoil group)	600mm²	0.052	0.086	0.206 (0.292)	0.332 (0.034)	3 020	4 990	11 960 (16 950)	19 280 (1 970)
Data sources:	Cable dimensions: BS 6346: 1989 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: BICC p964 (nearest equiv)								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, Aluminium wire armoured to BS 5467: 1997 (In trefoil group)	300mm²	0.060	0.087	0.240 (0.370)	0.370 (0.036)	3 480	5 050	13 900 (21 500)	21 480 (2 090)
	400mm²	0.047	0.087	0.188 (0.267)	0.371 (0.036)	2 730	5 050	10 900 (15 500)	21 540 (2 090)
	500mm²	0.037	0.086	0.146 (0.237)	0.366 (0.036)	2 150	4 990	8 500 (13 800)	21 250 (2 090)
Data sources:	Cable dimensions: BS 5467: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: calculated								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, unarmoured to BS 7889: 1997 (In trefoil group)	300mm²	0.060	0.078	0.240	0.332	3 480	4 530	13 900	19 280
	400mm²	0.047	0.077	0.188	0.329	2 730	4 470	10 900	19 100
	500mm²	0.037	0.077	0.146	0.328	2 150	4 470	8 500	19 040
Data sources:	Cable dimensions: BS 7889: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C								

	X_1 values: calculated

[1] % values quoted at 415V

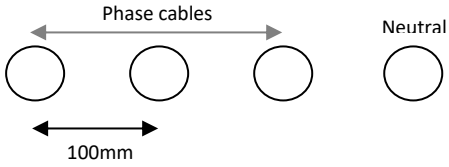
[2] Main zero sequence data are for earth return via neutral conductor. Data in brackets are earth return via the armouring (where relevant)

Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0[2]	X_0[2]	R_1%	X_1%	R_0%	X_0%
LV Mains single-core cables, in trefoil group - Historic Types									
Single-core stranded **Copper** conductor, Paper insulated, Lead sheathed, to BS 480/6480 (Imperial sizes) (In trefoil group)	0.40in²	0.077	0.085	0.307 (1.676)	0.380 (0.046)	4 470	4 940	17 800 (97 300)	22 060 (2 670)
	0.50in²	0.062	0.083	0.248 (1.416)	0.372 (0.044)	3 600	4 820	14 400 (82 200)	21 600 (2 550)
	0.60in²	0.050	0.081	0.198 (1.174)	0.345 (0.037)	2 900	4 700	11 500 (68 200)	20 030 (2 150)
	0.75in²	0.040	0.080	0.159 (1.003)	0.337 (0.035)	2 320	4 650	9 200 (58 200)	19 570 (2 030)
	1.00in²	0.033	0.078	0.130 (0.762)	0.333 (0.034)	1 910	4 530	7 500 (44 200)	19 330 (1 970)
Data sources:	Cable dimensions: BS 480: 1966 R_1, X_1 values: BICC p945 (nearest equivalent) R_1 value corrected to 20°C								
Single-core stranded **Copper** conductor, VIR insulated, unarmoured (In trefoil group)	0.40in²	0.077	0.083	0.307	0.353	4 470	4 820	17 800	20 500
	0.50in²	0.062	0.081	0.248	0.348	3 600	4 700	14 400	20 210
	0.60in²	0.050	0.078	0.198	0.335	2 900	4 530	11 500	19 450
	0.75in²	0.040	0.077	0.159	0.328	2 320	4 470	9 200	19 040
	1.00in²	0.033	0.075	0.130	0.324	1 910	4 350	7 500	18 810
Data sources:	Cable dimensions: estimated from BS 480: 1966 R_1 values: BICC p945 (nearest equivalent) R_1 value corrected to 20°C X_1 values: calculated								

[1] % values quoted at 415V

[2] Main zero sequence data are for earth return via neutral conductor. Data in brackets are earth return via the sheath (where relevant)

4.8.2 Flat Formation of Phase and Neutral Cables Installed at 100mm Cable Spacing (Single Layer of Cables)



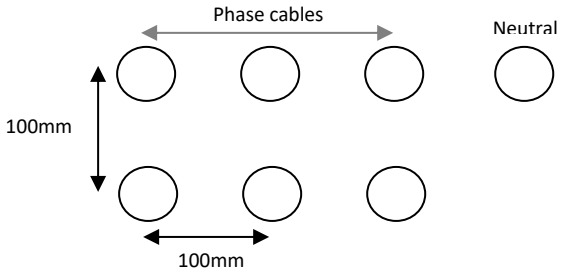
Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0[2]	X_0[2]	R_1%	X_1%	R_0%	X_0%
LV Mains single-core cables, in flat formation (single layer of cables) - Modern Types									
Single-core solid **Aluminium** 4 x 90° sector shaped conductor, PVC insulated, PVC sheathed, Aluminium strip armoured to BS 6346: 1989 (In flat formation)	600mm²	0.052	0.154	0.206 (0.292)	0.686 (0.094)	3 020	8 940	11 960 (16 950)	39 830 (5 460)
Data sources:	Cable dimensions: BS 6346: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: Calculated								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, Aluminium wire armoured to BS 5467: 1997 (In flat formation)	300mm²	0.060	0.166	0.240 (0.370)	0.735 (0.101)	3 480	9 640	13 900 (21 500)	42 680 (5 860)
	400mm²	0.047	0.159	0.188 (0.267)	0.704 (0.098)	2 730	9 230	10 900 (15 500)	40 880 (5 690)
	500mm²	0.037	0.152	0.146 (0.237)	0.677 (0.094)	2 150	8 830	8 500 (13 800)	39 310 (5 460)
Data sources:	Cable dimensions: BS 5467: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: calculated								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, unarmoured to BS 7889: 1997 (In flat formation)	300mm²	0.060	0.166	0.240	0.735	3 480	9 640	13 900	42 680
	400mm²	0.047	0.159	0.188	0.704	2 730	9 230	10 900	40 880
	500mm²	0.037	0.152	0.146	0.677	2 150	8 830	8 500	39 310
Data sources:	Cable dimensions: BS 7889: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: calculated								
LV Mains single-core cables, in flat formation (single layer of cables) - Historic Types									
Single-core stranded **Copper** conductor, Paper insulated, Lead sheathed, to BS 480/6480 (Imperial sizes) (In flat formation)	0.40in²	0.077	0.184	0.307 (1.676)	0.803 (0.115)	4 470	10 680	17 800 (97 300)	46 620 (6 680)
	0.50in²	0.062	0.176	0.248 (1.416)	0.773 (0.110)	3 600	10 220	14 400 (82 200)	44 880 (6 390)
	0.60in²	0.050	0.162	0.198 (1.174)	0.719 (0.100)	2 900	9 410	11 500 (68 200)	41 750 (5 810)

	0.75in²	0.040	0.155	0.159 (1.003)	0.690 (0.095)	2 320	9 000	9 200 (58 200)	40 060 (5 520)
	1.00in²	0.033	0.145	0.130 (0.762)	0.648 (0.089)	1 920	8 420	7 500 (44 200)	37 620 (5 170)
Data sources:	Cable dimensions: BS 480: 1966 R_1 values: BICC p945 (nearest equiv) R_1 value corrected to 20°C X_1 values: Calculated								
Single-core stranded **Copper** conductor, VIR insulated, unarmoured (In flat formation)	0.40in²	0.077	0.184	0.307	0.803	4 470	10 680	17 800	46 620
	0.50in²	0.062	0.176	0.248	0.773	3 600	10 220	14 400	44 480
	0.60in²	0.050	0.162	0.198	0.719	2 900	9 410	11 500	41 750
	0.75in²	0.040	0.155	0.159	0.690	2 320	9 000	9 200	40 060
	1.00in²	0.033	0.145	0.130	0.648	1 920	8 420	7 500	37 620
Data sources:	Cable dimensions: estimated from BS 480: 1966 R_1 values: BICC p945 (nearest equivalent) R_1 value corrected to 20°C X_1 values: calculated								
Consac cables used as single core-cables by bunching the three cores together (In flat formation)	3 x 185mm²	0.055	0.153	0.220 (0.208)	0.682 (0.092)	3 190	8 880	12 800 (12 100)	39 600 (5 340)
Data sources:	Cable dimensions ENA TS 09-8 R_1 values: ENA TS 09-8 R_1 value corrected to 20°C X_1 values: calculated								

[1] % values quoted at 415V

[2] Main zero sequence data are for earth return via neutral conductor. Data in brackets are earth return via the sheath/armouring (where relevant)

4.8.3 Flat Formation of Phase and Neutral Cables Installed at 100mm Cable Spacing (Double Layer of Phase Cables)



Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0[2]	X_0[2]	R_1%	X_1%	R_0%	X_0%
LV Mains single-core cables, in flat formation (double layer of phase cables) - Modern Types									
Single-core solid **Aluminium** 4 x 90° sector shaped conductor, PVC insulated, PVC sheathed, Aluminium strip armoured to BS 6346: 1989 (In flat formation, double phase layer)	600mm²	0.026	0.163	0.180 (0.266)	0.711 (0.098)	1 510	9 460	10 450 (15 440)	41 280 (5 690)
Data sources:	Cable dimensions: BS 6346: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: Calculated								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, Aluminium wire armoured to BS 5467: 1997 (In flat formation, double phase layer)	300mm²	0.030	0.175	0.210 (0.340)	0.759 (0.106)	1 740	10 160	12 200 (19 700)	44 070 (6 150)
	400mm²	0.024	0.167	0.165 (0.244)	0.729 (0.102)	1 390	9 700	9 600 (14 200)	42 330 (5 920)
	500mm²	0.018	0.160	0.128 (0.218)	0.701 (0.098)	1 050	9 290	7 400 (12 700)	40 700 (5 690)
Data sources:	Cable dimensions: BS 5467: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: calculated								
Single-core stranded **Copper** conductor, XLPE insulated, PVC sheathed, unarmoured to BS 7889: 1997 (In flat formation, double phase layer)	300mm²	0.030	0.175	0.210	0.759	1 740	10 160	12 200	44 070
	400mm²	0.024	0.167	0.165	0.729	1 390	9 700	9 600	42 330
	500mm²	0.018	0.160	0.128	0.701	1 050	9 290	7 400	40 700
Data sources:	Cable dimensions: BS 7889: 1997 R_1 values: BS 6360: 1991 R_1 is dc value at 20°C X_1 values: calculated								

[1] % values quoted at 415V

[2] Main zero sequence data are for earth return via neutral conductor. Data in brackets are earth return via the armouring (where relevant)

Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0[2]	X_0[2]	R_1%	X_1%	R_0%	X_0%
LV Mains single-core cables, in flat formation (double layer of phase cables) - Historic Types									
Single-core stranded **Copper** conductor, Paper insulated, Lead sheathed, to BS 480/6480 (Imperial sizes) (In flat formation, double phase layer)	0.40in²	0.038	0.192	0.269 (1.638)	0.828 (0.119)	2 210	11 150	15 600 (95 100)	48 080 (6 910)
	0.50in²	0.031	0.185	0.217 (1.385)	0.798 (0.114)	1 800	10 740	12 600 (80 400)	46 330 (6 620)
	0.60in²	0.025	0.171	0.174 (1.149)	0.743 (0.105)	1 450	9 930	10 100 (66 700)	43 140 (6 040)
	0.75in²	0.020	0.164	0.140 (0.983)	0.714 (0.099)	1 160	9 520	8 100 (57 100)	41 460 (5 750)
	1.00in²	0.016	0.153	0.114 (0.746)	0.672 (0.094)	930	8 880	6 600 (43 300)	39 020 (5 460)
Data sources:	Cable dimensions: BS 480: 1966 R_1 values: BICC p945 (nearest equiv) R_1 corrected to 20°C X_1 values: Calculated								
Single-core stranded **Copper** conductor, VIR insulated, unarmoured (In flat formation, double phase layer)	0.40in²	0.038	0.192	0.269	0.828	2 210	11 150	15 600	48 080
	0.50in²	0.031	0.185	0.217	0.798	1 800	10 740	12 600	46 330
	0.60in²	0.025	0.171	0.174	0.743	1 450	9 930	10 100	43 140
	0.75in²	0.020	0.164	0.140	0.714	1 160	9 520	8 100	41 460
	1.00in²	0.016	0.153	0.114	0.672	930	8 880	6 600	30 020
Data sources:	Cable dimensions: estimated from BS 480: 1966 R_1 values: BICC p945 (nearest equivalent) R_1 value corrected to 20°C X_1 values: calculated								
Consac cables used as single core-cables by bunching the three cores together (In flat formation, double phase layer)	3 x 185mm²	0.028	0.168	0.193 (0.181)	0.731 (0.103)	1 630	9 750	11 200 (10 500)	42 440 (5 980)
Data sources:	Cable dimensions ENA TS 09-8 R_1 values: ENA TS 09-8 R_1 value corrected to 20°C X_1 values: calculated								

[1] % values quoted at 415V

[2] Main zero sequence data are for earth return via neutral conductor. Data in brackets are earth return via the sheath (where relevant)

4.9 LV Service Cables

4.9.1 LV Three-Phase Service Cables

Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0	X_0	R_1%	X_1%	R_0%	X_0%
LV 3-phase service cables - Modern Types									
3-phase **CNE** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-11	25mm²	1.200	0.077	5.100	0.116	69 700	4 470	296 000	6 740
Data sources:	Cable dimensions: BS 7870-3-11 R_1 value: BS 7870-3-11 R values are dc values at 20°C X values: Calculated								
3-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21	25mm²	1.200	0.077	4.800	0.118	69 700	4 470	279 000	6 850
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
LV 3-phase service cables - Historic Types									
3-phase **CNE** stranded **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-10	25mm²	1.200	0.082	5.100	0.121	69 700	4 760	296 000	7 030
Data sources:	Cable dimensions: BS 7870-3-10 R_1 value: BS 7870-3-10 R values are dc values at 20°C X values: Calculated								
3-phase **CNE** Solid **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-10	16mm²	1.150	0.084	4.750	0.121	66 800	4 880	276 000	7 030
Data sources:	Cable dimensions: BS 7870-3-10 R_1 value: BS 7870-3-10 R values are dc values at 20°C X values: Calculated								
4-core stranded **Copper** conductor, paper insulated Lead sheathed, Steel tape armoured to BS 6480 **Assumes earth return via the sheath only (including armouring)**	16mm²	1.149	0.080	4.260	0.092	66 700	4 650	247 000	5 340
Data sources:	Cable dimensions: BS 6480: 1988 R_1, X_1 values: BICC p945 R_1 value corrected to 20° Assumes neutral core same size as phase core								

4-core stranded **Copper** conductor, paper insulated Lead sheathed, Steel tape armoured cable to BS 480 **Assumes earth return via the sheath only (including armouring)**	0.0145in^2	1.903	0.089	5.250	0.148	110 500	5 170	305 000	8 590
	0.0225in^2	1.257	0.086	4.610	0.114	73 000	4 990	267 000	6 620
Data sources:	Cable dimensions: BS 480: 1966 R_1 value corrected to 20°			R_1, X_1 values: Supplied by Pirelli Assumes neutral core same size as phase core					

[1] % values quoted at 415V.

4.9.2 LV Single-phase Service Cables

For the single-phase CNE service cables, the impedances for the phase (R_p, X_p) and the neutral conductors (R_n, X_n) are given and only one entry is required since both load current and a fault current return is via the neutral conductor.

For split concentric and 2-core PILC cables two entries are provided; (i) load and fault current return via the neutral wires (R_p, X_p, R_n, X_n) and (ii) fault current return via the earth wires or sheath, as relevant (R_p, X_p, R_e (or R_{sh}), X_e (or X_{sh})).

Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
LV Single-phase service cables - Modern Types									
Single-phase **CNE** Solid **Aluminium** phase conductors, concentric Copper wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-11		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	35mm²	0.868	0.077	0.910	0.077	50 400	4 470	52 800	4 470
Data sources:	Cable dimensions: BS 7870-3-11 R_1 value: BS 7870-3-11 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, XLPE insulated. BS 7870-3-21 **Load/fault current return via the neutral wires**		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	35mm²	0.868	0.092	0.760	0.092	50 400	5 340	44 100	5 340
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21 **Fault current return via the earth wires**		**Rp**	**Xp**	**Re**	**Xe**	**Rp%**	**Xp%**	**Re%**	**Xe%**
	35mm²	0.868	0.095	1.200	0.095	50 400	5 520	69 700	5 520
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
Single-phase **CNE** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-11		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	4mm²	4.61	0.091	4.80	0.091	268 000	5 280	279 000	5 280
Data sources:	Cable dimensions: BS 7870-3-11 R_1 value: BS 7870-3-11 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	4mm²	4.61	0.091	4.80	0.091	268 000	5 280	279 000	5 280

Load/fault current return via the neutral wires									
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21 **Fault current return via the earth wires**		**Rp**	**Xp**	**Re**	**Xe**	**Rp%**	**Xp%**	**Re%**	**Xe%**
	4mm^2	4.61	0.097	4.80	0.097	268 000	5 630	279 000	5 630
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								

[1] % values quoted at 415V

Cable type	Size	Impedance (Ω / km)				100MVA base / km [1]			
LV Single-phase service cables - Historic Types									
Single-phase **CNE** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor**, XLPE** insulated. BS 7870-3-11		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	25mm²	1.200	0.079	1.300	0.079	69 700	4 590	75 500	4 590
Data sources:	Cable dimensions: BS 7870-3-11 R_1 value: BS 7870-3-11 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21 **Load/fault current return via the neutral wires**		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	25mm²	1.200	0.085	1.200	0.085	69 700	4 940	69 700	4 940
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **XLPE** insulated. BS 7870-3-21 **Fault current return via the earth wires**		**Rp**	**Xp**	**Re**	**Xe**	**Rp%**	**Xp%**	**Re%**	**Xe%**
	25mm²	1.200	0.088	1.200	0.088	69 700	5 110	69 700	5 110
Data sources:	Cable dimensions: BS 7870-3-21 R_1 value: BS 7870-3-21 R values are dc values at 20°C X values: Calculated								
Single-phase **CNE** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-10		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	25mm²	1.200	0.084	1.300	0.084	69 700	4 880	75 500	4 880
Data sources:	Cable dimensions: BS 7870-3-10 R_1 value: BS 7870-3-10 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-20 **Load/fault current return via the neutral wires**		Rp	Xp	Rn	Xn	Rp%	Xp%	Rn%	Xn%
	25mm²	1.200	0.088	1.200	0.088	69 700	5 110	69 700	5 110
Data sources:	Cable dimensions: BS 7870-3-20 R_1 value: BS 7870-3-20 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Solid **Aluminium** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-20 **Fault current return via the earth wires**		Rp	Xp	Re	Xe	Rp%	Xp%	Re%	Xe%
	25mm²	1.200	0.091	1.200	0.091	69 700	5 280	69 700	5 280

Data sources:	Cable dimensions: BS 7870-3-20 R_1 value: BS 7870-3-20 R values are dc values at 20°C X values: Calculated								
Single-phase **CNE** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, **PVC** insulated. BS 7870-3-10		Rp	Xp	Rn	Xn	Rp%	Xp%	Rn%	Xn%
	4mm²	4.61	0.094	4.80	0.094	268 000	5 460	279 000	5 460
	16mm²	1.150	0.083	1.200	0.083	66 800	4 820	69 700	4 820
	25mm²	0.727	0.081	0.760	0.081	42 200	4 700	44 100	4 700
Data sources:	Cable dimensions: BS 7870-3-10 R_1 value: BS 7870-3-10 R values are dc values at 20°C X values: Calculated								

[1] % values quoted at 415V

Cable type	**Size**	**Impedance (Ω / km)**				**100MVA base / km** [1]			
LV Single-phase service cables - Historic Types (Continued)									
Single-phase **Split Concentric** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, PVC insulated. BS 7870-3-20 **Load/fault current return via the neutral wires**		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	4mm²	4.61	0.093	4.80	0.093	268 000	5 400	279 000	5 400
	16mm²	1.150	0.088	1.200	0.088	66 800	5 110	69 700	5 110
	25mm²	0.727	0.092	0.760	0.092	42 200	5 340	44 100	5 340
Data sources:	Cable dimensions: BS 7870-3-20 R_1 value: BS 7870-3-20 R values are dc values at 20°C X values: Calculated								
Single-phase **Split Concentric** Stranded **Copper** phase conductors, concentric **Copper** wire neutral/earth conductor, PVC insulated. BS 7870-3-20 **Fault current return via the earth wires**		**Rp**	**Xp**	**Re**	**Xe**	**Rp%**	**Xp%**	**Re%**	**Xe%**
	4mm²	4.61	0.098	4.80	0.098	268 000	5 690	279 000	5 690
	16mm²	1.150	0.092	1.200	0.092	66 800	5 340	69 700	5 340
	25mm²	0.727	0.094	1.200	0.094	42 200	5 460	69 700	5 460
Data sources:	Cable dimensions: BS 7870-3-20 R_1 value: BS 7870-3-20 R values are dc values at 20°C X values: Calculated								
2-core **Copper** conductor, paper insulated Lead sheathed, Steel tape armoured cable to BS 480 **Load/fault current return via the neutral wires**		**Rp**	**Xp**	**Rn**	**Xn**	**Rp%**	**Xp%**	**Rn%**	**Xn%**
	0.0070in²	3.97	0.099	3.97	0.099	230 000	5 750	230 000	5 750
	0.0145in²	1.903	0.090	1.903	0.090	110 500	5 230	110 500	5 230
	0.0225in²	1.257	0.085	1.257	0.085	73 000	4 940	73 000	4 940
Data sources:	Cable dimensions: BS 480: 1966 R_1 value: BS480 R_1 values corrected to 20° X values: Calculated								
2-core **Copper** conductor, paper insulated Lead sheathed, Steel		**Rp**	**Xp**	**Rsh**	**Xsh**	**Rp%**	**Xp%**	**Rsh%**	**Xsh%**

tape armoured cable to BS 480 **Fault current return via the sheath**	0.0070in^2	3.97	0.099	2.873	0.029	230 000	5 750	167 000	1 660
	0.0145in^2	1.903	0.090	2.441	0.022	110 500	5 230	141 700	1 270
	0.0225in^2	1.257	0.085	2.243	0.021	73 000	4 940	130 200	1 190
Data sources:	Cable dimensions: BS 480: 1966 R_1 values corrected to 20°			R_1 value: BS480 X values: Calculated					

[1] % values quoted at 415V

5 Overhead Line Impendence Values

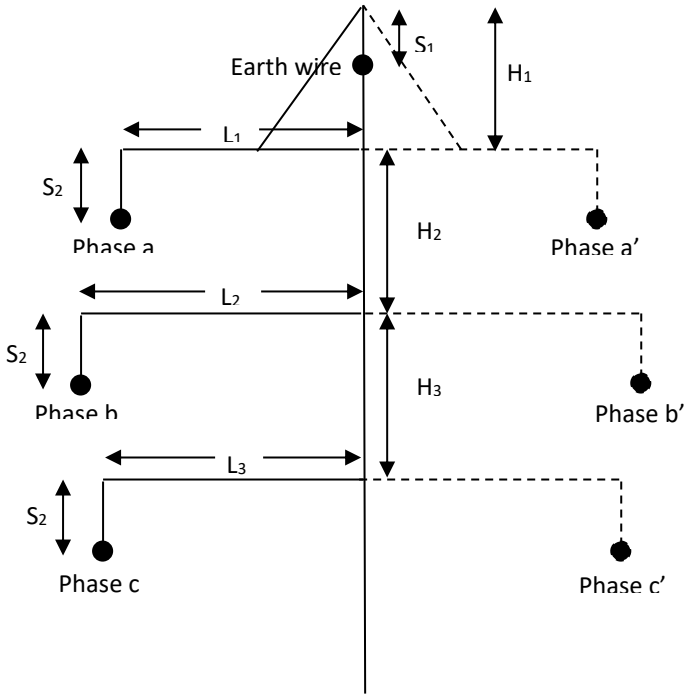
The positive sequence values of resistance are quoted at 20ºC for all the lines. For other values of operating temperature use the appropriate temperature coefficient of resistance in CP205 Table 1 'Temperature coefficients of resistance for conductor materials' to calculate the resistance at the required temperature. Note that if a different temperature is selected then the zero sequence resistance will also need to be re-calculated. The positive sequence reactance values have been calculated (See CP205 sub-section 4.2 for details of the method of calculation) using the conductor spacings given in the tables of constructional details below. All calculations of zero sequence impedance are based on an earth return either completely or partly via the ground using an Earth Resistivity value of 100Ωm. Where zero sequence impedances are required at different values of soil resisitivity, use the methods given in CP205, section 6 to calculate the requisite values.

Values of positive sequence line susceptance are included in the tables. The values quoted are derived from the positive sequence capacitance calculated (See CP205 sub-section 3.2 for details of the method of calculation) using the conductor spacings given in the tables of constructional details below. If zero sequence susceptance values are required then refer to the same section in CP205 for the method of calculation.

5.1 132kV Double Circuit Tower Lines, Single Earth Wire

The general tower configuration shown in figure 1 below, with each circuit assumed to be a mirror image of the other and symmetrically displaced relative to the earth wire. This is the case for the construction designs of 132kV tower lines used in the Network and so has been used for the impedance calculations.

Figure 1 – General Configuration of a 132kV Double Circuit Tower Line with One Earth Wire



Whilst the termination and angle towers have slightly different dimension from the intermediate towers, the effect on circuit impedance is ignored and the impedances are based on the intermediate tower dimensions only since these are the most numerous on a circuit.

The tables of impedances are for the two circuits run split and treated as two separate circuits.

NOTE

(a) Because of the above assumption, the values of impedance for the double circuit line run split can be applied to a single circuit line with one earth wire running on the same construction as that of the double circuit line.

(b) For the purposes of fault calculations, the impedances can be considered as applicable for transformer feeders run in parallel for the situation with the downstream lower voltage busbars run with the bus section circuit breaker or isolator closed. The impedance of the two transformers in series will significantly reduce the contribution to a fault on one circuit from the other circuit.

(c) Impedance values are not provided for feeder circuits (i.e. non-transformer feeders) run in parallel since this is an unusual situation in the Network. If impedance values are required, they can be calculated using the method given in CP205 sub-section 6.2.2 (b).

5.1.1 L2 Construction

L2 275kVconstruction. Dimensions taken from CEGB drawing: 35/5542, dated 10/3/1976
S_1 = 0.340m[1]
S_2 = 3.810m (12.5ft)[2] S_2 = 2.013m [3]
H_1 = 2.286m (7.5ft)
H_2 = 7.772m (25.5ft)
H_3 = 7.848m (25.75ft)
L_1 = 5.486m (18.0ft)
L_2 = 5.715m (18.75ft)
L_3 = 6.096m (20.0ft)

NOTE

(a) Earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

(b) Suspension insulator string length equal to a 275kV insulator set

(c) Suspension insulator string length as per standard 132kV insulator set, assumed the same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (μS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0 *	X_0 *		R_1%	X_1%	R_0% *	X_0% *
132kV bare conductor, double circuit line, L2 construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.446	0.346 (0.351)	1.057 (1.043)	2.53	0.090	0.256	0.199 (0.202)	0.606 (0.599)
	175mm² Lynx	175mm² Lynx	0.158	0.446	0.279 (0.281)	1.018 (1.002)	2.53	0.090	0.256	0.160 (0.161)	0.584 (0.575)
	400mm² Zebra	70mm² Horse	0.067	0.424	0.256 (0.261)	1.035 (1.021)	2.67	0.039	0.243	0.147 (0.150)	0.594 (0.586)
	400mm² Zebra	175mm² Lynx	0.067	0.424	0.189 (0.191)	0.996 (0.980)	2.67	0.039	0.243	0.108 (0.109)	0.572 (0.562)
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.436	0.280 (0.285)	1.047 (1.034)	2.61	0.053	0.250	0.161 (0.164)	0.601 (0.593)
	300mm² Upas	175mm² Lynx	0.092	0.436	0.213 (0.215)	1.008 (0.992)	2.61	0.053	0.250	0.122 (1.123)	0.579 (0.569)
	500mm² Rubus	70mm² Horse	0.057	0.421	0.246 (0.250)	1.032 (1.019)	2.71	0.033	0.242	0.141 (0.144)	0.592 (0.585)
	500mm² Rubus	175mm² Lynx	0.057	0.421	0.178 (0.180)	0.993 (0.977)	2.71	0.033	0.242	0.102 (0.103)	0.570 (0.561)
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

* Main data are for a circuit with a suspension length equal to a 275kV insulator set Data in brackets are for a circuit with a standard length 132kV insulator set

5.1.2 L3 Construction

L3 275kV construction. Dimensions taken from CEGB drawing: 35/5543, dated 4/11/1977
S_1 = 0.340m[1]
S_2 = 3.129m[2] S_2 = 2.013m[3]
H_1 = 2.134m
H_2 = 6.096m
H_3 = 6.096m
L_1 = 4.039m
L_2 = 4.267m
L_3 = 4.572m

NOTE:

(a) Earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

(b) Suspension insulator string length equal to a 275kV insulator set

(c) Suspension insulator string length as per standard 132kV insulator set, assumed the same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0 *	X_0 *		R_1%	X_1%	R_0% *	X_0% *
132kV bare conductor, double circuit line, L3 construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.430	0.356 (0.360)	1.063 (1.052)	2.62	0.090	0.247	0.204 (0.207)	0.610 (0.604)
	175mm² Lynx	175mm² Lynx	0.158	0.430	0.282 (0.284)	1.019 (1.005)	2.62	0.090	0.247	0.162 (0.163)	0.585 (0.577)
	400mm² Zebra	70mm² Horse	0.067	0.408	0.265 (0.270)	1.041 (1.030)	2.77	0.039	0.234	0.152 (0.155)	0.597 (0.591)
	400mm² Zebra	175mm² Lynx	0.067	0.408	0.192 (0.193)	0.997 (0.983)	2.77	0.039	0.234	0.110 (0.111)	0.572 (0.564)
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.421	0.290 (0.294)	1.053 (1.042)	2.71	0.053	0.242	0.166 (0.169)	0.605 (0.598)
	300mm² Upas	175mm² Lynx	0.092	0.421	0.216 (0.218)	1.009 (0.996)	2.71	0.053	0.242	0.124 (0.125)	0.579 (0.571)
	500mm² Rubus	70mm² Horse	0.057	0.406	0.255 (0.259)	1.038 (1.027)	2.82	0.033	0.233	0.146 (0.149)	0.596 (0.589)
	500mm² Rubus	175mm² Lynx	0.057	0.406	0.181 (0.183)	0.994 (0.980)	2.82	0.033	0.233	0.104 (0.105)	0.570 (0.563)
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

* Main data are for a circuit with a suspension length equal to a 275kV insulator set Data in brackets are for a circuit with a standard length 132kV insulator set

5.1.3 L3 (C) Construction

L3(C) 275kV construction. Dimensions taken from CEGB drawing: 35/8192 dated 6/7/1978
S_1 = 0.340m[1]
S_2 = 3.333m[2] S_2 = 2.013m[3]
H_1 = 2.134m
H_2 = 6.701m
H_3 = 6.701m
L_1 = 4.115m
L_2 = 6.629m
L_3 = 4.801m

NOTE:

(a) Earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

(b) Suspension insulator string length equal to a 275kV insulator set

(c) Suspension insulator string length as per standard 132kV insulator set, assumed the same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (μS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0 *	X_0 *		R_1%	X_1%	R_0% *	X_0% *
132kV bare conductor, double circuit line, L3(C) construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.438	0.352 (0.357)	1.056 (1.044)	2.57	0.090	0.252	0.202 (0.205)	0.606 (0.599)
	175mm² Lynx	175mm² Lynx	0.158	0.438	0.281 (0.283)	1.014 (0.999)	2.57	0.090	0.252	0.161 (0.162)	0.582 (0.574)
	400mm² Zebra	70mm² Horse	0.067	0.416	0.262 (0.266)	1.034 (1.022)	2.72	0.039	0.239	0.150 (0.153)	0.5594 (0.587)
	400mm² Zebra	175mm² Lynx	0.067	0.416	0.191 (0.192)	0.992 (0.977)	2.72	0.039	0.239	0.110 (0.110)	0.569 (0.561)
Data sources:	Conductor dimensions: BS 215: 1970					R_1 values: BS 215: 1970		R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.429	0.286 (0.291)	1.047 (1.035)	2.66	0.053	0.246	0.164 (0.167)	0.601 (0.594)
	300mm² Upas	175mm² Lynx	0.092	0.429	0.215 (0.216)	1.005 (0.990)	2.66	0.053	0.246	0.123 (0.124)	0.577 (0.568)
	500mm² Rubus	70mm² Horse	0.057	0.414	0.251 (0.256)	1.032 (1.020)	2.76	0.033	0.237	0.144 (0.147)	0.592 (0.585)
	500mm² Rubus	175mm² Lynx	0.057	0.414	0.180 (0.182)	0.989 (0.975)	2.76	0.033	0.237	0.103 (0.104)	0.568 (0.559)
Data sources:	Conductor dimensions: BS EN 50182: 2001					R_1 values: BS EN 50182: 2001		R_1 is dc value at 20°C			

* Main data are for a circuit with a suspension length equal to a 275kV insulator set Data in brackets are for a circuit with a standard length 132kV insulator set

5.1.4 L4(M) Construction

L4(M) 132kV construction. Dimensions taken from CEGB drawing: 35/8299 dated 10/3/1976
S_1 = 0.340m*
S_2 = 2.013m
H_1 = 1.165m
H_2 = 3.750m
H_3 = 3.750m
L_1 = 2.800m
L_2 = 4.200m
L_3 = 3.200m

* Earth wire position below top of tower dimension supplied by Construction section.

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, L4(M) construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.402	0.377	1.065	2.81	0.090	0.231	0.216	0.611
	175mm² Lynx	175mm² Lynx	0.158	0.402	0.290	1.008	2.81	0.090	0.231	0.166	0.579
	400mm² Zebra	70mm² Horse	0.067	0.380	0.287	1.043	2.99	0.039	0.218	0.164	0.598
	400mm² Zebra	175mm² Lynx	0.067	0.380	0.199	0.987	2.99	0.039	0.218	0.114	0.566
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.392	0.311	1.055	2.92	0.053	0.225	0.178	0.606
	300mm² Upas	175mm² Lynx	0.092	0.392	0.224	1.000	2.92	0.053	0.225	0.128	0.573
	500mm² Rubus	70mm² Horse	0.057	0.377	0.276	1.040	3.04	0.033	0.216	0.158	0.597
	500mm² Rubus	175mm² Lynx	0.057	0.377	0.189	0.984	3.04	0.033	0.216	0.108	0.565
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

5.1.5 L7(C) Construction

L7(C) 132kV construction. Dimensions taken from CEGB drawing: 35/7601 dated 7/2/1969
S_1 = 0.340m*
S_2 = 2.013m
H_1 = 1.448m
H_2 = 4.420m
H_3 = 3.708m
L_1 = 3.124m
L_2 = 4.699m
L_3 = 3.480m

* Earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, L7(C) construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.407	0.372	1.068	2.78	0.090	0.234	0.213	0.613
	175mm² Lynx	175m m² Lynx	0.158	0.407	0.288	1.014	2.78	0.090	0.234	0.165	0.582
	400mm² Zebra	70mm² Horse	0.067	0.385	0.281	1.046	2.95	0.039	0.221	0.162	0.600
	400mm² Zebra	175m m² Lynx	0.067	0.385	0.198	0.992	2.95	0.039	0.221	0.113	0.569
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.398	0.306	1.058	2.88	0.053	0.228	0.175	0.607
	300mm² Upas	175m m² Lynx	0.092	0.398	0.222	1.005	2.88	0.053	0.228	0.127	0.577
	500mm² Rubus	70mm² Horse	0.057	0.382	0.271	1.043	3.00	0.033	0.219	0.155	0.599
	500mm² Rubus	175m m² Lynx	0.057	0.382	0.187	0.990	3.00	0.033	0.219	0.107	0.568
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

5.1.6 PL1 D2 Construction

PL1 D2 132kV construction. Dimensions taken from CEGB drawing 35/943
S_1 = 0.340m*
S_2 = 2.013m*
H_1 = 1.219m (4.0ft)
H_2 = 3.810m (12.5ft)
H_3 = 3.657m (12.0ft)
L_1 = 3.148m (10.33ft)
L_2 = 4.724m (15.5ft)
L_3 = 3.810m (12.5ft)

* 132kV suspension insulator set length and earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line,PL1 D2 construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.402	0.375	1.071	2.81	0.090	0.231	0.215	0.614
	175mm² Lynx	175mm² Lynx	0.158	0.402	0.289	1.016	2.81	0.090	0.231	0.166	0.583
	400mm² Zebra	70mm² Horse	0.067	0.380	0.284	1.049	2.99	0.039	0.218	0.163	0.602
	400mm² Zebra	175mm² Lynx	0.067	0.380	0.199	0.994	2.99	0.039	0.218	0.114	0.570
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.392	0.308	1.061	2.92	0.053	0.225	0.177	0.609
	300mm² Upas	175mm² Lynx	0.092	0.392	0.223	1.006	2.92	0.053	0.225	0.128	0.577
	500mm² Rubus	70mm² Horse	0.057	0.377	0.274	1.046	3.04	0.033	0.216	0.157	0.600
	500mm² Rubus	175mm² Lynx	0.057	0.377	0.188	0.991	3.04	0.033	0.216	0.108	0.569
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

5.1.7 PL16_175ACSR Construction

PL16_175ACSR D2 132kV construction. Dimensions taken CEGB drawing 35/5522 dated 27/3/1962
S_1 = 0.340m*
S_2 = 2.013m*
H_1 = 1.600m (5.25ft)
H_2 = 3.962m (13.0ft)
H_3 = 3.657m (12.0ft)
L_1 = 3.353m (11.0ft)
L_2 = 4.648m (15.25ft)
L_3 = 3.734m (12.25ft)

* 132kV suspension insulator set length and earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, PL16_175ACSR construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.402	0.372	1.077	2.81	0.090	0.231	0.213	0.618
	175mm² Lynx	175mm² Lynx	0.158	0.402	0.288	1.023	2.81	0.090	0.231	0.165	0.587
	400mm² Zebra	70mm² Horse	0.067	0.380	0.281	1.055	2.99	0.039	0.218	0.161	0.605
	400mm² Zebra	175mm² Lynx	0.067	0.380	0.197	1.002	2.99	0.039	0.218	0.113	0.575
Data sources:	Conductor dimensions: BS 215: 1970					R_1 values: BS 215: 1970		R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.393	0.306	1.068	2.91	0.053	0.226	0.175	0.613
	300mm² Upas	175mm² Lynx	0.092	0.393	0.222	1.014	2.91	0.053	0.226	0.127	0.582
	500mm² Rubus	70mm² Horse	0.057	0.378	0.271	1.052	3.04	0.033	0.217	0.155	0.604
	500mm² Rubus	175mm² Lynx	0.057	0.378	0.187	0.999	3.04	0.033	0.217	0.107	0.573
Data sources:	Conductor dimensions: BS EN 50182: 2001					R_1 values: BS EN 50182: 2001		R_1 is dc value at 20°C			

5.1.8 PL16_400ACSR Construction

PL16_400ACSR 132kV construction. Dimensions taken CEGB drawing 35/5523 dated 27/3/1962
S_1 = 0.340m*
S_2 = 2.013m*
H_1 = 1.701m (5.58ft)
H_2 = 3.734m (12.25ft)
H_3 = 3.657m (12.0ft)
L_1 = 3.734m (12.25ft)
L_2 = 4.648m (15.25ft)
L_3 = 3.734m (12.25ft)

* 132kV suspension insulator set length and earth wire position below top of tower assumed same as for L4(M) construction – see sub-section 5.1.4

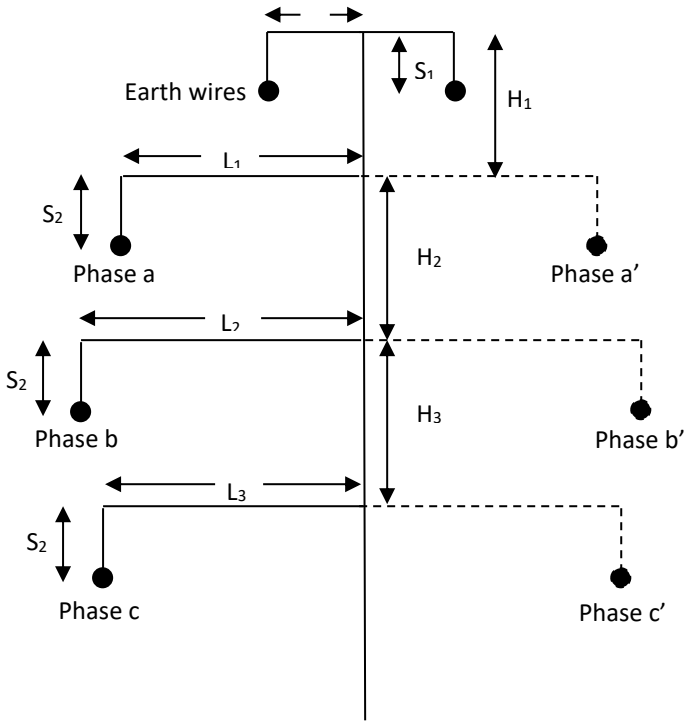
Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, PL16_400ACSR construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.400	0.371	1.084	2.83	0.090	0.230	0.213	0.622
	175mm² Lynx	175mm² Lynx	0.158	0.400	0.287	1.031	2.83	0.090	0.230	0.165	0.591
	400mm² Zebra	70mm² Horse	0.067	0.378	0.281	1.062	3.01	0.039	0.217	0.161	0.609
	400mm² Zebra	175mm² Lynx	0.067	0.378	0.197	1.009	3.01	0.039	0.217	0.113	0.579
Data sources:	Conductor dimensions: BS 215: 1970					R_1 values: BS 215: 1970		R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.391	0.305	1.074	2.93	0.053	0.224	0.175	0.616
	300mm² Upas	175mm² Lynx	0.092	0.391	0.221	1.021	2.93	0.053	0.224	0.127	0.586
	500mm² Rubus	70mm² Horse	0.057	0.375	0.270	1.059	3.06	0.033	0.215	0.155	0.608
	500mm² Rubus	175mm² Lynx	0.057	0.375	0.187	1.006	3.06	0.033	0.215	0.107	0.577
Data sources:	Conductor dimensions: BS EN 50182: 2001					R_1 values: BS EN 50182: 2001		R_1 is dc value at 20°C			

5.2 132kV Double Circuit Tower Lines, Double Earth Wire

The general tower configuration shown in figure 2 below, with each circuit assumed to be a mirror image of the other and symmetrically displaced relative to the earth wire. This is the case for the construction designs of 132kV tower lines used in the Network and so has been used for the impedance calculations.

Figure 2 – General Configuration of a 132kV Double Circuit Tower Line with Two Earth Wires



Whilst the termination and angle towers have slightly different dimensions from the intermediate towers, the effect on circuit impedance is ignored and the impedances are based on the intermediate tower dimensions only since these are the most numerous on a circuit.

The tables of impedances are for the two circuits run split and treated as two separate circuits. For the purposes of fault calculations, the impedances can be considered as applicable for transformer feeders run in parallel for the situation with the downstream lower voltage busbars run with the bus section circuit breaker or isolator closed. The impedance of the two transformers in series will significantly reduce the contribution to a fault on one circuit from the other circuit.

NOTE: Impedance values are not provided for feeder circuits (ie non-transformer feeders) run in parallel since this is an unusual situation in the Network. If impedance values are required, they can be calculated using the method given in CP205 sub-section 6.2.2 (b).

5.2.1 PL4 D2 Construction

PL4 D2 132kV construction. Dimensions taken from CEGB drawing 35/1043
E = 2.133m (7.0ft)
S_1 = 0.340m*
S_2 = 2.013m*
H_1 = 1.829m (6.0ft)
H_2 = 4.191m (13.75ft)
H_3 = 3.657m (12.0ft)
L_1 = 3.505m (11.5ft)
L_2 = 4.877m (16.0ft)
L_3 = 3.962m (13.0ft)

* 132kV suspension insulator set length and earth wire position below earth wire cross-arm assumed same as for L4(M) construction – see sub-section 5.1.4

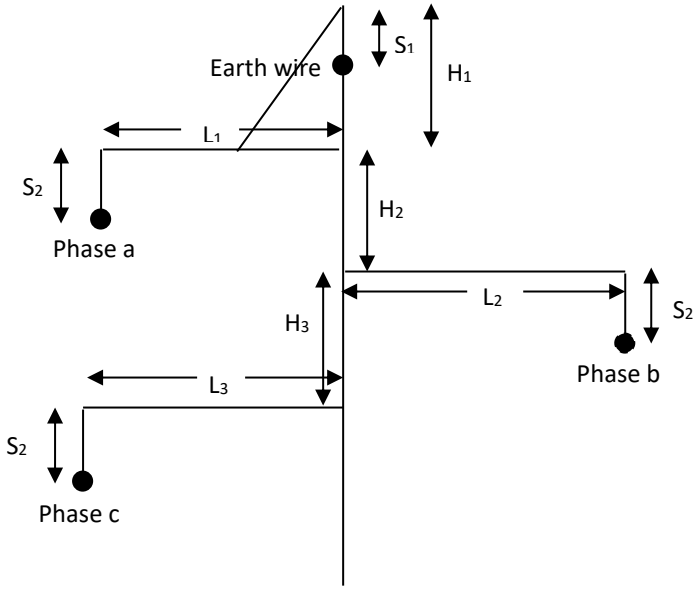
Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, PL4 D2 construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.404	0.349	0.934	2.80	0.090	0.232	0.200	0.536
	175mm² Lynx	175mm² Lynx	0.158	0.404	0.259	0.893	2.80	0.090	0.232	0.149	0.513
	400mm² Zebra	70mm² Horse	0.067	0.382	0.259	0.912	2.97	0.039	0.219	0.148	0.523
	400mm² Zebra	175mm² Lynx	0.067	0.382	0.169	0.871	2.97	0.039	0.219	0.097	0.500
Data sources:	Conductor dimensions: BS 215: 1970				R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.395	0.283	0.924	2.90	0.053	0.227	0.162	0.530
	300mm² Upas	175mm² Lynx	0.092	0.395	0.193	0.884	2.90	0.053	0.227	0.111	0.507
	500mm² Rubus	70mm² Horse	0.057	0.380	0.248	0.909	3.02	0.033	0.218	0.142	0.522
	500mm² Rubus	175mm² Lynx	0.057	0.380	0.159	0.869	3.02	0.033	0.218	0.091	0.499
Data sources:	Conductor dimensions: BS EN 50182: 2001				R_1 values: BS EN 50182: 2001			R_1 is dc value at 20°C			

5.3 132kV Single Circuit Tower Lines

The general tower configuration shown in figure 3 below.

Figure 3 – General Configuration of a 132kV Single Circuit Tower Line



Whilst the termination and angle towers have slightly different dimensions from the intermediate towers, the effect on circuit impedance is ignored and the impedances are based on the intermediate tower dimensions only since these are the most numerous on a circuit.

5.3.1 PL1 S2 Construction

PL1 S2 132kV construction. Dimensions taken from CEGB drawing 35/171
S_1 = 0.340m*
S_2 = 2.013m*
H_1 = 1.829m (6.0ft)
H_2 = 4.191m (13.75ft)
H_3 = 3.657m (12.0ft)
L_1 = 3.505m (11.5ft)
L_2 = 4.877m (16.0ft)
L_3 = 3.962m (13.0ft)

* 132kV suspension insulator set length and earth wire position below earth wire cross-arm assumed same as for L4(M) construction – see sub-section 5.1.4

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Conductor Size		Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
	Phase	Earth	R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
132kV bare conductor, double circuit line, PL1 D2 construction											
ACSR stranded, phase conductors	175mm² Lynx	70mm² Horse	0.158	0.410	0.387	1.021	2.75	0.090	0.235	0.222	0.586
	175mm² Lynx	175mm² Lynx	0.158	0.410	0.294	0.959	2.75	0.090	0.235	0.168	0.550
	400mm² Zebra	70mm² Horse	0.067	0.388	0.297	0.999	2.92	0.039	0.223	0.171	0.573
	400mm² Zebra	175mm² Lynx	0.067	0.388	0.203	0.937	2.92	0.039	0.223	0.117	0.538
Data sources:	Conductor dimensions: BS 215: 1970					R_1 values: BS 215: 1970		R_1 is dc value at 20°C			
AAAC stranded, phase conductors	300mm² Upas	70mm² Horse	0.092	0.401	0.321	1.012	2.85	0.053	0.230	0.184	0.581
	300mm² Upas	175mm² Lynx	0.092	0.401	0.228	0.949	2.85	0.053	0.230	0.131	0.545
	500mm² Rubus	70mm² Horse	0.057	0.386	0.287	0.996	2.97	0.033	0.221	0.164	0.572
	500mm² Rubus	175mm² Lynx	0.057	0.386	0.193	0.934	2.97	0.033	0.221	0.111	0.536
Data sources:	Conductor dimensions: BS EN 50182: 2001					R_1 values: BS EN 50182: 2001		R_1 is dc value at 20°C			

5.4 33kV Single Circuit Wood Pole Lines

National Std. Spacing (ENA TS 43-20)
d(ab) = 1.2m
d(bc) = 1.2m
d(ac) = 2.4m

Earth resistivity value used to calculate zero sequence impedance = 100Ωm.

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV bare conductor 3 phase overhead lines (Metric sizes) - National Std. Spacing (ENA TS 43-20)										
Hard drawn stranded **Copper**, bare conductors	3x 16mm²	1.082	0.405	1.231	1.627	2.78	9.94	3.72	11.30	14.94
	3x 32mm²	0.541	0.383	0.689	1.605	2.94	4.97	3.52	6.33	14.74
	3x 100mm²	0.176	0.354	0.324	1.576	3.20	1.616	3.25	2.98	14.47
Data sources:	Conductor dimensions: BS 7884: 1997 X_1 values: calculated			R_1 values: BS 7884: 1997			R_1 is dc value at 20°C			
Aluminium alloy stranded, bare conductors	3x 25mm² Almond	1.093	0.390	1.241	1.612	2.88	10.04	3.58	11.40	14.80
	3x 50mm² Hazel	0.550	0.368	0.698	1.590	3.05	5.05	3.38	6.41	14.60
	3x 100mm² Oak	0.277	0.347	0.425	1.568	3.24	2.54	3.19	3.90	14.40
	3x 150mm² Ash	0.183	0.333	0.331	1.555	3.38	1.680	3.06	3.04	14.28
	3x 175mm² Elm	0.157	0.328	0.305	1.550	3.43	1.442	3.01	2.80	14.23
	3x 200mm² Poplar	0.139	0.320	0.287	1.542	3.48	1.276	2.94	2.64	14.16
	3x 300mm² Upas	0.092	0.307	0.240	1.529	3.63	0.845	2.82	2.20	14.04
Data sources:	Conductor dimensions: BS 3242: 1970 X_1 values: calculated			R_1 values: BS 3242: 1970			R_1 is dc value at 20°C			
ACSR stranded, bare conductors	3x 25mm² Gopher	1.093	0.386	1.241	1.608	2.88	10.04	3.54	11.40	14.77
	3x 50mm² Rabbit	0.543	0.364	0.691	1.586	3.06	4.99	3.34	6.35	14.56
	3x 70mm² Horse	0.394	0.336	0.542	1.558	3.24	3.62	3.09	4.98	14.31
	3x 75mm² Racoon *	0.366	0.351	0.514	1.573	3.17	3.36	3.22	4.72	14.44
	3x 100mm² Dog	0.273	0.342	0.421	1.564	3.25	2.51	3.14	3.87	14.36
	3x 150mm² Dingo	0.182	0.327	0.330	1.549	3.36	1.671	3.00	3.03	14.22
	3x 175mm² Caracal	0.156	0.322	0.304	1.544	3.41	1.433	2.96	2.79	14.18
	3x 175mm² Lynx	0.158	0.317	0.306	1.539	3.46	1.451	2.91	2.81	14.13

	3x 200mm² Jaguar	0.137	0.318	0.285	1.540	3.45	1.258	2.92	2.62	14.14
	3x 400mm² Zebra	0.067	0.295	0.215	1.516	3.74	0.615	2.71	1.970	13.92
Data sources:	Conductor dimensions: BS 215: 1970 R_1 values: BS 215: 1970 R_1 is dc value at 20°C X_1 values: calculated * 75mm² Racoon not a BS metric size - calculated using 0.075in² imperial copper equivalent									

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
33kV bare conductor 3 phase overhead lines (Imperial sizes) - National Std. Spacing (ENA TS 43-20)										
Hard drawn stranded **Copper**, bare conductors	3x 0.025in²	1.087	0.405	1.235	1.627	2.78	9.98	3.72	11.34	14.94
	3x 0.05in²	0.543	0.383	0.691	1.605	2.94	4.99	3.52	6.35	14.74
Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated									
Aluminium alloy stranded, bare conductors	3x 0.025in² Cu equiv	1.084	0.390	1.232	1.612	2.88	9.95	3.58	11.31	14.80
	3x 0.05in² Cu equiv	0.543	0.368	0.691	1.590	3.05	4.99	3.38	6.35	14.60
Data sources:	Conductor dimensions: BS 3242: 1960 R_1 values: BS 3242: 1960 R_1 is dc value at 20°C X_1 values: calculated									
ACSR stranded, bare conductors	3x 0.025in² Cu equiv	1.096	0.386	1.244	1.607	2.88	10.06	3.54	11.42	14.76
	3x 0.05in² Cu equiv	0.544	0.364	0.692	1.585	3.06	5.00	3.34	6.35	14.55
	3x 0.075in² Cu equiv	0.366	0.351	0.514	1.573	3.17	3.36	3.22	4.72	14.44
Data sources:	Conductor dimensions: BS 215: 1956 R_1 values: BS 215: 1956 R_1 is dc value at 20°C X_1 values: calculated									

5.5 11kV / 6.6kV Bare Conductor 3-phase Lines

National Std. Spacing (ENA TS 43-10) [a]
d(ab) = 1.05m
d(bc) = 0.95m
d(ac) = 2.00m

[a] The position of the centre pin insulator is staggered at each pole so that the mean conductor spacing between the outer and inner conductors along a line is equal, equal to 1.0 m. The impedance values below are calculated using 1.0m spacing.

Earth resistivity value used to calculate zero sequence impedance = 100Ωm

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV bare conductor 3 phase overhead lines (Metric sizes) - National Std. Spacing (ENA TS 43-10)										
Hard drawn stranded **Cadmium - Copper** bare conductors	3x 22mm²	0.988	0.400	1.136	1.644	2.89	81.7	33.1	93.9	135.9
Data sources:	Conductor dimensions: BS 7884: 1997 X_1 values: calculated			R_1 values: BS 7884: 1997			R_1 is dc value at 20°C			
Hard drawn stranded **Copper**, bare conductors	3x 16mm²	1.082	0.405	1.231	1.650	2.86	89.4	33.5	101.7	136.4
	3x 32mm²	0.541	0.383	0.689	1.628	3.04	44.7	31.7	56.9	134.5
	3x 38mm² *	0.466	0.382	0.614	1.627	3.07	38.5	31.6	50.7	134.4
	3x 70mm²	0.259	0.364	0.407	1.608	3.19	21.4	30.1	33.6	132.9
	3x 100mm²	0.176	0.352	0.324	1.596	3.31	14.55	29.1	26.8	131.9
Data sources:	Conductor dimensions: BS 7884: 1997 X_1 values: calculated * 38mm² not a BS metric size - calculated using 0.06in² imperial equivalent			R_1 values: BS 7884: 1997			R_1 is dc value at 20°C			
Aluminium alloy stranded, bare conductors	3x 25mm² Almond	1.093	0.390	1.241	1.635	2.97	90.3	32.2	102.6	135.1
	3x 50mm² Hazel	0.550	0.368	0.698	1.613	3.15	45.4	30.4	57.7	133.3
	3x 100mm² Oak	0.277	0.347	0.425	1.591	3.36	22.9	28.7	35.1	131.5
	3x 150mm² Ash	0.183	0.330	0.331	1.575	3.51	15.12	27.3	27.4	130.2
	3x 200mm² Poplar	0.139	0.321	0.287	1.566	3.61	11.49	26.5	23.7	129.4
Data sources:	Conductor dimensions: BS 3242: 1970 X_1 values: calculated			R_1 values: BS 3242: 1970			R_1 is dc value at 20°C			
HD Aluminium stranded, bare conductors	3x 50mm² Ant	0.542	0.372	0.690	1.617	3.11	44.8	30.7	57.0	133.6
	3x 100mm² Wasp	0.270	0.350	0.418	1.595	3.32	22.3	28.9	34.5	131.8

Data sources:	Conductor dimensions: BS 215: 1970 X_1 values: calculated			R_1 values: BS 215: 1970			R_1 is dc value at 20°C			
ACSR stranded, bare conductors	3x 25mm² Gopher	1.093	0.386	1.241	1.630	2.97	90.3	31.9	102.6	134.7
	3x 50mm² Rabbit	0.543	0.364	0.691	1.608	3.16	44.9	30.1	57.1	132.9
	3x 70mm² Horse	0.393	0.343	0.541	1.588	3.36	32.5	28.3	44.7	131.2
	3x 100mm² Dog	0.273	0.342	0.421	1.587	3.37	22.6	28.3	34.8	131.2
	3x 150mm² Dingo	0.182	0.327	0.330	1.571	3.48	15.04	27.0	27.3	129.8
	3x 175mm² Caracal	0.156	0.322	0.304	1.567	3.53	12.89	26.6	25.1	129.5
	3x 175mm² Lynx	0.158	0.317	0.306	1.562	3.59	13.06	26.2	25.3	129.1
Data sources:	Conductor dimensions: BS 215: 1970 X_1 values: calculated			R_1 values: BS 215: 1970			R_1 is dc value at 20°C			

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV bare conductor 3 phase overhead lines (Imperial sizes) - National Std. Spacing (ENA TS 43-10)										
Hard drawn stranded **Cadmium - Copper** bare conductors	3x 0.017in² Cu equiv (3 strand)	1.578	0.412	1.726	1.657	2.81	130.4	34.0	142.6	136.9
	3x 0.022in² Cu equiv (3 strand)	1.238	0.405	1.386	1.649	2.87	102.3	33.5	114.5	136.3
	3x 0.022in² Cu equiv (7 strand)	1.231	0.408	1.379	1.653	2.83	101.7	33.7	114.0	136.6
	3x 0.025in² Cu equiv (3 strand)	1.088	0.401	1.236	1.645	2.90	89.9	33.1	102.1	135.9
	3x 0.025in² Cu equiv (7 strand)	1.100	0.404	1.248	1.649	2.85	90.9	33.4	103.1	136.3
	3x 0.035in² Cu equiv (3 strand)	0.795	0.391	0.943	1.636	2.98	65.7	32.3	77.9	135.2
	3x 0.035in² Cu equiv (7 strand)	0.793	0.394	0.941	1.639	2.93	65.5	32.6	77.8	135.5
	3x 0.040in² Cu equiv (3 strand)	0.687	0.386	0.835	1.631	3.01	56.8	31.9	69.0	134.8
	3x 0.040in² Cu equiv (7 strand)	0.678	0.389	0.826	1.634	2.97	56.0	32.1	68.3	135.0
	3x 0.050in² Cu equiv (7 strand)	0.553	0.383	0.701	1.628	3.02	45.7	31.7	57.9	134.5

Data sources:	Conductor dimensions: BS 672: 1957 R_1 values: BS 672: 1957 R_1 is dc value at 20°C X_1 values: calculated									
Hard drawn **solid Copper,** bare conductors	3x 0.025in² (7 SWG)	1.129	0.414	1.277	1.659	2.75	93.3	34.2	105.5	137.1
	3x 0.035in² (5 SWG)	0.777	0.402	0.925	1.647	2.84	64.2	33.2	76.4	136.1
	3x 0.05in² (3 SWG)	0.550	0.391	0.698	1.636	2.92	45.5	32.3	57.7	135.2
	3x 0.07in² (1 SWG)	0.388	0.380	0.536	1.625	3.01	32.1	31.4	44.3	134.3
Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated									
Hard drawn stranded **Copper**, bare conductors	3x 0.022in²	1.231	0.413	1.379	1.657	2.79	101.7	34.1	114.0	137.0
	3x 0.025in²	1.087	0.405	1.235	1.650	2.86	89.9	33.5	102.1	136.4
	3x 0.04in²	0.705	0.395	0.853	1.640	2.92	58.3	32.6	70.5	135.5
	3x 0.05in²	0.543	0.383	0.691	1.628	3.04	44.9	31.7	57.1	134.6
	3x 0.058in² *	0.466	0.382	0.614	1.627	3.03	38.5	31.6	50.7	134.5
	3x 0.10in²	0.273	0.365	0.421	1.610	3.18	22.6	30.2	34.8	133.1
Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated * 0.058in² is also referred to 0.06in² The entry applies to both designations									
Aluminium alloy stranded, bare conductors	3x 0.025in² Cu equiv	1.084	0.390	1.232	1.635	2.96	89.6	32.2	101.8	135.1
	3x 0.04in² Cu equiv	0.682	0.375	0.830	1.620	3.09	56.4	31.0	68.6	133.9
	3x 0.05in² Cu equiv	0.543	0.368	0.691	1.613	3.15	44.9	30.4	57.1	133.3
Data sources:	Conductor dimensions: BS 3242: 1960 R_1 values: BS 3242: 1960 R_1 is dc value at 20°C X_1 values: calculated									
ACSR stranded, bare conductors	3x 0.025in² Cu equiv	1.096	0.386	1.244	1.630	2.97	90.6	31.9	102.8	134.7
	3x 0.05in² Cu equiv	0.544	0.364	0.692	1.608	3.16	45.0	30.1	57.2	132.9
	3x 0.10in² Cu equiv	0.274	0.342	0.422	1.587	3.37	22.6	28.3	34.9	131.2
Data sources:	Conductor dimensions: BS 215: 1956 R_1 values: BS 215: 1956 R_1 is dc value at 20°C X_1 values: calculated									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

5.6 11kV / 6.6kV Bare Conductor Single Phase Lines

National Std. Spacing (ENA TS 43-10)

Phase spacing = 2.0m

Earth resistivity value used to calculate zero sequence impedance = 100Ωm

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV bare conductor single phase overhead lines (Metric sizes) - National Std. Spacing (ENA TS 43-10)										
Hard drawn stranded **Cadmium** – **Copper** bare conductors	2x 22mm²	0.988	0.429	1.136	1.586	2.68	81.7	35.5	93.9	131.1
Data sources:	Conductor dimensions: BS 7884: 1997 R_1 values: BS 7884: 1997 R_1 is dc value at 20°C X_1 values: calculated									
Hard drawn stranded **Copper**, bare conductors	2x 16mm²	1.082	0.434	1.230	1.592	2.66	89.4	35.9	101.7	131.6
	2x 32mm²	0.541	0.413	0.689	1.570	2.81	44.7	34.1	56.9	129.8
	2x 38mm² *	0.466	0.411	0.614	1.569	2.80	38.5	34.0	50.7	129.6
	2x 70mm²	0.259	0.393	0.407	1.550	2.94	21.4	32.5	33.6	128.1
	2x 100mm²	0.176	0.381	0.324	1.538	3.04	14.55	31.5	26.8	127.1
Data sources:	Conductor dimensions: BS 7884: 1997 R_1 values: BS 7884: 1997 R_1 is dc value at 20°C X_1 values: calculated * 38mm² not a BS metric size - calculated using 0.06in² imperial equivalent									
Aluminium alloy stranded, bare conductors	2x 25mm² Almond	1.093	0.419	1.241	1.576	2.75	90.3	34.6	102.6	130.2
	2x 50mm² Hazel	0.550	0.397	0.698	1.555	2.91	45.5	32.8	57.7	128.5
	2x 100mm² Oak	0.277	0.376	0.425	1.533	3.08	22.9	31.1	35.1	126.7
	2x 150mm² Ash	0.183	0.359	0.331	1.517	3.21	15.12	29.7	27.4	125.4
	2x 200mm² Poplar	0.139	0.350	0.287	1.508	3.30	11.49	28.9	23.7	124.6
Data sources:	Conductor dimensions: BS 3242: 1970 R_1 values: BS 3242: 1970 R_1 is dc value at 20°C X_1 values: calculated									
HD Aluminium stranded, bare conductors	2x 50mm² Ant	0.542	0.401	0.690	1.559	2.88	44.8	33.1	57.0	128.8
	2x 100mm² Wasp	0.270	0.379	0.418	1.537	3.05	22.3	31.3	34.5	127.0
Data sources:	Conductor dimensions: BS 215: 1970 R_1 values: BS 215: 1970 R_1 is dc value at 20°C X_1 values: calculated									
ACSR stranded, bare conductors	2x 25mm² Gopher	1.093	0.415	1.241	1.572	2.75	90.3	34.3	102.6	129.9
	2x 50mm² Rabbit	0.543	0.393	0.691	1.550	2.91	44.9	32.5	57.1	128.1

	2x 70mm² Horse	0.393	0.372	0.541	1.530	3.08	32.5	30.7	44.7	126.4
	2x 100mm² Dog	0.273	0.371	0.421	1.529	3.09	22.6	30.7	34.8	126.4
	2x 150mm² Dingo	0.182	0.356	0.330	1.513	3.19	15.04	29.4	27.3	125.0
Data sources:	Conductor dimensions: BS 215: 1970 R_1 values: BS 215: 1970 R_1 is dc value at 20°C X_1 values: calculated									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV bare conductor single phase overhead lines (Imperial sizes) - National Std. Spacing (ENA TS 43-10)										
Hard drawn stranded **Cadmium - Copper**, bare conductors	2x 0.017in² Cu equiv (3 strand)	1.578	0.441	1.726	1.599	2.62	130.4	36.4	142.6	132.1
	2x 0.022in² Cu equiv (3 strand)	1.238	0.434	1.386	1.591	2.66	102.3	35.9	114.5	131.5
	2x 0.022in² Cu equiv (7 strand)	1.231	0.437	1.379	1.595	2.63	101.7	36.1	114.0	131.8
	2x 0.025in² Cu equiv (3 strand)	1.088	0.430	1.236	1.587	2.69	89.9	35.5	102.1	131.2
	2x 0.025in² Cu equiv (7 strand)	1.100	0.433	1.248	1.591	2.65	90.9	35.8	103.1	131.5
	2x 0.035in² Cu equiv (3 strand)	0.795	0.420	0.943	1.577	2.76	65.7	34.7	77.9	130.3
	2x 0.035in² Cu equiv (7 strand)	0.793	0.423	0.941	1.581	2.72	65.5	35.0	77.8	130.7
	2x 0.040in² Cu equiv (3 strand)	0.687	0.415	0.835	1.573	2.79	56.8	34.3	69.0	130.0
	2x 0.040in² Cu equiv (7 strand)	0.678	0.418	0.826	1.576	2.75	56.0	34.5	68.3	130.2
	2x 0.050in² Cu equiv (7 strand)	0.553	0.412	0.701	1.569	2.80	45.7	34.0	57.9	129.7
Data sources:	Conductor dimensions: BS 672: 1957 R_1 values: BS 672: 1957 R_1 is dc value at 20°C X_1 values: calculated									
Hard drawn **solid Copper**, bare conductors	2x 0.025in² (7 SWG)	1.129	0.443	1.277	1.600	2.57	93.3	36.6	105.5	132.2
	2x 0.035in² (5 SWG)	0.777	0.431	0.925	1.589	2.64	64.2	35.6	76.4	131.3
	2x 0.05in² (3 SWG)	0.550	0.420	0.698	1.578	2.71	45.5	34.7	57.7	130.4
	2x 0.07in² (1 SWG)	0.388	0.409	0.536	1.567	2.79	32.1	33.8	44.3	129.5

Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated									
Hard drawn **stranded Copper**, bare conductors	2x 0.022in²	1.231	0.442	1.379	1.599	2.60	101.7	36.5	114.0	132.1
	2x 0.025in²	1.087	0.434	1.235	1.592	2.66	89.9	35.9	102.1	131.6
	2x 0.04in²	0.705	0.424	0.853	1.582	2.71	58.3	35.0	70.5	130.7
	2x 0.05in²	0.543	0.413	0.691	1.570	2.81	44.9	34.1	57.1	129.8
	2x 0.058in² *	0.466	0.411	0.614	1.569	2.80	38.5	34.0	50.7	129.7
	2x 0.10in²	0.273	0.394	0.421	1.552	2.93	22.6	32.6	34.8	128.3
Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated * 0.058in² is also referred to 0.06in² The entry applies to both designations									
Aluminium alloy stranded, bare conductors	2x 0.025in² Cu equiv	1.084	0.421	1.232	1.579	2.75	89.6	34.8	101.8	130.5
	2x 0.04in² Cu equiv	0.682	0.407	0.830	1.564	2.85	56.4	33.6	68.6	129.3
	2x 0.05in² Cu equiv	0.543	0.400	0.691	1.557	2.91	44.9	33.1	57.1	128.7
Data sources:	Conductor dimensions: BS 3242: 1960 R_1 values: BS 3242: 1960 R_1 is dc value at 20°C X_1 values: calculated									
ACSR stranded, bare conductors	2x 0.025in² Cu equiv	1.096	0.415	1.244	1.572	2.75	90.6	34.3	102.8	129.9
	2x 0.05in² Cu equiv	0.544	0.393	0.692	1.550	2.91	45.0	32.5	57.2	128.1
	2x 0.10in² Cu equiv	0.274	0.378	0.422	1.536	3.09	22.6	31.2	34.9	126.9
Data sources:	Conductor dimensions: BS 215: 1956 R_1 values: BS 215: 1956 R_1 is dc value at 20°C X_1 values: calculated									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

5.7 11kV / 6.6kV Covered Conductor Lines

National Std. Spacing (ENA TS 43-122) [a]
d(ab) = 0.65
d(bc) = 0.75m
d(ac) = 1.40m

[a] The position of the centre pin insulator is staggered at each pole so that the mean conductor spacing between the outer and inner conductors along a line is equal, equal to 0.7m. The impedance values below are calculated using a 0.7m spacing.

Earth resistivity value used to calculate zero sequence impedance = 100Ωm

Line type	Size	Impedance (Ω / km)				Susceptance (µS/km)	100MVA base / km [1]			
		R_1	X_1	R_0	X_0		R_1%	X_1%	R_0%	X_0%
11kV / 6.6kV covered conductor - National Std. Spacing (ENA TS 43-121)										
3 phase overhead lines										
Aluminium alloy stranded, covered conductor s (ENA TS 43-121)	3x 50mm² CCC	0.720	0.359	0.868	1.671	3.23	59.5	29.7	71.7	138.1
	3x 120mm² CCC	0.288	0.327	0.436	1.639	3.54	23.8	27.0	36.0	135.5
	3x 185mm² CCC	0.188	0.313	0.336	1.625	3.70	15.54	25.9	27.8	134.3
Data sources:	Conductor dimensions: ENA TS 43-122 R_1 values: ENA TS 43-122 R_1 value corrected to 20°C X_1 values: calculated									
Single phase overhead lines										
Aluminium alloy stranded, covered conductor s (ENA TS 43-121)	2x 50mm² CCC	0.720	0.388	0.868	1.613	2.98	59.5	32.1	71.70	133.3
	2x 120mm² CCC	0.288	0.356	0.436	1.581	3.24	23.8	29.4	36.0	130.7
	2x 185mm² CCC	0.188	0.342	0.336	1.567	3.37	15.54	28.3	27.8	129.5
Data sources:	Conductor dimensions: ENA TS 43-122 R_1 values: ENA TS 43-122 R_1 value corrected to 20°C X_1 values: calculated									

[1] % values quoted at 11kV. For 6.6kV multiply by 2.778.

5.8 4-wire LV Open-wire Conductor Overhead Lines

In addition to the requirement for sequence impedance values for the case of the 3-phase conductors taken together as a group using the Geometric Mean Distance (GMD) between neutral and phase conductors (given in sub-section 5.8.1), there is a requirement in both CP331 and the software tool LV AFFIRM (described in CP227) for loop impedance values between a single phase conductor and the neutral to calculate the fuse protection for a LV distributor. This second requirement arises because in both CP331 and LV AFFIRM a worst condition for fuse reach is considered and taken to be a fault between the neutral and the phase conductor furthest from the neutral. Because of the wider spacing of these conductors compared to the 'average' spacing derived using the GMD, the reactance values for this worst case fault condition are higher. Therefore, loop impedance data tables are provided in sub-section 5.8.2 for this case to provide the data source for CP331 and LV AFFIRM.

5.8.1 4-wire LV Open-wire Conductor Overhead Lines using GMD Separation

National Std. Spacing (ENA TS 43-30)
d(ab) = 0.3m
d(bc) = 0.3m
d(ac) = 0.6m
d(cn) = 0.3m

The zero sequence impedance (R_0 & X_0) is based on the assumption that the zero sequence current is carried by the neutral conductor.

Line type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0	X_0	R_1%	X_1%	R_0%	X_0%
LV open-wire conductor overhead lines (Metric sizes) - National Std. Spacing (ENA TS 43-30)									
All **Aluminium** stranded, bare conductors	50mm² Ant	0.542	0.297	2.17	1.255	31 500	17 240	125 900	72 900
	100mm² Wasp	0.270	0.275	1.081	1.168	15 680	15 970	62 800	67 800
Data sources:	Conductor dimensions: BS 215: 1970 X_1 values: calculated			R_1 values: BS 215: 1970			R_1 is dc value at 20°C		
LV open-wire conductor overhead lines (Imperial sizes) - National Std. Spacing (ENA TS 43-30)									
Hard drawn **solid Copper**, bare conductors	0.025in² (7 SWG)	1.129	0.338	4.52	1.421	65 600	19 630	262 000	82 500
	0.035in² (5 SWG)	0.777	0.326	3.11	1.375	45 100	18 930	180 000	79 800
	0.05in² (3 SWG)	0.550	0.316	2.20	1.331	31 900	18 350	127 600	77 300
	0.07in² (1 SWG)	0.388	0.305	1.55	1.287	22 500	17 710	90 000	74 700
Data sources:	Conductor dimensions: BS 125: 1947 X_1 values: calculated			R_1 values: BS 125: 1947			R_1 is dc value at 20°C		

Hard drawn **stranded Copper**, bare conductors	0.025in^2	1.087	0.330	4.35	1.388	63 100	19 160	253 000	80 600
	0.04in^2	0.705	0.320	2.82	1.348	40 900	18 580	163 800	78 300
	0.05in^2	0.543	0.308	2.17	1.300	31 500	17 880	126 100	75 500
	0.058in^2 *	0.466	0.307	1.864	1.295	27 100	17 830	108 200	75 200
	0.075in^2	0.375	0.300	1.498	1.268	21 800	17 420	87 000	73 600
	0.10in^2	0.272	0.290	1.089	1.228	15 790	16 840	63 200	71 300
	0.15in^2	0.182	0.277	0.728	1.178	10 570	16 080	42 300	68 400
Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated * 0.058in^2 is also referred to 0.06in^2 The entry applies to both designations								
All **Aluminium** stranded, bare conductors (imperial sizes)	0.025in^2 Cu equiv	1.088	0.312	4.35	1.318	63 200	18 120	253 000	76 500
	0.04in^2 Cu equiv	0.670	0.303	2.68	1.281	38 900	17 590	155 600	74 400
	0.05in^2 Cu equiv	0.545	0.297	2.18	1.255	31 600	17 240	126 600	72 900
	0.06in^2 Cu equiv	0.452	0.291	1.807	1.232	26 200	16 900	104 900	71 500
	0.10in^2 Cu equiv	0.271	0.275	1.084	1.167	15 740	15 970	62 900	67 800
	0.15in^2 Cu equiv	0.182	0.262	0.729	1.117	10 570	15 210	42 300	64 900
Data sources:	Conductor dimensions: BS 215: 1956 R_1 values: BS 215: 1956 R_1 is dc value at 20°C X_1 values: calculated								

[1] % values quoted at 415V.

NOTE: The values of R_0 and X_0 can be used for 5-wire lines for situations when it can be assumed that the zero sequence currents flow only in the neutral conductor since the spacing between the phase conductors and the neutral is identical, the 5th wire being an earth wire fitted below the neutral wire. If values of R_0 and X_0 are required between the phase conductors and the earth wire in the 5th wire case, refer to CP205, section 6 to re-calculate the values based on the separation between these conductors.

5.8.2 4-Wire LV open-wire conductor overhead line loop impedance between the topmost phase conductor (phase a) and the neutral (taken to be the conductor below the lowest phase conductor)

National Std. Spacing (ENA TS 43-30)
d(an) = 0.9m

The zero sequence impedance (R_0 & X_0) is based on the assumption that the zero sequence current is carried by the neutral conductor.

Line type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0	X_0	R_1%	X_1%	R_0%	X_0%
LV open-wire conductor overhead lines (Metric sizes) - National Std. Spacing (ENA TS 43-30)									
All **Aluminium** stranded, bare conductors	50mm² Ant	0.542	0.351	2.17	1.404	31 500	20 400	125 900	81 500
	100mm² Wasp	0.270	0.329	1.081	1.317	15 680	19 100	62 800	76 500
Data sources:	Conductor dimensions: BS 215: 1970 X_1 values: calculated			R_1 values: BS 215: 1970			R_1 is dc value at 20°C		
LV open-wire conductor overhead lines (Imperial sizes) - National Std. Spacing (ENA TS 43-30)									
Hard drawn **solid Copper**, bare conductors	0.025in² (7 SWG)	1.129	0.393	4.52	1.571	65 600	22 800	262 000	91 200
	0.035in² (5 SWG)	0.777	0.381	3.11	1.524	45 100	22 100	180 000	88 500
	0.05in² (3 SWG)	0.550	0.370	2.20	1.480	31 900	21 500	127 600	85 900
	0.07in² (1 SWG)	0.388	0.359	1.55	1.436	22 500	20 800	90 000	83 400
Data sources:	Conductor dimensions: BS 125: 1947 X_1 values: calculated			R_1 values: BS 125: 1947			R_1 is dc value at 20°C		
Hard drawn **stranded Copper**, bare conductors	0.025in²	1.087	0.384	4.35	1.537	63 100	22 300	253 000	89 200
	0.04in²	0.705	0.374	2.82	1.497	40 900	21 700	163 800	86 900
	0.05in²	0.543	0.362	2.17	1.449	31 500	21 000	126 100	84 100
	0.058in² *	0.466	0.361	1.864	1.444	27 100	20 900	108 200	83 800
	0.075in²	0.375	0.354	1.498	1.417	21 800	20 600	87 000	82 300
	0.10in²	0.272	0.344	1.089	1.377	15 790	20 000	63 200	79 900
	0.15in²	0.182	0.332	0.728	1.327	10 570	19 300	42 300	77 000

Data sources:	Conductor dimensions: BS 125: 1947 R_1 values: BS 125: 1947 R_1 is dc value at 20°C X_1 values: calculated * 0.058in² is sometimes referred to 0.06in² The entry applies to both designations								
All Aluminium stranded, bare conductors (imperial sizes)	0.025in² Cu equiv	1.088	0.367	4.35	1.468	63 200	21 300	253 000	85 200
	0.04in² Cu equiv	0.670	0.358	2.68	1.430	38 900	20 800	155 600	83 000
	0.05in² Cu equiv	0.545	0.351	2.18	1.404	31 600	20 400	126 600	81 500
	0.06in² Cu equiv	0.452	0.345	1.807	1.381	26 200	20 000	104 900	80 200
	0.10in² Cu equiv	0.271	0.329	1.084	1.316	15 740	19 100	62 900	76 400
	0.15in² Cu equiv	0.182	0.317	0.729	1.266	10 570	18 410	42 300	73 500
Data sources:	Conductor dimensions: BS 215: 1956 R_1 values: BS 215: 1956 R_1 is dc value at 20°C X_1 values: calculated								

[1] % values quoted at 415V.

NOTE: Again, the R_0 and X_0 values can be used for 5-wire lines for situations when it can be assumed that the zero sequence currents flow only in the neutral conductor since the spacing between phase conductor a and the neutral is identical. If values of R_0 and X_0 are required between any other phase conductor and the neutral (or to earth in the 5th wire case), refer to CP205, section 6 to re-calculate the values based on the separation between the relevant conductors.

5.9 4-wire LV Aerial Bundled Conductor (ABC) Overhead Lines

As with the open-wire case, there is a requirement for sequence impedance values for both the case of the 3-phase conductors taken together as a group using the Geometric Mean Distance (GMD) between neutral and phase conductors (given in subsection 5.9.1) and between the neutral and the phase conductor furthest from the neutral. Again, this requirement arises because in both CP331 and LV AFFIRM, a worst condition for fuse reach is considered and taken to be a fault between the neutral and the phase conductor furthest from the neutral. Because of the wider spacing of these conductors compared to the 'average' spacing derived from the GMD the reactance values are higher. Therefore, loop impedance data tables are provided in subsection 5.9.2 for this case to provide the data source for CP331 and LV AFFIRM.

5.9.1 4-wire LV ABC Overhead Lines Using GMD Separation

National Std. Spacing (ENA TS 43-13) [a]	
35mm²	95mm²
d(ab) = 0.0101m	d(ab) = 0.0154m
d(bc) = 0.0101m	d(bc) = 0.0154m
d(ac) =0.0143m	d(ac) =0.0218m
d(cn) =0.0101m	d(cn) =0.0154m

[a] Assumes a tight bundle (i.e. all phases/neutral in contact) Conductor spacings for the other conductor sizes have been calculated using data in ENA TS 43-13

The zero sequence impedance (R_0 & X_0) is stated on the assumption that the zero sequence current is carried by the neutral conductor.

Line type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0	X_0	R_1%	X_1%	R_0%	X_0%
LV Aerial Bundled Conductor (ABC) overhead lines - National Std. Spacing (ENA TS 43-13)									
	25mm²	1.200	0.088	4.82	0.383	69 700	5 110	278 000	22 200
4 -core Aerial Bundled Conductor (ABC) (ENA TS 43-13)	35mm²	0.868	0.086	3.47	0.372	50 400	4 990	201 000	21 600
	50mm²	0.641	0.083	2.56	0.365	37.200	4 820	148 800	21 200
	70mm²	0.443	0.080	1.779	0.350	25 700	4 650	103 300	20 300
	95mm²	0.320	0.080	1.280	0.348	18 580	4 650	74 300	20 200
Data sources:	Conductor dimensions: ENA TS 43-13 R_1, R_0, X_1, X_0 values: ENA TS 43-13 R_1 value corrected to 20°C								

[1] % values quoted at 415V

NOTE: The values of R_0 and X_0 can be used for 5-wire ABC for situations when it can be assumed that the zero sequence currents flow only in the neutral conductor since the spacing between the phase conductors and the neutral is identical.

5.9.2 4-wire LV ABC Overhead Line Loop Impedance Between the Phase Conductor (Phase A) Furthest from the Neutral

National Std. Spacing (ENA TS 43-13)
Phase a to Neutral spacings calculated from data in ENA TS 43-30

The zero sequence impedance (R_0 & X_0) is based on the assumption that the zero sequence current is carried by the neutral conductor.

Line type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		R_1	X_1	R_0	X_0	R_1%	X_1%	R_0%	X_0%
LV Aerial Bundled Conductor (ABC) overhead lines - National Std. Spacing (ENA TS 43-13)									
	25mm²	1.200	0.107	4.82	0.427	69 700	6 210	278 000	24 800
4 -core Aerial Bundled Conductor (ABC) (ENA TS 43-13)	35mm²	0.868	0.104	3.47	0.417	50 400	6 040	201 000	24 200
	50mm²	0.641	0.102	2.56	0.408	37.200	5 920	148 800	23 700
	70mm²	0.443	0.099	1.779	0.396	25 700	5 750	103 300	23 000
	95mm²	0.320	0.098	1.280	0.394	18 580	5 690	74 300	22 900
Data sources:	Conductor dimensions: ENA TS 43-13 R_1, R_0, X_1, X_0 values: ENA TS 43-13 R_1 value corrected to 20°C								

[1] % values quoted at 415V.

NOTE: Again, the R_0 and X_0 values can be used for 5-wire lines for situations when it can be assumed that the zero sequence currents flow only in the neutral conductor since the spacing between the phase a conductor and the neutral is identical. If values of R_0 and X_0 are required between any other phase conductor and the neutral, refer to CP205, section 6 to re-calculate the values based on the separation between the relevant conductors.

5.10 LV Overhead Service Connections

For three-phase overhead service connections use the tables for 4-wire mains conductors in sub-sections 5.5 and 5.6 above.

For the single-phase CNE service cables, the impedances for the phase (R_p, X_p) and the neutral conductors (R_n, X_n) are given and only one table is required since both load current and a fault current return is via the neutral conductor. The spacing for the open-wire case is assumed to be 0.3m ie the phase separation of the ENA TS 43-30 specification. For the ABC case the two conductors are assumed to be bundled together.

Line type	Size	Impedance (Ω / km)				100MVA base / km [1]			
		Rp	Xp	Rn	Xn	Rp%	Xp%	Rn%	Xn%
LV Single-phase overhead service connections									
2 -core Aerial Bundled Conductor (ABC) (ENA TS 43-13)	25mm²	1.200	0.085	1.200	0.085	69 700	4 930	69 700	4 930
	35mm²	0.868	0.082	0.868	0.082	50 400	4 780	50 400	4 780
Data sources:	Conductor dimensions: ENA TS 43-13 R value: ENA TS 43-13 R values are dc values at 20°C X values: Calculated								
2-wire **All Aluminium** stranded, bare conductors	22mm²	1.227	0.308	1.227	0.308	71 200	17 880	71 200	17 880
	50mm²	0.542	0.282	0.542	0.282	31 500	16 370	31 500	16 370
Data sources:	Conductor dimensions: BS 215: 1970 R value: BS 215: 1970 R values are dc values at 20°C X values: calculated								
2-wire **All Aluminium** stranded, bare conductors (copper equivalent sizes)	0.025in² Cu equiv	1.088	0.298	1.088	0.298	63 200	17 300	63 200	17 300
	0.040in² Cu equiv	0.670	0.289	0.670	0.289	38 900	16 780	38 900	16 780
Data sources:	Conductor dimensions: BS 215: 1956 R value: BS 215: 1956 R values are dc values at 20°C X values: calculated								
2-wire **stranded Copper**, bare conductors	0.025in² (solid)	1.103	0.323	1.103	0.323	64 000	18 750	64 000	18 750
	0.025in² (stranded)	1.087	0.315	1.087	0.315	63 100	18 290	63 100	18 290
	0.040in² (stranded)	0.705	0.305	0.705	0.305	40 900	17 710	40 900	17 710
Data sources:	Conductor dimensions: BS 125: 1947 R value: BS 125: 1947 R values are dc values at 20°C X values: calculated								

[1] % values quoted at 415V.

6 Transformer Impendance Values

The zero sequence impedance (Z_0) depends on whether the windings are delta or star connected, and whether the neutral point of a star connected winding is earthed. (Note - any zero sequence currents will also be dependent on the neutral earthing arrangements of connected equipment but the transformer impedance values below do not take account of this factor.)

For many of the common connections the zero sequence impedance is either approximately equal to the positive and negative sequence values or is very high and usually regarded as infinite as indicated below:

Transformer connection	Impedance
HV delta/ LV star - neutral earthed	$Z_0 \sim Z_1$ & Z_2
HV star - neutral earthed /LV star - neutral earthed	$Z_0 \sim Z_1$ & Z_2
HV star - neutral unearthed /LV star - neutral earthed	$Z_0 >> Z_1$ & Z_2

Consequently, the tables of impedance values below provide only one value of impedance for each transformer for the positive and zero sequence components. The user will need to determine the transformer connection to establish whether or not the value is relevant.

Although the values are assumed to be equal, the zero sequence value, in practice, may be lower. In particular, primary transformers of the core type have a zero sequence value that is typically 85% of the positive or negative sequence value due to the effect of the transformer tank on core type transformers acting as a tertiary winding.

Therefore the impedance values below should be interpreted as indicated above and taken as typical values. The actual impedance values are available for all 132kV and 33kV transformers in the Network in the Long Term Development statement and users should use these values in preference if accuracy is important. Alternatively, the manufacturer's figures can be used in preference.

6.1 132kV/33kV Transformers

size (mVA)	R(Ω)	jX(Ω)	R%	jX%
30	2.61	52.3	1.500	30.0
60	2.18	43.6	1.300	25.0
90	2.23	44.5	1.300	25.6

Impedance and % values referred to 132kV

The resistance values assume a nominal X/R ratio of 20. The impedance values in Table 6.1 are to be treated as typical values and have been calculated using the following nominal % impedance values, taken from ES324:

30MVA - 9%

60MVA - 15%

90MVA - 23%

The actual values for most 132kV transformers in the Network are available in the Master Asset Management System (MAMS) and users should use these or values obtained from site, where relevant.

6.2 33kV/11kV or 6.6kV Transformers

SIZE (mVA)	R(Ω)	jX(Ω)	R%	jX%	Note
7.5	0.580	11.62	5.30	106.6	(1)
10	0.540	10.89	5.00	100.0	(1)
15	0.540	10.89	5.00	100.0	(1)
4 [8]	0.590	11.84	5.40	108.8	(2)
7.5 [15]	0.590	11.84	5.40	108.8	(2)
11.5 [23]	0.590	11.84	5.40	108.8	(2)
16 [32]	0.470	9.47	4.40	87.0	(2)
19 [38]	0.430	8.59	3.90	78.8	(2)

Impedance and % values referred to 33kV

NOTE:

(a) BSI Rated transformers. Size is the ONAN rating. Impedance values calculated using following nominal % impedance values taken from BEBS T3:

7.5MVA - 8.0%
10MVA - 10.0%
15MVA - 15.0%

(b) Long Term Emergency Rated transformers. Impedance values calculated at mid-position of the Impedance envelope at 'nominal-tap' position shown in Figure 1 of ES323.

Figures in [ ] indicate the Long Term Emergency Cyclic Rating with OFAF or ODAF cooling in operation.

6.3 Distribution Transformers (Three Phase and Single Phase)

SIZE (KVA) (SINGLE PHASE)	R(Ω)	JX(Ω)	R%	JX%
5	0.396	0.334	68 800	57 900
10	0.1760	0.1898	30 600	33 000
15	0.1087	0.1346	18 880	23 400
16	0.0995	0.1281	17 280	22 200
25	0.0564	0.0870	9 790	15 100
50	0.0245	0.0457	4 260	7 940
SIZE (KVA) (THREE PHASE)	R(Ω)	JX(Ω)	R%	JX%
25	0.1917	0.245	11 090	14 190
50	0.0807	0.1327	4 670	7 680
100	0.0342	0.0746	1 980	4 320
200	0.01456	0.0374	843	2 170
300	0.00874	0.0259	506	1 499
315	0.00830	0.0247	481	1 429
500	0.00469	0.01576	271	912
750	0.00288	0.01060	166.9	613
800	0.00268	0.00986	155.2	571
1 000	0.00202	0.00795	116.8	460
1 250	0.0015	0.0062	80.0	357
1 500	0.0012	0.0067	64.0	331

Impedance and % values referred to 415/240V

Sizes ≤ 1 000kVA, R & X data taken from ENA Engineering Recommendation P28.
Sizes > 1 000kVA extrapolated from the P28 data

6.4 Distribution Split-Phase (3-wire in 240V System) Transformers

size (KVA)	R(Ω)	jX(Ω)	R%	JX%
25	0.0786	0.0869	13 650	15 090
50	0.0362	0.0473	6 290	8 210
100	0.01521	0.0235	2 640	4 080

Impedance and % values referred to 240V

R and X data taken from ENA Engineering Recommendation P28.

6.5 Distribution Split-Phase (2-wire in 480V System) Transformers

size (KVA)	R(Ω)	jX(Ω)	R%	JX%
25	0.215	0.336	9 320	14 600
50	0.1005	0.1797	4 360	7 800
100	0.0410	0.0940	1 780	4 080

Impedance and % values referred to 480V

R and X data taken from ENA Engineering Recommendation P28.

7 Useful Formulae

% impedance on MVA base for ohmic value $= \frac{10^8 \times \text{MVA (base)} \times \text{ohm}}{V^2}$

Where V = phase-to-phase voltage.

% susceptance on MVA base for siemens value $= \frac{V^2 \times \text{siemens}}{10^4 \times \text{MVA (base)}}$

Where V = phase-to-phase voltage.

% on other base MVA $= \frac{\text{Base MVA} \times \text{Normal \%}}{\text{Machine or Transformer MVA}}$

Short circuit MVA $= \frac{\text{MVA base} \times 100}{Z\%}$

Where Z% is the impedance on the same MVA base.

NOTE: In many items of plant, resistance is so small in comparison with reactance as to be unimportant and it is sufficient to deal in reactance terms only. This is generally the case for generators, transformers, synchronous motors and reactors.

If R is less than 1/3 of X then the error will not be more than 5%.

On a 100MVA Base:

at	132kV	1Ω ≡	0.5739%	1siemens ≡	17 424%
at	33kV	1Ω ≡	9.1827%	1siemens ≡	1 089.0%
at	11kV	1Ω ≡	82.644%	1siemens ≡	121.00%
at	6.6kV	1Ω ≡	229.57%	1siemens ≡	43.560%
at	415V	1Ω ≡	58 063%	1siemens ≡	0.1722%

8 Documents Referenced

DOCUMENTS REFERENCED	
BS 125: 1947	Specification for hard-drawn copper conductors for overhead power transmission.
BS 215: 1956v & 1970	Specification for aluminium conductors and aluminium conductors, steel-reinforced for overhead power transmission.
BS 480: 1966	Specification for impregnated paper-insulated lead or lead alloy sheathed electric cables of rated voltage up to and including 33 000V.
BS 672: 1957	Specification for hard-drawn cadmium-copper conductors for overhead power transmission.
BS 3242: 1960 & 1970	Specification for aluminium alloy stranded conductors for overhead power transmission.
BS 5467: 1997	Specification for 600/1 000 V and 1 900/3 300 V armoured electric cables having thermosetting insulation.
BS 6346: 1989 & 1997	Specification for 600/1 000 V and 1 900/3 300 V armoured electric cables having PVC insulation.
BS 6360: 1991	Specification for Conductors in Insulated Cables and Cords
BS 6480: 1988	Specification for impregnated paper-insulated lead or lead alloy sheathed electric cables of rated voltage up to and including 33 000V.

BS 6622: 1999	Specification for cables with extruded cross-linked polyethylene or ethylene propylene rubber insulation for rated voltages 3.8/6.6 kV up to 19/33 kV.
BS 7870	LV and MV polymeric insulated cables for use by distribution and generation utilities. Section 3.10 2001: PVC insulated combined neutral and earth copper wire concentric cables with copper or aluminium conductors; Section 3.11 2001: XLPE insulated combined neutral and earth copper wire concentric cables with copper or aluminium conductors; Section 3.20 2001: PVC insulated split concentric cables with copper or aluminium conductors; Section 3.21 2001: XLPE insulated split concentric cables with copper or aluminium conductors Section 3.40 2001. XLPE insulated, copper wire waveform concentric cables with solid aluminium conductors. Section 4.10 1999. Single core 11kV and 33kV cables.
BS 7884: 1997	Copper and for use in substations having extruded insulation and rated voltages of 6 350/11 000 V and 19 000/33 000 V.
BS 7889: 1997	Electric Cables. Thermosetting Insulated Unarmoured Cables for a Voltage of 600/1000V
BS EN 50182: 2001	Conductors for Overhead Lines. Round Wire Concentric Lay Stranded Conductors
ENA BEBS C4	3-core Compacted Oval Conductor Corrugated Aluminium Sheathed 33kV Oil-filled Cable
ENA BEBS T3	Specification for Transformers for 33kV and 22kV Systems (up to 20MVA)
ENA TS 09-3	33kV Impregnated Paper Insulated Oil-filled and Gas Pressure Type Power Cables
ENA TS 09-8	Impregnated Paper Insulated 600/1000V Cable with Three Solid Aluminium Phase Conductors and Aluminium Sheath/Neutral Conductor (CONSAC)
ENA TS 09-12	Impregnated Paper Insulated Corrugated Aluminium Sheathed 6 350/11 000 Volt Cable
ENA TS 09-17	Single Core Cables for Use in Substations Having Extruded Insulators and Rated Voltage of 6 350/11 000 and 19 000/33 000 Volt

ENA TS 43-10	11 kV single circuit overhead lines of light construction on wood poles.
ENA TS 43-13	Aerial bundled conductors (ABC) insulated with cross-linked polyethylene for low voltage overhead distribution.
ENA TS 43-20	11 kV and 33 kV single circuit overhead lines of heavy construction on wood poles.
ENA TS 43-30	Low voltage overhead lines on wood poles.
ENA TS 43-121	Single Circuit Overhead Lines of Compact Covered Construction on Wood Poles for Use at High Voltage up to and including 33kV
ENA TS 43-122	XLPE covered conductors for overhead lines (having rated voltages Uo/U greater than 0.6/1 kV up to and including 19/33 kV).
ENA ER P28	Planning Limits for Voltage Fluctuations Caused by Industrial, Commercial and Domestic Equipment in the United Kingdom
EPD279	Distribution system Design General Requirements.
CP205	Network Component Impedance Data – Supporting Document.
CP227	LV AFFIRM - Network Design Workbook – Documentation.
CP331	Protection of LV Underground and Overhead Distributors and HV Protection of Distribution Transformers
ES323	33kV / 11kV or 6.6kV System Transformers
ES324	132kV / Lower Voltage Transformers and Earthing / Auxiliary Transformers.
BICC Cables	Electric Cables Handbook. Third Edition. 1997.
AEI Cables Ltd	Brochure of Technical Information: BS 6622: 1999 & BS 7835: 2000. Thermosetting Insulated Armoured Electric Cables for Voltages from 3.8/6.6kV up to 10/33kV.
Elektrim Kable	Cable Data Sheet supplied by Elektrim Kable S.A, Fordonska str.152, 85-957 Bydgoszcz, Oddzial: Bydgoska Fabryka Kabli.

9 Keywords

Design; Transformer; Cable; Line; Rating; Impedance