

## References

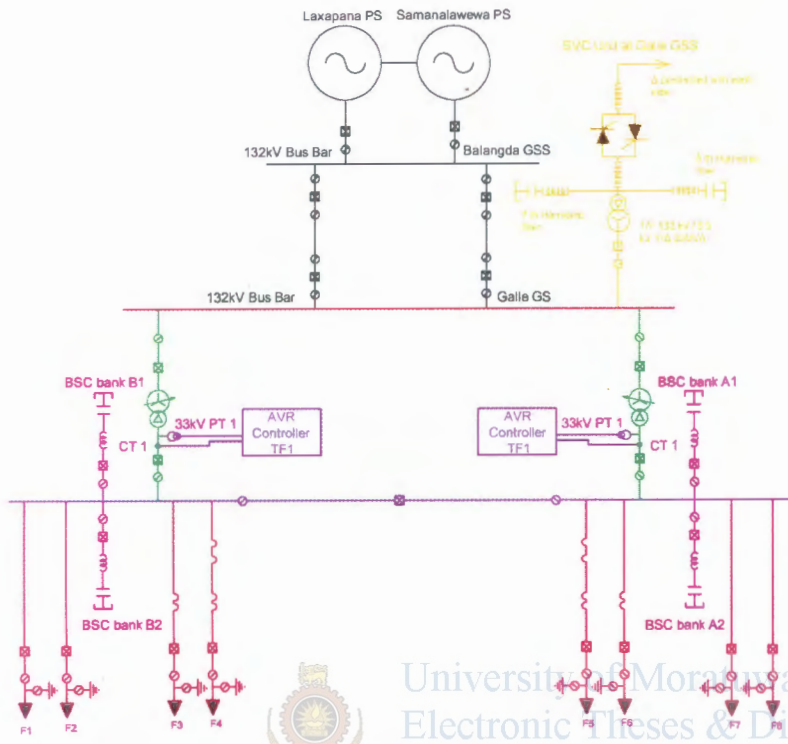
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- [1] Zoran Gajic, Daniel Karisson, Mike Kockott, “Advanced OLTC control to counteract power system voltage instability”
- [2] Kusumshanthi K.P “Benchmark the Sri Lankan power system by power quality monitoring & analysis” Master Thesis, University of Moratuwa , 2005. Chapter 8.2 pp 42
- [3] DDU Dopage “Optimising the use of breaker switch capacitor bank in CEB transmission network” Master Thesis, University of Moratuwa, 2009. Chapter 6 pp 42-48.
- [4] IEC 60871-1 Shunt capacitors for AC power systems having a rated voltage above 1000 V Part 1: General – Performance, testing and rating. Safety requirements – Guide for installation and operation – Section 4.
- [5] Taylor C.W. “Power system voltage stability” McGraw-Hill, 1993 Chapter 10. pp 242-251
- [6] ABB review 2009 part 3 pp 33-37
- [7] User Manual for PSCAD
- [8] Website <http://w.w.w.nepsi.com> (Reading reference)
- [9] Website <http://w.w.w.nokiancapacitors.com> “Reactors and shunt capacitor banks- An application note –EN TH08 11/2004” pp 2-4
- [10] MR- Tapcon transformer AVR controller manual
- [11] ABB Switch gear manual (For theoretical calculations)
- [12] Website <http://w.w.w.cooper capacitor.com> (Reading reference)
- [13] Suresh Kumar K.S “Applications of power capacitors in electrical distribution systems” pp 1-5

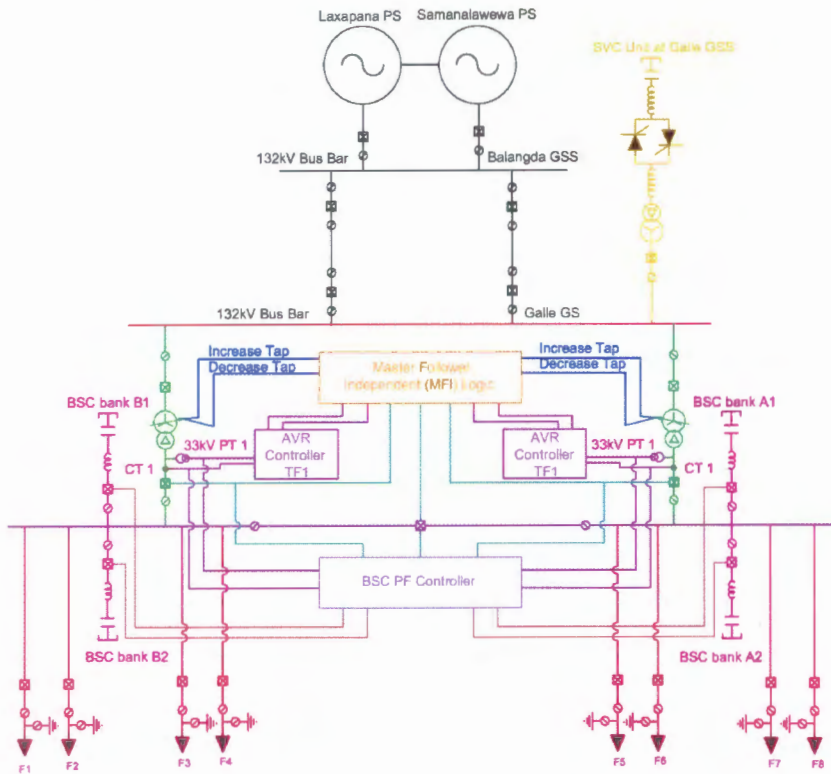
# Appendices

## Appendix A

### Appendix A1- Single line arrangement of the Galle GSS



### Appendix A2 - AVR and PF control circuit arrangement of the GSS



**Appendix A3-** Single unit (5MVA<sub>r</sub>) of the BSC bank at Galle GSS



## Appendix B

### Appendix (B1.1) - Fixed tap at rated V BSC are OFF (TA11 Tap 08)

Pload	Qload	Q33kv	P33kv	V33kv	Q132kV	P132kV	Vmax	Vmin	PF angle
4.500000	2.666667	14.65727	25.3598	31.6009	19.3146	25.6573	33.33	32.67	37.0047
4.855556	2.855556	15.5879	27.145	31.5082	20.468	27.4421			36.3762
5.211111	3.044444	16.50565	28.9047	31.4158	21.6215	29.2016			35.806
5.566667	3.233333	17.4106	30.6392	31.3233	22.7746	30.936			35.28425
5.922222	3.422222	18.30293	32.3489	31.2306	23.9275	32.6459			34.8156
6.277778	3.611111	19.18271	34.0346	31.1377	25.0799	34.3315			
6.633333	3.800000	20.0502	35.6963	31.045	26.2318	35.9941			33.96505
6.988889	3.988889	20.9095	37.3346	30.9524	27.3832	37.633			33.5936
7.344444	4.177778	21.6118	38.95	30.8594	28.5338	39.2491			33.25
7.700000	4.366667	22.5796	40.5425	30.7667	29.6837	40.8424			32.9321
8.055556	4.555556	23.3987	42.1124	30.674	30.8328	42.4134			32.63785
8.411111	4.744444	24.206	43.6605	30.5811	31.9808	43.9623			32.3643
8.766667	4.933333	25.0015	45.1866	30.4882	33.1279	45.4895			32.1104
9.122222	5.122222	25.7856	46.6911	30.3955	34.2738	46.995			31.87425
9.477778	5.311111	26.5568	48.1741	30.303	35.4185	48.4793			31.65445
9.833333	5.500000	27.319	49.6361	30.2102	36.5619	49.9424			31.44935

### Appendix (B1.2) - Tap is varying to bring the voltage to set BW limits BSC are OFF (TA11 Tap 10)

Pload	Qload	Q33kv	P33kv	V33kv	Q132kV	P132kV	Vmax	Vmin	PF angle
4.500000	2.666667	15.37391	26.6066	32.3607	20.9883	26.919	33.33	32.67	37.01835
4.855556	2.855556	16.34856	28.477	32.2646	22.186	28.7883			36.4023
5.211111	3.044444	17.3097	30.3204	32.1686	23.3842	30.6309			35.8379
5.566667	3.233333	18.25729	32.137	32.0726	24.5819	32.4469			35.3212
5.922222	3.422222	19.19127	33.9272	31.9762	25.779	34.237			34.8464
6.277778	3.611111	20.1121	35.6918	31.8801	26.9759	36.0016			34.41215
6.633333	3.800000	21.0198	37.4311	31.7836	28.1723	37.741			34.0118
6.988889	3.988889	21.9144	39.5138	31.6874	29.3679	39.4557			33.6419
7.344444	4.177778	22.7961	40.8352	31.5908	30.5627	41.1461			33.3006
7.700000	4.366667	23.6651	42.5009	31.4945	31.7568	42.8124			32.98465
8.055556	4.555556	24.5213	44.1425	31.3982	32.9498	44.4549			32.6916
8.411111	4.744444	25.365	45.7607	31.3017	34.1419	46.0739			32.41935
8.766667	4.933333	26.1961	47.3557	31.2053	35.3327	47.6699			32.1666
9.122222	5.122222	27.0151	48.9276	31.109	36.5224	49.2429			31.93125
9.477778	5.311111	27.8217	50.4768	31.0129	37.7106	50.7932			31.71195
9.833333	5.500000	28.6165	52.0034	30.9164	38.8973	52.3211			31.50715



**Appendix (B1.3) - Tap is varying to bring the voltage to set BW limits BSC are OFF (TA11 Tap 12 )**

Pload	Qload	Q33kv	P33kv	V33kv	Q132kv	P132kv	Vmax	Vmin	PF angle
4.500000	2.666667	16.13711	27.9375	33.1497	22.9931	28.2721	33.33	32.67	37.02775
4.855556	2.855556	17.15891	29.8987	33.0496	24.237	30.2314			36.41805
5.211111	3.044444	18.16598	31.8306	32.9499	25.4802	32.1619			35.8548
5.566667	3.233333	19.1588	33.7344	32.8501	26.7332	34.0645			35.3438
5.922222	3.422222	20.1371	35.6102	32.7499	27.9654	35.9396			34.87475
6.277778	3.611111	21.1015	37.4585	32.6499	29.207	37.7875			34.4441
6.633333	3.800000	22.0518	39.2799	32.5499	30.4479	39.6087			34.04775
6.988889	3.988889	22.9881	41.0748	32.4497	31.6836	41.4036			33.68075
7.344444	4.177778	23.9109	42.8438	32.3494	32.9268	43.1728			33.34375
7.700000	4.366667	24.8201	44.5868	32.2493	34.1648	44.9162			33.0308
8.055556	4.555556	25.7157	46.3041	32.1493	35.4017	46.6344			32.7406
8.411111	4.744444	26.5979	47.9969	32.0491	36.6373	48.3278			32.4712
8.766667	4.933333	27.4669	49.6646	31.9489	37.8714	49.9963			32.21985
9.122222	5.122222	28.3228	51.3076	31.8491	39.1045	51.6403			31.98685
9.477778	5.311111	29.1655	52.9269	31.7488	40.3357	53.2607			31.7688
9.833333	5.500000	29.9954	54.5222	31.6486	41.5655	54.1571			31.5685

**Appendix (B1.4)**



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Tap is varying to bring the voltage to set BW limits BSC are OFF (TA11 Tap 14 )

Pload	Qload	Q33kv	P33kv	V33kv	Q132kv	P132kv	Vmax	Vmin	PF angle
4.500000	2.666667	15.74952	27.2611	32.7516	21.9438	27.5836	33.33	32.67	37.03205
4.855556	2.855556	16.74743	29.1764	32.6537	23.1646	29.4974		Tap 11	36.41235
5.211111	3.044444	18.61444	32.623	33.351	26.6813	32.9678		Tap 13	35.86065
5.566667	3.233333	19.63077	34.5722	33.2492	27.9469	34.9156		Tap 13	35.3505
5.922222	3.422222	20.632	36.4927	33.147	29.2115	36.835		Tap 13	34.88325
6.277778	3.611111	21.6194	38.3848	33.0451	30.4754	38.7265		Tap 13	34.4553
6.633333	3.800000	22.592	40.2491	32.9431	31.7384	40.5904		Tap 13	34.0605
6.988889	3.988889	23.5503	42.0861	32.8409	33.0002	42.4273		Tap 13	33.6961
7.344444	4.177778	24.4945	43.896	32.7387	34.2612	44.2373		Tap 13	33.35985
7.700000	4.366667	25.4245	45.6795	32.6367	35.5208	46.0211		Tap 13	33.0488
8.055556	4.555556	26.9846	48.6044	32.9268	38.2716	48.9608		Tap 14	32.7753
8.411111	4.744444	27.9077	50.376	32.8222	39.5509	50.7329		Tap 14	32.50995
8.766667	4.933333	28.8167	52.1206	32.7183	40.8268	52.4782		Tap 14	32.2615
9.122222	5.122222	29.7117	53.8392	32.6146	42.1019	54.1976		Tap 14	32.0305
		30.4377	55.1637	33.0068	43.781	55.5385		Tap 15	32.04815
9.477778	5.311111	30.5928	55.5322	32.5101	43.3752	55.8916		Tap 14	31.81545
		31.3386	56.895	32.9004	45.0745	57.2708		Tap 15	31.83385
9.833333	5.500000	31.4602	57.1995	32.4063	44.6465	57.5601		Tap 14	31.6146
		33.0134	60.0429	33.1896	48.2172	60.4385		Tap 16	

Appendix (B2.1)

One BSC bank is ON 5Mvar

Pload	Qload	Q33kv	P33kv	V33kv	Q132kv	P132kv	Vmax	Vmin	PF angle
4.500000	2.666667	10.3323	25.9544	31.952	15.1069	26.2479	33.33	Tap 08	30.20765
		10.83654	27.2274	32.7237	16.6337	27.5385		Tap 10	30.3885
4.855556	2.855556	11.23831	27.7787	31.8579	16.297	28.0714		Tap 08	30.00265
		12.15258	29.8529	33.02	18.7786	30.1741		Tap 11	30.00235
5.211111	3.044444	12.27842	29.5753	31.7632	17.4662	29.8675		Tap 08	29.7939
		13.2312	31.781	32.9201	20.0731	32.1007		Tap 11	30.01725
5.566667	3.233333	13.2312	31.3467	31.6691	18.6752	31.6387		Tap 08	29.60075
		14.2102	33.681	32.8202	21.2942	34.0003		Tap 11	29.79855
5.922222	3.422222	14.17099	33.0926	31.5741	19.864	33.3846		Tap 08	29.41805
		15.21926	35.5521	32.7206	22.5525	35.8698		Tap 11	29.5914
6.277778	3.611111	15.09732	17.5933	31.4801	21.0516	35.1047		Tap 08	29.9378
		16.21245	37.796	32.6203	23.8091	37.7132		Tap 11	29.39765
6.633333	3.800000	16.0104	36.5082	31.3854	22.2385	36.8008		Tap 08	29.06865
		17.61033	40.1734	32.912	26.1869	40.5031		Tap 12	29.28745
6.988889	3.988889	16.91076	38.1796	31.2908	23.4245	38.4728		Tap 08	28.9104
		18.59892	42.0058	32.8098	27.4655	42.3352		Tap 12	29.12005
7.344444	4.177778	17.79903	39.8276	31.1958	24.6106	40.12114		Tap 08	28.76745
		19.57159	43.8111	32.7075	28.7415	44.1406		Tap 12	28.95825
7.700000	4.366667	18.67417	41.4319	31.101	25.7951	41.7459		Tap 08	28.62685
		20.5307	45.5896	32.6052	30.0169	45.9192		Tap 12	28.8093
8.055556	4.555556	19.53705	43.0524	31.0063	26.9791	43.3479		Tap 08	28.5007
		21.9994	48.5001	32.8936	32.6107	48.8448		Tap 13	28.7266
8.411111	4.744444	20.3876	44.63	30.9113	28.1617	44.9267		Tap 08	28.3804
		22.9518	50.2666	32.7891	33.906	50.6117		Tap 13	28.59945
8.766667	4.933333	21.2256	46.1855	30.8163	29.3427	46.4832		Tap 08	28.26895
		23.8901	52.0061	32.6848	35.1996	52.3519		Tap 13	28.48005
9.122222	5.122222	22.0519	47.7178	30.7215	30.5232	48.0167		Tap 08	28.1629
		24.8141	53.7201	32.5807	36.4919	54.0667		Tap 13	28.37165
		25.419	55.0346	32.9719	37.9925	55.3982		Tap 14	28.41325
9.477778	5.311111	22.8659	49.2288	30.6269	31.7021	49.529		Tap 08	28.0679
		25.7248	55.4074	32.4763	37.7822	55.7549		Tap 13	28.27055
		26.3509	56.7601	32.8654	39.3045	57.1244		Tap 14	28.3112
9.833333	5.500000	23.6679	50.7186	30.532	32.8801	51.0202		Tap 08	27.98295
		26.6208	57.0695	31.372	39.0704	57.418		Tap 13	28.176
		27.267	58.4602	32.7591	40.617	58.8255		Tap 14	28.21665



**Appendix (B2.2) two capacitor banks on**

Pload	Qload	Q33kv	P33kv	V33kv	Q132kV	P132kV	Vmax	Vmin	PF angle
4.500000	2.666667	5.79073	26.7043	32.3197	10.7224	26.9832	33.33	Tap 08	23.09325
		6.07324	28.0255	33.1049	12.0582	28.3195		Tap 10	
4.855556	2.855556	6.8217	28.5662	32.2228	11.9658	28.8445		Tap 08	23.43645
		7.15511	29.9775	33.0047	13.3436	30.267		Tap 10	23.469
5.211111	3.044444	7.83855	30.3999	32.1255	13.2019	30.6779		Tap 08	23.69695
		8.22192	31.8995	32.904	14.6275	32.186		Tap 10	23.7137
5.566667	3.233333	8.8413	32.2062	32.0289	14.4364	32.4842		Tap 08	23.8961
		9.27364	33.7926	32.8039	15.9098	34.0804		Tap 10	23.9028
5.922222	3.422222	9.83005	33.9859	31.932	15.6694	34.2641		Tap 08	24.05045
		10.31058	35.6572	32.7036	17.1907	35.9445		Tap 10	24.0524
6.277778	3.611111	10.80528	35.7389	31.8342	16.9008	36.0177		Tap 08	24.16905
		11.6069	38.4132	32.9965	19.3812	38.7082		Tap 11	24.21075
6.633333	3.800000	11.767	37.4664	31.7375	18.1308	37.7459		Tap 08	24.2631
		12.64109	40.2649	32.8943	20.6824	40.5601		Tap 11	24.29755
6.988889	3.988889	12.71531	39.1682	31.6406	19.3591	39.4489		Tap 08	24.337
		13.6585	42.0893	32.7915	21.9818	42.3848		Tap 11	24.36825
7.344444	4.177778	13.65032	40.8457	31.5431	20.5856	41.1273		Tap 08	24.396
		14.66141	43.8861	32.6813	23.2795	44.1823		Tap 11	24.4258
7.700000	4.366667	14.57227	42.4987	31.4458	21.8107	42.7813		Tap 08	24.44405
		16.03108	46.7754	32.9788	25.6793	48.0812		Tap 12	24.5276
8.055556	4.555556	15.48121	44.1274	31.3488	23.0342	44.4114		Tap 08	24.5836
		17.02831	48.5596	32.874	26.9964	48.8662		Tap 12	24.56405
8.411111	4.744444	16.37715	45.7326	31.2515	24.2558	46.0176		Tap 08	24.51675
		18.01085	50.3168	32.769	28.3118	50.6245		Tap 12	24.59575
8.766667	4.933333	17.26044	47.3142	31.1539	25.4759	47.6009		Tap 08	24.54545
		18.97911	52.0472	32.6639	29.6249	52.3562		Tap 12	24.62315
9.122222	5.122222	18.13119	48.8726	31.0569	26.6941	49.1608		Tap 08	24.5703
		19.93282	53.7515	32.5592	30.9359	54.0619		Tap 12	24.6475
		20.4179	55.0674	32.951	32.2385	55.3885		Tap 13	24.71135
9.477778	5.311111	18.98931	50.4082	30.9599	27.9104	50.698		Tap 08	24.59225
		20.8724	55.43	32.4544	32.2449	55.7419		Tap 12	24.52095
		21.3794	56.785	32.8441	33.5701	57.1066		Tap 13	24.73115
9.833333	5.500000	19.83486	51.9213	30.8625	29.1247	52.2158		Tap 08	24.613
		21.7979	57.0829	32.3491	33.5514	57.3963		Tap 12	24.6921
		22.3264	58.4743	32.7368	34.8996	58.7985		Tap 13	24.75085

**Appendix (B2.3) three capacitor bank on**

Pload	Qload	Q33kv	P33kv	V33kv	Q132kV	P132kV	Vmax	Vmin	PF angle	Tap
4.500000	2.666667	0.988573	27.2229	32.7095	5.86058	27.5112	33.33	32.67	11.9661	Tap 0
		1.011018	27.8917	33.1066	6.38655	28.1874			11.82285	Tap 0
4.855556	2.855556	2.0777	29.1275	32.6107	7.13354	29.4144			13.1104	Tap 0
		2.12212	29.8418	33.0061	7.6851	30.1395			13.03685	Tap 0
5.211111	3.044444	3.15174	31.0033	32.5114	8.40558	31.2895			14.1561	Tap 0
		3.22261	31.7619	32.9048	8.98233	32.0549			14.05295	Tap 0
5.566667	3.233333	4.2116	32.8507	32.4124	9.67751	33.1368			15.01575	Tap 0
		4.40719	34.4826	33.2034	10.9561	34.7835			14.8634	Tap 1
5.922222	3.422222	5.25472	34.6691	32.3129	10.9451	34.9549			15.72625	Tap 0
		5.50401	36.3895	33.1	12.2773	36.6898			15.60725	Tap 1
6.277778	3.611111	6.28583	36.4636	32.213	12.2164	36.7503			16.3843	Tap 0
		6.58498	38.2685	32.9962	13.5971	38.5685			16.25665	Tap 1
6.633333	3.800000	7.30163	38.231	32.1133	13.4843	38.5175			16.93905	Tap 0
		7.65125	40.1191	32.8932	14.916	40.419			16.82455	Tap 1
6.988889	3.988889	8.30362	39.9717	32.014	14.7514	40.2588			17.4276	Tap 0
		8.70178	41.9421	32.7889	16.2329	42.2422			17.3237	Tap 1
7.344444	4.177778	9.29152	41.6866	31.9134	16.0171	41.9745			17.8588	Tap 0
		9.7376	42.7373	32.6848	17.5485	44.031			17.76415	Tap 1
7.700000	4.366667	10.26526	43.3767	31.8133	17.2815	43.6656			18.24675	Tap 0
		11.01652	46.6228	32.9762	19.7783	46.9333			18.1547	Tap 1
8.055556	4.555556	11.22564	45.0416	31.7135	18.5443	45.3315			18.59355	Tap 0
		12.047	48.4052	32.8697	21.1155	48.7165			18.5108	Tap 1
8.411111	4.744444	12.17235	46.6816	31.6135	19.8057	46.9727			18.9056	Tap 0
		13.06266	50.1608	32.7634	22.4512	50.4728			18.83385	Tap 1
8.766667	4.933333	13.10548	48.2978	31.5138	21.0655	48.5902			19.1918	Tap 0
		14.06389	51.89	32.6573	23.786	52.203			19.1368	Tap 1
9.122222	5.122222	14.02568	49.8903	31.4135	22.3242	50.1882			19.4576	Tap 0
		15.05037	53.592	32.5514	25.1176	53.906			19.39785	Tap 1
		15.41358	54.906	32.9448	26.2295	55.231			19.4282	Tap 1
9.477778	5.311111	14.93258	51.3984	31.3137	23.5804	51.7535			19.6948	Tap 0
		16.02219	55.2689	32.4454	26.4478	55.5843			19.64895	Tap 1
		16.40744	56.6204	32.8367	27.5827	56.9467			19.672	Tap 1
9.833333	5.500000	15.82614	53.0029	31.2137	24.835	53.3			19.915	Tap 0
		16.97971	56.9195	32.3393	27.7758	57.2363			19.8775	Tap 1
		17.3875	58.3085	32.7284	28.9348	58.6361			19.90155	Tap 1