

6. CONCLUSIONS AND FURTHER RESEARCH AREA

6.1. Conclusion

The research project is about the selection of voltage between 220 kV and 400 kV for the future transmission interconnection of bulk power transmission lines in Sri Lanka power system. The study was mainly focused on the major bulk power transmission from Sampur, Ambalangoda and Hambanthota generation stations to the load centers.

First data related for 400 kV was collected. Then two different system configurations were developed based on the two system voltages, 220 kV versus 400 kV for years 2025 and 2032 and they were modeled in PSS@E (Power System Simulator for Engineering) software. Next, theoretical justification was developed and performed voltage stability studies (PV, QV analysis) in order to find out the technical feasibility of the two system configurations. Finally, the economic analysis between the two configurations was carried out to evaluate the economic feasibility of the two options.

According to the technical analysis on the power system, it shows that there is no significant reactive power compensation needed to operate power system in both options. However 400 kV option improves the voltage profile of the system than 220 kV voltage. The voltage improvement is significant for the Southern power transfer than the North Eastern power transfer. Further maximum power transfer capability of the southern power transfer shows significantly high capability in 400 kV than 220 kV.

Economic feasibility analysis mainly governs by the loss saving achieved through 400 kV voltage option over 220 kV voltage option. For base case and other several sensitivity cases other than one case, 400 kV option shows better economic feasibility than 220 kV option.

Therefore as a final conclusion, 400 kV option is recommended over 220 kV option considering both technical and economic factors.

6.2. Further research area

This study can be further enhanced by introducing following factors to the technical and economic analysis

1. Modeling of minimum generation and load scenario in order to find the inductive reactive power requirement under low load condition
2. Technical aspects: Conductor type optimization (Low Loss Conductor), transmission tower optimization
3. Economic aspects: Costing of Right of Way (ROW), Costing of corona loss effect and future escalation of land prices and Emission cost (environmental cost) into economic analysis

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Appendix A –Detailed Calculation Sheets of the Sensitivity Analysis

Case 1: Discount Rate 5%

Case 1: NPV Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)	Discounted Total (MLKR)	Cumulative Total (MLKR)
2025	13921.8	360.7	-13561.2	-13561	-13561
2026	137.8	849.2	711.3	677	-12884
2027	137.8	916.9	779.1	707	-12177
2028	137.8	1004.7	866.9	749	-11428
2029	137.8	1073.8	936.0	770	-10658
2030	137.8	1142.9	1005.1	788	-9871
2031	137.8	1271.2	1133.3	846	-9025
2032	137.8	1402.7	1264.9	899	-8126
2033	137.8	1542.0	1404.2	950	-7176
2034	137.8	1662.9	1525.1	983	-6193
2035	137.8	1783.8	1645.9	1010	-5182
2036	137.8	1904.6	1766.8	1033	-4149
2037	137.8	2025.4	1887.6	1051	-3098
2038	137.8	2146.3	2008.5	1065	-2033
2039	137.8	2267.1	2129.3	1075	-957
2040	137.8	2388.0	2250.2	1082	125
2041	137.8	2508.8	2371.0	1086	1211
2042	137.8	2629.7	2491.9	1087	2298
2043	137.8	2750.5	2612.7	1086	3384
2044	137.8	2871.4	2733.6	1082	4466
2045	137.8	2992.3	2854.4	1076	5542
2046	137.8	3113.1	2975.3	1068	6609
2047	137.8	3233.9	3096.1	1058	7668
2048	137.8	3354.8	3217.0	1047	8715
2049	137.8	3475.6	3337.8	1035	9750
2050	137.8	3596.5	3458.7	1021	10772
2051	137.8	3717.3	3579.5	1007	11778
2052	137.8	3838.2	3700.4	991	12769
2053	137.8	3959.0	3821.2	975	13744
2054	137.8	4079.9	3942.1	958	14702
2055	137.8	4200.8	4062.9	940	15642
				NPV	15642

Case 1: Benefit to Cost Ratio Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Discounted Benefit (B)	Discounted Investment (C)
2025	13921.8	360.7	361	-13922
2026	137.8	849.2	809	-131
2027	137.8	916.9	832	-125
2028	137.8	1004.7	868	-119
2029	137.8	1073.8	883	-113
2030	137.8	1142.9	896	-108
2031	137.8	1271.2	949	-103
2032	137.8	1402.7	997	-98
2033	137.8	1542.0	1044	-93
2034	137.8	1662.9	1072	-89
2035	137.8	1783.8	1095	-85
2036	137.8	1904.6	1114	-81
2037	137.8	2025.4	1128	-77
2038	137.8	2146.3	1138	-73
2039	137.8	2267.1	1145	-70
2040	137.8	2388.0	1149	-66
2041	137.8	2508.8	1149	-63
2042	137.8	2629.7	1147	-60
2043	137.8	2750.5	1143	-57
2044	137.8	2871.4	1136	-55
2045	137.8	2992.3	1128	-52
2046	137.8	3113.1	1117	-49
2047	137.8	3233.9	1106	-47
2048	137.8	3354.8	1092	-45
2049	137.8	3475.6	1078	-43
2050	137.8	3596.5	1062	-41
2051	137.8	3717.3	1045	-39
2052	137.8	3838.2	1028	-37
2053	137.8	3959.0	1010	-35
2054	137.8	4079.9	991	-33
2055	137.8	4200.8	972	-32
			31683	-16041
			Benefit/Cost	1.9751

Case 2: 5% annual electricity cost increase

Case 2: EIRR Calculation Sheet

Year	Cost in (MLKR)			Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)
	Investment	Trans. O&M cost	Total Cost		
2025	13784	137.8	13921.8	378.7	-13543.1
2026		137.8	137.8	891.6	753.8
2027		137.8	137.8	962.8	824.9
2028		137.8	137.8	1055.0	917.1
2029		137.8	137.8	1127.5	989.7
2030		137.8	137.8	1200.1	1062.2
2031		137.8	137.8	1334.7	1196.9
2032		137.8	137.8	1472.8	1335.0
2033		137.8	137.8	1619.2	1481.3
2034		137.8	137.8	1746.0	1608.2
2035		137.8	137.8	1872.9	1735.1
2036		137.8	137.8	1999.8	1862.0
2037		137.8	137.8	2126.7	1988.9
2038		137.8	137.8	2253.6	2115.8
2039		137.8	137.8	2380.5	2242.7
2040		137.8	137.8	2507.4	2369.6
2041		137.8	137.8	2634.3	2496.5
2042		137.8	137.8	2761.2	2623.3
2043		137.8	137.8	2888.1	2750.2
2044		137.8	137.8	3015.0	2877.1
2045		137.8	137.8	3141.9	3004.0
2046		137.8	137.8	3268.8	3130.9
2047		137.8	137.8	3395.6	3257.8
2048		137.8	137.8	3522.5	3384.7
2049		137.8	137.8	3649.4	3511.6
2050		137.8	137.8	3776.3	3638.5
2051		137.8	137.8	3903.2	3765.4
2052		137.8	137.8	4030.1	3892.3
2053		137.8	137.8	4157.0	4019.2
2054		137.8	137.8	4283.9	4146.1
2055		137.8	137.8	4410.8	4272.9
				EIRR	11.2%

Case 2: NPV Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)	Discounted Total (MLKR)	Cumulative Total (MLKR)
2025	13921.8	378.7	-13543.1	-13543	-13543
2026	137.8	891.6	753.8	685	-12858
2027	137.8	962.8	824.9	682	-12176
2028	137.8	1055.0	917.1	689	-11487
2029	137.8	1127.5	989.7	676	-10811
2030	137.8	1200.1	1062.2	660	-10152
2031	137.8	1334.7	1196.9	676	-9476
2032	137.8	1472.8	1335.0	685	-8791
2033	137.8	1619.2	1481.3	691	-8100
2034	137.8	1746.0	1608.2	682	-7418
2035	137.8	1872.9	1735.1	669	-6749
2036	137.8	1999.8	1862.0	653	-6096
2037	137.8	2126.7	1988.9	634	-5462
2038	137.8	2253.6	2115.8	613	-4850
2039	137.8	2380.5	2242.7	591	-4259
2040	137.8	2507.4	2369.6	567	-3692
2041	137.8	2634.3	2496.5	543	-3148
2042	137.8	2761.2	2623.3	519	-2629
2043	137.8	2888.1	2750.2	495	-2135
2044	137.8	3015.0	2877.1	470	-1664
2045	137.8	3141.9	3004.0	447	-1218
2046	137.8	3268.8	3130.9	423	-795
2047	137.8	3395.6	3257.8	400	-395
2048	137.8	3522.5	3384.7	378	-17
2049	137.8	3649.4	3511.6	357	340
2050	137.8	3776.3	3638.5	336	676
2051	137.8	3903.2	3765.4	316	992
2052	137.8	4030.1	3892.3	297	1289
2053	137.8	4157.0	4019.2	279	1567
2054	137.8	4283.9	4146.1	261	1829
2055	137.8	4410.8	4272.9	245	2074
				NPV	2074

Case 2: Benefit to Cost Ratio Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Discounted Benefit (B)	Discounted Investment (C)
2025	13921.8	-13543.1	379	-13922
2026	137.8	753.8	811	-125
2027	137.8	824.9	796	-114
2028	137.8	917.1	793	-104
2029	137.8	989.7	770	-94
2030	137.8	1062.2	745	-86
2031	137.8	1196.9	753	-78
2032	137.8	1335.0	756	-71
2033	137.8	1481.3	755	-64
2034	137.8	1608.2	740	-58
2035	137.8	1735.1	722	-53
2036	137.8	1862.0	701	-48
2037	137.8	1988.9	678	-44
2038	137.8	2115.8	653	-40
2039	137.8	2242.7	627	-36
2040	137.8	2369.6	600	-33
2041	137.8	2496.5	573	-30
2042	137.8	2623.3	546	-27
2043	137.8	2750.2	519	-25
2044	137.8	2877.1	493	-23
2045	137.8	3004.0	467	-20
2046	137.8	3130.9	442	-19
2047	137.8	3257.8	417	-17
2048	137.8	3384.7	393	-15
2049	137.8	3511.6	371	-14
2050	137.8	3638.5	349	-13
2051	137.8	3765.4	328	-12
2052	137.8	3892.3	307	-11
2053	137.8	4019.2	288	-10
2054	137.8	4146.1	270	-9
2055	137.8	4272.9	253	-8
			17295	-15221
			Benefit/Cost	1.1362

Case 3: 2% Transmission O&M cost percentage

Case 3: EIRR Calculation Sheet

Year	Cost in (MLKR)			Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)
	Investment	Trans. O&M cost	Total Cost		
2025	13784	275.7	14059.7	360.7	-13699.0
2026		275.7	275.7	849.2	573.5
2027		275.7	275.7	916.9	641.2
2028		275.7	275.7	1004.7	729.0
2029		275.7	275.7	1073.8	798.1
2030		275.7	275.7	1142.9	867.3
2031		275.7	275.7	1271.2	995.5
2032		275.7	275.7	1402.7	1127.0
2033		275.7	275.7	1542.0	1266.4
2034		275.7	275.7	1662.9	1387.2
2035		275.7	275.7	1783.8	1508.1
2036		275.7	275.7	1904.6	1628.9
2037		275.7	275.7	2025.4	1749.8
2038		275.7	275.7	2146.3	1870.6
2039		275.7	275.7	2267.1	1991.5
2040		275.7	275.7	2388.0	2112.3
2041		275.7	275.7	2508.8	2233.2
2042		275.7	275.7	2629.7	2354.0
2043		275.7	275.7	2750.5	2474.9
2044		275.7	275.7	2871.4	2595.7
2045		275.7	275.7	2992.3	2716.6
2046		275.7	275.7	3113.1	2837.4
2047		275.7	275.7	3233.9	2958.3
2048		275.7	275.7	3354.8	3079.1
2049		275.7	275.7	3475.6	3200.0
2050		275.7	275.7	3596.5	3320.8
2051		275.7	275.7	3717.3	3441.7
2052		275.7	275.7	3838.2	3562.5
2053		275.7	275.7	3959.0	3683.4
2054		275.7	275.7	4079.9	3804.2
2055		275.7	275.7	4200.8	3925.1
				EIRR	9.9%

Case 3: NPV Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)	Discounted Total (MLKR)	Cumulative Total (MLKR)
2025	14059.7	360.7	-13699.0	-13699	-13699
2026	275.7	849.2	573.5	521	-13178
2027	275.7	916.9	641.2	530	-12648
2028	275.7	1004.7	729.0	548	-12100
2029	275.7	1073.8	798.1	545	-11555
2030	275.7	1142.9	867.3	538	-11016
2031	275.7	1271.2	995.5	562	-10454
2032	275.7	1402.7	1127.0	578	-9876
2033	275.7	1542.0	1266.4	591	-9285
2034	275.7	1662.9	1387.2	588	-8697
2035	275.7	1783.8	1508.1	581	-8116
2036	275.7	1904.6	1628.9	571	-7545
2037	275.7	2025.4	1749.8	558	-6987
2038	275.7	2146.3	1870.6	542	-6445
2039	275.7	2267.1	1991.5	524	-5921
2040	275.7	2388.0	2112.3	506	-5415
2041	275.7	2508.8	2233.2	486	-4929
2042	275.7	2629.7	2354.0	466	-4463
2043	275.7	2750.5	2474.9	445	-4018
2044	275.7	2871.4	2595.7	424	-3594
2045	275.7	2992.3	2716.6	404	-3190
2046	275.7	3113.1	2837.4	383	-2807
2047	275.7	3233.9	2958.3	363	-2443
2048	275.7	3354.8	3079.1	344	-2099
2049	275.7	3475.6	3200.0	325	-1774
2050	275.7	3596.5	3320.8	306	-1468
2051	275.7	3717.3	3441.7	289	-1179
2052	275.7	3838.2	3562.5	272	-907
2053	275.7	3959.0	3683.4	255	-652
2054	275.7	4079.9	3804.2	240	-412
2055	275.7	4200.8	3925.1	225	-187
				NPV	-187

Case 3: Benefit to Cost Ratio Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Discounted Benefit (B)	Discounted Investment (C)
2025	14059.7	360.7	361	-14060
2026	275.7	849.2	772	-251
2027	275.7	916.9	758	-228
2028	275.7	1004.7	755	-207
2029	275.7	1073.8	733	-188
2030	275.7	1142.9	710	-171
2031	275.7	1271.2	718	-156
2032	275.7	1402.7	720	-141
2033	275.7	1542.0	719	-129
2034	275.7	1662.9	705	-117
2035	275.7	1783.8	688	-106
2036	275.7	1904.6	668	-97
2037	275.7	2025.4	645	-88
2038	275.7	2146.3	622	-80
2039	275.7	2267.1	597	-73
2040	275.7	2388.0	572	-66
2041	275.7	2508.8	546	-60
2042	275.7	2629.7	520	-55
2043	275.7	2750.5	495	-50
2044	275.7	2871.4	469	-45
2045	275.7	2992.3	445	-41
2046	275.7	3113.1	421	-37
2047	275.7	3233.9	397	-34
2048	275.7	3354.8	375	-31
2049	275.7	3475.6	353	-28
2050	275.7	3596.5	332	-25
2051	275.7	3717.3	312	-23
2052	275.7	3838.2	293	-21
2053	275.7	3959.0	275	-19
2054	275.7	4079.9	257	-17
2055	275.7	4200.8	241	-16
			16471	-16658
			Benefit/Cost	0.9888

Case 4: Taking generation energy unit cost as 10.73 LKR/kWh and average generation capacity cost as 1.2 MLKR/MW

Case 4: EIRR Calculation Sheet

Year	Cost in (MLKR)			Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)
	Investment	Trans. O&M cost	Total Cost		
2025	13784	137.8	13921.8	200.0	-13721.8
2026		137.8	137.8	471.1	333.2
2027		137.8	137.8	508.6	370.8
2028		137.8	137.8	557.0	419.2
2029		137.8	137.8	595.3	457.5
2030		137.8	137.8	633.6	495.8
2031		137.8	137.8	704.8	566.9
2032		137.8	137.8	777.7	639.9
2033		137.8	137.8	857.0	719.1
2034		137.8	137.8	923.9	786.1
2035		137.8	137.8	990.9	853.1
2036		137.8	137.8	1057.9	920.0
2037		137.8	137.8	1124.9	987.0
2038		137.8	137.8	1191.8	1054.0
2039		137.8	137.8	1258.8	1121.0
2040		137.8	137.8	1325.8	1187.9
2041		137.8	137.8	1392.7	1254.9
2042		137.8	137.8	1459.7	1321.9
2043		137.8	137.8	1526.7	1388.8
2044		137.8	137.8	1593.6	1455.8
2045		137.8	137.8	1660.6	1522.8
2046		137.8	137.8	1727.6	1589.7
2047		137.8	137.8	1794.5	1656.7
2048		137.8	137.8	1861.5	1723.7
2049		137.8	137.8	1928.5	1790.6
2050		137.8	137.8	1995.4	1857.6
2051		137.8	137.8	2062.4	1924.6
2052		137.8	137.8	2129.4	1991.5
2053		137.8	137.8	2196.4	2058.5
2054		137.8	137.8	2263.3	2125.5
2055		137.8	137.8	2330.3	2192.5
				EIRR	5.7%

Case 4: NPV Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Net Benefit (MLKR)	Discounted Total (MLKR)	Cumulative Total (MLKR)
2025	13921.8	200.0	-13721.8	-13722	-13722
2026	137.8	471.1	333.2	303	-13419
2027	137.8	508.6	370.8	306	-13112
2028	137.8	557.0	419.2	315	-12798
2029	137.8	595.3	457.5	312	-12485
2030	137.8	633.6	495.8	308	-12177
2031	137.8	704.8	566.9	320	-11857
2032	137.8	777.7	639.9	328	-11529
2033	137.8	857.0	719.1	335	-11193
2034	137.8	923.9	786.1	333	-10860
2035	137.8	990.9	853.1	329	-10531
2036	137.8	1057.9	920.0	322	-10209
2037	137.8	1124.9	987.0	314	-9894
2038	137.8	1191.8	1054.0	305	-9589
2039	137.8	1258.8	1121.0	295	-9294
2040	137.8	1325.8	1187.9	284	-9009
2041	137.8	1392.7	1254.9	273	-8736
2042	137.8	1459.7	1321.9	262	-8475
2043	137.8	1526.7	1388.8	250	-8225
2044	137.8	1593.6	1455.8	238	-7987
2045	137.8	1660.6	1522.8	226	-7760
2046	137.8	1727.6	1589.7	215	-7546
2047	137.8	1794.5	1656.7	204	-7342
2048	137.8	1861.5	1723.7	192	-7150
2049	137.8	1928.5	1790.6	182	-6968
2050	137.8	1995.4	1857.6	171	-6796
2051	137.8	2062.4	1924.6	161	-6635
2052	137.8	2129.4	1991.5	152	-6483
2053	137.8	2196.4	2058.5	143	-6340
2054	137.8	2263.3	2125.5	134	-6206
2055	137.8	2330.3	2192.5	126	-6081
				NPV	-6081

Case 4: Benefit to Cost Ratio Calculation Sheet

Year	Total Cost (MLKR)	Benefit due to Loss reduction (MLKR)	Discounted Benefit (B)	Discounted Investment (C)
2025	13921.8	200.0	200	-13922
2026	137.8	471.1	428	-125
2027	137.8	508.6	420	-114
2028	137.8	557.0	418	-104
2029	137.8	595.3	407	-94
2030	137.8	633.6	393	-86
2031	137.8	704.8	398	-78
2032	137.8	777.7	399	-71
2033	137.8	857.0	400	-64
2034	137.8	923.9	392	-58
2035	137.8	990.9	382	-53
2036	137.8	1057.9	371	-48
2037	137.8	1124.9	358	-44
2038	137.8	1191.8	345	-40
2039	137.8	1258.8	331	-36
2040	137.8	1325.8	317	-33
2041	137.8	1392.7	303	-30
2042	137.8	1459.7	289	-27
2043	137.8	1526.7	275	-25
2044	137.8	1593.6	261	-23
2045	137.8	1660.6	247	-20
2046	137.8	1727.6	233	-19
2047	137.8	1794.5	220	-17
2048	137.8	1861.5	208	-15
2049	137.8	1928.5	196	-14
2050	137.8	1995.4	184	-13
2051	137.8	2062.4	173	-12
2052	137.8	2129.4	162	-11
2053	137.8	2196.4	152	-10
2054	137.8	2263.3	143	-9
2055	137.8	2330.3	134	-8
			9141	-15221
			Benefit/Cost	0.6005