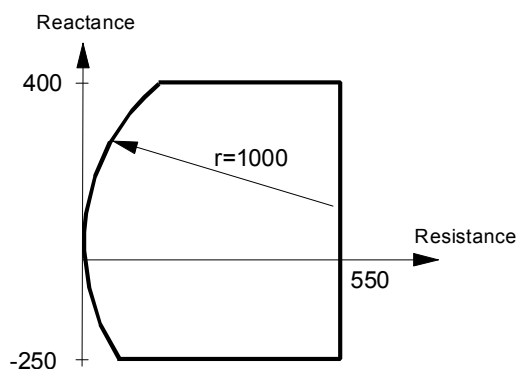


APPENDIX A

A1 SUPPLY SYSTEM HARMONIC SELF IMPEDANCE LOCI AS SEEN FROM THE TERTIARY TERMINALS (FOR SVC COMPONENT RATING PURPOSES, SEE ALSO CLAUSE 3.43)

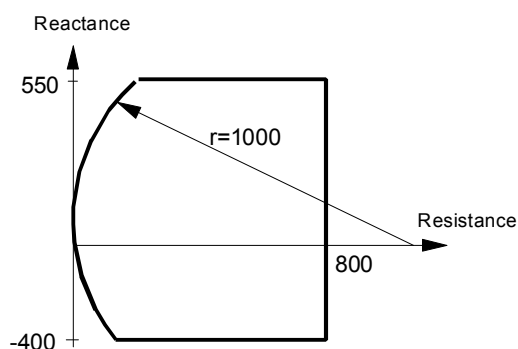
Harmonics 1.75 to 4.25



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

At 2nd harmonic only values in the inductive region should be considered

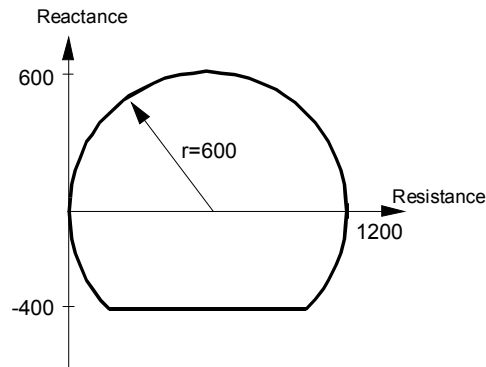
Harmonics 4.75 to 7.25



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

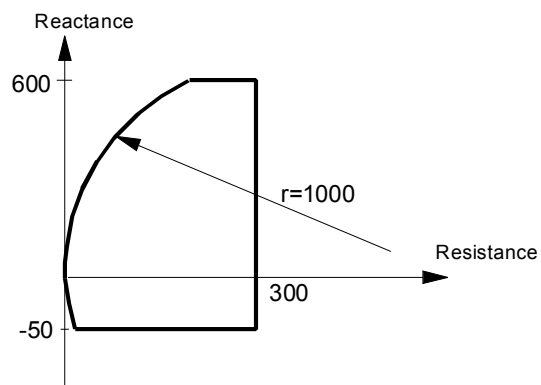
ALL FIGURES ARE % ON 100 MVA BASE

Harmonics 7.75 to 13.25



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

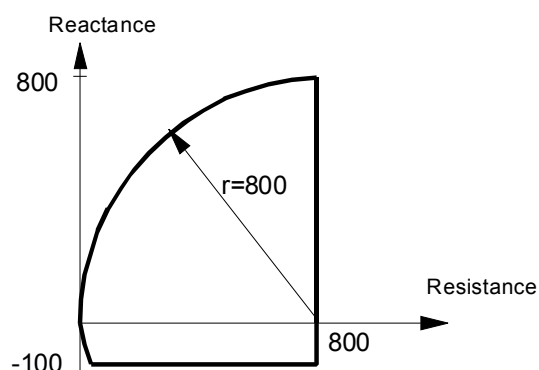
Harmonics 13.75 to 19.25



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

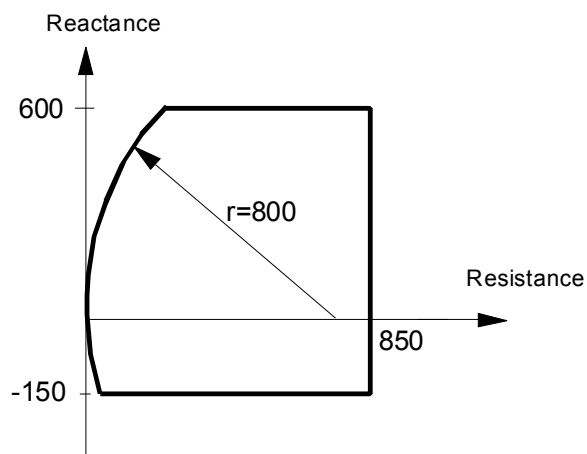
ALL FIGURES ARE % ON 100 MVA BASE

Harmonics 19.75 to 25.25



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

Harmonics 25.75 to 31.00



Minimum self resistance	= 1.00 %
Maximum inductive angle	= 80°
Maximum capacitive angle	= 70°

ALL FIGURES ARE % ON 100 MVA BASE

A2 SELF AND TRANSFER HARMONIC IMPEDANCES (FOR DETERMINATION OF SVC HARMONIC PERFORMANCE ONLY, SEE ALSO CLAUSE 4.10)

The following tables contain details of the self impedances (as seen from the tertiary terminals of the transformer) and transfer impedances to the LV and HV terminals of the transformer for the following families of transformer voltage ratio:-

HV/LV Ratio
400 / 275 kV
400 / 132 kV
275 / 132 kV
275 / 66 kV

For ease of use and to provide more accurate data, especially at low order harmonics, the impedances have been divided into the harmonic ranges detailed below:-

Case Number	Harmonic Range	
	From	To
1	1.75	2.25
2	2.5	3.25
3	3.5	5.25
4	5.5	7.25
5	7.5	9.25
6	9.5	11.5
7	11.75	13.5
8	13.75	19.25
9	19.5	31

Notes:

- For each range of harmonics shown, the following data is provided:-
 - The vertical and horizontal axes represent the self reactance and resistance respectively, as seen from the transformer tertiary terminals, in per unit on 100 MVA base.
 - Each cell in the table contains the maximum value of transfer impedance in per unit on 100 MVA base for that self impedance range, e.g. for case 1 in the 400/275 kV voltage ratio transformer class the maximum transfer impedance to the transformer LV terminals in the range $0.240 \text{ pu} < \text{self reactance} < 0.255 \text{ pu}$, $0.075 \text{ pu} < \text{self resistance} < 0.09 \text{ pu}$ is 0.084 pu.

In assessing the self impedance data provided in the tables, the Tenderer shall assume that the self impedance at each harmonic can lie anywhere within the impedance polygon encompassing all the cells, subject to the limiting angles of self impedance in the inductive and capacitive regions together with minimum values of self resistance.

- For those designs of SVC that generate harmonic currents, in determining compliance with the harmonic performance criteria specified in clause 4.10, the Tenderer shall at each harmonic determine the particular values of self impedance and associated transfer impedance which leads to the maximum value of LV and HV harmonic voltage distortion. Should the Tenderer assess that the maximum distortion occurs for a value of self impedance for which no value of transfer impedance is directly associated, the Tenderer shall assume that the 'nearest' largest value of transfer impedance is to be used.
- At each harmonic the SVC design shall comply with both the HV and LV performance requirements for all HV/LV combinations given.

Points producing the limiting angles

400/275 kV Transformers

Harmonic Range	Inductive/capacitive	Self impedance	Self impedance angle	Self resistance	Transfer to LV	Transfer to HV
1.75 to 2.25	Inductive	0.2277	87.77	0.008860038	0.0484	0.0104
	Capacitive	0	0	0	0	0
2.5 to 3.25	Inductive	0.3666	87.7	0.014712315	0.024	0.0049
	Capacitive	0	0	0	0	0
3.5 to 5.25	Inductive	0.5584	86.92	0.030002974	0.0375	0.0085
	Capacitive	0	0	0	0	0
5.5 to 7.25	Inductive	0.8666	85.84	0.06286483	0.0494	0.0076
	Capacitive	0	0	0	0	0
7.5 to 9.25	Inductive	0.8414	84.36	0.082690836	0.0972	0.0196
	Capacitive	0	0	0	0	0
9.5 to 11.5	Inductive	1.4051	82.82	0.175619111	0.1103	0.0172
	Capacitive	0	0	0	0	0
11.75 to 13.5	Inductive	1.2909	81.66	0.187241153	0.1309	0.0041
	Capacitive	0	0	0	0	0
13.75 to 19.25	Inductive	1.5256	80.41	0.254159857	0.1732	0.0249
	Capacitive	0	0	0	0	0
19.5 to 31.25	Inductive	2.0387	76.47	0.476962965	0.2724	0.0194
	Capacitive	0	0	0	0	0

400/132 kV Transformers

Harmonic Range	Inductive/capacitive	Self impedance	Self impedance angle	Self resistance	Transfer to LV	Transfer to HV
1.75 to 2.25	Inductive	0.1631	87.89	0.006005036	0.0751	0.0106
	Capacitive	0	0	0	0	0
2.5 to 3.25	Inductive	0.2321	87.59	0.009759813	0.1064	0.0141
	Capacitive	0.5605	339.89	0.526328702	0.7377	0.725
3.5 to 5.25	Inductive	0.3248	86.81	0.018074225	0.1489	0.0198
	Capacitive	0.2788	322.62	0.221541892	0.404	0.068
5.5 to 7.25	Inductive	0.5122	84.91	0.045442616	0.2362	0.0345
	Capacitive	0	0	0	0	0
7.5 to 9.25	Inductive	0.6997	84.02	0.072895658	0.3116	0.0266
	Capacitive	0	0	0	0	0
9.5 to 11.5	Inductive	0.8795	82.44	0.115710854	0.4049	0.0569
	Capacitive	0	0	0	0	0
11.75 to 13.5	Inductive	1.5035	81.22	0.229495548	0.0555	0.0336
	Capacitive	0	0	0	0	0
13.75 to 19.25	Inductive	1.7728	79.93	0.309976238	0.0442	0.058
	Capacitive	0.8638	349.35	0.848920567	1.1154	0.0214
19.5 to 31.25	Inductive	0.9597	76.36	0.226317042	0.0538	0.0161
	Capacitive	0	0	0	0	0

275/132 kV Transformers

Harmonic Range	Inductive/capacitive	Self impedance	Self impedance angle	Self resistance	Transfer to LV	Transfer to HV
1.75 to 2.25	Inductive	0.6376	87.98	0.022474347	0.069	0.0134
	Capacitive	0	0	0	0	0
2.5 to 3.25	Inductive	0.9298	87.42	0.041854276	0.1184	0.0159
	Capacitive	0.5562	348.93	0.545850972	0.6214	0.0576
3.5 to 5.25	Inductive	0.491	86.38	0.031001196	0.1668	0.0087
	Capacitive	0.2326	354.72	0.231613051	0.3839	0.0426
5.5 to 7.25	Inductive	1.6972	84.86	0.152051542	0.1048	0.0086
	Capacitive	0	0	0	0	0
7.5 to 9.25	Inductive	1.0589	83.28	0.123909738	0.3664	0.0214
	Capacitive	0	0	0	0	0
9.5 to 11.5	Inductive	2.9449	82.31	0.394066564	0.1481	0.0219
	Capacitive	0	0	0	0	0
11.75 to 13.5	Inductive	3.7142	81.33	0.559890488	0.0869	0.0122
	Capacitive	0	0	0	0	0
13.75 to 19.25	Inductive	4.3622	80.06	0.752988987	0.0663	0.0022
	Capacitive	0	0	0	0	0
19.5 to 31.25	Inductive	6.1462	76.2	1.466074337	0.0423	0.0007
	Capacitive	0	0	0	0	0

275/66 kV Transformers

Harmonic Range	Inductive/capacitive	Self impedance	Self impedance angle	Self resistance	Transfer to LV	Transfer to HV
1.75 to 2.25	Inductive	0.2427	87.13	0.01215199	0.0202	0.1057
	Capacitive	0	0	0	0	0
2.5 to 3.25	Inductive	0.2283	85.27	0.018825695	0.1183	0.0156
	Capacitive	0	0	0	0	0
3.5 to 5.25	Inductive	0.3557	82.66	0.045443183	0.2013	0.0323
	Capacitive	0.4641	327.52	0.391504989	0.6846	0.0777
5.5 to 7.25	Inductive	0.7393	80.01	0.128251024	0.026	0.1894
	Capacitive	0.3185	348.64	0.312260243	0.39	0.0351
7.5 to 9.25	Inductive	0.9179	81.66	0.133138628	0.019	0.2289
	Capacitive	0	0	0	0	0
9.5 to 11.5	Inductive	0.9811	81.61	0.143138069	0.0242	0.2533
	Capacitive	0	0	0	0	0
11.75 to 13.5	Inductive	1.2409	80.56	0.203525816	0.0283	0.3418
	Capacitive	0.6194	339.81	0.581339898	0.8422	0.0237
13.75 to 19.25	Inductive	1.4657	79.49	0.267354135	0.0338	0.4166
	Capacitive	0.766	332.58	0.679943493	0.0025	1.0115
19.5 to 31.25	Inductive	2.0908	45.59	0.520314257	0.0694	0.6232
	Capacitive	1.4429	341.59	1.369053685	1.6816	0.0305

Transformers

Case 1

[illegible]

to the LV, Harmonic Range
Minimum self resistance
Maximum inductive angle
Maximum capacitive angle

	0.465	0.45	0.435	0.42	0.405	0.39	0.375	0.36	0.345	0.33	0.315	0.3	0.285	0.265	0.255	0.24	0.225	0.21	0.195	0.18	0.165	0.15	0.135	0.12	0.105	0.09	0.075	0.06	0.045	0.03	0.015	0.00	
x	0	0	0	0	0	0	0	0	0	0	0	0.0099	0.0071	0.27	0.0108	0.0124	0.0115	0.0086	0.018	0.0089	0	0	0	0.135	0.12	0	0	0	0	0	0	0.015	0
	0	0	0	0	0	0	0	0	0	0.0159	0	0	0.0138	0	0.0185	0.0205	0.0177	0.0121	0.0148	0.0152	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0.0223	0	0	0	0	0	0	0.0173	0.0212	0	0.0225	0	0	0	0	0	0	0	0	0	0	0	0	
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.0195	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
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	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0													

to the HV, Harmonic Range

1.75 to 2.25

Case 2	0.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.54	0	0	0.0388	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.52	0	0	0.0337	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.48	0	0	0.034	0.0368	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.46	0	0	0.0372	0.039	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.44	0	0.0261	0.0308	0.1006	0	0.0991	0	0	0	0	0	0	0	0	0	0	0	0
	0.42	0	0.0321	0.0297	0	0.0781	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.4	0	0.0266	0.0917	0.0909	0.0533	0.0378	0	0	0	0	0	0	0	0	0	0	0	0
	0.38	0	0.0787	0.0806	0.0751	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.36	0	0.0384	0.0709	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.34	0	0.0672	0.0714	0.0259	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.32	0	0.0258	0.0657	0.0253	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.3	0	0.043	0.0242	0.0262	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.28	0	0.0345	0.0186	0.0254	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.26	0	0.0205	0.0283	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.24	0	0.0246	0.0279	0.0356	0.0444	0	0	0	0	0	0	0	0	0	0	0	0	0

Case 2	0.62	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.58	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.56	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.54	0	0	0.0127	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.52	0	0	0.0073	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.48	0	0	0.01	0.0025	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.46	0	0.0045	0.0027	0.0016	0	0.0208	0	0	0	0	0	0	0	0	0	0	0	0
	0.44	0	0.0041	0.0028	0.0197	0	0.0155	0	0	0	0	0	0	0	0	0	0	0	0
	0.42	0	0.0071	0.019	0.0191	0.0249	0.0218	0	0	0	0	0	0	0	0	0	0	0	0
	0.4	0	0.0143	0.0167	0.015	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.38	0	0.0103	0.0143	0.0119	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.36	0	0.0052	0.0131	0.0051	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.34	0	0.009	0.0082	0.016	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.32	0	0.0057	0.0098	0.0065	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.28	0	0.024	0.0077	0.009	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	0.26	0	0.0125	0.0125	0.0151	0.0144	0.0191	0	0	0	0	0	0	0	0	0	0	0	0
	0.24	0	0.0127	0	0	0	0.0212	0	0	0	0	0	0	0	0	0	0	0	0
	0.22	0	0	0	0	0	0.0279	0	0	0	0	0	0	0	0	0	0	0	0

to the LV, Harmonic Range
Minimum self resistance
Maximum inductive angle
Maximum capacitive angle

2.5 to 3.25
0.013453
87.7
0

to the HV, Harmonic Range
2.5 to 3.25

R

[illegible]

[illegible]



 **Documents**
Document Sharing Hub

[illegible]

to the HV, Harmonic Range	13.75	to	19.25

to the HV, Harmonic Range	13.75	to	19.25

to the LV, Harmonic Range	19.5	to 31
Minimum self resistance	0.445447	
Maximum inductive angle	76.47	
Maximum capacitive angle	0	

400/132 kV Transformers

Case 1

[illegible]

to the LV Harmonic	1.75	to	2.25
Minimum self resistance	0.00601		
Maximum inductive angle	87.89		
Maximum capacitive angle	0		

[illegible]

	1.75	to	2.25
to the HV, Harmonic Range			