same 31 bus as in ALf, but the magnitude is 0.904 p.u.; likewise, the maximum voltage is also on bus 46, but the magnitude is 1.057 p.u. The maximum phase is like in ALF on the same bus. However, the minimum phase angle is zero deg, which is found on bus 1 in both simulations.

The power system consists of 42 fixed PQ loads. As shown in Table 2 (Appendix), the line flows are similar in both simulations of the system. The actual system has 1250.8 Mw of active power and 321.1 Mvar of reactive power. The simulation results have shown that the total line active power loss is 27.86 Mw and 121.67 Mvar of reactive power losses. However, the maximum active power loss is 3.9 Mw and the reactive power loss is 19.96 Mvar, as found in lines 1–15. Similarly, when a scaled power system is considered, it has 11.26 kw of active power and 3.02 kvar of reactive power loads. The simulation result of the scaled system has shown that the total active power loss is 255.5 watts and the reactive power loss is 1.11 kvar. Although the losses found in lines 1–15 are the same as in ALF, the maximum active power loss is 35.31 watts and the maximum reactive power is 180.5 var.

4.2 Comparative Analysis

This section has shown the comparative analysis of voltage, phase angle, line power flows, and percentage of losses of line powers from Figure 2 to Figure 7. This analysis is very useful to compare the results on any bus and in any line. Figure 2 shows that the bus voltage has decreased at most of the buses for the SLF solution.

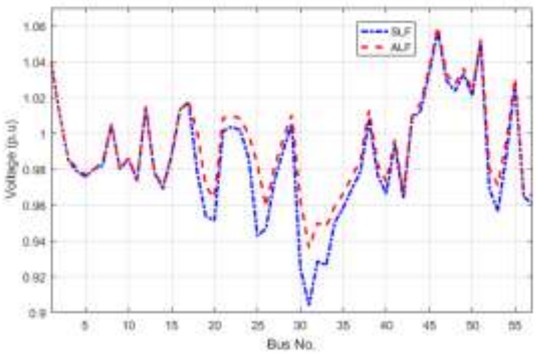

Fig. 2: Magnitude of bus voltage in p.u.

When comparing phase angles in Figure 3, there is no difference between phase angles. However, negligible differences were found at buses 31, 32, and 33.

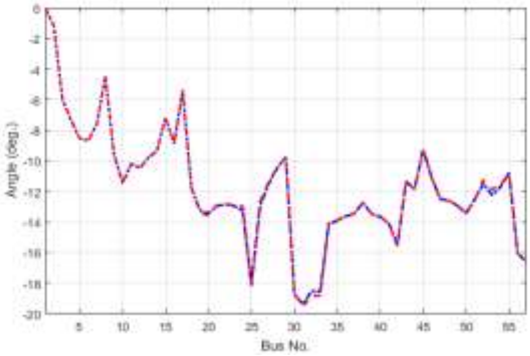

Fig. 3: Magnitude of phase angle at bus in deg.

As shown in Figure 4, the active power flow in the transmission lines from the bus is the same in all. However, few lines have carried more active power; those lines are 1-2, 2-3, 8-9, 1-15, 1-16, and 1-17, most of them connected to bus 1.

Similarly, Figure 5 shows the reactive power of transmission lines in the view of the bus, which is the same for all lines. However, lines 1-2 and 12–13 have carried more reactive power.

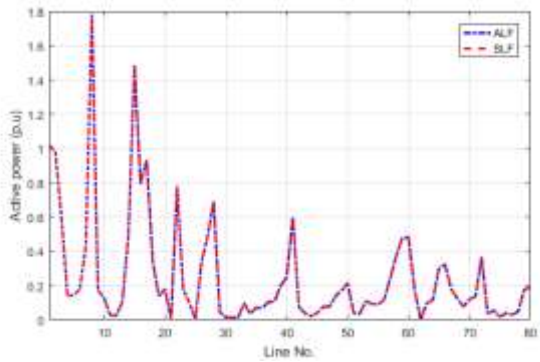

Fig. 4: From bus active power of transmission line.

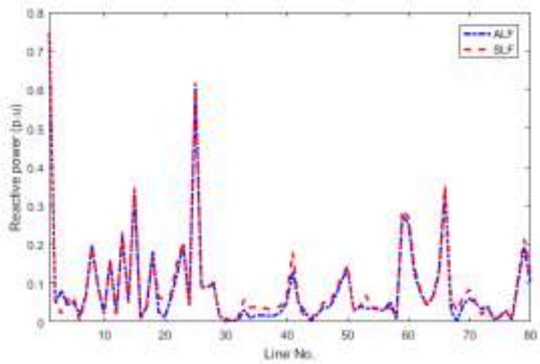

Fig. 5: From bus reactive power of transmission line.

Figure 6 and Figure 7 show the percentage of active and reactive power losses, respectively. Maximum power losses are found in lines 1-2, 2-3, 8-9, 1-15, 1-6, and 1-17. As shown in Figure 6, all the transformers carry zero active power; the maximum power loss is found at 3.9% in lines 1–15. Even though there is no active power loss in the transformer, the reactive power has flown in all; the maximum reactive power is 19.96%, which is found in the same line.

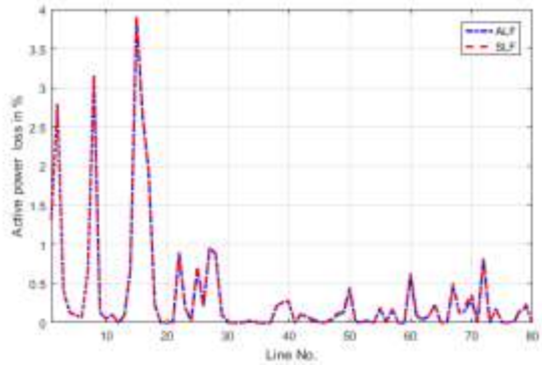

Fig. 6: Transmission line active power loss in percentage.

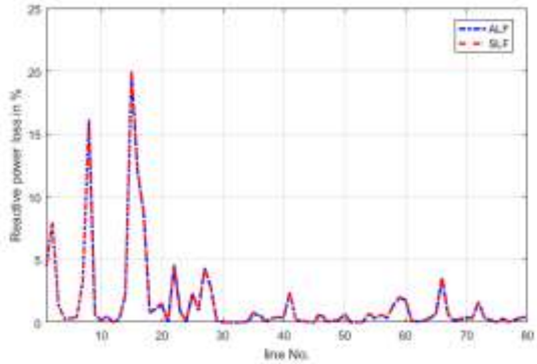

Fig. 7: Transmission line reactive power loss in percentage.

5 Conclusions

In this work, the scaling procedure was used to design a low-voltage power flow model of an IEEE 57 bus power system network. The scaled model was designed by using the actual SL factor, which is derived from the actual system voltages and scaling voltages. By using the power balance method, the NR load flow solution is obtained for both the ALF and SLF models. The simulation results have been thoroughly compared for analysis of the accuracy of the scaling method, and it was shown that the suggested scaling procedure can be used to design practical low-voltage power system models. The analysis of the results has shown good computational capacity, efficiency, accuracy, and robust behaviour-scaling procedures. A better understanding of this scaled modelling procedure is very useful for designing the low-voltage real-time power system model. It is very useful in academic research to assess the real-time performance of power systems. The results presented in this paper are very useful for designing a low-voltage IEEE 57 bus-equivalent network model. This model can help researchers assess the real-time behaviour of the network for various power system research applications.

Acknowledgment:
We would like to show our gratitude to Vignan's Foundation for Science, Technology, and Research for their encouragement during this work.

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APPENDIX

Table 1. Bus voltage results of both actual and scaled Load Flows

bus	RLF		ALF	
	V (volts)	Angle (deg.)	V (volts)	Angle (deg.)
1	1.040	0.000	1.040	0.000
2	1.010	-1.189	1.010	-1.188
3	0.985	-5.992	0.985	-5.988
4	0.979	-7.297	0.981	-7.337
5	0.976	-8.543	0.976	-8.546
6	0.980	-8.687	0.980	-8.674
7	0.982	-7.589	0.984	-7.601
8	1.005	-4.496	1.005	-4.478
9	0.980	-9.613	0.980	-9.585
10	0.986	-11.484	0.986	-11.450
11	0.973	-10.213	0.974	-10.193
12	1.015	-10.497	1.015	-10.471
13	0.978	-9.818	0.979	-9.804
14	0.969	-9.358	0.970	-9.350
15	0.987	-7.194	0.988	-7.190
16	1.013	-8.877	1.013	-8.859
17	1.017	-5.406	1.017	-5.396
18	0.978	-11.748	1.001	-11.730
19	0.953	-13.345	0.970	-13.227
20	0.951	-13.591	0.964	-13.444
21	1.001	-12.887	1.008	-12.929
22	1.004	-12.837	1.010	-12.874
23	1.002	-12.888	1.008	-12.940
24	0.986	-12.988	0.999	-13.292
25	0.943	-18.022	0.983	-18.173
26	0.947	-12.678	0.959	-12.981
27	0.974	-11.399	0.982	-11.514
28	0.990	-10.431	0.997	-10.482
29	1.005	-9.764	1.010	-9.772
30	0.925	-18.667	0.963	-18.720
31	0.904	-19.512	0.936	-19.384
32	0.929	-18.792	0.950	-18.512
33	0.926	-18.833	0.948	-18.552
34	0.950	-14.089	0.959	-14.149
35	0.958	-13.867	0.966	-13.906
36	0.969	-13.614	0.976	-13.635
37	0.979	-13.432	0.985	-13.446
38	1.008	-12.726	1.013	-12.735
39	0.977	-13.480	0.983	-13.491

bus	RLF		ALF	
	V (volts)	Angle (deg.)	V (volts)	Angle (deg.)
40	0.966	-13.643	0.973	-13.658
41	0.994	-14.118	0.996	-14.077
42	0.964	-15.556	0.967	-15.533
43	1.008	-11.379	1.010	-11.354
44	1.013	-11.857	1.017	-11.856
45	1.034	-9.291	1.036	-9.270
46	1.057	-11.141	1.060	-11.116
47	1.030	-12.537	1.033	-12.512
48	1.023	-12.626	1.027	-12.611
49	1.033	-12.971	1.036	-12.936
50	1.021	-13.454	1.023	-13.413
51	1.051	-12.578	1.052	-12.533
52	0.969	-11.249	0.980	-11.498
53	0.956	-11.874	0.971	-12.253
54	0.988	-11.560	0.996	-11.710
55	1.028	-10.847	1.031	-10.801
56	0.965	-16.064	0.968	-16.065
57	0.961	-16.576	0.965	-16.584

Table 2. From bus active and reactive powers of both Actual and scaled load flows

FB	TB	Scaled load flow		Actual load flow	
		Pf (watts)	Qf (var)	Pf (Mwatts)	Qf (Mvar)
1	2	919.32	674.83	102.09	75.00
2	3	880.47	-41.89	97.77	-4.64
3	4	538.90	-19.88	60.21	-8.18
4	5	123.50	-49.31	13.80	-4.43
4	6	128.65	-59.10	14.16	-5.09
6	7	-159.97	2.70	-17.78	-1.71
6	8	-382.14	-59.18	-42.50	-6.56
8	9	1605.48	178.10	178.03	19.83
9	10	155.43	-80.85	17.17	-9.23
9	11	116.47	25.31	12.90	2.07
9	12	22.81	-142.66	2.55	-15.85
9	13	20.89	-12.95	2.32	-1.96
13	14	-92.45	209.12	-10.35	22.34
13	15	-441.01	44.09	-48.89	4.89
1	15	1342.11	312.16	148.99	33.79
1	16	714.68	-7.84	79.25	-0.87
1	17	841.54	35.41	93.34	3.94
3	15	307.41	-151.30	33.77	-18.19
4	18	124.13	55.53	13.96	2.44

FB	TB	Scaled load flow		Actual load flow	
		Pf (watts)	Qf (var)	Pf (Mwatts)	Qf (Mvar)
4	18	158.90	53.80	17.87	1.19
5	6	5.28	-65.69	0.67	-6.24
7	8	-698.51	-137.96	-77.94	-12.41
10	12	-159.97	-183.50	-17.60	-20.09
11	13	-89.54	-37.14	-9.93	-4.39
12	13	-3.39	556.18	-0.49	60.35
12	16	-301.92	79.91	-33.40	8.82
12	17	-437.50	83.03	-48.46	9.17
14	15	-621.36	-92.64	-68.84	-9.60
18	19	38.23	6.05	4.63	1.39
19	20	7.72	-0.54	1.23	0.63
21	20	13.00	9.82	1.08	0.39
21	22	-13.00	-9.82	-1.08	-0.39
22	23	86.81	52.13	9.65	3.11
23	24	30.00	33.06	3.34	1.00
24	25	62.08	35.16	7.07	1.71
24	25	59.65	33.79	6.79	1.65
24	26	-92.14	-29.07	-10.54	-1.55
26	27	-92.14	-29.62	-10.54	-1.61
27	28	-177.76	-37.06	-20.04	-2.43
28	29	-221.55	-61.45	-24.90	-5.13
7	29	537.94	161.52	60.09	13.03
25	30	65.03	31.91	7.56	4.63
30	31	31.75	14.38	3.85	2.66
31	32	-20.97	-12.50	-2.03	-0.35
32	33	34.27	17.17	3.81	1.91
34	32	70.05	45.24	7.46	3.79
34	35	-70.05	-45.24	-7.46	-3.79
35	36	-124.49	-70.27	-13.50	-6.55
36	37	-156.58	-104.36	-17.07	-10.61
37	38	-192.18	-130.73	-21.05	-13.70
37	39	34.39	24.83	3.86	2.93
36	40	31.03	34.11	3.46	4.09
22	38	-99.83	-61.99	-10.73	-3.51
11	41	82.91	33.60	9.19	3.53
41	42	79.91	31.41	8.88	3.27
41	43	-104.66	-28.83	-11.59	-2.95
38	44	-220.68	34.44	-24.35	5.23
15	45	337.66	6.43	37.33	-0.73
14	46	433.57	260.70	47.89	27.40
46	47	433.57	242.67	47.89	25.47
47	48	160.61	124.67	17.59	12.43

FB	TB	Scaled load flow		Actual load flow	
		Pf	Qf	Pf	Qf
		(watts)	(var)	(Mwatts)	(Mvar)
48	49	-0.40	-71.56	0.08	-7.38
49	50	84.66	35.37	9.66	4.43
50	51	-105.04	-60.25	-11.42	-6.20
10	51	269.21	117.47	29.64	12.51
13	49	292.61	315.12	32.43	33.80
29	52	160.89	51.14	17.92	2.55
52	53	112.27	25.47	12.55	-0.25
53	54	-68.93	-60.31	-7.57	-4.47
54	55	-107.74	-75.27	-11.82	-6.06
11	43	122.66	46.11	13.59	4.85
44	45	-330.26	16.88	-36.52	3.28
40	56	30.95	33.99	3.46	4.07
56	41	-49.34	4.00	-5.43	0.66
56	42	-14.21	11.25	-1.58	1.46
39	57	34.34	24.75	3.85	2.92
57	56	-25.96	4.04	-2.85	0.61
38	49	-43.58	-103.17	-4.66	-10.53
38	48	-158.11	-191.96	-17.22	-19.39
9	55	172.35	115.63	18.93	10.38

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)
The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself
We would like to show our gratitude to Vignan's Foundation for Science, Technology, and Research for their encouragement during this work.

Conflict of Interest
The authors have no conflicts of interest to declare.