BANGLADESH UNIVERSITY OF ENGINEERING AND TECHNOLOGY

Department of Electrical and Electronic Engineering

Project Report

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Course Title : Power System I Laboratory

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Project Title

Investigating the effect of HVDC connection
and large industrial loads in IEEE 39-bus network

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Introduction:

Here is the IEEE 39 bus (New England) test system. IEEE 39 bus system is well known as 10-machine New-England Power System. Its nominal frequency is 50 Hz.

The procedures we followed:

- To perform load-flow analysis of a 39-bus system
- To investigate the effect of HVDC connection in the network
- To observe the effect of large Industrial Loads
- To increase active generation of 9 generators
- To use distributed swing
- To add SVC to the system
- To add shunt capacitors to the system

Load flow gives the sinusoidal steady-state of the entire system and voltage magnitudes and angles at each bus can be obtained. It decreases unexpected downtime, reduces operating and maintenance costs. It helps to decide the best operation of the existing system and for planning the future expansion of the system and helps in containing initial capital investment and future operating costs. In this project, we are given a 39-bus network, with 12 transformers, 10 generators, and 19 static loads. This network is solved using the Newton-Raphson method and, flat start and apply constraint condition. Then, an HVDC line is to be added between bus no. 9 and 39. A high-voltage, direct current (HVDC) electric power transmission system (also called a power superhighway or an electrical superhighway) uses direct current (DC) for the bulk transmission of electrical power. High-voltage DC (HVDC) transmission is considered advantageous and in some cases superior to AC in applications such as long underwater cable crossing, long-distance bulk power transmission, stable AC interconnection, interties with low short-circuit levels, coupling 50/60 Hz systems, and long-distance underground cable systems. We are assigned to include 12 induction motors to bus no.03. For a particular power generation schedule and load profile, due to an erroneous calculation of system losses, the specified generation may not be able to meet the demand, or may do so in an inefficient manner. As a result, the usual operating strategy has been to allow one generation to stray from the timetable in order to optimize the overall operation. The swing generation is the name given to this generation. If the variation from the required value is substantial, allocating this surplus power to a single generator may be inappropriate. The swing generation can now be distributed over any number of generators in CYMFLOW.A static VAR compensator (SVC) is a set of electrical devices for providing fast-acting reactive power on high-voltage electricity transmission networks. SVCs are part of the Flexible AC transmission system device family, regulating voltage, power factor, harmonics, and stabilizing the system. A static VAR compensator has no significant moving parts (other than internal switchgear). Shunt capacitive compensation method is generally used to improve the power factor. Whenever an inductive load is connected to the transmission line, the power factor lags because of the lagging load current. To compensate for it, a shunt capacitor is connected, which draws current leading to the source voltage. The net result is an improvement in the power factor.

Load Flow Output and Explanation:

Generator Table

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	250	166.2	300.21	83.3	2.866	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1000	222.26	1024.4	97.6	9.946	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	530.98	141.36	549.47	96.6	5.595	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	650	144.41	665.85	97.6	6.773	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	632	52.49	634.18	99.7	6.359	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	508	140.7	527.12	96.4	5.207	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	650	225.28	687.93	94.5	6.556	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	560	203.49	595.83	94	5.602	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	540	19.49	540.35	99.9	5.257	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	830	49.49	831.47	99.8	8.1	560	-240	38	1.026

The generator data is given in rated MVA and operating MVA conditions. The fixed power generators are included in the system and they supply their nominal real power with varying reactive powers. The swing type generator can vary the real power as well and it can absorb or supply power as required by the system. As we can see, the power factors of the generators are good, and most of the generators are operating below their rated range, i.e under-loaded state.

Bus Table

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.036	-8.8	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.959	-5.2	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.956	-6.1	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.936	-6.1	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.958	-5.9	0.95	1.05	0	0	0	0	0	0	0	0

[3]

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
14	345	0.959	-7.7	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.967	-7.9	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.987	-6.2	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.991	-7.4	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.989	-8.4	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.989	-0.4	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.018	-5.8	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.987	-1.4	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.994	-3.6	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.02	1.1	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.019	0.8	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.995	-6.1	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.028	-4.4	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.017	-5.6	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.999	-7.7	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.019	-1.8	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.02	1.1	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.99	-8.8	0.95	1.05	0	0	322	2.4	0	0	0	0
30	16.5	1.048	-3.5	0.95	1.05	250	166.2	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	530.98	141.36	9.2	4.6	0	0	0	0
32	16.5	0.983	2.7	0.95	1.05	650	144.41	0	0	0	0	0	0
33	16.5	0.997	4.8	0.95	1.05	632	52.49	0	0	0	0	0	0
34	16.5	1.012	3.8	0.95	1.05	508	140.7	0	0	0	0	0	0
35	16.5	1.049	6	0.95	1.05	650	225.28	0	0	0	0	0	0
36	16.5	1.064	8.9	0.95	1.05	560	203.49	0	0	0	0	0	0
37	16.5	1.028	2.4	0.95	1.05	540	19.49	0	0	0	0	0	0
38	16.5	1.026	8.2	0.95	1.05	830	49.49	0	0	0	0	0	0
39	345	1.03	-10.5	0.95	1.05	1000	222.26	1104	250	0	0	0	0
4	345	0.953	-9.9	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.952	-8.7	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.953	-8	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.945	-10.4	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.946	-11	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1.008	-10.7	0.95	1.05	0	0	0	0	0	0	0	0

Bus voltages are shown in per-unit values. The closer this value is to unity, the better is the operating condition of the system. We can see that the bus voltages on Buses B12, B7, B8 are beyond the limit of 0.95. The voltage of those buses is lower than nominal operating conditions.

This can be fixed by swinging the power flow in this bus, namely by adding a VAR compensator. Besides those, B36 bus is overloaded which is outside the limit 1.05 which is 1.064.

Static Load Table

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

The load summary is the same as the static load data that was provided in the problem statement, and no additional analysis is required in this part. only load 12 is underloaded.

Branch Table

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	316.53	27.68	317.74	99.6	3.338	-13.7	0.9	-0.75
L20	15	16	L20	Line	345	63	-311.29	-174.87	357.04	-87.2	3.691	142.8	1.2	-3.8
L30	25	26	L30	Line	345	216.5	70.3	0.48	70.31	100	0.684	-4.8	0.17	-51.85
L11	6	7	L11	Line	345	61.7	420.29	58.07	424.28	99.1	4.452	-15.8	1.19	8.13
L21	16	17	L21	Line	345	59.7	230.66	-68.57	240.64	95.9	2.438	10.4	0.41	-7.91

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L31	26	27	L31	Line	345	98.5	261.9	92.37	277.71	94.3	2.731	-25	1.08	-13.02
L12	6	11	L12	Line	345	55	-358.82	-4.3	358.85	-100	3.766	171.4	0.99	-1.02
L22	16	19	L22	Line	345	130.7	-502.44	39.61	504	-99.7	5.107	178.3	4.18	21.45
L32	26	28	L32	Line	345	317.7	-140.79	-26.8	143.32	-98.2	1.409	163.7	0.83	-71.65
L13	7	8	L13	Line	345	30.8	185.3	-34.05	188.4	98.4	1.994	0	0.16	-5.15
L23	16	21	L23	Line	345	90.5	-327.99	-34.86	329.83	-99.4	3.342	167.7	0.88	-10
L33	26	29	L33	Line	345	418.9	-189.98	-30.25	192.37	-98.8	1.892	165.4	2.02	-84.61
L14	8	9	L14	Line	345	243.3	-21.23	-176.47	177.74	-11.9	1.879	85.9	0.66	-25.86
L24	16	24	L24	Line	345	39.5	-41.72	-139.56	145.66	-28.6	1.476	100.5	0.06	-5.45
L34	28	29	L34	Line	345	101.2	-347.62	17.25	348.05	-99.9	3.417	-179	1.64	-8.16
L15	9	39	L15	Line	345	167.6	-21.89	-150.61	152.19	-14.4	1.511	87.6	0.08	-122.46
L25	17	18	L25	Line	345	55	210.04	0.64	210.04	100	2.119	-7.6	0.31	-9.24
L16	10	11	L16	Line	345	28.8	360.68	45.64	363.56	99.2	3.789	-12.4	0.58	-0.5
L26	17	27	L26	Line	345	116	20.21	-61.29	64.54	31.3	0.651	64.3	0.03	-31.4
L17	10	13	L17	Line	345	28.8	287.02	7.05	287.11	100	2.992	-6.6	0.36	-2.85
L27	21	22	L27	Line	345	93	-602.87	-139.85	618.88	-97.4	6.228	163.3	3.04	27.6
L18	13	14	L18	Line	345	67.7	279.39	-37.19	281.85	99.1	2.942	1.7	0.77	-7.14
L28	22	23	L28	Line	345	64.3	42.21	-3.67	42.37	99.6	0.416	6	0.01	-19.01
L19	14	15	L19	Line	345	145.4	8.74	-55.45	56.14	15.6	0.585	73.3	0.03	-33.58
L29	23	24	L29	Line	345	234.6	353.13	48.88	356.5	99.1	3.499	-7	2.75	6.97
L1	1	2	L1	Line	345	275.5	-126.12	20.31	127.75	-98.7	1.234	-179.6	0.63	-66.31
L2	1	39	L2	Line	345	167.6	126.12	-20.31	127.75	98.7	1.234	0.4	0.15	-76.2
L3	2	3	L3	Line	345	101.2	362.35	155.47	394.29	91.9	3.872	-29.1	2	-2.67
L4	2	25	L4	Line	345	57.6	-239.6	82.49	253.4	-94.6	2.489	-166.8	4.44	-9.84
L5	3	4	L5	Line	345	142.8	90.05	156.18	180.28	49.9	1.821	-68.9	0.48	-13.07
L6	3	18	L6	Line	345	89.1	-51.69	-0.44	51.7	-100	0.522	170.7	0.03	-20.56
L7	4	5	L7	Line	345	85.8	-141.2	12.92	141.79	-99.6	1.488	175.4	0.18	-9.31
L8	4	14	L8	Line	345	86.5	-269.23	-27.67	270.64	-99.5	2.84	164.3	0.64	-2.27
L9	5	6	L9	Line	345	17.4	-457.91	-5.45	457.94	-100	4.811	170.6	0.46	2.08

There is no Line burdened with reactive power flow of more than 200 MVAR. And Line L3, L5, L14, L15, L20 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

Transformer Table

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-249.51	-151.34	291.82	-85.5	2.866	142.9	0.49	14.87
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-0.26	-41.99	41.99	-0.6	0.448	84.3	0.03	0.87
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-824.75	52.87	826.44	-99.8	8.1	-175.3	5.25	102.35
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	-7.24	-46.01	46.58	-15.5	0.497	92.9	0.04	1.08
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	122.55	13.23	123.26	99.4	1.246	-6.5	0.11	2.14
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-519.84	-61.31	523.44	-99.3	5.493	165.3	1.94	75.45
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-647.71	-52.69	649.85	-99.7	6.773	170.2	2.29	91.72
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-629.17	4.92	629.19	-100	6.359	-179.9	2.83	57.41
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-505.56	-91.91	513.85	-98.4	5.207	168.3	2.44	48.79
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-648.12	-163.78	668.49	-97	6.556	166.9	1.88	61.49
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-558.43	-118.13	570.79	-97.8	5.602	168.9	1.57	85.36
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-538.34	44.65	540.19	-99.7	5.257	-179.6	1.66	64.14

In the transformer report, we can see how much power is being transferred through each of the transformers. Here, the power losses in each of the transformers are also shown. The transformers are essential while transferring power to buses that have different operating voltages. Here, T01 and T02 are under-loaded, and T10 is loaded near to nominal operating region.

Transformer Table (%Loading in terms of Capability)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]
T10	2	30	1000	29.2	1500	19.5	100	100
T01	12	11	300	14	450	9.3	100	100
T11	29	38	1000	82.6	1500	55.1	100	100
T02	12	13	300	15.5	450	10.4	100	100
T12	19	20	1000	12.3	1500	8.2	100	100
T03	6	31	700	74.8	1050	49.9	100	100
T04	10	32	800	81.2	1200	54.2	100	100
T05	19	33	800	78.6	1200	52.4	100	100
T06	20	34	600	85.6	900	57.1	100	100
T07	22	35	800	83.6	1200	55.7	100	100
T08	23	36	700	81.5	1050	54.4	100	100
T09	25	37	700	77.2	1050	51.4	100	100

From the above table, we can pick up the fact that all the transformers are operating within the normal rating set by their design. Here for smooth observation, the transformers operating above or close to 80 percent of the normal rating are highlighted.

Abnormal Report

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]	Ang sol - [deg]
7	0	345	0.95	1.05	0.945	-10.4
8	0	345	0.95	1.05	0.946	-11
12	0	138	0.95	1.05	0.936	-6.1
36	0	16.5	0.95	1.05	1.064	8.9
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]	Emergency Loading Limit - [pu]	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]		
L10	5	8	3.338	5.976		
L20	15	16	3.691	5.976		
L30	25	26	0.684	5.976		
L11	6	7	4.452	5.976		

ID						
L21	16	17	2.438	5.976		
L31	26	27	2.731	5.976		
L12	6	11	3.766	5.976		
L22	16	19	5.107	5.976		
L32	26	28	1.409	5.976		
L13	7	8	1.994	5.976		
L23	16	21	3.342	5.976		
L33	26	29	1.892	5.976		
L14	8	9	1.879	5.976		
L24	16	24	1.476	5.976		
L34	28	29	3.417	5.976		
L15	9	39	1.511	5.976		
L25	17	18	2.119	5.976		
L16	10	11	3.789	5.976		
L26	17	27	0.651	5.976		
L17	10	13	2.992	5.976		
L18	13	14	2.942	5.976		
L28	22	23	0.416	5.976		
L19	14	15	0.585	5.976		
L29	23	24	3.499	5.976		
L1	1	2	1.234	5.976		
L2	1	39	1.234	5.976		
L3	2	3	3.872	5.976		
L4	2	25	2.489	5.976		
L5	3	4	1.821	5.976		
L6	3	18	0.522	5.976		
L7	4	5	1.488	6.573		
L8	4	14	2.84	5.976		
L9	5	6	4.811	5.976		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T10	2	30	291.817	500		
T01	12	11	41.992	150		
T02	12	13	46.575	150		
T12	19	20	123.261	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						

ID						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	

From the abnormal report and our analytical approach got the almost same result for the buses. Several buses were beyond their limiting value. for the line value and transformers, there was no abnormality for the overloading condition. There were some under loading conditions for both cases.

Summary Report:

Summary Data	Active Power	Reactive Power
Total generation	6150.978	1365.157
Spinning reserve	9239.022	
Static Load	6097.1	1408.9
Shunt loads	0	0
Motor loads	0	0
Total load	6097.1	1408.9
Line / cable losses	33.344	-649.414
Transformer losses	20.534	605.672
Total losses	53.877	-43.742
Mismatches	0	-0.001

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

Load Flow Output and Explanation after adding HVDC:

Bus Table

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.006	-11.2	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.928	3.2	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.919	2.2	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.901	2.3	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.926	2.5	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.928	0.8	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.949	0.8	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.974	2.5	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.976	1.4	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.971	0.4	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.985	8.4	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1	3.6	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.984	7.4	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.985	5.2	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.015	9.9	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.014	9.7	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.983	2.7	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.014	4.8	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.006	3.4	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.985	1.2	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.013	7.2	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.016	10.1	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.966	0.1	0.95	1.05	0	0	322	2.4	0	0	0	0
30	16.5	1.048	11.4	0.95	1.05	800	303.26	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	14.31	313.22	9.2	4.6	0	0	0	0
32	16.5	0.983	11.3	0.95	1.05	650	298.16	0	0	0	0	0	0
33	16.5	0.997	13.6	0.95	1.05	632	83.11	0	0	0	0	0	0
34	16.5	1.012	12.6	0.95	1.05	508	154.76	0	0	0	0	0	0
35	16.5	1.049	14.8	0.95	1.05	650	260.34	0	0	0	0	0	0
36	16.5	1.064	17.7	0.95	1.05	560	223.13	0	0	0	0	0	0
37	16.5	1.028	11.7	0.95	1.05	540	78.3	0	0	0	0	0	0
38	16.5	1.026	17.2	0.95	1.05	830	74.83	0	0	0	0	0	0
39	345	1.03	-19.7	0.95	1.05	1000	573.87	1104	250	0	0	0	0
4	345	0.915	-1.4	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.899	-0.3	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.903	0	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.874	-1.1	0.95	1.05	0	0	233.8	84	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
8	345	0.864	-0.8	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.783	14.9	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-21.6	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.772	18.3	0.95	1.05	0	0	0	0	0	0	0	0

Bus voltages are shown in per-unit values. The closer this value is to unity, the better is the operating condition of the system. We can see that the bus voltages on Buses B4,B5,B6,B7,B8,B9, B10,B11 B12,B13,B14,B15 and B9_INV are beyond limit of 0.95.The voltage of those buses is lower than nominal operating conditions. This can be fixed by swinging the power flow in this bus, namely by adding a VAR compensator. Here bus B36 is outside the limit 1.05 which is 1.064.

After adding the HVDC line some of the buses cross their nominal range(0.95-1.05). Bus 4,5,6,9,10,11,13,14,15 and B9_INV_cross their range value after adding HVDC line. The DC-line has more capacity for active power transfer in comparison to the original AC line, which was transporting a considerable amount of reactive power.

We have added a HVDC line between BUS 39 and BUS 9. After adding HVDC line there is a significant change in the voltages of the buses near the bus 9.

<u>Schematic Diagram of HVDC Line Addition in the Power System between Bus 39 and 9:</u>

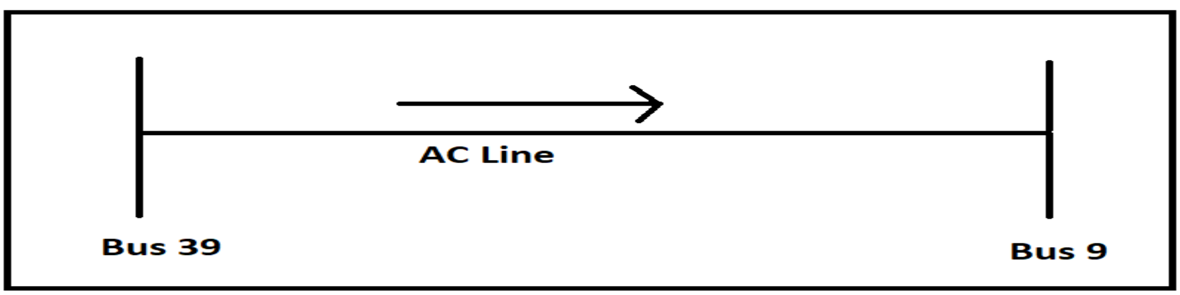

Figure:Before HVDC Addition

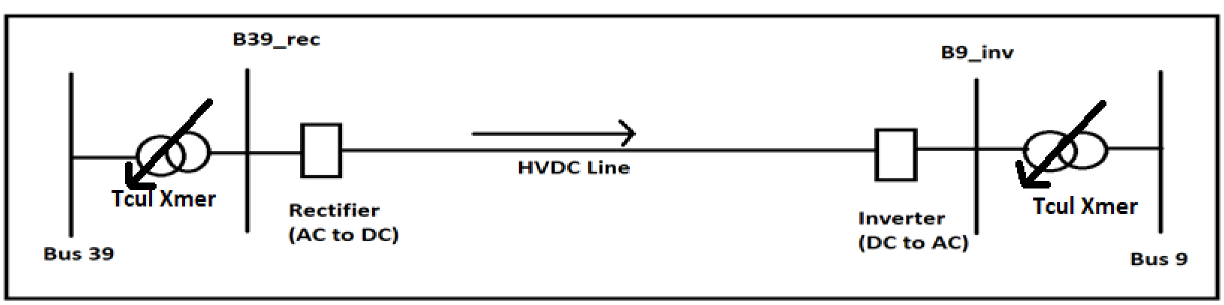

Figure:After HVDC Addition

The maintenance of constant voltage at the two ends requires reactive power control as the line loading is increased. So there is a relative need of reactive power in the bus 9. Because of that buses near the bus 9 also feel scarcity of reactive power. Bus 39 and buses closer to it such as bus 1, bus 2 supply the reactive power. As a result their overall voltage rating remains closer to unity. But the reactive power is relatively being fed to the bus 9 and buses closer to them such as bus 5,6,7,8 etc. As a result their voltage decreased from unity and dropped down from nominal value of 0.95 pu. Although DC converter station requires reactive power related to the power transmitted, the DC line itself does not require any reactive power.

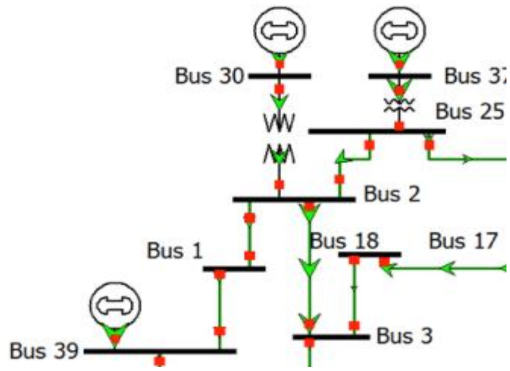

Figure: Bus 39 and buses closer to it

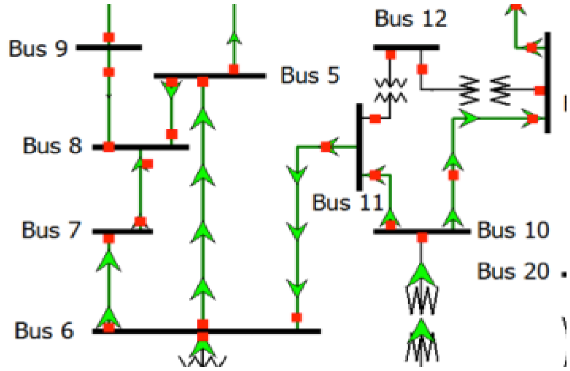

Figure: Bus 9 and buses closer to it

<u>Comparison of voltage of the buses closure to BUS 9</u>

Bus	V sol (pu) Before adding HVDC	V sol (pu) After adding HVDC
4	0.953	0.915
5	0.952	0.899
6	0.953	0.903
7	0.945	0.874
8	0.946	0.864
9	1.008	0.783

<u>Comparison of voltage of the buses closure to BUS 39</u>

Bus	V sol (pu) Before adding HVDC	V sol (pu) After adding HVDC
1	1.036	1.006
2	1.018	1
39	1.03	1.03

Voltage of bus 4 to 9 drops from 0.95 to less value. Most significant change has been found in BUS 9. On the other hand voltage of the buses close to BUS 39 increases.

Generator Report

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	800	303.26	855.55	93.5	8.167	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1000	573.87	1152.96	86.7	11.194	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	14.31	313.22	313.55	4.6	3.193	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	650	298.16	715.12	90.9	7.274	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	632	83.11	637.44	99.1	6.392	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	508	154.76	531.05	95.7	5.246	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	650	260.34	700.2	92.8	6.673	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	560	223.13	602.81	92.9	5.668	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	540	78.3	545.65	99	5.309	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	830	74.83	833.37	99.6	8.119	560	-240	38	1.026

The generator data is given in rated MVA and operating MVA conditions. The fixed power generators are included in the system and they supply their nominal real power with varying reactive powers. The swing type generator can vary the real power as well and it can absorb or supply power as required by the system. As we can see, the power factors of the generators are good, and most of the generators are operating below their rated range, i.e under-loaded state. G2 is highlighted because it is operated under too much nominal limit.

We can see that after adding the HVDC line power factor of the G2 decreased from 96.6 to 4.6 which is a significant change. Power factor improved for the G10 and G4. More reactive power is being drawn by the generators after adding the HVDC line. It can be seen that the bus sustains a considerable voltage drop due to the HVDC link failing to transport the reactive power consumed at the node from the generator.

Static Load Table

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

The load summary is the same as the static load data that was provided in the problem statement, and no additional analysis is required in this part. Only L12 is under-loaded as it is highlighted. There is no effect on the static load side after adding the HVDC line.

Branch Table

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	84.1	266.08	279.05	30.1	3.105	-72.8	0.81	-0.23
L20	15	16	L20	Line	345	63	-327.04	-228	398.67	-82	4.203	145.9	1.56	0.44
L30	25	26	L30	Line	345	216.5	78.09	-6.24	78.34	99.7	0.772	9.4	0.2	-50.28
L11	6	7	L11	Line	345	61.7	185.35	274.22	330.99	56	3.664	-55.9	0.82	3.71
L21	16	17	L21	Line	345	59.7	214.05	-39.77	217.72	98.3	2.235	13.1	0.35	-8.35
L31	26	27	L31	Line	345	98.5	269.59	105.36	289.45	93.1	2.878	-17.9	1.2	-11.18
L12	6	11	L12	Line	345	55	-384.9	-132.87	407.18	-94.5	4.507	161	1.41	4.99
L22	16	19	L22	Line	345	130.7	-502.31	-2.49	502.32	-100	5.157	-177.7	4.24	22.73
L32	26	28	L32	Line	345	317.7	-140.89	-37.49	145.79	-96.6	1.45	168.5	0.84	-70.19
L13	7	8	L13	Line	345	30.8	-49.27	186.51	192.91	-25.5	2.207	-105.9	0.2	-3.58
L23	16	21	L23	Line	345	90.5	-327.73	-61.8	333.5	-98.3	3.424	171.9	0.92	-8.8
L33	26	29	L33	Line	345	418.9	-189.81	-40.82	194.15	-97.8	1.931	171.3	2.04	-82.83
L14	8	9	L14	Line	345	243.3	-488.18	280.4	562.98	-86.7	6.515	-151	9.96	132.14
L24	16	24	L24	Line	345	39.5	-41.61	-156.68	162.11	-25.7	1.664	107.4	0.08	-4.94

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L34	28	29	L34	Line	345	101.2	-347.73	5.09	347.76	-100	3.433	-172	1.65	-7.79
L25	17	18	L25	Line	345	55	201.06	39.94	204.99	98.1	2.101	-9.9	0.31	-8.82
L16	10	11	L16	Line	345	28.8	385.3	177.32	424.14	90.8	4.569	-21.5	0.84	2.81
L26	17	27	L26	Line	345	116	12.65	-71.36	72.47	17.5	0.743	81.3	0.05	-30.32
L17	10	13	L17	Line	345	28.8	262.06	15.04	262.49	99.8	2.827	-0.1	0.32	-2.83
L27	21	22	L27	Line	345	93	-602.65	-168	625.63	-96.3	6.354	169.6	3.16	30.04
L18	13	14	L18	Line	345	67.7	252.31	-35.67	254.82	99	2.75	10.5	0.68	-7.22
L28	22	23	L28	Line	345	64.3	42.24	-1.41	42.27	99.9	0.416	11.8	0.01	-18.82
L19	14	15	L19	Line	345	145.4	-6.87	-105.18	105.4	-6.5	1.136	94.5	0.17	-30.18
L29	23	24	L29	Line	345	234.6	353.12	68.57	359.72	98.2	3.548	-1.3	2.84	9.03
L1	1	2	L1	Line	345	275.5	-609.23	112.4	619.51	-98.3	6.157	179.3	13.58	89.22
L2	1	39	L2	Line	345	167.6	609.23	-112.4	619.51	98.3	6.157	-0.7	3.72	15.25
L3	2	3	L3	Line	345	101.2	405.56	187.75	446.9	90.7	4.47	-21.3	2.65	6.05
L4	2	25	L4	Line	345	57.6	-232.37	17.95	233.07	-99.7	2.331	-172	3.84	-10.11
L5	3	4	L5	Line	345	142.8	123.62	217.73	250.37	49.4	2.591	-60.3	0.94	-4.23
L6	3	18	L6	Line	345	89.1	-42.71	-38.43	57.46	-74.3	0.595	138.1	0.03	-19.67
L7	4	5	L7	Line	345	85.8	-119.5	115.37	166.1	-71.9	1.816	-137.4	0.28	-6.61
L8	4	14	L8	Line	345	86.5	-257.82	-77.42	269.19	-95.8	2.944	161.8	0.68	-0.68
L9	5	6	L9	Line	345	17.4	-203.87	-144.1	249.65	-81.7	2.778	144.4	0.15	-1.53

Line no. 5,10, 11,14,20 are burdened with reactive power flow of more than 200 MVAR. And Line 3,16,13,24are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

After adding HVDC lines L5, L10, L11, L14, L20 are flowing more reactive power. As after adding the HVDC line the power losses decrease in the line. More reactive power is transmitted through the lines which we need to compensate.

DC Line Table

ID	Bus From	Bus To	DBase ID	DC Current	DC Power Losses	Commut. X (Rectifier)	Commut. X (Inverter)	Alpha	Gamma	Gamma Min
DC1	B39_REC	B9_INV	DC1	1000	1	2.83	2.83	23.4	0	10

ID	PF (Rectifier)	PF (Inverter)	DC Voltage (Rectifier)	DC Voltage (Inverter)	DC Power (Rectifier)	DC Power (Inverter)	AC Volt (Rectifier)	AC Volt (Inverter)
DC1	0.93	0.96	501	500	501	500	102	77.2

Here, the DC bus voltages are 501(at rectifier), 500(at inverter), DC power flow 501(at rectifier), 500(at inverter) are shown.

ID	P to Converter (Rectifier)	Q to Converter (Rectifier)	P to Converter (Inverter)	Q to Converter (Inverter)	P from Network (Rectifier)	Q from Network (Rectifier)	P from Network (Inverter)	Q from Network (Inverter)
DC1	501	177	-499	117	502	196	-498	148

Here, we can see that the power to converter (at rectifier) is 501, power to converter (at inverter) is -499, power from network (at rectifier) is 502, power from network (at inverter) is -498.

Transformer Table

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-796	-182.5	816.66	-97.5	8.167	170.6	4	120.74
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	1.87	-35.96	36.01	5.2	0.4	89.3	0.03	0.69
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-824.73	27.99	825.2	-99.9	8.119	-168	5.27	102.82
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	-9.37	-52.04	52.88	-17.7	0.587	102.5	0.06	1.5
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	122.58	-0.11	122.58	100	1.245	8.5	0.11	2.14
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-4.48	-283.9	283.95	-1.6	3.143	90.9	0.64	24.71
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-647.36	-192.3	675.33	-95.9	7.274	166.7	2.64	105.8
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-629.14	-25.11	629.64	-99.9	6.392	-173.9	2.86	58
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-505.52	-105.24	516.36	-97.9	5.246	175.7	2.48	49.52
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-648.05	-196.6	677.22	-95.7	6.673	173	1.95	63.71
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-558.39	-135.7	574.66	-97.2	5.668	176	1.61	87.37
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-538.31	-12.9	538.46	-100	5.309	-176.6	1.69	65.4
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.2	538.53	93.1	5.228	-41	0.52	19.33

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-498.14	148.2	519.73	-95.8	6.639	-148.5	0.83	31.17

In the transformer report, we can see how much power is being transferred through each of the transformers. Here, the power losses in each of the transformers are also shown. The transformers are essential while transferring power to buses that have different operating voltages. No transformer is overloaded in the above report but T01, T02, T03 are underloaded.

After adding the HVDC line the power factor of the T03 has decreased. But overall power factor for the other transformers has increased.

Transformer Table (%Loading in terms of Capability)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	81.7	1500	54.4	100	100						
T01	12	11	300	12	450	8	100	100						
T11	29	38	1000	82.5	1500	55	100	100						
T02	12	13	300	17.6	450	11.8	100	100						
T12	19	20	1000	12.3	1500	8.2	100	100						
T03	6	31	700	40.6	1050	27	100	100						
T04	10	32	800	84.4	1200	56.3	100	100						
T05	19	33	800	78.7	1200	52.5	100	100						
T06	20	34	600	86.1	900	57.4	100	100						
T07	22	35	800	84.7	1200	56.4	100	100						
T08	23	36	700	82.1	1050	54.7	100	100						
T10	2	30	1000	81.7	1500	54.4	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	65	1200	43.3	100	100	90	110	1	1	1	B9_INV

From the above table, we can pick up the fact that all the transformers are operating within the normal rating set by their design. Here for smooth observation, the transformers operating above or close to 80 percent of the normal rating are highlighted.

Abnormal Report

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
4	0	345	0.95	1.05	0.915	-1.4
5	0	345	0.95	1.05	0.899	-0.3
6	0	345	0.95	1.05	0.903	0
7	0	345	0.95	1.05	0.874	-1.1
8	0	345	0.95	1.05	0.864	-0.8
9	0	345	0.95	1.05	0.783	14.9
B9_INV	0	100	0.95	1.05	0.772	18.3
10	0	345	0.95	1.05	0.928	3.2
11	0	345	0.95	1.05	0.919	2.2
12	0	138	0.95	1.05	0.901	2.3
13	0	345	0.95	1.05	0.926	2.5
14	0	345	0.95	1.05	0.928	0.8
15	0	345	0.95	1.05	0.949	0.8
36	0	16.5	0.95	1.05	1.064	17.7
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	3.105	5.976		
L20	15	16	4.203	5.976		
L30	25	26	0.772	5.976		
L11	6	7	3.664	5.976		
L21	16	17	2.235	5.976		
L31	26	27	2.878	5.976		
L12	6	11	4.507	5.976		
L22	16	19	5.157	5.976		
L32	26	28	1.45	5.976		
L13	7	8	2.207	5.976		
L23	16	21	3.424	5.976		
L33	26	29	1.931	5.976		
L24	16	24	1.664	5.976		
L34	28	29	3.433	5.976		
L25	17	18	2.101	5.976		
L16	10	11	4.569	5.976		

ID						
L26	17	27	0.743	5.976		
L17	10	13	2.827	5.976		
L18	13	14	2.75	5.976		
L28	22	23	0.416	5.976		
L19	14	15	1.136	5.976		
L29	23	24	3.548	5.976		
L3	2	3	4.47	5.976		
L4	2	25	2.331	5.976		
L5	3	4	2.591	5.976		
L6	3	18	0.595	5.976		
L7	4	5	1.816	6.573		
L8	4	14	2.944	5.976		
L9	5	6	2.778	5.976		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	36.009	150		
T02	12	13	52.878	150		
T12	19	20	122.585	500		
T03	6	31	283.952	350		

From the abnormal report and our analytical approach got the almost same result for the buses. Several buses were beyond their limiting value. for the line value and transformers, there was no abnormality for the overloading condition. There were some under loading conditions for both cases.

Summary Report

Summary Data	Active Power	Reactive Power
Total generation	**6184.313**	**2362.987**
Spinning reserve	**9205.688**	
Static Load	**6097.1**	**1408.9**

Summary Data	Active Power	Reactive Power
Shunt loads	**0**	**0**
Motor loads	**0**	**0**
Total load	**6097.1**	**1408.9**
Line / cable losses	**60.508**	**-72.786**
Transformer losses	**24.676**	**732.904**
Total losses	**86.184**	**954.119**
Mismatches	**1.029**	**-0.031**

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

After adding the HVDC line the total power losses have been increased from 53.877 MW to 86.184 MW. Transformer and cable losses increased simultaneously. HVDC offers various advantages. It can be used for system interconnection and control of power flow as well. The major benefit of HVDC is its incorporated ability for fault-current blocking, which is not possible with synchronous AC links. In addition, HVDC can effectively support the surrounding AC systems in case of transient fault conditions and it serves as a firewall against cascading disturbances. Although the main reason for selecting HVDC transmission lines is often economic, there are some other reasons for HVDC may be the best feasible way to interconnect two asynchronous networks, reduce fault currents, employing in long underground cable circuits, eliminate network congestion, distortion transmit restriction in an interconnected system, ability for controlling power line flow. In all of these applications, HVDC nicely complements the ac transmission system. AC line has no power flow control capabilities and the distribution of the power flow is determined by Kirchoff's law. However, the HVDC not only can control power flow through the transmission line but also can decrease the transmission line losses and maintain the voltage at a constant value.

MODIFIED RESULTS and OUTPUTS after INDUCTION MOTOR ADDITION:

Our system is capable of incorporating 10 induction motors without load flow diverging. We are assigned to include 12 induction motors to bus no.03 and we ended up with 10 induction motors without load flow diverging which satisfies the minimum criterion of inclusion of at least 10 induction motor to the designated bus.

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	0.99	-42.7	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.862	-14.2	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.849	-14.5	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.83	-15.3	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.857	-16	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.854	-20.4	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.898	-24.6	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.935	-24.3	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.924	-27	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.903	-29.1	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.972	-18.2	0.95	1.05	0	0	0	0	0	0	0	0
2	345	0.961	-26.9	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.977	-19.3	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.957	-21.5	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1	-16.6	0.95	1.05	0	0	0	0	0	0	0	0
23	345	0.999	-16.9	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.948	-24.2	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	0.988	-25.7	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	0.976	-26.1	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.945	-27.9	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	0.998	-22.2	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.006	-19.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.874	-31.2	0.95	1.05	0	0	322	2.4	800	387.46	0	0
30	16.5	1.048	-18.9	0.95	1.05	800	529.28	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	861.6	700.55	9.2	4.6	0	0	0	0
32	16.5	0.95	-5.2	0.95	1.05	650	448.06	0	0	0	0	0	0
33	16.5	0.997	-13	0.95	1.05	632	175.72	0	0	0	0	0	0
34	16.5	1.012	-14.1	0.95	1.05	508	197.29	0	0	0	0	0	0
35	16.5	1.049	-11.7	0.95	1.05	650	366.45	0	0	0	0	0	0
36	16.5	1.064	-8.7	0.95	1.05	560	282.55	0	0	0	0	0	0
37	16.5	1.028	-18.7	0.95	1.05	540	195.35	0	0	0	0	0	0
38	16.5	1.026	-12.1	0.95	1.05	830	142.39	0	0	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
39	345	1.03	-51.3	0.95	1.05	1000	642.79	1104	250	0	0	0	0
4	345	0.828	-23.4	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.817	-16.4	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.827	-14.9	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.787	-16.6	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.773	-16.5	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.651	4.9	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-53.3	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.637	9.8	0.95	1.05	0	0	0	0	0	0	0	0

Here we can see that Bus No. 3,4,5,6,7,8,9,10,11,12,12,14,15,16,17,18,24,27 are outside the voltage limit which is at Under Voltage condition. We have marked those buses with red color. Because all of their voltages are less than 0.95 per unit.

BRANCH TABLE

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	40.23	316.89	319.43	12.6	3.908	-99.1	1.27	8.3
L20	15	16	L20	Line	345	63	-76.94	-349.81	358.17	-21.5	3.987	77.8	1.38	0.02
L30	25	26	L30	Line	345	216.5	21.89	9.78	23.98	91.3	0.243	-49.8	0.06	-48.89
L11	6	7	L11	Line	345	61.7	236.67	342.17	416.04	56.9	5.031	-70.2	1.54	16.28
L21	16	17	L21	Line	345	59.7	461.95	84.67	469.65	98.4	5.023	-34.7	1.77	10.97
L31	26	27	L31	Line	345	98.5	213.16	174.21	275.29	77.4	2.821	-65.3	1.17	-9.78
L12	6	11	L12	Line	345	55	-81.59	-220.99	235.58	-34.6	2.849	95.4	0.55	-3.35
L22	16	19	L22	Line	345	130.7	501.44	-122.88	516.27	-97.1	5.522	141.9	4.81	31.12
L32	26	28	L32	Line	345	317.7	141.05	-64.76	155.21	-90.9	1.59	129.3	0.93	-65.71
L13	7	8	L13	Line	345	30.8	1.33	241.89	241.89	0.5	3.073	106.3	0.38	-0.31
L23	16	21	L23	Line	345	90.5	326.72	-138.55	354.89	-92.1	3.796	132.7	1.12	-3.81
L33	26	29	L33	Line	345	418.9	189.27	-67.78	201.04	-94.1	2.06	134.2	2.16	-77.33
L14	8	9	L14	Line	345	243.3	482.09	374.79	610.64	-78.9	7.901	158.7	14.61	212.43
L24	16	24	L24	Line	345	39.5	-41.11	-205.37	209.44	-19.6	2.24	77	0.15	-3.15
L34	28	29	L34	Line	345	101.2	347.98	-26.65	349	-99.7	3.498	153.4	1.7	-6.6
L25	17	18	L25	Line	345	55	390.88	206.44	442.04	88.4	4.784	-54.8	1.62	7.99
L16	10	11	L16	Line	345	28.8	107.3	253.31	275.09	39	3.19	-81.2	0.41	-0.88
L26	17	27	L26	Line	345	116	69.31	-132.74	149.74	46.3	1.621	35.4	0.29	-24.25
L17	10	13	L17	Line	345	28.8	539.25	56.56	542.2	99.5	6.287	-20.2	1.58	11.63
L27	21	22	L27	Line	345	93	601.84	-249.74	651.6	-92.4	6.807	135.9	3.61	39.07
L18	13	14	L18	Line	345	67.7	554.79	-9.63	554.88	100	6.472	-15	3.77	29.68

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L28	22	23	L28	Line	345	64.3	42.33	5.29	42.66	99.2	0.426	-23.8	0.01	-18.25
L19	14	15	L19	Line	345	145.4	245.38	-197.01	314.68	78	3.683	18.4	2.32	-0.2
L29	23	24	L29	Line	345	234.6	353.08	126.9	375.19	94.1	3.757	-36.6	3.22	16.88
L1	1	2	L1	Line	345	275.5	609.49	173.58	633.73	-96.2	6.402	153.2	14.81	107.46
L2	1	39	L2	Line	345	167.6	609.49	-173.58	633.73	96.2	6.402	-26.8	3.98	23.04
L3	2	3	L3	Line	345	101.2	456.37	515.43	688.43	66.3	7.163	-75.4	6.82	57.8
L4	2	25	L4	Line	345	57.6	-285.7	-71.81	294.59	-97	3.065	139	6.53	-5.87
L5	3	4	L5	Line	345	142.8	442.34	239.26	502.9	-88	5.751	177.2	4.37	55.55
L6	3	18	L6	Line	345	89.1	230.12	-171.49	286.99	-80.2	3.282	112.1	1.14	-3.04
L7	4	5	L7	Line	345	85.8	642.37	146.01	658.76	-97.5	7.954	169.4	5.06	72.15
L8	4	14	L8	Line	345	86.5	304.33	-146.3	337.67	-90.1	4.077	130.9	1.31	11.4
L9	5	6	L9	Line	345	17.4	687.67	-243.03	729.35	-94.3	8.924	144.2	1.59	17.74

From the above report we can see that Line No. 3,5,9,10,11,12,13,14,16,20,24,25,27 gives the passage of reactive power of more than 200 MVAR which are red colored in this table and Line No. 1,2,6,19,31 gives the passage of reactive power of more than 150 MVAR but less than 200 MVAR which are yellow colored in this table.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	800	529.28	959.24	83.4	9.157	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1000	642.79	1188.77	84.1	11.54	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	861.6	700.55	1110.47	77.6	11.308	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	650	448.06	789.47	82.3	8.314	448	-192	32	0.95
G4	33	G4	Generator	800	16.5	PV	632	175.72	655.97	96.3	6.578	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	508	197.29	544.97	93.2	5.383	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	650	366.45	746.18	87.1	7.111	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	560	282.55	627.24	89.3	5.898	392	-168	36	1.064

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G8	37	G8	Generator	700	16.5	PV	540	195.35	574.25	94	5.587	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	830	142.39	842.13	98.6	8.204	560	-240	38	1.026

Here the power factor of generator 2 is below 80% which is yellow colored and the power factor of others generator is between 80 to 100 percent.

TRANSFORMER TABLE

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed -Tap Xmer	1000	345	16.5	794.97	-377.5	880.05	-90.3	9.157	127.7	5.03	151.78
T01	12	11	T01	Fixed -Tap Xmer	300	138	345	-24.7	-35.37	43.14	-57.3	0.52	109.6	0.04	1.18
T11	29	38	T11	Fixed -Tap Xmer	1000	345	16.5	824.62	-37.4	825.46	-99.9	8.204	158.2	5.38	104.99
T02	12	13	T02	Fixed -Tap Xmer	300	138	345	17.2	-52.63	55.37	31.1	0.667	56.6	0.07	1.94
T12	19	20	T12	Fixed -Tap Xmer	1000	345	230	122.73	-39.71	129	95.1	1.327	-0.3	0.12	2.43
T03	6	31	T03	Fixed -Tap Xmer	700	345	16.5	844.33	-381.94	926.7	-91.1	11.206	140.8	8.07	314.01
T04	10	32	T04	Fixed -Tap Xmer	800	345	16.5	646.55	-309.87	716.96	-90.2	8.314	140.2	3.45	138.2
T05	19	33	T05	Fixed -Tap Xmer	800	345	16.5	628.97	-114.29	639.27	-98.4	6.578	151.5	3.03	61.42
T06	20	34	T06	Fixed -Tap Xmer	600	230	16.5	505.39	-145.14	525.82	-96.1	5.383	144.7	2.61	52.15
T07	22	35	T07	Fixed -Tap Xmer	800	345	16.5	-647.78	-294.1	711.42	-91.1	7.111	138.9	2.21	72.35
T08	23	36	T08	Fixed -Tap Xmer	700	345	16.5	558.26	-187.95	589.05	-94.8	5.898	144.5	1.74	94.6
T09	25	37	T09	Fixed -Tap Xmer	700	345	16.5	538.13	-122.91	551.99	-97.5	5.587	141.4	1.87	72.44

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.51	196.16	538.51	93.1	5.228	-72.7	0.52	19.33
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-496.7	162.36	522.56	-95.1	8.03	-157	1.22	45.6

Transformer no. 03 (T03) is overloaded.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	88	1500	58.7	100	100						
T01	12	11	300	14.4	450	9.6	100	100						
T11	29	38	1000	82.5	1500	55	100	100						
T02	12	13	300	18.5	450	12.3	100	100						
T12	19	20	1000	12.9	1500	8.6	100	100						
T03	6	31	700	132.4	1050	88.3	100	100						
T04	10	32	800	89.6	1200	59.7	100	100						
T05	19	33	800	79.9	1200	53.3	100	100						
T06	20	34	600	87.6	900	58.4	100	100						
T07	22	35	800	88.9	1200	59.3	100	100						
T08	23	36	700	84.2	1050	56.1	100	100						
T09	25	37	700	78.9	1050	52.6	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	65.3	1200	43.5	100	100	90	110	1	1	1	B9_INV

Here the transformers which loading capacities are above 85 percent are highlighted. From the table we can see that the loading capacity of T03, T04, T06, T07, T10 are above or close to 85 percent. T03 is overloaded.

Motor Table

ID	Bus ID	DBase ID	Type	V sol [pu]	S [MVA]	P. Factor [%]	I [pu]
IM1	3	IM1	Induction Motor	0.874	888.89	90	10.165

Our system supports inclusion of 10 induction motor with load flow converging. Here, we can see all the motors are running with 0.9 power factor. Due to heavy lagging reactive power consumption, reactive current component is flowing considerably toward bus no. 03. Therefore the bus voltage of the induction motors is outside the voltage limit namely heavily under voltage.

Abnormal Report

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
3	0	345	0.95	1.05	0.874	-31.2
4	0	345	0.95	1.05	0.828	-23.4
5	0	345	0.95	1.05	0.817	-16.4
6	0	345	0.95	1.05	0.827	-14.9
7	0	345	0.95	1.05	0.787	-16.6
8	0	345	0.95	1.05	0.773	-16.5
9	0	345	0.95	1.05	0.651	4.9
B9_INV	0	100	0.95	1.05	0.637	9.8
10	0	345	0.95	1.05	0.862	-14.2
11	0	345	0.95	1.05	0.849	-14.5
12	0	138	0.95	1.05	0.83	-15.3
13	0	345	0.95	1.05	0.857	-16
14	0	345	0.95	1.05	0.854	-20.4
15	0	345	0.95	1.05	0.898	-24.6
16	0	345	0.95	1.05	0..935	-24.3
17	0	345	0.95	1.05	0.924	-27
18	0	345	0.95	1.05	0.903	-29.1
24	0	345	0.95	1.05	0.948	-24.2
27	0	345	0.95	1.05	0.945	-27.9
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	3.908	4.482		
L20	15	16	3.987	4.482		
L30	25	26	0.243	4.482		

ID						
L31	26	27	2.821	4.482		
L12	6	11	2.849	4.482		
L32	26	28	1.59	4.482		
L13	7	8	3.073	4.482		
L23	16	21	3.796	4.482		
L33	26	29	2.06	4.482		
L24	16	24	2.24	4.482		
L34	28	29	3.498	4.482		
L16	10	11	3.19	4.482		
L26	17	27	1.621	4.482		
L28	22	23	0.426	4.482		
L19	14	15	3.683	4.482		
L29	23	24	3.757	4.482		
L4	2	25	3.065	4.482		
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]		
L6	3	18	3.282	4.482		
L8	4	14	4.077	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
T03	6	31	926.699	700	1050	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	43.143	150		
T02	12	13	55.37	150		
T12	19	20	128.996	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
G3	32	650	448.06	-192	448	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload and overload condition exists in the system being analyzed.

Summary Report

Summary Data	Active Power	Reactive Power
Total generation	7031.604	3680.44
Spinning reserve	8358.396	
Static Load	6097.1	1408.9
Shunt loads	0	0
Motor loads	800	387.458
Total load	6897.1	1796.358
Line / cable losses	96.047	458.08
Transformer losses	35.378	1132.419
Total losses	132.422	1884.499
Mismatches	2.082	-0.416

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

AFTER INCREASING the ACTIVE GENERATION of GENERATORS:

Background for Active Generation Increase:

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	844.33	-381.94	926.7	-91.1	11.206	140.8	8.07	314.01

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]
T03	6	31	700	132.4	1050	88.3	100	100

Transformer no. 3(T03) is overloaded dangerously as the real power flowing through it is about 144.33 MW higher than its rating (700 MVA). We have noticed that T03 is directly connected to Swing Generator bus (BUS NO. 31). And at BUS 31 only T03 is connected and no other element except the swing generator is connected. Therefore, the real power imbalances supplied by the swing generator is directly flowing through the Transformer 03(T03). Therefore, we have planned to increase the active GENERATION of the remaining 9 generators so that real power imbalance (844.33 MW) supplied by the swing generator will be less than before. And thereby, T03 will not be overloaded. Therefore, we have decided to increase the active generation of each generator (except the swing generator) by 15 MW.

MODIFIED RESULTS and OUTPUTS after ACTIVE GENERATION INCREASE:

Bus Table

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	0.993	-35.5	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.886	-10.3	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.874	-10.8	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.855	-11.4	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.881	-11.9	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.876	-15.6	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.91	-18.6	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.942	-17.8	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.931	-20.5	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.912	-22.7	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.974	-11.3	0.95	1.05	0	0	0	0	0	0	0	0
2	345	0.966	-20.3	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.978	-12	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.962	-14.9	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.002	-9.9	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.001	-10.1	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.954	-17.7	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	0.992	-19	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	0.98	-19.3	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.951	-21.2	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	0.999	-15.3	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.007	-12.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.886	-25	0.95	1.05	0	0	322	2.4	800	387.46	0	0
30	16.5	1.048	-12.1	0.95	1.05	815	504.1	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	700.88	563.39	9.2	4.6	0	0	0	0
32	16.5	0.972	-1.6	0.95	1.05	665	447.97	0	0	0	0	0	0
33	16.5	0.997	-5.9	0.95	1.05	647	163.11	0	0	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
34	16.5	1.012	-6.5	0.95	1.05	538	193.56	0	0	0	0	0	0
35	16.5	1.049	-4.8	0.95	1.05	665	351.97	0	0	0	0	0	0
36	16.5	1.064	-1.8	0.95	1.05	575	276.02	0	0	0	0	0	0
37	16.5	1.028	-11.8	0.95	1.05	555	179.34	0	0	0	0	0	0
38	16.5	1.026	-4.9	0.95	1.05	845	136.81	0	0	0	0	0	0
39	345	1.03	-43.9	0.95	1.05	1015	626.68	1104	250	0	0	0	0
4	345	0.851	-18.7	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.844	-12.9	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.853	-11.7	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.817	-13.2	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.804	-13.1	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.701	5.9	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-45.8	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.688	10.1	0.95	1.05	0	0	0	0	0	0	0	0

Here we can see that Bus No. 3,4,5,6,7,8,9,10,11,12,12,14,15,16,17 and 18 are outside the voltage limit which is at Under Voltage condition. The voltages are less than 0.95 per unit. On the other hand, we can see that the voltage at Bus No. 36 is 1.064 per unit which is greater than 1.05 per unit. Therefore, we can understand that the Bus No. 36 is at Over Voltage condition.

Branch Table

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	45.93	290.6	294.21	15.6	3.486	-93.9	1.01	4.06
L20	15	16	L20	Line	345	63	144.28	-300.3	333.16	-43.3	3.661	97.1	1.16	-2.53
L30	25	26	L30	Line	345	216.5	22.04	9.57	24.03	91.7	0.242	-42.4	0.06	-49.3
L11	6	7	L11	Line	345	61.7	227.67	316.7	390.04	58.4	4.574	-66	1.27	11.7
L21	16	17	L21	Line	345	59.7	468.52	77.72	474.92	98.7	5.043	-27.3	1.78	10.96
L31	26	27	L31	Line	345	98.5	227.85	163.31	280.33	81.3	2.861	-54.9	1.2	-9.7
L12	6	11	L12	Line	345	55	151.82	-208.25	257.71	-58.9	3.022	114.4	0.62	-3.1
L22	16	19	L22	Line	345	130.7	545.47	-92.41	553.24	-98.6	5.875	152.6	5.46	38.9
L32	26	28	L32	Line	345	317.7	148.28	-59.28	159.69	-92.9	1.63	138.9	1	-65.34
L13	7	8	L13	Line	345	30.8	-7.4	221	221.12	-3.3	2.707	105.2	0.3	-1.67
L23	16	21	L23	Line	345	90.5	344.12	-121.32	364.88	-94.3	3.875	142.7	1.17	-3.2
L33	26	29	L33	Line	345	418.9	196.58	-62.16	206.18	-95.3	2.104	143.1	2.3	-76.31
L14	8	9	L14	Line	345	243.3	484.78	333.21	588.25	-82.4	7.313	158.6	12.53	177.17

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L24	16	24	L24	Line	345	39.5	-53.38	-194.06	201.26	-26.5	2.137	87.5	0.13	-3.49
L34	28	29	L34	Line	345	101.2	355.29	-21.54	355.94	-99.8	3.561	161.3	1.77	-5.97
L25	17	18	L25	Line	345	55	412.16	189.79	453.76	90.8	4.872	-45.2	1.68	8.47
L16	10	11	L16	Line	345	28.8	172.16	241.77	296.8	58	3.349	-64.9	0.46	-0.75
L26	17	27	L26	Line	345	116	54.57	-123.03	134.59	40.5	1.445	45.6	0.22	-25.52
L17	10	13	L17	Line	345	28.8	489.44	70.04	494.43	99	5.579	-18.5	1.25	7.71
L27	21	22	L27	Line	345	93	619.29	-233.12	661.72	-93.6	6.881	144.4	3.7	40.38
L18	13	14	L18	Line	345	67.7	499.86	9.02	499.94	100	5.676	-12.9	2.9	19.26
L28	22	23	L28	Line	345	64.3	39.76	4.92	40.06	99.2	0.4	-17	0.01	-18.35
L19	14	15	L19	Line	345	145.4	176.97	-161.48	239.57	73.9	2.735	26.8	1.25	-14.18
L29	23	24	L29	Line	345	234.6	365.45	116.88	383.68	95.2	3.833	-27.9	3.34	18.51
L1	1	2	L1	Line	345	275.5	594.25	163.65	616.38	-96.4	6.207	159.9	13.93	96.54
L2	1	39	L2	Line	345	167.6	594.25	-163.65	616.38	96.4	6.207	-20.1	3.74	16.85
L3	2	3	L3	Line	345	101.2	501.87	473.05	689.67	72.8	7.142	-63.6	6.77	56.79
L4	2	25	L4	Line	345	57.6	300.08	-53.32	304.78	-98.5	3.156	149.6	6.95	-5.49
L5	3	4	L5	Line	345	142.8	375.58	180.68	416.78	-90.1	4.704	-179.3	2.93	31.3
L6	3	18	L6	Line	345	89.1	251.31	-154.29	294.89	-85.2	3.328	123.5	1.18	-2.97
L7	4	5	L7	Line	345	85.8	559.85	105.58	569.71	-98.3	6.694	172	3.59	47.9
L8	4	14	L8	Line	345	86.5	318.66	-140.2	348.14	-91.5	4.091	137.6	1.32	11.03
L9	5	6	L9	Line	345	17.4	609.36	-232.93	652.36	-93.4	7.729	146.2	1.19	12.38

From the above report we can see that Line No. 3,9,10,11,12,14,16,20,27 gives the passage of reactive power of more than 200 MVAR and Line No. 1, 2, 5, 6, 19, 24, 25, and 31 gives the passage of reactive power of more than 150 MVAR but less than 200 MVAR.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	815	504.1	958.3	85	9.148	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1015	626.68	1192.88	85.1	11.58	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	700.88	563.39	899.24	77.9	9.157	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	665	447.97	801.81	82.9	8.252	448	-192	32	0.972
G4	33	G4	Generator	800	16.5	PV	647	163.11	667.24	97	6.691	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	538	193.56	571.76	94.1	5.648	336	-144	34	1.012

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G6	35	G6	Generator	800	16.5	PV	665	351.97	752.4	88.4	7.171	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	575	276.02	637.82	90.2	5.997	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	555	179.34	583.26	95.2	5.675	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	845	136.81	856	98.7	8.339	560	-240	38	1.026

Here the power factor of generator 2 is below 80% and the power factor of others generator is between 80 to 100 percent.

TRANSFORMER TABLE

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVA]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-809.98	-352.62	883.41	-91.7	9.148	136.2	5.02	151.48
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-19.22	-36.36	41.13	-46.7	0.481	106.5	0.04	1.01
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-839.44	-28.32	839.91	-99.9	8.339	165.9	5.56	108.48
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	11.72	-51.64	52.96	22.1	0.62	65.8	0.06	1.67
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	92.94	-31.76	98.22	94.6	1.009	7.6	0.07	1.4
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-686.41	-353.76	772.21	-88.9	9.055	141.1	5.27	205.03
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-661.6	-311.81	731.39	-90.5	8.252	144.4	3.4	136.16
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-643.87	-99.56	651.52	-98.8	6.691	160	3.13	63.55
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-535.13	-136.16	552.18	-96.9	5.648	153.7	2.87	57.4
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-662.75	-278.41	718.85	-92.2	7.171	147.3	2.25	73.56
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-573.2	-178.21	600.27	-95.5	5.997	152.6	1.8	97.81
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-553.07	-104.61	562.87	-98.3	5.675	150.3	1.93	74.73

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVA]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.51	196.19	538.52	93.1	5.228	-65.3	0.52	19.33
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-497.31	156.04	521.21	-95.4	7.44	-156.7	1.05	39.15

Transformer no. 03 (T03) is overloaded.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Set point Min	Set point Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	88.3	1500	58.9	100	100						
T01	12	11	300	13.7	450	9.1	100	100						
T11	29	38	1000	84	1500	56	100	100						
T02	12	13	300	17.7	450	11.8	100	100						
T12	19	20	1000	9.8	1500	6.5	100	100						
T03	6	31	700	110.3	1050	73.5	100	100						
T04	10	32	800	91.4	1200	60.9	100	100						
T05	19	33	800	81.4	1200	54.3	100	100						
T06	20	34	600	92	900	61.4	100	100						
T07	22	35	800	89.9	1200	59.9	100	100						
T08	23	36	700	85.8	1050	57.2	100	100						
T09	25	37	700	80.4	1050	53.6	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	65.2	1200	43.4	100	100	90	110	1	1	1	B9_INV

Here the transformers which loading capacities are above 85 percent are highlighted. From the table we can see that the loading capacity of T03, T04, T06, T07, T08 and T10 are above 85 percent. T03 is overloaded. But, the main fact is that the real power flowing through T03 is 686.41 MW which is less than the rating of T03 of 700 MVA. The reactive power flowing through T03 is 353.76 MVAR. We can easily solve the reactive power compensation and the T03 will not be overloaded.

Motor Table

ID	Bus ID	DBase ID	Type	V sol [pu]	S [MVA]	P. Factor [%]	I [pu]
IM1	3	IM1	Induction Motor	0.886	888.89	90	10.033

Our system supports inclusion of 10 induction motor with load flow converging. Here, we can see all the motors are running with 0.9 power factor. Due to heavy lagging reactive power consumption, reactive current component is flowing considerably toward bus no. 03. Therefore the bus voltage of the induction motors is outside the voltage limit namely heavily under voltage.

Static Load

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

Here we can see Load 12 at bus no. 12 has power factor of only 8.5 percent lagging. It is not operating at good condition.

DC Line Report

ID	Bus From	Bus To	D Base ID	DC Current	DC Power Losses	Commut. X (Rectifier)	Commut. X (Inverter)	Alpha	Gamma	Gamma Min	PF (Rectifier)	PF (Inverter)	DC Voltage (Rectifier)	DC Voltage (Inverter)	DC Power (Rectifier)	DC Power (Inverter)
DC 1	B39_REC	B9_INV	DC1	999	1	2.83	2.83	23.2	0	10	0.93	0.95	502	501	501	500

Here, the DC bus voltages are 502(at rectifier), 501(at inverter), DC power flow 501(at rectifier), 500(at inverter) are shown.

ID	Bus From	Bus To	D Base ID	AC Volt (Rectifier)	AC Volt (Inverter)	P to Converter (Rectifier)	Q to Converter (Rectifier)	P to Converter (Inverter)	Q to Converter (Inverter)	P from Network (Rectifier)	Q from Network (Rectifier)	P from Network (Inverter)	Q from Network (Inverter)
DC 1	B39_REC	B9_INV	DC1	102	68.8	501	177	-498	117	502	196	-497	156

Here, we can see that the power to converter (at rectifier) is 501, power to converter (at inverter) is -498, power from network (at rectifier) is 502, power from network(at inverter) is -497.

Abnormal Report

ID					
BUSES OUTSIDE VOLTAGE LIMITS (100 %)					
Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]
3	0	345	0.95	1.05	0.886
4	0	345	0.95	1.05	0.851
5	0	345	0.95	1.05	0.844
6	0	345	0.95	1.05	0.853
7	0	345	0.95	1.05	0.817
8	0	345	0.95	1.05	0.804
9	0	345	0.95	1.05	0.701
B9_INV	0	100	0.95	1.05	0.688
10	0	345	0.95	1.05	0.886
11	0	345	0.95	1.05	0.874
12	0	138	0.95	1.05	0.855
13	0	345	0.95	1.05	0.881
14	0	345	0.95	1.05	0.876
15	0	345	0.95	1.05	0.91
16	0	345	0.95	1.05	0.942
17	0	345	0.95	1.05	0.931
18	0	345	0.95	1.05	0.912

ID					
OVERLOADED LINES & CABLES (WITHIN 100 %)					
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**
UNDERLOADED LINES & CABLES (WITHIN 50 %)					
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	
L10	5	8	3.486	4.482	
L20	15	16	3.661	4.482	
L30	25	26	0.242	4.482	
L31	26	27	2.861	4.482	
L12	6	11	3.022	4.482	
L32	26	28	1.63	4.482	
L13	7	8	2.707	4.482	
L23	16	21	3.875	4.482	
L33	26	29	2.104	4.482	
L24	16	24	2.137	4.482	
L34	28	29	3.561	4.482	
L16	10	11	3.349	4.482	
L26	17	27	1.445	4.482	
L28	22	23	0.4	4.482	
L19	14	15	2.735	4.482	
L29	23	24	3.833	4.482	
L4	2	25	3.156	4.482	
L6	3	18	3.328	4.482	
L8	4	14	4.091	4.482	
OVERLOADED TRANSFORMERS (WITHIN 100 %)					
ID	**Bus From**	**Bus To**	**Power Flow - [MVA]**	**Loading Limit - [MVA]**	**Emergency Loading Limit - [MVA]**
T03	6	31	772.205	700	1050
UNDERLOADED TRANSFORMERS (WITHIN 50 %)					
ID	**Bus From**	**Bus To**	**Power Flow - [MVA]**	**Loading Limit - [MVA]**	
T01	12	11	41.127	150	
T02	12	13	52.957	150	
T12	19	20	98.217	500	

ID					
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)					
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)					
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]

Summary Report

Summary Data	Active Power	Reactive Power
Total generation	7020.881	3442.946
Spinning reserve	8369.119	
Static Load	6097.1	1408.9
Shunt loads	0	0
Motor loads	800	387.458
Total load	6897.1	1796.358
Line / cable losses	88.161	322.072
Transformer losses	32.977	1030.774
Total losses	122.135	1646.846
Mismatches	1.646	-0.257

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

DISTRIBUTED SWING:

In the load flow calculation, voltage magnitudes, voltage phase angles and certain equipment settings are computed for a given power generation schedule and a given load profile. The specified generation might not satisfy the load, or might satisfy the load in an inefficient manner, due to an inaccurate estimate of system losses. For this reason, the operating strategy traditionally has been to allow one generation to deviate from the schedule to improve the resulting operation. This generation is called the **swing** generation. Allotting this excess power to a single generator can prove unacceptable if the deviation from the desired value is large.

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	0.995	-30.3	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.896	-7.7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.884	-8.3	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.865	-8.7	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.891	-9	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.885	-12.4	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.915	-14.5	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.944	-13.5	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.934	-16.1	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.915	-18.4	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.974	-6.6	0.95	1.05	0	0	0	0	0	0	0	0
2	345	0.968	-15.6	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.978	-7.3	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.963	-10.5	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.003	-5.4	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.002	-5.6	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.956	-13.3	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	0.994	-14.2	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	0.981	-14.6	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.953	-16.6	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1	-10.3	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.007	-7.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.891	-20.7	0.95	1.05	0	0	322	2.4	800	387.46	0	0
30	16.5	1.048	-7.3	0.95	1.05	830.29	494.5	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	500.56	9.2	4.6	0	0	0	0
32	16.5	0.981	1.1	0.95	1.05	677.48	448	0	0	0	0	0	0
33	16.5	0.997	-1.2	0.95	1.05	659.14	159.2	0	0	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
34	16.5	1.012	-1.7	0.95	1.05	548.09	192.38	0	0	0	0	0	0
35	16.5	1.049	-0.2	0.95	1.05	677.48	348.15	0	0	0	0	0	0
36	16.5	1.064	3	0.95	1.05	585.79	274.97	0	0	0	0	0	0
37	16.5	1.028	-6.9	0.95	1.05	565.41	172.89	0	0	0	0	0	0
38	16.5	1.026	0.2	0.95	1.05	860.86	137.67	0	0	0	0	0	0
39	345	1.03	-38.4	0.95	1.05	1034.05	613.54	1104	250	0	0	0	0
4	345	0.861	-15.5	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.855	-10.5	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.864	-9.4	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.829	-10.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.817	-10.8	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.719	7.4	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-40.3	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.707	11.4	0.95	1.05	0	0	0	0	0	0	0	0

BUS VOLTAGE IMPROVEMENT COMPARISON

Bus ID	Voltage Before Distributed Swing	Voltage After Distributed Swing
10	0.886	0.896
11	0.874	0.884
12	0.855	0.865
13	0.881	0.891
14	0.876	0.885
15	0.91	0.915
16	0.942	0.944
17	0.931	0.934
18	0.912	0.915
3	0.886	0.891
4	0.851	0.861
5	0.844	0.855
6	0.853	0.864
7	0.817	0.829
8	0.804	0.817
9	0.701	0.719
9_INV	0.688	0.707
36	1.064	1.064

We can see that bus 3 to 18 are still in undervoltage condition & bus 36 in overvoltage condition. But it’s noticeable that upon using distributed swing, the voltage has been improved slightly but steadily in undervoltage condition. And no change is seen in bus 36.

GENERATOR TABLE

ID	Bus ID	DBase ID	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	1000	16.5	PV	830.29	494.5	966.39	85.9	9.226	560	-240	30	1.048
G1	39	G1	10000	345	PV	1034.05	613.54	1202.37	86	11.673	5600	-2400	39	1.03
G2	31	G2	700	16.5	SW	0	500.56	500.56	0	5.097	392	-168	31	0.982
G3	32	G3	800	16.5	PV	677.48	448	812.21	83.4	8.281	448	-192	32	0.981
G4	33	G4	800	16.5	PV	659.14	159.2	678.09	97.2	6.8	448	-192	33	0.997
G5	34	G5	600	16.5	PV	548.09	192.38	580.88	94.4	5.738	336	-144	34	1.012
G6	35	G6	800	16.5	PV	677.48	348.15	761.7	88.9	7.259	448	-192	35	1.049
G7	36	G7	700	16.5	PV	585.79	274.97	647.11	90.5	6.085	392	-168	36	1.064
G8	37	G8	700	16.5	PV	565.41	172.89	591.26	95.6	5.753	392	-168	37	1.028
G9	38	G9	1000	16.5	PV	860.86	137.67	871.79	98.7	8.493	560	-240	38	1.026

If swing generators have been connected at two or more buses in a subnetwork, all but one will lose this status during the computation. This allows the voltage phase angles of the others to be adjusted by the calculation.

Previously, the swing generator was supplying real power more than its rated value. Now If Pgen=0 MW is entered at a swing bus, then the program will reschedule its generation. The difference between the total load and the total generation in a subnetwork is shared evenly by the zero MW swing generations in that subnetwork. No generator is overloaded in the above report table.

Distributed Swing Report

ID	P Desired [MW]	P calculated [MW]
G10	815	830.29
G3	665	677.48

ID	P Desired [MW]	P calculated [MW]
G4	647	659.14
G5	269	548.09
G6	665	677.48
G7	575	585.79
G8	555	565.41
G9	845	860.86
G1	1015	1034.05

Large values are input to reflect the large power capacity of the swing bus. In this case, scheduled power generation is excessively large. The program reduces all generations to fit the global load on the network.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	51.37	282.12	286.76	17.9	3.353	-90.2	0.94	2.74
L20	15	16	L20	Line	345	63	-192.82	-275.89	336.59	-57.3	3.68	110.4	1.18	-2.48
L30	25	26	L30	Line	345	216.5	23.13	10.73	25.5	90.7	0.257	-39.1	0.06	-49.4
L11	6	7	L11	Line	345	61.7	221.16	308.22	379.36	58.3	4.392	-63.8	1.18	9.98
L21	16	17	L21	Line	345	59.7	464.51	74.81	470.5	98.7	4.983	-22.6	1.74	10.35
L31	26	27	L31	Line	345	98.5	244.24	157.9	290.83	84	2.964	-47.5	1.28	-8.91
L12	6	11	L12	Line	345	55	-205.01	-199.5	286.06	-71.7	3.312	126.3	0.75	-1.83
L22	16	19	L22	Line	345	130.7	-567.15	-79.26	572.66	-99	6.065	158.6	5.83	43.31
L32	26	28	L32	Line	345	317.7	-155.93	-56.02	165.69	-94.1	1.689	145.7	1.1	-64.4
L13	7	8	L13	Line	345	30.8	-13.81	214.25	214.69	-6.4	2.589	-104.6	0.27	-2.12
L23	16	21	L23	Line	345	90.5	-357.62	-112.84	375	-95.4	3.971	149	1.23	-2.25
L33	26	29	L33	Line	345	418.9	-204.24	-58.74	212.52	-96.1	2.166	149.4	2.47	-74.57
L14	8	9	L14	Line	345	243.3	-485.65	319.76	581.46	-83.5	7.116	-157.4	11.86	165.73
L24	16	24	L24	Line	345	39.5	-62.74	-188.41	198.58	-31.6	2.103	94.9	0.13	-3.61
L34	28	29	L34	Line	345	101.2	-363.03	-19.22	363.54	-99.9	3.637	166.7	1.84	-5.15
L25	17	18	L25	Line	345	55	424.55	181.99	461.91	91.9	4.944	-39.3	1.72	8.97
L16	10	11	L16	Line	345	28.8	221.42	235.24	323.06	68.5	3.604	-54.4	0.53	-0.12
L26	17	27	L26	Line	345	116	38.23	-117.53	123.59	30.9	1.323	55.9	0.18	-26.22
L17	10	13	L17	Line	345	28.8	452.63	75.63	458.91	98.6	5.12	-17.1	1.05	5.48
L27	21	22	L27	Line	345	93	-632.86	-225.59	671.86	-94.2	6.976	149.9	3.8	42.18
L18	13	14	L18	Line	345	67.7	459.12	17.38	459.45	99.9	5.158	-11.2	2.4	13.32

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L28	22	23	L28	Line	345	64.3	38.51	4.98	38.83	99.2	0.387	-12.7	0.01	-18.39
L19	14	15	L19	Line	345	145.4	127.94	-143.37	192.16	66.6	2.171	35.9	0.76	-20.49
L29	23	24	L29	Line	345	234.6	374.94	113.05	391.61	95.7	3.91	-22.4	3.47	20.45
L1	1	2	L1	Line	345	275.5	-574.95	157.21	596.05	-96.5	5.989	165	12.98	85.11
L2	1	39	L2	Line	345	167.6	574.95	-157.21	596.05	96.5	5.989	-15	3.48	10.14
L3	2	3	L3	Line	345	101.2	546.29	455.86	711.51	76.8	7.353	-55.5	7.16	61.2
L4	2	25	L4	Line	345	57.6	-309.03	-43.31	312.05	-99	3.225	156.4	7.27	-5.15
L5	3	4	L5	Line	345	142.8	-319.27	150.46	352.94	-90.5	3.962	-175.5	2.08	17.19
L6	3	18	L6	Line	345	89.1	-263.6	-145.66	301.17	-87.5	3.381	130.3	1.22	-2.64
L7	4	5	L7	Line	345	85.8	-493.9	85.58	501.26	-98.5	5.822	174.3	2.71	33.66
L8	4	14	L8	Line	345	86.5	-327.45	-136.31	354.69	-92.3	4.12	141.9	1.34	11.12
L9	5	6	L9	Line	345	17.4	-547.99	-230.2	594.38	-92.2	6.949	146.7	0.96	9.32

Line no. 10, 20,11,13,14,16,3,27,9 are burdened with reactive power flow of more than 200 MVAR and Line 31,12, 24, 25, 1, 2,5 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

So here we can’t say any improvement or degradation in VAR flowing, rather it just distributed accordingly to rated apparent power and calculated real power.

TRANSFORMER REPORT

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-825.19	-340.45	892.66	-92.4	9.226	141.9	5.11	154.05
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-15.1	-36.78	39.76	-38	0.46	103.6	0.03	0.92
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-855.09	-25.15	855.45	-100	8.493	171.1	5.77	112.52
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.6	-51.22	51.78	14.7	0.599	72.8	0.06	1.56
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	82.92	-29	87.85	94.4	0.902	12.6	0.06	1.12
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-565.1	-348.25	663.79	-85.1	7.686	138.9	3.8	147.71
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-674.05	-310.88	742.28	-90.8	8.281	147.6	3.43	137.12

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-655.9	-93.56	662.54	-99	6.8	165.2	3.24	65.64
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-545.13	-133.13	561.15	-97.1	5.738	158.9	2.96	59.25
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-675.17	-272.76	728.18	-92.7	7.259	152.6	2.31	75.39
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-583.94	-174.28	609.39	-95.8	6.085	157.8	1.85	100.69
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-563.43	-96.1	571.57	-98.6	5.753	156.1	1.99	76.79
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.51	196.19	538.52	93.1	5.228	-59.8	0.52	19.33
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-497.51	154.03	520.81	-95.5	7.242	-155.4	0.99	37.09

No transformer is overloaded in the above report after distributed swing.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]	Ang sol - [deg]
3	0	345	0.9	1.1	0.891	-20.7
4	0	345	0.9	1.1	0.861	-15.5
5	0	345	0.9	1.1	0.855	-10.5
6	0	345	0.9	1.1	0.864	-9.4
7	0	345	0.9	1.1	0.829	-10.9
8	0	345	0.9	1.1	0.817	-10.8
9	0	345	0.9	1.1	0.719	7.4
B9_INV	0	100	0.9	1.1	0.707	11.4
10	0	345	0.9	1.1	0.896	-7.7
11	0	345	0.9	1.1	0.884	-8.3
12	0	138	0.9	1.1	0.865	-8.7
13	0	345	0.9	1.1	0.891	-9
14	0	345	0.9	1.1	0.885	-12.4

ID						
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]	Emergency Loading Limit - [pu]	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]		
L10	5	8	3.353	4.482		
L20	15	16	3.68	4.482		
L30	25	26	0.257	4.482		
L11	6	7	4.392	4.482		
L31	26	27	2.964	4.482		
L12	6	11	3.312	4.482		
L32	26	28	1.689	4.482		
L13	7	8	2.589	4.482		
L23	16	21	3.971	4.482		
L33	26	29	2.166	4.482		
L24	16	24	2.103	4.482		
L34	28	29	3.637	4.482		
L16	10	11	3.604	4.482		
L26	17	27	1.323	4.482		
L28	22	23	0.387	4.482		
L19	14	15	2.171	4.482		
L29	23	24	3.91	4.482		
L4	2	25	3.225	4.482		
L5	3	4	3.962	4.482		
L6	3	18	3.381	4.482		
L8	4	14	4.12	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	39.756	150		
T02	12	13	51.783	150		

ID						
T12	19	20	87.851	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]	Ang sol - [deg]
3	0	345	0.9	1.1	0.891	-20.7
4	0	345	0.9	1.1	0.861	-15.5
5	0	345	0.9	1.1	0.855	-10.5
6	0	345	0.9	1.1	0.864	-9.4
7	0	345	0.9	1.1	0.829	-10.9
8	0	345	0.9	1.1	0.817	-10.8
9	0	345	0.9	1.1	0.719	7.4
B9_INV	0	100	0.9	1.1	0.707	11.4
10	0	345	0.9	1.1	0.896	-7.7
11	0	345	0.9	1.1	0.884	-8.3
12	0	138	0.9	1.1	0.865	-8.7
13	0	345	0.9	1.1	0.891	-9
14	0	345	0.9	1.1	0.885	-12.4

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, only underload condition exists in the system being analyzed. Underload condition is reported when the loading falls below 50% of the rated condition. The under loaded conditions are less important to deal with. The Overload conditions are of concern.

Motor

ID	Bus ID	DBase ID	Type	V sol [pu]	S [MVA]	P. Factor [%]	I [pu]
IM1	3	IM1	Induction Motor	0.891	888.89	90	9.979

We can see the induction motor at swing bus 3 is beyond voltage limit.

STATIC LOAD

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

The load summary is the same as the static load data that was calculated in increasing active generation part, and no additional analysis is required in this part. Only L12 is under-loaded as it is highlighted. There is no effect on the static load side after adding distributed swing.

DC Line Report

ID	Bus From	Bus To	DBase ID	DC Current	DC Power Losses	Commut. X (Rectifier)	Commut. X (Inverter)	Alpha	Gamma	Gamma Min
DC1	B39_REC	B9_INV	DC1	999	1	2.83	2.83	23.3	0	10

ID	PF (Rectifier)	PF (Inverter)	DC Voltage (Rectifier)	DC Voltage (Inverter)	DC Power (Rectifier)	DC Power (Inverter)	AC Volt (Rectifier)	AC Volt (Inverter)
DC1	0.93	0.95	501	500	501	500	102	70.7

Here, the DC bus voltages are 501(at rectifier), 500(at inverter), DC power flow 501(at rectifier), 500(at inverter) are shown.

ID	P to Converter (Rectifier)	Q to Converter (Rectifier)	P to Converter (Inverter)	Q to Converter (Inverter)	P from Network (Rectifier)	Q from Network (Rectifier)	P from Network (Inverter)	Q from Network (Inverter)
DC1	501	177	-499	117	502	196	-498	154

Here, we can see that the power to converter (at rectifier) is 501, power to converter (at inverter) is -499, power from network (at rectifier) is 502, power from network (at inverter) is -498.

SUMMARY REPORT

Summary Data	Active Power	Reactive Power
Total generation	6438.586	3341.846
Spinning reserve	8951.414	
Static Load	6097.1	1408.9
Shunt loads	0	0
Motor loads	800	387.458
Total load	6897.1	1796.358
Line / cable losses	84.996	262.512
Transformer losses	32.099	989.179
Total losses	118.093	1545.691
Mismatches	-576.607	-0.202

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

STATIC VAR COMPENSATION:

STEP-1(SVC-1 at Bus No. 3 Addition):

From the standpoint of logical intuition, it is decided to append a static VAR compensator element to bus 3 where 10 industrial induction motor loads are already attached. The industrial induction motor loads are at 0.9 lagging power factor and with a 90 percent efficiency level. Therefore, they consume a considerable amount of reactive power and thereby play a vital role in increasing the reactive current component in the power system network line. As, we know the effect of line loss and line voltage drop are rendered severe due to this reactive current component in the lines of the power network, it is imperative that this lagging reactive power flow and flow of reactive component of the current in the lines be mitigated with great care.

To illustrate, we have followed a methodology built-up on the admixture of smart guess and logical intuition. As our main focus for step one is bus no.3, we can simultaneously describe and work our way out in solving the low voltage level of the bus no. 3.

BUS TABLE (with focus on bus no. 03) :

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
3	345	0.891	-20.7	0.95	1.05	0	0	322	2.4	800	387.46	0	0

BRANCH TABLE (with focus on the line L3 to bus no. 3)

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]
L3	2	3	L3	Line	345	101.2	546.29	455.86	711.51	76.8	7.353	-55.5

From the aforementioned extracted sections of our previous informative tables in the point of distributed swing application, we have noticed that the per unit voltage level at bus no. 3 is 0.891 and line no. 3 (L3) has gone into bus 3. The Reactive power flowing through the line is 455.86 MVAR. So, we have appended a STATIC VAR COMPENSATOR with Q-max of 456 and Q-min of -456 MVAR.

After adding the SVC1_(at 3) at bus no. 3 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SVC1_(at 3) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.006	-29.1	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.917	-7.5	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.906	-8.1	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.888	-8.5	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.914	-8.8	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.913	-12	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.938	-14	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.965	-12.9	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.966	-15.5	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.959	-17.6	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.982	-6.3	0.95	1.05	0	0	0	0	0	0	0	0
2	345	0.994	-15	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.982	-7	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.978	-10.1	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.011	-5	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.01	-5.2	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.975	-12.8	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.012	-13.4	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.001	-13.9	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.978	-15.9	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.01	-9.7	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.014	-6.6	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.954	-19.8	0.95	1.05	0	455.96	322	2.4	800	387.46	0	0
30	16.5	1.048	-6.9	0.95	1.05	828.83	342.37	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	400.34	9.2	4.6	0	0	0	0
32	16.5	0.983	1	0.95	1.05	676.28	357.07	0	0	0	0	0	0
33	16.5	0.997	-0.8	0.95	1.05	657.98	108.83	0	0	0	0	0	0
34	16.5	1.012	-1.4	0.95	1.05	547.13	169.18	0	0	0	0	0	0
35	16.5	1.049	0.1	0.95	1.05	676.28	290.33	0	0	0	0	0	0
36	16.5	1.064	3.2	0.95	1.05	584.76	242.46	0	0	0	0	0	0
37	16.5	1.028	-6.2	0.95	1.05	564.42	89.36	0	0	0	0	0	0
38	16.5	1.026	0.7	0.95	1.05	859.34	92.84	0	0	0	0	0	0
39	345	1.03	-37.1	0.95	1.05	1032.22	568.67	1104	250	0	0	0	0
4	345	0.898	-14.9	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.883	-10.2	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.889	-9.2	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.858	-10.6	0.95	1.05	0	0	233.8	84	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
8	345	0.847	-10.5	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.761	6.1	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-39	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.749	9.7	0.95	1.05	0	0	0	0	0	0	0	0

Bus no. 10,11,12,13,14,15,4,5,6,7,8,9 and 9_INV are outside the voltage limit which is red colored in the table and in fact they are experiencing under voltages. Here bus no. 36 is also outside limit which is experiencing over voltage.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SVC1 ADDITION)

Bus ID	Voltage Before SVC_1 Addition(p.u)	Voltage After SVC_1 Addition(p.u)
10	.896	.917
11	.884	.906
12	.865	.888
13	.891	.914
14	.885	.913
15	.915	.938
16	.944	.965
17	.934	.966
18	.915	.959
3	.891	.954
4	.861	.898
5	.855	.889
6	.864	.889
7	.829	.858
8	.817	.847
9	.719	.761
9_INV	.707	.749

We are focusing the buses mentioned above in the table. The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit.

BRANCH TABLE

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	50.06	272.48	277.04	18.1	3.137	-89.8	0.82	0.43
L20	15	16	L20	Line	345	63	-195.02	-258.13	323.52	-60.3	3.448	113.1	1.03	-4.73
L30	25	26	L30	Line	345	216.5	28.14	7.45	29.11	96.7	0.288	-28.2	0.06	-51.35
L11	6	7	L11	Line	345	61.7	220.4	284.51	359.89	61.2	4.048	-61.4	1	6.76
L21	16	17	L21	Line	345	59.7	459.54	-36.8	461.01	99.7	4.775	-8.4	1.59	7.74
L31	26	27	L31	Line	345	98.5	248.05	121.43	276.18	89.8	2.76	-39.9	1.11	-11.81
L12	6	11	L12	Line	345	55	-205.68	-174.96	270.03	-76.2	3.038	130.4	0.63	-3.82
L22	16	19	L22	Line	345	130.7	-565.58	-14.79	565.77	-100	5.861	165.6	5.47	38.12
L32	26	28	L32	Line	345	317.7	-155.09	-38.34	159.76	-97.1	1.596	152.3	1.03	-67.46
L13	7	8	L13	Line	345	30.8	-14.4	193.75	194.29	-7.4	2.265	-104.9	0.21	-3.24
L23	16	21	L23	Line	345	90.5	-356.88	-71.75	364.03	-98	3.771	155.7	1.12	-5.08
L33	26	29	L33	Line	345	418.9	-203.87	-41.29	208.01	-98	2.079	154.7	2.37	-78.4
L14	8	9	L14	Line	345	243.3	-487.37	293.04	568.69	-85.7	6.711	-159.5	10.56	142.95
L24	16	24	L24	Line	345	39.5	-62.13	-162.37	173.85	-35.7	1.801	98	0.09	-4.56
L34	28	29	L34	Line	345	101.2	-362.12	1.52	362.13	-100	3.587	170.6	1.8	-6.04
L25	17	18	L25	Line	345	55	423.8	42.41	425.91	99.5	4.41	-21.2	1.36	3.78
L16	10	11	L16	Line	345	28.8	221.88	206.59	303.17	73.2	3.306	-50.5	0.44	-1.3
L26	17	27	L26	Line	345	116	34.15	-86.95	93.41	36.6	0.967	53.1	0.09	-29.21
L17	10	13	L17	Line	345	28.8	451.38	29.49	452.34	99.8	4.932	-11.2	0.97	4.36
L27	21	22	L27	Line	345	93	-632	-181.67	657.6	-96.1	6.724	153.9	3.54	36.98
L18	13	14	L18	Line	345	67.7	457.94	-28.48	458.83	99.8	5.021	-5.3	2.27	11.04
L28	22	23	L28	Line	345	64.3	38.59	1.3	38.61	99.9	0.382	-7	0.01	-18.69
L19	14	15	L19	Line	345	145.4	125.6	-129.03	180.07	69.8	1.972	33.8	0.62	-23.89
L29	23	24	L29	Line	345	234.6	374.07	81.5	382.84	97.7	3.792	-17.5	3.24	15.88
L1	1	2	L1	Line	345	275.5	-576.64	116.55	588.3	-98	5.847	162.4	12.3	74.53
L2	1	39	L2	Line	345	167.6	576.64	-116.55	588.3	98	5.847	-17.6	3.34	5.91
L3	2	3	L3	Line	345	101.2	539.26	221.24	582.88	92.5	5.866	-37.4	4.53	28.42
L4	2	25	L4	Line	345	57.6	-303.75	30.49	305.28	-99.5	3.072	170.7	6.67	-6.53
L5	3	4	L5	Line	345	142.8	-323.68	276.97	426.01	-76	4.464	-159.2	2.67	24.76
L6	3	18	L6	Line	345	89.1	-263.6	-18.05	264.21	-99.8	2.768	156.3	0.84	-9.42
L7	4	5	L7	Line	345	85.8	-497.4	150.79	519.75	-95.7	5.788	-178.1	2.69	32.5
L8	4	14	L8	Line	345	86.5	-328.95	-82.58	339.16	-97	3.777	151	1.13	6.92
L9	5	6	L9	Line	345	17.4	-550.15	-154.19	571.35	-96.3	6.47	154.1	0.84	7.46

Line no. 10, 20, 11,14,16,3,5 are burdened with reactive power flow of more than 200 MVAR. And Line 12, 13, 24, 27, 7, 9 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SVC_1 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SVC_1	Line MVAR After Addition of SVC_1
10	5	8	282.12	272.48
20	15	16	-275.89	-258.52
11	6	7	308.22	284.51
13	7	8	214.25	193.75
14	8	9	319.76	293.04
16	10	11	235.24	206.59
27	21	22	-225.59	-181.67
3	2	3	455.86	221.24
9	5	6	-230.2	-154.19

After addition of first Static VAR Compensator at bus no. 3, we can see line MVAR is reduced in those line mentioned in the table above. The lines L9,L13,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit. And the other lines L3,L10,L11,L14,L16,L20 which are highlighted with red color are improved in terms of MVAR but they are still outside limit.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	828.83	342.37	896.76	92.4	8.561	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1032.22	568.67	1178.51	87.6	11.442	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	400.34	400.34	0	4.077	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	676.28	357.07	764.76	88.4	7.779	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	657.98	108.83	666.92	98.7	6.688	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	547.13	169.18	572.69	95.5	5.657	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	676.28	290.33	735.97	91.9	7.014	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	584.76	242.46	633.03	92.4	5.952	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	564.42	89.36	571.45	98.8	5.56	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	859.34	92.84	864.34	99.4	8.42	560	-240	38	1.026
SVC 1_3	3	SVC 1_3	Static Var Compensator	456	345	PV	0	455.96	455.96	0	4.778	456	-456	3	0.954

No generator is overloaded in the above report table. Only the Static VAR compensator is at the reactive limit which is of no concern.

TRANSFORMER REPORT

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-824.43	-209.71	850.69	-96.9	8.561	150.7	4.4	132.65
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-15.09	-35.92	38.96	-38.7	0.438	104.3	0.03	0.84
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-853.67	17.77	853.85	-100	8.42	174.6	5.67	110.6
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.59	-52.08	52.63	14.4	0.592	73.2	0.06	1.53
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	83.8	-7.57	84.14	99.6	0.857	-1.1	0.05	1.01
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-565.7	-271.2	627.35	-90.2	7.057	145.2	3.2	124.54
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-673.26	-236.08	713.45	-94.4	7.779	153.2	3.02	120.99
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-654.85	-45.34	656.42	-99.8	6.688	169.8	3.13	63.49
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-544.25	-111.59	555.57	-98	5.657	161.5	2.88	57.59
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-674.13	-219.95	709.1	-95.1	7.014	156.9	2.15	70.38
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-582.99	-146.11	601.02	-97	5.952	160.7	1.77	96.35
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-562.56	-17.63	562.84	-100	5.56	164.8	1.86	71.74
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.21	538.53	93.1	5.228	-58.5	0.52	19.33
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-497.94	150.09	520.07	-95.7	6.836	-157.1	0.88	33.05

No transformer is overloaded in the above report after the inclusion of SVC_1 at bus no. 3.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	**2**	**30**	**1000**	**85.1**	**1500**	**56.7**	**100**	**100**						
T01	12	11	300	13	450	8.7	100	100						
T11	**29**	**38**	**1000**	**85.4**	**1500**	**56.9**	**100**	**100**						
T02	12	13	300	17.5	450	11.7	100	100						
T12	19	20	1000	8.4	1500	5.6	100	100						
T03	**6**	**31**	**700**	**89.6**	**1050**	**59.7**	**100**	**100**						
T04	**10**	**32**	**800**	**89.2**	**1200**	**59.5**	**100**	**100**						
T05	19	33	800	82.1	1200	54.7	100	100						
T06	**20**	**34**	**600**	**92.6**	**900**	**61.7**	**100**	**100**						
T07	**22**	**35**	**800**	**88.6**	**1200**	**59.1**	**100**	**100**						
T08	**23**	**36**	**700**	**85.9**	**1050**	**57.2**	**100**	**100**						
T09	25	37	700	80.4	1050	53.6	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	65	1200	43.3	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	828.83
G3	665	676.28
G4	647	657.98
G5	269	547.13
G6	665	676.28
G7	575	584.76
G8	555	564.42
G9	845	859.34
G1	1015	1032.22

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

STEP-2(SVC-2 at Bus No. 9 Addition):

After appending SVC_1 , we have noticed that bus no. 10,11,12,13,14,15,4,5,6,7,8,9 and 9_INV are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into the buses which are heavily under voltage(under 0.9 pu) among the aforementioned buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SVC of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	.888	88
4	.898	276.97
5	.883	150.79
6	.889	154.19
7	.858	284.51
8	.847	466.23
9	.761	293.04

From the above table, we can see that bus no. 9 is heavily affected by line losses and voltage drop in the lines due to reactive current component. Though bus no. 8 is burdened by more line MVAR, its voltage is not as bad as that of bus no. 9. It is because bus no. 8 is absorbing 466.23 MVAR as well as giving away 293.04 MVAR to bus no. 9. So our focus is on bus no. 9. So, we have appended a STATIC VAR COMPENSATOR (SVC_2) with Q-max of 294 and Q-min of -294 MVAR at bus no. 9.

After adding the SVC_2 (at 9) at bus no. 9 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SVC2 (at bus 9) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.009	-28	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.948	-7.1	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.944	-7.7	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.924	-8.1	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.945	-8.3	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.944	-11.3	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.956	-13.1	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.977	-12.1	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.978	-14.5	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.974	-16.6	0.95	1.05	0	0	158	30	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
19	345	0.985	-5.5	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.001	-14.1	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.984	-6.2	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.986	-9.2	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.015	-4.3	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.014	-4.5	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.986	-11.9	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.018	-12.4	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.008	-12.9	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.988	-14.9	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.013	-8.8	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.016	-5.7	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.972	-18.7	0.95	1.05	0	455.99	322	2.4	800	387.46	0	0
30	16.5	1.048	-5.9	0.95	1.05	827.17	298.33	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	202.05	9.2	4.6	0	0	0	0
32	16.5	0.983	1.2	0.95	1.05	674.93	202.7	0	0	0	0	0	0
33	16.5	0.997	-0.1	0.95	1.05	656.66	81.7	0	0	0	0	0	0
34	16.5	1.012	-0.6	0.95	1.05	546.03	156.64	0	0	0	0	0	0
35	16.5	1.049	0.9	0.95	1.05	674.93	259.16	0	0	0	0	0	0
36	16.5	1.064	3.9	0.95	1.05	583.58	224.87	0	0	0	0	0	0
37	16.5	1.028	-5.2	0.95	1.05	563.28	64.43	0	0	0	0	0	0
38	16.5	1.026	1.6	0.95	1.05	857.61	76.49	0	0	0	0	0	0
39	345	1.03	-36	0.95	1.05	1030.15	556.58	1104	250	0	0	0	0
4	345	0.935	-14	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.936	-9.7	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.939	-8.8	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.929	-10.1	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.928	-10	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.987	1.1	0.95	1.05	0	294.03	0	0	0	0	0	0
B39_REC	100	1.016	-37.9	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.978	3.3	0.95	1.05	0	0	0	0	0	0	0	0

Here we can see that bus no. 4, 5, 6, 7, 8, 10, 11, 12, 13, 14 are outside the voltage limit namely under voltage. Here we also see that bus no. 36 is also outside limit namely over voltage.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SVC_2 ADDITION)

Bus ID	Voltage Before SVC_2 Addition(p.u)	Voltage After SVC_2 Addition(p.u)
10	.917	.948
11	.906	.944
12	.888	.924
13	.914	.945
14	.913	.944
15	.938	.956
16	.965	.977
17	.966	.978
18	.959	.974
3	.954	.972
4	.898	.935
5	.889	.936
6	.889	.939
7	.858	.929
8	.847	.928
9	.761	.987
9_INV	.749	.978

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit. From the table, we also that bus no. 9,15,9_INV are now within limit which are outside limit before.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.83	60.24	75.09	59.7	0.802	-63.1	0.06	-12
L20	15	16	L20	Line	345	63	-195.78	-200.86	280.49	-69.8	2.935	121.2	0.75	-8.18
L30	25	26	L30	Line	345	216.5	30.46	2.62	30.57	99.6	0.3	-17.3	0.06	-52.06
L11	6	7	L11	Line	345	61.7	218.38	89.7	236.08	92.5	2.514	-31.1	0.38	-3.94
L21	16	17	L21	Line	345	59.7	454.78	-48.67	457.38	99.4	4.683	-5.9	1.53	6.64
L31	26	27	L31	Line	345	98.5	248.77	104.66	269.89	92.2	2.678	-35.7	1.04	-12.92
L12	6	11	L12	Line	345	55	-208.51	-42.14	212.73	-98	2.265	159.8	0.35	-8.15
L22	16	19	L22	Line	345	130.7	-563.4	20.74	563.78	-99.9	5.772	170	5.33	35.88
L32	26	28	L32	Line	345	317.7	-154.21	-31.97	157.49	-97.9	1.563	155.4	1.01	-68.55
L13	7	8	L13	Line	345	30.8	-15.8	9.64	18.51	-85.4	0.199	-158.7	0	-6.7
L23	16	21	L23	Line	345	90.5	-355.67	-49.06	359.04	-99.1	3.676	160.1	1.07	-6.44
L33	26	29	L33	Line	345	418.9	-203.16	-35.01	206.15	-98.5	2.046	157.3	2.33	-79.8
L14	8	9	L14	Line	345	243.3	-493.03	-87.42	500.72	-98.5	5.396	159.9	6.59	69.65
L24	16	24	L24	Line	345	39.5	-61.24	-147.98	160.15	-38.2	1.64	100.4	0.08	-5.02
L34	28	29	L34	Line	345	101.2	-361.21	8.98	361.33	-100	3.566	172.7	1.78	-6.39
L25	17	18	L25	Line	345	55	419.93	17.05	420.27	99.9	4.296	-16.8	1.29	2.59

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L16	10	11	L16	Line	345	28.8	223.84	73.33	235.55	95	2.484	-25.2	0.25	-3.85
L26	17	27	L26	Line	345	116	33.33	-72.36	79.67	41.8	0.814	50.8	0.06	-30.28
L17	10	13	L17	Line	345	28.8	448.52	26.64	449.31	99.8	4.738	-10.5	0.9	3.13
L27	21	22	L27	Line	345	93	-630.74	-157.62	650.14	-97	6.594	156.8	3.41	34.35
L18	13	14	L18	Line	345	67.7	454.76	-23.42	455.37	99.9	4.817	-5.4	2.09	8.03
L28	22	23	L28	Line	345	64.3	38.7	-0.73	38.71	100	0.381	-3.2	0.01	-18.86
L19	14	15	L19	Line	345	145.4	124.61	-76.22	146.07	85.3	1.548	20.2	0.39	-28.36
L29	23	24	L29	Line	345	234.6	373.05	64.36	378.56	98.5	3.733	-14.3	3.13	13.59
L1	1	2	L1	Line	345	275.5	-578.7	104.95	588.14	-98.4	5.829	162.3	12.19	72.56
L2	1	39	L2	Line	345	167.6	578.7	-104.95	588.14	98.4	5.829	-17.7	3.33	5.35
L3	2	3	L3	Line	345	101.2	532.5	154.05	554.33	96.1	5.536	-30.2	4.02	21.85
L4	2	25	L4	Line	345	57.6	-300.45	49.13	304.44	-98.7	3.041	175.2	6.55	-6.87
L5	3	4	L5	Line	345	142.8	-333.68	193.5	385.72	-86.5	3.967	-168.6	2.1	14.32
L6	3	18	L6	Line	345	89.1	-259.85	4.83	259.89	-100	2.673	162.4	0.79	-10.71
L7	4	5	L7	Line	345	85.8	-508.7	36.19	509.98	-99.7	5.453	170.1	2.38	26.38
L8	4	14	L8	Line	345	86.5	-327.08	-41.01	329.64	-99.2	3.525	158.8	0.98	3.76
L9	5	6	L9	Line	345	17.4	-555.91	-50.43	558.19	-99.6	5.961	165.1	0.71	5.42

Line no. 20 is burdened with reactive power flow of more than 200 MVAR. And Line 3, 5 and 27 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SVC_2 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SVC_2	Line MVAR After Addition of SVC_2
10	5	8	272.48	60.24
20	15	16	-258.52	-200.86
11	6	7	284.51	89.7
13	7	8	193.75	9.64
14	8	9	293.04	-87.42
16	10	11	206.59	73.33
27	21	22	-181.67	-157.62
3	2	3	221.24	154.05
9	5	6	-154.19	-50.43
5	3	4	276.97	193.5

After addition of second Static VAR Compensator at bus no. 9, we can see line MVAR is reduced in those line mentioned above in the table. The lines L3,L5,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit. The line L20 which are highlighted with red color are improved in terms of MVAR but they are still outside limit. And the MVARs are heavily reduced in the rest of the lines mentioned above in the table.

GENERATOR REPORT

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	827.17	298.33	879.32	94.1	8.394	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1030.15	556.58	1170.89	88	11.368	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	202.05	202.05	0	2.058	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.93	202.7	704.71	95.8	7.168	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.66	81.7	661.72	99.2	6.636	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	546.03	156.64	568.06	96.1	5.612	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.93	259.16	722.97	93.4	6.89	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.58	224.87	625.41	93.3	5.881	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.28	64.43	566.96	99.4	5.516	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.61	76.49	861.02	99.6	8.388	560	-240	38	1.026
SVC1_3	3	SVC1_3	Static Var Compensator	456	345	PV	0	455.99	455.99	0	4.69	456	-456	3	0.972
SVC2_9	9	SVC2_9	Static Var Compensator	294	345	PV	0	294.03	294.03	0	2.98	294	-294	9	0.987

No generator is overloaded in the above report table. Only the two Static VAR compensators are at the reactive limit which is of no concern.

TRANSFORMER TABLE:

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-822.94	-170.8	840.48	-97.9	8.394	154.2	4.23	127.54
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-14.69	-42.17	44.65	-32.9	0.483	101.1	0.04	1.02

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-851.98	33.26	852.63	-99.9	8.388	176.5	5.63	109.76
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.19	-45.83	46.39	15.5	0.502	73	0.04	1.1
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	84.85	4.04	84.95	99.9	0.862	-8.2	0.05	1.03
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-566.49	-103.41	575.85	-98.4	6.132	160.9	2.42	94.04
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-672.36	-99.97	679.75	-98.9	7.168	164.4	2.57	102.74
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-653.58	-19.19	653.86	-100	6.636	172.8	3.08	62.51
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-543.2	-99.98	552.32	-98.3	5.612	163.4	2.83	56.66
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-672.85	-191.25	699.5	-96.2	6.89	159.9	2.08	67.92
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-581.85	-130.83	596.38	-97.6	5.881	162.9	1.73	94.05
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-561.46	6.18	561.49	-100	5.516	168.2	1.83	70.61
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.27	538.56	93.1	5.229	-57.4	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.62	136.96	518.05	-96.4	5.251	-163.5	0.52	19.5

No transformer is overloaded after the SVC2 (at 9) annexation.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	84	1500	56	100	100						
T01	12	11	300	14.9	450	9.9	100	100						
T11	29	38	1000	85.3	1500	56.8	100	100						
T02	12	13	300	15.5	450	10.3	100	100						
T12	19	20	1000	8.5	1500	5.7	100	100						
T03	6	31	700	82.3	1050	54.8	100	100						
T04	10	32	800	85	1200	56.6	100	100						
T05	19	33	800	81.7	1200	54.5	100	100						
T06	20	34	600	92.1	900	61.4	100	100						
T07	22	35	800	87.4	1200	58.3	100	100						

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T08	23	36	700	85.2	1050	56.8	100	100						
T09	25	37	700	80.2	1050	53.5	100	100						
Tcul XMer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.8	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	827.17
G3	665	674.93
G4	647	656.66
G5	269	546.03
G6	665	674.93
G7	575	583.58
G8	555	563.28
G9	845	857.61
G1	1015	1030.15

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

STEP-3(SVC-3 at Bus No. 4 Addition):

After appending SVC_3, we have noticed that bus no. 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14 are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into the buses which are heavily under voltage among the aforementioned buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SVC of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	.924	88
4	.935	193.5
5	.936	36.19
6	.939	50.43
7	.929	89.7
8	.928	69.88

From the above table, it is noticed that bus no. 12 has the lowest per unit voltage but the lines associated with it are carrying 88 MVAR reactive powers. But bus no. 4 is not far good than bus no. 12 and additionally the line associated with it is carrying 193.5 MVAR reactive power which is roughly 2 times higher than case in bus no. 12. This relatively high MVAR is essentially affecting the voltages of adjacent buses of bus no. 4 (i.e. bus no. 5, 6, 7, 8) in an adverse way. So, we have appended a STATIC VAR COMPENSATOR (SVC_3) with Q-max of 194 and Q-min of -194 MVAR at bus no. 4.

After adding the SVC_3 (at 4) at bus no. 4 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SVC3 (at bus 4) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.011	-27.4	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.96	-7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.957	-7.6	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.938	-8	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.959	-8.2	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.961	-11.1	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.966	-12.8	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.984	-11.7	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.986	-14.1	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.984	-16.1	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.988	-5.2	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.006	-13.7	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.986	-5.9	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.991	-8.9	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.018	-4	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.017	-4.2	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.992	-11.5	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.022	-11.9	0.95	1.05	0	0	224	47.2	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
26	345	1.012	-12.5	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.994	-14.5	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.016	-8.4	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.018	-5.3	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.985	-18.2	0.95	1.05	0	456.08	322	2.4	800	387.46	0	0
30	16.5	1.048	-5.6	0.95	1.05	826.88	268.11	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	143.11	9.2	4.6	0	0	0	0
32	16.5	0.983	1.1	0.95	1.05	674.69	142.19	0	0	0	0	0	0
33	16.5	0.997	0.2	0.95	1.05	656.43	65.18	0	0	0	0	0	0
34	16.5	1.012	-0.3	0.95	1.05	545.84	149.04	0	0	0	0	0	0
35	16.5	1.049	1.1	0.95	1.05	674.69	240.23	0	0	0	0	0	0
36	16.5	1.064	4.2	0.95	1.05	583.38	214.24	0	0	0	0	0	0
37	16.5	1.028	-4.8	0.95	1.05	563.09	47.41	0	0	0	0	0	0
38	16.5	1.026	2	0.95	1.05	857.31	66.02	0	0	0	0	0	0
39	345	1.03	-35.5	0.95	1.05	1029.79	547.7	1104	250	0	0	0	0
4	345	0.962	-13.7	0.95	1.05	0	194	500	184	0	0	0	0
5	345	0.953	-9.6	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.954	-8.7	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.944	-9.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.944	-9.9	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1	1	0.95	1.05	0	286.65	0	0	0	0	0	0
B39_REC	100	1.016	-37.4	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.992	3	0.95	1.05	0	0	0	0	0	0	0	0

Here we can that bus no. 7, 8 and 12 are outside the voltage limit namely under voltage.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SVC3 ADDITION)

Bus ID	Voltage Before SVC_3 Addition(p.u)	Voltage After SVC_3 Addition(p.u)
10	.948	.96
11	.944	.957
12	.924	.938
13	.945	.959
14	.944	.961
15	.956	.966
16	.977	.984
17	.978	.986
18	.974	.984
3	.972	.985
4	.935	.962

Bus ID	Voltage Before SVC_3 Addition(p.u)	Voltage After SVC_3 Addition(p.u)
5	**.936**	**.953**
6	**.939**	**.954**
7	**.929**	**.944**
8	**.928**	**.944**
9	**.987**	**1.0**
9_INV	**.978**	**.992**

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit and the other buses mentioned in the table are within limit after addition of SVC_3.

BRANCH TABLE

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.61	67.83	81.18	54.9	0.852	-66.3	0.07	-12.35
L20	15	16	L20	Line	345	63	-198.37	-168.23	260.1	-76.3	2.692	126.9	0.63	-9.7
L30	25	26	L30	Line	345	216.5	31.97	0	31.97	100	0.313	-11.9	0.05	-52.51
L11	6	7	L11	Line	345	61.7	218.29	83.15	233.59	93.4	2.449	-29.5	0.36	-4.57
L21	16	17	L21	Line	345	59.7	451.75	-60.46	455.78	99.1	4.634	-4.1	1.49	6.02
L31	26	27	L31	Line	345	98.5	250.02	93.89	267.07	93.6	2.638	-33.1	1.01	-13.53
L12	6	11	L12	Line	345	55	-209.57	-23.3	210.87	-99.4	2.21	165	0.34	-8.7
L22	16	19	L22	Line	345	130.7	-563.06	43.19	564.72	-99.7	5.741	172.7	5.28	35.04
L32	26	28	L32	Line	345	317.7	-154.03	-27.64	156.49	-98.4	1.546	157.4	1	-69.18
L13	7	8	L13	Line	345	30.8	-15.87	3.72	16.3	-97.4	0.173	-176.7	0	-6.94
L23	16	21	L23	Line	345	90.5	-355.56	-34.69	357.25	-99.5	3.632	162.7	1.04	-7.12
L33	26	29	L33	Line	345	418.9	-203.08	-30.74	205.39	-98.9	2.029	158.9	2.32	-80.58
L14	8	9	L14	Line	345	243.3	-493.33	-85.17	500.63	-98.5	5.303	160.3	6.37	65.03
L24	16	24	L24	Line	345	39.5	-61.13	-138.86	151.72	-40.3	1.542	102	0.07	-5.29
L34	28	29	L34	Line	345	101.2	-361.02	13.94	361.29	-99.9	3.557	173.8	1.77	-6.56
L25	17	18	L25	Line	345	55	418.23	-3.63	418.24	100	4.241	-13.6	1.26	1.96
L16	10	11	L16	Line	345	28.8	224.82	52.8	230.94	97.4	2.404	-20.2	0.23	-4.2
L26	17	27	L26	Line	345	116	32.03	-62.86	70.55	45.4	0.715	48.9	0.04	-30.94
L17	10	13	L17	Line	345	28.8	447.41	-8.96	447.5	100	4.659	-5.9	0.87	2.62
L27	21	22	L27	Line	345	93	-630.6	-142.58	646.52	-97.5	6.525	158.4	3.34	32.96
L18	13	14	L18	Line	345	67.7	453.64	-59.24	457.49	99.2	4.77	-0.8	2.04	7
L28	22	23	L28	Line	345	64.3	38.71	-1.96	38.76	99.9	0.381	-1.1	0.01	-18.96
L19	14	15	L19	Line	345	145.4	121.94	-45.54	130.16	93.7	1.354	9.4	0.31	-30.31

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L29	23	24	L29	Line	345	234.6	372.87	53.78	376.73	99	3.705	-12.4	3.08	12.41
L1	1	2	L1	Line	345	275.5	-579.04	96.74	587.07	-98.6	5.806	162	12.08	70.71
L2	1	39	L2	Line	345	167.6	579.04	-96.74	587.07	98.6	5.806	-18	3.31	4.68
L3	2	3	L3	Line	345	101.2	530.39	106.59	541	98	5.375	-25	3.78	18.57
L4	2	25	L4	Line	345	57.6	-298.77	62.91	305.32	-97.9	3.034	178.2	6.54	-7.02
L5	3	4	L5	Line	345	142.8	-337.18	130.06	361.4	-93.3	3.67	-177.1	1.79	8.36
L6	3	18	L6	Line	345	89.1	-258.2	24.18	259.33	-99.6	2.633	167.2	0.77	-11.4
L7	4	5	L7	Line	345	85.8	-510.25	108.58	521.67	-97.8	5.425	178.3	2.36	25.56
L8	4	14	L8	Line	345	86.5	-328.72	23.12	329.54	-99.8	3.427	170.3	0.94	2.41
L9	5	6	L9	Line	345	17.4	-557.22	15.19	557.42	-100	5.848	172	0.68	4.95

From the above report, we can see that no line is giving the passage of reactive power of more than 200MVAR and only one line (Line no. 20) is giving gateway for reactive power flow of more than 150 MVAR but less than 200 MVAR.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SVC3 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SVC_3	Line MVAR After Addition of SVC_3
10	**5**	**8**	**60.24**	**67.83**
20	**15**	**16**	**-200.86**	**-168.23**
11	**6**	**7**	**236.08**	**83.15**
13	**7**	**8**	**9.64**	**3.72**
14	**8**	**9**	**-87.42**	**-85.17**
16	**10**	**11**	**73.33**	**52.8**
27	**21**	**22**	**-157.62**	**-142.58**
3	**2**	**3**	**154.05**	**106.59**
9	**5**	**6**	**-50.43**	**15.19**

After addition of third Static VAR Compensator at bus no. 4, we can see line MVAR is reduced in those line mentioned above in the table. The lines L20,,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit. No line is outside limit.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	826.88	268.11	869.26	95.1	8.298	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1029.8	547.7	1166.38	88.3	11.324	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	143.11	143.11	0	1.457	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.69	142.19	689.51	97.9	7.014	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.43	65.18	659.66	99.5	6.615	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	545.84	149.04	565.82	96.5	5.589	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.69	240.23	716.18	94.2	6.826	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.38	214.24	621.47	93.9	5.844	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.09	47.41	565.08	99.6	5.498	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.31	66.02	859.85	99.7	8.377	560	-240	38	1.026
SVC 3_4	4	SVC 3_4	Static Var Compensator	194	345	PV	0	194	194	0	2.017	194	-194	4	0.962
SVC 1_3	3	SVC 1_3	Static Var Compensator	456	345	PV	0	456.08	456.08	0	4.631	456	-456	3	0.985
SVC 2_9	9	SVC 2_9	Static Var Compensator	294	345	PV	0	286.65	286.65	0	2.867	294	-294	9	1

No generator is overloaded in the above generator table after the addition SVC_3.

TRANSFORMER TABLE

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed -Tap Xmer	1000	345	16.5	-822.75	-143.47	835.16	-98.5	8.298	156.5	4.13	124.64
T01	12	11	T01	Fixed -Tap Xmer	300	138	345	-14.64	-41.44	43.95	-33.3	0.469	101.5	0.04	0.96
T11	29	38	T11	Fixed -Tap Xmer	1000	345	16.5	-851.7	43.44	852.81	-99.9	8.377	177.6	5.61	109.46
T02	12	13	T02	Fixed -Tap Xmer	300	138	345	7.14	-46.56	47.11	15.2	0.502	73.3	0.04	1.1
T12	19	20	T12	Fixed -Tap Xmer	1000	345	230	85.02	11.21	85.76	99.1	0.868	-12.7	0.05	1.04
T03	6	31	T03	Fixed -Tap Xmer	700	345	16.5	-566.62	-49.61	568.79	-99.6	5.963	166.3	2.29	88.9
T04	10	32	T04	Fixed -Tap Xmer	800	345	16.5	-672.23	-43.83	673.66	-99.8	7.014	169.2	2.46	98.35
T05	19	33	T05	Fixed -Tap Xmer	800	345	16.5	-653.37	-3.06	653.37	-100	6.615	174.6	3.06	62.12
T06	20	34	T06	Fixed -Tap Xmer	600	230	16.5	-543.03	-92.83	550.9	-98.6	5.589	164.4	2.81	56.22
T07	22	35	T07	Fixed -Tap Xmer	800	345	16.5	-672.65	-173.58	694.68	-96.8	6.825	161.5	2.04	66.65
T08	23	36	T08	Fixed -Tap Xmer	700	345	16.5	-581.67	-121.38	594.2	-97.9	5.844	164	1.71	92.87
T09	25	37	T09	Fixed -Tap Xmer	700	345	16.5	-561.27	22.74	561.73	-99.9	5.498	170.4	1.81	70.15
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.28	538.56	93.1	5.229	-56.8	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.7	136.45	517.99	-96.5	5.18	-163.8	0.51	18.98

No transformer is overloaded in the above transformer table after the addition of SVC_3.

TRANSFORMER TABLE (% LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	83.5	1500	55.7	100	100						
T01	12	11	300	14.6	450	9.8	100	100						
T11	29	38	1000	85.3	1500	56.9	100	100						
T02	12	13	300	15.7	450	10.5	100	100						
T12	19	20	1000	8.6	1500	5.7	100	100						
T03	6	31	700	81.3	1050	54.2	100	100						
T04	10	32	800	84.2	1200	56.1	100	100						
T05	19	33	800	81.7	1200	54.4	100	100						
T06	20	34	600	91.8	900	61.2	100	100						
T07	22	35	800	86.8	1200	57.9	100	100						
T08	23	36	700	84.9	1050	56.6	100	100						
T09	25	37	700	80.2	1050	53.5	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.7	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	826.88
G3	665	674.69
G4	647	656.43
G5	269	545.84
G6	665	674.69
G7	575	583.38
G8	555	563.09
G9	845	857.31
G1	1015	1029.79

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

STEP-4 (SVC-4 at Bus No. 12 Addition):

After appending SVC_3, we have noticed that bus no. 7, 8 and 12 are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into the buses which are heavily under voltage among the aforementioned buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SVC of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	.924	88
7	.929	83.15
8	.928	71.55

Here we can observe that bus no. 12 has the lowest voltage in per unit and the lines associated with it are carrying the highest MVAR of 88. So the next target should be bus 12. Therefore, we have decided to append the next static VAR compensator SVC_4 at bus 12 with Q-max of 88 and Q-min of -88 MVAR.

After adding the SVC_4 (at 12) at bus no. 12 the modified situation and results are given below.

BUS REPORT

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.012	-27.3	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.968	-7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.965	-7.6	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.967	-8	0.95	1.05	0	88.09	7.5	88	0	0	0	0
13	345	0.968	-8.2	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.968	-11	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.97	-12.7	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.986	-11.6	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.988	-14	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.986	-16	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.988	-5.1	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.008	-13.5	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.986	-5.8	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.992	-8.8	0.95	1.05	0	0	274	115	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
22	345	1.019	-3.9	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.018	-4.1	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.994	-11.4	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.023	-11.8	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.013	-12.3	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.996	-14.4	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.016	-8.2	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.018	-5.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.987	-18.1	0.95	1.05	0	456.05	322	2.4	800	387.46	0	0
30	16.5	1.048	-5.5	0.95	1.05	826.79	261.55	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	120.96	9.2	4.6	0	0	0	0
32	16.5	0.983	1.1	0.95	1.05	674.62	103.8	0	0	0	0	0	0
33	16.5	0.997	0.3	0.95	1.05	656.36	60.14	0	0	0	0	0	0
34	16.5	1.012	-0.2	0.95	1.05	545.78	146.72	0	0	0	0	0	0
35	16.5	1.049	1.2	0.95	1.05	674.62	234.45	0	0	0	0	0	0
36	16.5	1.064	4.3	0.95	1.05	583.32	211	0	0	0	0	0	0
37	16.5	1.028	-4.7	0.95	1.05	563.03	43.59	0	0	0	0	0	0
38	16.5	1.026	2.1	0.95	1.05	857.22	63.37	0	0	0	0	0	0
39	345	1.03	-35.3	0.95	1.05	1029.68	545.79	1104	250	0	0	0	0
4	345	0.967	-13.6	0.95	1.05	0	194	500	184	0	0	0	0
5	345	0.959	-9.5	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.96	-8.6	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.949	-9.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.949	-9.8	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1	1	0.95	1.05	0	273.31	0	0	0	0	0	0
B39_REC	100	1.016	-37.2	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.992	3	0.95	1.05	0	0	0	0	0	0	0	0

From the bus table after SVC_4 addition, only two buses are outside of the pre-set voltage limit namely under voltage. And they are bus no. 7 and 8.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SVC_4 ADDITION)

Bus ID	Voltage Before SVC_4 Addition(p.u)	Voltage After SVC_4 Addition(p.u)
10	.96	.968
11	.957	.965
12	.938	.967
13	.959	.968
14	.961	.968
15	.966	.97
16	.984	.986
17	.986	.988
18	.984	.986
3	.985	.987
4	.962	.967
5	.953	.959
6	.954	.96
7	.944	.949
8	.944	.949
9	1.0	1.0
9_INV	.992	.992

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit and the other buses mentioned in the table are within limit after addition of SVC_4.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.6	73.48	85.96	51.9	0.897	-68.3	0.07	-12.39
L20	15	16	L20	Line	345	63	-198.6	-154.68	251.73	-78.9	2.596	129.4	0.58	-10.25
L30	25	26	L30	Line	345	216.5	32.26	-0.99	32.27	100	0.316	-10.1	0.05	-52.63
L11	6	7	L11	Line	345	61.7	218.21	88.9	235.63	92.6	2.456	-30.8	0.37	-4.65
L21	16	17	L21	Line	345	59.7	451.38	-60.53	455.42	99.1	4.62	-4	1.49	5.85
L31	26	27	L31	Line	345	98.5	250.23	90.84	266.21	94	2.627	-32.3	1	-13.69
L12	6	11	L12	Line	345	55	-209.16	-56	216.52	-96.6	2.257	156.4	0.35	-8.75

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L22	16	19	L22	Line	345	130.7	-562.96	50.11	565.18	-99.6	5.734	173.5	5.27	34.82
L32	26	28	L32	Line	345	317.7	-153.97	-26.54	156.24	-98.5	1.542	157.9	1	-69.34
L13	7	8	L13	Line	345	30.8	-15.95	9.55	18.59	-85.8	0.196	-159	0	-7
L23	16	21	L23	Line	345	90.5	-355.52	-30.26	356.81	-99.6	3.62	163.5	1.04	-7.31
L33	26	29	L33	Line	345	418.9	-203.05	-29.66	205.21	-99	2.025	159.3	2.32	-80.78
L14	8	9	L14	Line	345	243.3	-493.43	-73.57	498.89	-98.9	5.258	161.7	6.27	63.28
L24	16	24	L24	Line	345	39.5	-61.09	-136.04	149.13	-41	1.513	102.6	0.07	-5.37
L34	28	29	L34	Line	345	101.2	-360.97	15.19	361.29	-99.9	3.555	174.2	1.77	-6.6
L25	17	18	L25	Line	345	55	418.09	-6.25	418.14	100	4.231	-13.1	1.25	1.82
L16	10	11	L16	Line	345	28.8	224.65	39.76	228.14	98.5	2.356	-17.1	0.22	-4.41
L26	17	27	L26	Line	345	116	31.81	-60.14	68.04	46.8	0.688	48.1	0.04	-31.11
L17	10	13	L17	Line	345	28.8	447.56	-32.34	448.72	99.7	4.634	-2.9	0.86	2.39
L27	21	22	L27	Line	345	93	-630.56	-137.95	645.47	-97.7	6.505	158.9	3.32	32.56
L18	13	14	L18	Line	345	67.7	454.11	-37.86	455.69	99.7	4.708	-3.4	1.99	6.19
L28	22	23	L28	Line	345	64.3	38.71	-2.33	38.78	99.8	0.381	-0.5	0.01	-18.99
L19	14	15	L19	Line	345	145.4	121.69	-32.54	125.96	96.6	1.301	3.9	0.29	-30.86
L29	23	24	L29	Line	345	234.6	372.82	50.54	376.23	99.1	3.697	-11.8	3.06	12.07
L1	1	2	L1	Line	345	275.5	-579.15	94.96	586.88	-98.7	5.801	162	12.05	70.34
L2	1	39	L2	Line	345	167.6	579.15	-94.96	586.88	98.7	5.801	-18	3.3	4.55
L3	2	3	L3	Line	345	101.2	529.9	96.51	538.62	98.4	5.346	-23.8	3.74	17.95
L4	2	25	L4	Line	345	57.6	-298.42	65.62	305.55	-97.7	3.033	178.9	6.53	-7.05
L5	3	4	L5	Line	345	142.8	-337.76	118.21	357.85	-94.4	3.624	-178.8	1.74	7.42
L6	3	18	L6	Line	345	89.1	-258.07	26.53	259.43	-99.5	2.627	167.8	0.76	-11.54
L7	4	5	L7	Line	345	85.8	-510	107.19	521.14	-97.9	5.39	178.2	2.33	24.93
L8	4	14	L8	Line	345	86.5	-329.51	13.6	329.79	-99.9	3.411	168.7	0.93	2.1
L9	5	6	L9	Line	345	17.4	-556.92	8.77	556.99	-100	5.811	171.4	0.68	4.79

From the above report, we can see that no line is giving the passage of reactive power of more than 200MVAR and only one line (Line no. 20) is giving gateway for reactive power flow of more than 150 MVAR but less than 200 MVAR. L24 and L27 are carrying 136.04 and 137.95 MVAR reactive power.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SVC_4 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SVC_4	Line MVAR After Addition of SVC_4
10	5	8	67.83	73.48
20	15	16	-168.23	-154.68
11	6	7	83.15	88.9
13	7	8	3.72	9.55
14	8	9	-85.17	-73.57
16	10	11	52.8	39.76
27	21	22	-142.58	-137.95
3	2	3	106.59	96.51
9	5	6	15.19	8.77

After addition of fourth Static VAR Compensator at bus no. 12, we can see line MVAR is reduced in those line mentioned above in the table. The lines L20,L27 which are highlighted with yellow color are improved in terms of their MVAR but their MVARs are greater than 150. And the MVARs are less than 100 in the rest of the lines mentioned above in the table.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	826.79	261.55	867.17	95.3	8.278	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1029.68	545.79	1165.39	88.4	11.32	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	120.96	120.96	0	1.232	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.62	103.8	682.56	98.8	6.943	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.36	60.14	659.11	99.6	6.609	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	545.78	146.72	565.16	96.6	5.583	336	-144	34	1.012

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G6	35	G6	Generator	800	16.5	PV	674.62	234.45	714.2	94.5	6.807	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.32	211	620.3	94	5.833	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.03	43.59	564.71	99.7	5.494	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.22	63.37	859.56	99.7	8.374	560	-240	38	1.026
SVC3_4	4	SVC3_4	Static Var Compensator	194	345	PV	0	194	194	0	2.006	194	-194	4	0.967
SVC4_12	12	SVC4_12	Static Var Compensator	88	138	PV	0	88.09	88.09	0	0.911	88	-88	12	0.967
SVC1_3	3	SVC1_3	Static Var Compensator	456	345	PV	0	456.05	456.05	0	4.619	456	-456	3	0.987
SVC2_9	9	SVC2_9	Static Var Compensator	294	345	PV	0	273.31	273.31	0	2.733	294	-294	9	1

No generator in the above report is operating under overload condition.

TRANSFORMER REPORT

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-822.68	-137.51	834.09	-98.6	8.278	157	4.11	124.04
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-14.92	3.18	15.25	-97.8	0.158	-176	0	0.11
T11	29	38	T11	Fixed-Tap	1000	345	16.5	-851.61	46.01	852.85	-99.9	8.374	177.9	5.61	109.3

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
				Xmer											9
T02	12	13	T02	Fixed -Tap Xmer	300	138	345	7.42	-3.09	8.04	92.3	0.083	14.6	0	0.03
T12	19	20	T12	Fixed -Tap Xmer	1000	345	230	85.08	13.41	86.13	98.8	0.871	-14	0.05	1.05
T03	6	31	T03	Fixed -Tap Xmer	700	345	16.5	-566.66	-28.92	567.39	-99.9	5.913	168.4	2.25	87.44
T04	10	32	T04	Fixed -Tap Xmer	800	345	16.5	-672.21	-7.42	672.25	-100	6.943	172.4	2.41	96.38
T05	19	33	T05	Fixed -Tap Xmer	800	345	16.5	-653.3	1.88	653.3	-100	6.609	175.1	3.06	62.01
T06	20	34	T06	Fixed -Tap Xmer	600	230	16.5	-542.98	-90.64	550.49	-98.6	5.583	164.8	2.8	56.09
T07	22	35	T07	Fixed -Tap Xmer	800	345	16.5	-672.59	-168.17	693.29	-97	6.807	162.1	2.03	66.28
T08	23	36	T08	Fixed -Tap Xmer	700	345	16.5	-581.62	-118.48	593.56	-98	5.833	164.4	1.7	92.52
T09	25	37	T09	Fixed -Tap Xmer	700	345	16.5	-561.22	26.46	561.84	-99.9	5.494	170.9	1.81	70.05
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.28	538.56	93.1	5.229	-56.7	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.7	136.45	517.99	-96.5	5.18	-163.7	0.51	18.98

No transformer is overloaded after addition of SVC_4 at bus no. 12.

TRANSFORMER REPORT (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	83.4	1500	55.6	100	100						
T01	12	11	300	5.1	450	3.4	100	100						
T11	29	38	1000	85.3	1500	56.9	100	100						
T02	12	13	300	2.7	450	1.8	100	100						
T12	19	20	1000	8.6	1500	5.7	100	100						
T03	6	31	700	81.1	1050	54	100	100						
T04	10	32	800	84	1200	56	100	100						
T05	19	33	800	81.7	1200	54.4	100	100						
T06	20	34	600	91.7	900	61.2	100	100						
T07	22	35	800	86.7	1200	57.8	100	100						
T08	23	36	700	84.8	1050	56.5	100	100						
T09	25	37	700	80.3	1050	53.5	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.7	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	826.79
G3	665	674.62
G4	647	656.36
G5	269	545.78
G6	665	674.62
G7	575	583.32
G8	555	563.03
G9	845	857.22
G1	1015	1029.68

The distributed swing report illustrates that the targeted real power generation and the power calculated through distributed swing mechanism are slightly different. As we have seen before the swing calculated power accounts for the losses of the network.

STEP-5 (SVC_3 and SVC_4 ADJUSTMENT):

After appending SVC_4 at bus 12, we have noticed that the voltages at bus 7 and 8 are yet to be within the safe voltage limit (0.949 and 0.949 per unit). Literally they are at a stone's throw from the desired voltage limit. So adding another SVC would seem less efficient and costly. Therefore we have decided to increase the positive and negative reactive limits of the existing static VAR compensators by a necessary amount. Here we have followed some randomized guessing. And finally we have increased the Q-max and Q-min of SVC_3 to +215 and -215 MVAR. Likewise, we have also increased the Q-max and Q-min of SVC_4 to +90 and -90 MVAR.

After adjusting SVC_3 (at bus 4) and SVC_4 (at bus 12) the modified situation and results are given below.

BUS REPORT

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.012	-27.2	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.969	-7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.967	-7.6	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.968	-8	0.95	1.05	0	90.07	7.5	88	0	0	0	0
13	345	0.969	-8.2	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.97	-11	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.971	-12.6	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.986	-11.6	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.989	-14	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.987	-16	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.989	-5.1	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.008	-13.5	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.986	-5.7	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.993	-8.8	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.019	-3.9	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.018	-4.1	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.995	-11.4	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.023	-11.8	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.014	-12.3	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.996	-14.3	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.016	-8.2	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.019	-5.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.989	-18	0.95	1.05	0	456	322	2.4	800	387.46	0	0
30	16.5	1.048	-5.4	0.95	1.05	826.77	258.53	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	115.54	9.2	4.6	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
32	16.5	0.983	1.1	0.95	1.05	674.6	97.62	0	0	0	0	0	0
33	16.5	0.997	0.3	0.95	1.05	656.34	58.47	0	0	0	0	0	0
34	16.5	1.012	-0.2	0.95	1.05	545.77	145.96	0	0	0	0	0	0
35	16.5	1.049	1.3	0.95	1.05	674.6	232.55	0	0	0	0	0	0
36	16.5	1.064	4.3	0.95	1.05	583.3	209.93	0	0	0	0	0	0
37	16.5	1.028	-4.6	0.95	1.05	563.01	41.89	0	0	0	0	0	0
38	16.5	1.026	2.1	0.95	1.05	857.2	62.32	0	0	0	0	0	0
39	345	1.03	-35.3	0.95	1.05	1029.65	544.89	1104	250	0	0	0	0
4	345	0.97	-13.6	0.95	1.05	0	215.09	500	184	0	0	0	0
5	345	0.96	-9.5	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.961	-8.6	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.951	-9.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.95	-9.8	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1	1	0.95	1.05	0	269.77	0	0	0	0	0	0
B39_REC	100	1.016	-37.2	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.992	3	0.95	1.05	0	0	0	0	0	0	0	0

From the above bus voltage report, we can say that no bus voltage is outside the pre-set safe limit.

BUS VOLTAGE IMPROVEMENT COMPARISON(AFTER SVC(3,4) ADJUSTMENT)

Bus ID	Voltage Before SVC_(3,4) adjustment(p.u)	Voltage After SVC_(3,4) adjustment(p.u)
10	.968	.969
11	.965	.967
12	.967	.968
13	.968	.969
14	.968	.97
15	.97	.971
16	.986	.986
17	.988	.989
18	.986	.987
3	.987	.989
4	.967	.97
5	.959	.96
6	.96	.961
7	.949	.951
8	.949	.95
9	1.0	1.0
9_INV	.992	.992

If we take a closer look at the bus voltage improvement table, we can see that all the voltages of the buses under focus are within limit.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.59	75.83	87.97	50.7	0.916	-69.1	0.08	-12.39
L20	15	16	L20	Line	345	63	-198.86	-151.28	249.87	-79.6	2.574	130.1	0.57	-10.38
L30	25	26	L30	Line	345	216.5	32.41	-1.26	32.43	99.9	0.317	-9.6	0.05	-52.67
L11	6	7	L11	Line	345	61.7	218.2	89.61	235.88	92.5	2.455	-31	0.37	-4.68
L21	16	17	L21	Line	345	59.7	451.09	-61.7	455.29	99.1	4.615	-3.8	1.48	5.79
L31	26	27	L31	Line	345	98.5	250.36	89.75	265.96	94.1	2.623	-32	0.99	-13.75
L12	6	11	L12	Line	345	55	-209.23	-55.57	216.49	-96.6	2.253	156.5	0.35	-8.8
L22	16	19	L22	Line	345	130.7	-562.93	52.4	565.37	-99.6	5.731	173.7	5.27	34.76
L32	26	28	L32	Line	345	317.7	-153.96	-26.11	156.15	-98.6	1.54	158.1	1	-69.4
L13	7	8	L13	Line	345	30.8	-15.97	10.29	18.99	-84.1	0.2	-157.1	0	-7.02
L23	16	21	L23	Line	345	90.5	-355.52	-28.8	356.68	-99.7	3.616	163.8	1.04	-7.38
L33	26	29	L33	Line	345	418.9	-203.05	-29.23	205.14	-99	2.023	159.5	2.32	-80.85
L14	8	9	L14	Line	345	243.3	-493.46	-70.47	498.46	-99	5.247	162.1	6.24	62.84
L24	16	24	L24	Line	345	39.5	-61.09	-135.11	148.28	-41.2	1.503	102.7	0.07	-5.39
L34	28	29	L34	Line	345	101.2	-360.95	15.69	361.29	-99.9	3.554	174.3	1.77	-6.62
L25	17	18	L25	Line	345	55	417.94	-8.32	418.02	100	4.226	-12.8	1.25	1.77
L16	10	11	L16	Line	345	28.8	224.73	38.13	227.94	98.6	2.351	-16.6	0.22	-4.44
L26	17	27	L26	Line	345	116	31.67	-59.17	67.12	47.2	0.679	47.9	0.04	-31.18
L17	10	13	L17	Line	345	28.8	447.47	-36.63	448.96	99.7	4.631	-2.3	0.86	2.36
L27	21	22	L27	Line	345	93	-630.55	-136.42	645.14	-97.7	6.499	159	3.31	32.42
L18	13	14	L18	Line	345	67.7	454.03	-41.26	455.9	99.6	4.703	-3	1.99	6.08
L28	22	23	L28	Line	345	64.3	38.71	-2.46	38.79	99.8	0.381	-0.2	0.01	-19
L19	14	15	L19	Line	345	145.4	121.42	-29.29	124.9	97.2	1.288	2.6	0.29	-31.01
L29	23	24	L29	Line	345	234.6	372.81	49.47	376.08	99.1	3.694	-11.6	3.06	11.95
L1	1	2	L1	Line	345	275.5	-579.17	94.14	586.77	-98.7	5.799	162	12.04	70.15
L2	1	39	L2	Line	345	167.6	579.17	-94.14	586.77	98.7	5.799	-18	3.3	4.48
L3	2	3	L3	Line	345	101.2	529.71	91.73	537.6	98.5	5.333	-23.3	3.72	17.68
L4	2	25	L4	Line	345	57.6	-298.26	67.01	305.7	-97.6	3.032	179.2	6.53	-7.06
L5	3	4	L5	Line	345	142.8	-338.08	111.7	356.05	-95	3.601	-179.7	1.72	6.96
L6	3	18	L6	Line	345	89.1	-257.93	28.49	259.49	-99.4	2.625	168.3	0.76	-11.6
L7	4	5	L7	Line	345	85.8	-510.1	115.76	523.07	-97.5	5.395	179.2	2.34	24.97
L8	4	14	L8	Line	345	86.5	-329.7	20.07	330.31	-99.8	3.407	169.9	0.93	2.02
L9	5	6	L9	Line	345	17.4	-557.02	14.97	557.22	-100	5.804	172	0.67	4.76

Only L20 is allowing a MVAR flow of greater than 151.28(greater than 150 but less than 200).

LINE MVAR IMPROVEMENT COMPARISION (AFTER SVC ADJUSTMENT)

Line Id	From Bus	To Bus	Line MVAR Before Adjustment of SVC_(3,4)	Line MVAR After Adjustment of SVC_(3,4)
10	5	8	73.48	75.83
20	15	16	-154.68	-151.28
11	6	7	88.9	89.61
13	7	8	9.55	10.29
14	8	9	-73.57	-70.47
16	10	11	39.76	38.13
27	21	22	-137.95	-136.42
3	2	3	96.51	91.73
9	5	6	8.77	14.97

After adjustment of third and fourth Static VAR Compensator at bus no. 4 and 12 respectively, we can see line MVAR is reduced in those line mentioned above in the table which we are focusing. The line L20 which is highlighted with yellow color is improved in terms of its MVAR and its value is greater than 150. And the MVARs are less than 150 in the rest of the lines mentioned above in the table.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled Bus ID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	826.77	258.53	866.25	95.4	8.27	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1029.65	544.89	1164.95	88.4	11.31	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	115.54	115.54	0	1.177	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.6	97.62	681.63	99	6.934	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.34	58.47	658.94	99.6	6.608	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	545.77	145.96	564.95	96.6	5.581	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.6	232.55	713.56	94.5	6.801	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.3	209.93	619.93	94.1	5.829	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.01	41.89	564.57	99.7	5.493	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.2	62.32	859.46	99.7	8.373	560	-240	38	1.026
SVC3_4	4	SVC3_4	Static Var Compensator	215	345	PV	0	215.09	215.09	0	2.218	215	-215	4	0.97

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled Bus ID	Ctrld Bus/V [pu]
SVC4_12	12	SVC4_12	Static Var Compensator	90	138	PV	0	90.07	90.07	0	0.93	90	-90	12	0.968
SVC1_3	3	SVC1_3	Static Var Compensator	456	345	PV	0	456	456	0	4.612	456	-456	3	0.989
SVC2_9	9	SVC2_9	Static Var Compensator	294	345	PV	0	269.77	269.77	0	2.698	294	-294	9	1

From the generator table, it is noticed that all the generators are operating within their rating and no generator is overloaded.

TRANSFORMER TABLE

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-822.67	-134.75	833.63	-98.7	8.27	157.2	4.1	123.78
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-14.92	4.31	15.53	-96.1	0.16	-171.9	0	0.11
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-851.59	47.04	852.89	-99.8	8.373	178	5.61	109.36
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.42	-2.24	7.75	95.7	0.08	8.8	0	0.03
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	85.09	14.13	86.25	98.6	0.872	-14.5	0.05	1.05
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-566.66	-23.82	567.16	-99.9	5.902	169	2.24	87.12
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-672.2	-1.5	672.2	-100	6.934	172.9	2.4	96.12
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-653.29	3.51	653.29	-100	6.608	175.3	3.06	61.98
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-542.96	-89.92	550.36	-98.7	5.581	164.9	2.8	56.04
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-672.57	-166.39	692.85	-97.1	6.8	162.2	2.02	66.16
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-581.6	-117.52	593.36	-98	5.829	164.5	1.7	92.4
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-561.2	28.13	561.91	-99.9	5.493	171.1	1.81	70.02

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.28	538.56	93.1	5.229	-56.6	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.7	136.45	517.99	-96.5	5.18	-163.7	0.51	18.98

From the above transformer report, we can see that no transformer is operating under overloaded condition.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	83.4	1500	55.6	100	100						
T01	12	11	300	5.2	450	3.5	100	100						
T11	29	38	1000	85.3	1500	56.9	100	100						
T02	12	13	300	2.6	450	1.7	100	100						
T12	19	20	1000	8.6	1500	5.8	100	100						
T03	6	31	700	81	1050	54	100	100						
T04	10	32	800	84	1200	56	100	100						
T05	19	33	800	81.7	1200	54.4	100	100						
T06	20	34	600	91.7	900	61.2	100	100						
T07	22	35	800	86.6	1200	57.7	100	100						
T08	23	36	700	84.8	1050	56.5	100	100						
T09	25	37	700	80.3	1050	53.5	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.7	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING REPORT

ID	P Desired [MW]	P calculated [MW]
G10	815	826.77
G3	665	674.6
G4	647	656.34
G5	269	545.77
G6	665	674.6
G7	575	583.3
G8	555	563.01
G9	845	857.2
G1	1015	1029.65

The distributed swing report illustrates that the targeted real power generation and the power calculated through distributed swing mechanism are slightly different. As we have seen before the swing calculated power accounts for the losses of the network.

STATIC LOAD TABLE

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

The load summary is the same as the static load data that was calculated in increasing active generation part, and no additional analysis is required in this part. Only L12 is under-loaded as it is highlighted. There is no effect on the static load side after adding distributed swing.

DC LINE TABLE (DC QUANTITIES)

ID	Bus From	Bus To	DBase ID	DC Current	DC Power Losses	PF (Rectifier)	PF (Inverter)	DC Voltage (Rectifier)	DC Voltage (Inverter)	DC Power (Rectifier)	DC Power (Inverter)
DC1	B39_REC	B9_INV	DC1	1000	1	0.93	0.96	500	499	501	500

Here, the DC bus voltages are 500(at rectifier), 499(at inverter), DC power flow 501(at rectifier), 500(at inverter) are shown.

DC LINE TABLE (AC QUANTITIES)

ID	Bus From	Bus To	D Base ID	AC Volt (Rectifier)	AC Volt (Inverter)	P to Converter (Rectifier)	Q to Converter (Rectifier)	P to Converter (Inverter)	Q to Converter (Inverter)	P from Network (Rectifier)	Q from Network (Rectifier)	P from Network (Inverter)	Q from Network (Inverter)
DC1	B39_REC	B9_INV	DC1	102	99.2	501	177	-500	117	502	196	-500	136

Here, we can see that the power to converter (at rectifier) is 501, power to converter (at inverter) is -500, power from network (at rectifier) is 502, and power from network (at inverter) is -500.

MOTOR TABLE

ID	Bus ID	DBase ID	Type	V sol [pu]	S [MVA]	P. Factor [%]	I [pu]
IM1	3	IM1	Induction Motor	0.989	888.89	90	8.991

Our system supports inclusion of 10 induction motor with load flow converging. Here, we can see all the motors are running with 0.9 power factor. Due to heavy lagging reactive power consumption, reactive current component is flowing considerably toward bus no. 03. Therefore the bus voltage of the induction motors was outside the voltage limit namely heavily under voltage. But after adding Static VAR Compensator, we see that the bus voltage of the induction motors is now within limit which is 0.989 pu.

SUMMARY REPORT

Summary Data	Active Power	Reactive Power
Total generation	6411.246	2798.629
Spinning reserve	8978.754	
Static Load	6097.1	1408.9
Shunt loads	0	0
Motor loads	800	387.458
Total load	6897.1	1796.358
Line / cable losses	64.624	-94.632
Transformer losses	26.828	802.484
Total losses	92.451	1001.852
Mismatches	-578.306	0.419

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, and transformers losses. This data gives an overview of the power condition of the system.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	Zone	kV Base	Vmin - [pu]	Vmax - [pu]	V sol - [pu]	Ang sol - [deg]
36	0	16.5	0.95	1.05	1.064	4.3
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]	Emergency Loading Limit - [pu]	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [pu]	Loading Limit - [pu]		
L10	5	8	0.916	4.482		
L20	15	16	2.574	4.482		
L30	25	26	0.317	4.482		
L11	6	7	2.455	4.482		
L31	26	27	2.623	4.482		
L12	6	11	2.253	4.482		
L32	26	28	1.54	4.482		
L13	7	8	0.2	4.482		
L23	16	21	3.616	4.482		
L33	26	29	2.023	4.482		
L24	16	24	1.503	4.482		
L34	28	29	3.554	4.482		
L25	17	18	4.226	4.482		
L16	10	11	2.351	4.482		
L26	17	27	0.679	4.482		
L28	22	23	0.381	4.482		
L19	14	15	1.288	4.482		
L29	23	24	3.694	4.482		
L4	2	25	3.032	4.482		
L5	3	4	3.601	4.482		
L6	3	18	2.625	4.482		
L8	4	14	3.407	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						

ID						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	15.531	150		
T02	12	13	7.752	150		
T12	19	20	86.254	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload but not overload condition exists in the system being analyzed. Bus no. 36 is over voltage which is outside the voltage limit.

Bus no. 36 is a purely generator connected bus; it can be called voltage controlled bus. As we know for load flow solution the magnitude of the voltage of the voltage controlled bus is a known quantity and therefore it must be fixed all the way through load flow analysis. It can alter its value in the case of its reactive limit violation. In that case, bus 36 will behave as PQ bus. But the reactive limit of the generator 7 (G07) is not violated. And therefore bus voltage of 36 is always a fixed quantity and that is 1.064 per unit which is outside the voltage limit of .95 to 1.05.

SHUNT CAPACITOR COMPENSATION:

STEP-1(SC-1 at Bus No. 3 Addition):

From the standpoint of logical intuition, it is decided to append a SHUNT CAPACITOR element to bus 3 where 10 industrial induction motor loads are already attached. The industrial induction motor loads are at 0.9 lagging power factor and with a 90 percent efficiency level. Therefore, they consume a considerable amount of reactive power and thereby play a vital role in increasing the reactive current component in the power system network line. As, we know the effect of line loss and line voltage drop are rendered severe due to this reactive current component in the lines of the power network, it is imperative that this lagging reactive power flow and flow of reactive component of the current in the lines be mitigated with great care.

To illustrate, we have followed a methodology built-up on the admixture of smart guess and logical intuition. As our main focus for step one is bus no.3, we can simultaneously describe and work our way out in solving the low voltage level of the bus no. 3.

BUS TABLE (with focus on bus no. 03) :

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
3	345	0.891	-20.7	0.95	1.05	0	0	322	2.4	800	387.46	0	0

BRANCH TABLE (with focus on the line L3 to bus no. 3)

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]
L3	2	3	L3	Line	345	101.2	546.29	455.86	711.51	76.8	7.353	-55.5

From the aforementioned extracted sections of our previous informative tables in the point of distributed swing application, we have noticed that the per unit voltage level at bus no. 3 is 0.891 and line no. 3 (L3) has gone into bus 3. The Reactive power flowing through the line is 455.86 MVAR. So, we have appended a SHUNT CAPACITOR with Q-RATING of 456 MVAR After adding the SC1_ (at 3) at bus no. 3 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SC1_ (at bus 3) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.005	-29.2	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.915	-7.5	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.904	-8.1	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.886	-8.5	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.912	-8.8	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.911	-12	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.936	-14	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.963	-13	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.963	-15.5	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.955	-17.7	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.981	-6.3	0.95	1.05	0	0	0	0	0	0	0	0
2	345	0.991	-15.1	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.982	-7	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.977	-10.1	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.01	-5.1	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.009	-5.3	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.974	-12.8	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.011	-13.5	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	0.999	-13.9	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.976	-16	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.009	-9.7	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.013	-6.7	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.948	-19.9	0.95	1.05	0	0	322	2.4	800	387.46	0	-456
30	16.5	1.048	-6.9	0.95	1.05	828.93	356.45	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	409.03	9.2	4.6	0	0	0	0
32	16.5	0.983	1	0.95	1.05	676.37	365.85	0	0	0	0	0	0
33	16.5	0.997	-0.9	0.95	1.05	658.06	113.42	0	0	0	0	0	0
34	16.5	1.012	-1.4	0.95	1.05	547.19	171.29	0	0	0	0	0	0
35	16.5	1.049	0.1	0.95	1.05	676.37	295.59	0	0	0	0	0	0
36	16.5	1.064	3.2	0.95	1.05	584.83	245.41	0	0	0	0	0	0
37	16.5	1.028	-6.3	0.95	1.05	564.49	97.09	0	0	0	0	0	0
38	16.5	1.026	0.7	0.95	1.05	859.44	96.95	0	0	0	0	0	0
39	345	1.03	-37.2	0.95	1.05	1032.35	572.84	1104	250	0	0	0	0
4	345	0.895	-15	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.881	-10.3	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.887	-9.2	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.855	-10.6	0.95	1.05	0	0	233.8	84	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
8	345	0.845	-10.5	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.757	6.2	0.95	1.05	0	0	0	0	0	0	0	0
B39_REC	100	1.016	-39.2	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.746	9.8	0.95	1.05	0	0	0	0	0	0	0	0

Bus no. 10,11,12,13,14,15,4,5,6,7,8,9 and 9_INV are outside the voltage limit and in fact they are experiencing under voltages. And the bus no. 36 is experiencing over voltage.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SC_1 ADDITION)

Bus ID	Voltage Before SC_1 Addition(p.u)	Voltage After SC_1 Addition(p.u)
10	.896	0.915
11	.884	0.904
12	.865	0.886
13	.891	0.912
14	.885	0.911
15	.915	0.936
16	.944	0.963
17	.934	0.963
18	.915	0.955
3	.891	0.948
4	.861	0.895
5	.855	0.881
6	.864	0.887
7	.829	0.855
8	.817	0.845
9	.719	0.757
9_INV	.707	0.746

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit.

BRANCH TABLE:

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	50.17	273.09	277.66	18.1	3.153	-89.8	0.83	0.6
L20	15	16	L20	Line	345	63	-194.8	-259.58	324.54	-60	3.467	112.9	1.04	-4.54
L30	25	26	L30	Line	345	216.5	27.68	7.73	28.74	96.3	0.284	-29.1	0.06	-51.17
L11	6	7	L11	Line	345	61.7	220.45	286.49	361.49	61	4.077	-61.7	1.01	7.01
L21	16	17	L21	Line	345	59.7	459.93	-26.13	460.67	99.8	4.781	-9.7	1.59	7.87
L31	26	27	L31	Line	345	98.5	247.67	124.84	277.36	89.3	2.777	-40.7	1.12	-11.57

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L12	6	11	L12	Line	345	55	-205.61	-177.41	271.56	-75.7	3.062	130	0.64	-3.65
L22	16	19	L22	Line	345	130.7	-565.68	-20.81	566.06	-99.9	5.875	164.9	5.5	38.5
L32	26	28	L32	Line	345	317.7	-155.15	-40	160.23	-96.8	1.604	151.6	1.03	-67.19
L13	7	8	L13	Line	345	30.8	-14.36	195.48	196	-7.3	2.292	-104.8	0.21	-3.15
L23	16	21	L23	Line	345	90.5	-356.93	-75.59	364.84	-97.8	3.787	155.1	1.13	-4.85
L33	26	29	L33	Line	345	418.9	-203.89	-42.93	208.36	-97.9	2.086	154.2	2.38	-78.07
L14	8	9	L14	Line	345	243.3	-487.24	295.12	569.65	-85.5	6.743	-159.3	10.66	144.73
L24	16	24	L24	Line	345	39.5	-62.17	-164.81	176.14	-35.3	1.828	97.7	0.1	-4.47
L34	28	29	L34	Line	345	101.2	-362.19	-0.41	362.19	-100	3.59	170.2	1.8	-5.96
L25	17	18	L25	Line	345	55	423.79	55.85	427.45	99.1	4.439	-23	1.38	4.09
L16	10	11	L16	Line	345	28.8	221.82	209.41	305.05	72.7	3.333	-50.9	0.45	-1.19
L26	17	27	L26	Line	345	116	34.55	-89.85	96.27	35.9	1	53.4	0.1	-28.95
L17	10	13	L17	Line	345	28.8	451.49	34.11	452.77	99.7	4.946	-11.8	0.98	4.45
L27	21	22	L27	Line	345	93	-632.05	-185.74	658.78	-95.9	6.746	153.5	3.56	37.42
L18	13	14	L18	Line	345	67.7	458.05	-23.87	458.67	99.9	5.03	-5.8	2.27	11.21
L28	22	23	L28	Line	345	64.3	38.59	1.64	38.62	99.9	0.382	-7.5	0.01	-18.67
L19	14	15	L19	Line	345	145.4	125.83	-130.18	181.06	69.5	1.988	33.9	0.63	-23.6
L29	23	24	L29	Line	345	234.6	374.13	84.4	383.53	97.5	3.801	-18	3.26	16.26
L1	1	2	L1	Line	345	275.5	-576.52	120.36	588.95	-97.9	5.86	162.6	12.36	75.47
L2	1	39	L2	Line	345	167.6	576.52	-120.36	588.95	97.9	5.86	-17.4	3.35	6.28
L3	2	3	L3	Line	345	101.2	539.85	243.57	592.25	91.2	5.975	-39.4	4.71	30.66
L4	2	25	L4	Line	345	57.6	-304.25	23.46	305.15	-99.7	3.078	169.3	6.69	-6.45
L5	3	4	L5	Line	345	142.8	-323.3	264.07	417.44	-77.4	4.401	-160.6	2.59	23.71
L6	3	18	L6	Line	345	89.1	-263.56	-30.8	265.35	-99.3	2.798	153.5	0.85	-9.04
L7	4	5	L7	Line	345	85.8	-497.1	144.21	517.6	-96	5.786	-178.8	2.69	32.52
L8	4	14	L8	Line	345	86.5	-328.79	-87.85	340.33	-96.6	3.804	150.1	1.14	7.25
L9	5	6	L9	Line	345	17.4	-549.95	-161.4	573.15	-96	6.508	153.4	0.85	7.61

Line no. 10, 20, 11,14,16,3,5 are burdened with reactive power flow of more than 200 MVAR. And Line 12, 13, 24, 27, 9 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SC_1 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SC_1	Line MVAR After Addition of SC_1
10	5	8	282.12	273.09
20	15	16	-275.89	-259.58
11	6	7	308.22	286.49
13	7	8	214.25	195.48
14	8	9	319.76	295.12
16	10	11	235.24	209.41
27	21	22	-225.59	-185.74
3	2	3	455.86	243.57
9	5	6	-230.2	-161.4

After addition of first Shunt Capacitor at bus no. 3, we can see line MVAR is reduced in those line mentioned in the table above. The lines L9,L13,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit. And the other lines L3,L10,L11,L14,L16,L20 which are highlighted with red color are improved in terms of MVAR but they are still outside limit.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	828.93	356.45	902.32	91.9	8.614	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1032.35	572.84	1180.63	87.4	11.46	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	409.03	409.03	0	4.165	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	676.37	365.85	768.97	88	7.822	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	658.06	113.42	667.76	98.5	6.696	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	547.19	171.29	573.38	95.4	5.664	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	676.37	295.59	738.14	91.6	7.035	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	584.83	245.41	634.23	92.2	5.964	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	564.49	97.09	572.77	98.6	5.573	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	859.44	96.95	864.89	99.4	8.426	560	-240	38	1.026

No generator is overloaded in the above report table.

SHUNT CAPACITOR TABLE

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	R [MW]	X [MVAR]	Type
SC1_3	3	SC1_3	0	-443.1	443.1	0	0	-456	Shunt Capacitor

Here we used a shunt capacitor of rating 456 MVAR in our first step from our logical intution. From the above table we see that it works with 443.1 MVAR. So we can say that our addition of first shunt capacitor is compatible with our system.

TRANSFORMER REPORT

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-824.48	-222.14	853.88	-96.6	8.614	149.8	4.45	134.3
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-15.1	-36	39.04	-38.7	0.44	104.2	0.03	0.84
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-853.76	13.79	853.87	-100	8.426	174.3	5.68	110.75
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.6	-52	52.55	14.5	0.593	73.2	0.06	1.53
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	83.74	-9.54	84.29	99.4	0.859	0.2	0.05	1.02
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-565.65	-278.09	630.31	-89.7	7.108	144.6	3.25	126.34
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-673.31	-243.52	715.99	-94	7.822	152.6	3.06	122.33
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-654.92	-49.77	656.81	-99.7	6.696	169.4	3.14	63.65
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-544.31	-113.56	556.03	-97.9	5.664	161.2	2.89	57.73
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-674.2	-224.79	710.69	-94.9	7.035	156.5	2.17	70.8
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-583.05	-148.69	601.71	-96.9	5.964	160.4	1.78	96.72
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-562.62	-25.02	563.18	-99.9	5.573	164	1.86	72.07
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.21	538.53	93.1	5.228	-58.6	0.52	19.33
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-497.9	150.39	520.12	-95.7	6.868	-157	0.89	33.36

No transformer is overloaded in the above report after the inclusion of SC_1 at bus bus no. 3.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	85.4	1500	56.9	100	100						
T01	12	11	300	13	450	8.7	100	100						
T11	29	38	1000	85.4	1500	56.9	100	100						
T02	12	13	300	17.5	450	11.7	100	100						

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T12	19	20	1000	8.4	1500	5.6	100	100						
T03	6	31	700	90	1050	60	100	100						
T04	10	32	800	89.5	1200	59.7	100	100						
T05	19	33	800	82.1	1200	54.7	100	100						
T06	20	34	600	92.7	900	61.8	100	100						
T07	22	35	800	88.8	1200	59.2	100	100						
T08	23	36	700	86	1050	57.3	100	100						
T09	25	37	700	80.5	1050	53.6	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	65	1200	43.3	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	828.93
G3	665	676.37
G4	647	658.06
G5	269	547.19
G6	665	676.37
G7	575	584.83
G8	555	564.49
G9	845	859.44
G1	1015	1032.35

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
3	0	345	0.95	1.05	0.948	-19.9
4	0	345	0.95	1.05	0.895	-15
5	0	345	0.95	1.05	0.881	-10.3
6	0	345	0.95	1.05	0.887	-9.2
7	0	345	0.95	1.05	0.855	-10.6
8	0	345	0.95	1.05	0.845	-10.5
9	0	345	0.95	1.05	0.757	6.2
B9_INV	0	100	0.95	1.05	0.746	9.8
10	0	345	0.95	1.05	0.915	-7.5
11	0	345	0.95	1.05	0.904	-8.1
12	0	138	0.95	1.05	0.886	-8.5
13	0	345	0.95	1.05	0.912	-8.8
14	0	345	0.95	1.05	0.911	-12
15	0	345	0.95	1.05	0.936	-14
36	0	16.5	0.95	1.05	1.064	3.2
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	3.153	4.482		
L20	15	16	3.467	4.482		
L30	25	26	0.284	4.482		
L11	6	7	4.077	4.482		
L31	26	27	2.777	4.482		
L12	6	11	3.062	4.482		
L32	26	28	1.604	4.482		
L13	7	8	2.292	4.482		
L23	16	21	3.787	4.482		
L33	26	29	2.086	4.482		
L24	16	24	1.828	4.482		
L34	28	29	3.59	4.482		

ID						
L25	17	18	4.439	4.482		
L16	10	11	3.333	4.482		
L26	17	27	1	4.482		
L28	22	23	0.382	4.482		
L19	14	15	1.988	4.482		
L29	23	24	3.801	4.482		
L4	2	25	3.078	4.482		
L5	3	4	4.401	4.482		
L6	3	18	2.798	4.482		
L8	4	14	3.804	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [MVA]**	**Loading Limit - [MVA]**	**Emergency Loading Limit - [MVA]**	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	39.041	150		
T02	12	13	52.547	150		
T12	19	20	84.285	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	**Bus From**	**P Gen - [MW]**	**Q Gen - [MVAR]**	**Q Min - [MVAR]**	**Q Max - [MVAR]**	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	**Bus From**	**Bus To**	**Tap Pos - [%]**	**Min Tap - [%]**	**Max Tap - [%]**	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload but not overload condition exists in the system being analyzed.

Bus no. 36 is a purely generator connected bus; it can be called voltage controlled bus. As we know for load flow solution the magnitude of the voltage of the voltage controlled bus is a known quantity and therefore it must be fixed all the way through load flow analysis. It can alter its value in the case of its reactive limit violation. In that case, bus 36 will behave as PQ bus. But the reactive limit of the generator 7 (G07) is not violated. And therefore bus voltage of 36 is always a fixed quantity and that is 1.064 per unit which is outside the voltage limit of .95 to 1.05.

STEP-2(SC-2 at Bus No. 9 Addition):

After appending SC_1 , we have noticed that bus no. 10,11,12,13,14,15,4,5,6,7,8,9 and 9_INV are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into those buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SHUNT CAPACITOR of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	0.886	88
4	0.895	264.07
5	0.881	144.21
6	0.887	161.4
7	0.855	286.49
8	0.845	468.57
9	0.757	295.12

From the above table, we can see that bus no. 9 is heavily affected by line losses and voltage drop in the lines due to reactive current component. Though bus no. 8 is burdened by more line MVAR, its voltage is not as bad as that of bus no. 9. It is because bus no. 8 is absorbing 468.57 MVAR as well as giving away 295.12 MVAR to bus no. 9. So our focus is on bus no. 9. So, we have appended a SHUNT CAPACITOR (SC_2) with Q-RATING of 296 MVAR at bus no. 9.

After adding the SC_2 (at 9) at bus no. 9 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SC2_ (at bus 9) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.008	-28	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.947	-7.1	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.942	-7.7	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.922	-8.1	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.943	-8.4	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.942	-11.3	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.954	-13.1	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.975	-12.1	0.95	1.05	0	0	329	32.3	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
17	345	0.976	-14.6	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.971	-16.6	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.985	-5.5	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1	-14.1	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.984	-6.2	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.985	-9.3	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.015	-4.3	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.014	-4.5	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.984	-11.9	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.017	-12.4	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.006	-12.9	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.986	-14.9	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.013	-8.8	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.016	-5.8	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.968	-18.7	0.95	1.05	0	0	322	2.4	800	387.46	0	-456
30	16.5	1.048	-6	0.95	1.05	827.22	307.72	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	211.25	9.2	4.6	0	0	0	0
32	16.5	0.983	1.1	0.95	1.05	674.97	211.06	0	0	0	0	0	0
33	16.5	0.997	-0.1	0.95	1.05	656.7	84.99	0	0	0	0	0	0
34	16.5	1.012	-0.6	0.95	1.05	546.07	158.16	0	0	0	0	0	0
35	16.5	1.049	0.8	0.95	1.05	674.97	262.94	0	0	0	0	0	0
36	16.5	1.064	3.9	0.95	1.05	583.62	226.99	0	0	0	0	0	0
37	16.5	1.028	-5.3	0.95	1.05	563.32	69.6	0	0	0	0	0	0
38	16.5	1.026	1.6	0.95	1.05	857.67	79.3	0	0	0	0	0	0
39	345	1.03	-36.1	0.95	1.05	1030.22	559.36	1104	250	0	0	0	0
4	345	0.932	-14.1	0.95	1.05	0	0	500	184	0	0	0	0
5	345	0.934	-9.8	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.937	-8.8	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.926	-10.1	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.925	-10	0.95	1.05	0	0	522	176	0	0	0	0
9	345	0.98	1.3	0.95	1.05	0	0	0	0	0	0	0	-296
B39_REC	100	1.016	-38	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.972	3.4	0.95	1.05	0	0	0	0	0	0	0	0

Here we can see that bus no. 4, 5, 6, 7, 8, 10, 11, 12, 13, 14 are outside the voltage limit namely under voltage. And the bus no. 36 is outside voltage limit which is 1.064.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SC_2 ADDITION)

Bus ID	Voltage Before SC_2 Addition(p.u)	Voltage After SC_2 Addition(p.u)
10	0.915	0.947
11	0.904	0.942
12	0.886	0.922
13	0.912	0.943
14	0.911	0.942
15	0.936	0.954
16	0.963	0.975
17	0.963	0.976
18	0.955	0.971
3	0.948	0.968
4	0.895	0.932
5	0.881	0.934
6	0.887	0.937
7	0.855	0.926
8	0.845	0.925
9	0.757	0.98
9_INV	0.746	0.972

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to 1.05 per unit. The other buses are within limit.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.9	65.57	79.47	56.5	0.851	-65.3	0.07	-11.82
L20	15	16	L20	Line	345	63	-195.55	-203	281.87	-69.4	2.954	120.8	0.76	-8.03
L30	25	26	L30	Line	345	216.5	30.14	2.88	30.28	99.5	0.298	-17.9	0.05	-51.93
L11	6	7	L11	Line	345	61.7	218.38	95.43	238.32	91.6	2.544	-32.4	0.39	-3.74
L21	16	17	L21	Line	345	59.7	455.1	-41.87	457.02	99.6	4.686	-6.8	1.53	6.72
L31	26	27	L31	Line	345	98.5	248.5	107.09	270.59	91.8	2.688	-36.2	1.05	-12.76
L12	6	11	L12	Line	345	55	-208.35	-46.75	213.53	-97.6	2.28	158.5	0.36	-8.04
L22	16	19	L22	Line	345	130.7	-563.46	16.29	563.69	-100	5.78	169.6	5.34	36.08
L32	26	28	L32	Line	345	317.7	-154.25	-33.12	157.76	-97.8	1.567	154.9	1.01	-68.38
L13	7	8	L13	Line	345	30.8	-15.82	15.17	21.92	-72.2	0.237	-146.3	0	-6.64
L23	16	21	L23	Line	345	90.5	-355.69	-51.9	359.46	-99	3.686	159.6	1.07	-6.29
L33	26	29	L33	Line	345	418.9	-203.16	-36.15	206.36	-98.5	2.05	157	2.34	-79.59
L14	8	9	L14	Line	345	243.3	-492.99	-76.79	498.93	-98.8	5.395	161.1	6.6	70.13
L24	16	24	L24	Line	345	39.5	-61.26	-149.79	161.83	-37.9	1.659	100.1	0.08	-4.97
L34	28	29	L34	Line	345	101.2	-361.25	7.66	361.34	-100	3.568	172.4	1.78	-6.34
L25	17	18	L25	Line	345	55	419.95	25.88	420.75	99.8	4.31	-18.1	1.3	2.76
L16	10	11	L16	Line	345	28.8	223.7	78.03	236.92	94.4	2.503	-26.4	0.25	-3.78

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L26	17	27	L26	Line	345	116	33.62	-74.47	81.71	41.1	0.837	51.1	0.06	-30.12
L17	10	13	L17	Line	345	28.8	448.68	29.57	449.66	99.8	4.75	-10.9	0.9	3.2
L27	21	22	L27	Line	345	93	-630.76	-160.61	650.89	-96.9	6.608	156.5	3.42	34.64
L18	13	14	L18	Line	345	67.7	454.94	-20.66	455.41	99.9	4.827	-5.8	2.1	8.2
L28	22	23	L28	Line	345	64.3	38.7	-0.49	38.7	100	0.381	-3.6	0.01	-18.84
L19	14	15	L19	Line	345	145.4	124.84	-78.13	147.28	84.8	1.564	20.7	0.39	-28.13
L29	23	24	L29	Line	345	234.6	373.08	66.46	378.95	98.5	3.739	-14.6	3.14	13.84
L1	1	2	L1	Line	345	275.5	-578.64	107.5	588.54	-98.3	5.836	162.5	12.23	73.17
L2	1	39	L2	Line	345	167.6	578.64	-107.5	588.54	98.3	5.836	-17.5	3.34	5.58
L3	2	3	L3	Line	345	101.2	532.89	169.14	559.09	95.3	5.593	-31.7	4.11	23
L4	2	25	L4	Line	345	57.6	-300.8	44.43	304.06	-98.9	3.042	174.3	6.55	-6.83
L5	3	4	L5	Line	345	142.8	-333.36	187.54	382.49	-87.2	3.95	-169.4	2.08	14.14
L6	3	18	L6	Line	345	89.1	-259.86	-3.64	259.89	-100	2.684	160.5	0.79	-10.52
L7	4	5	L7	Line	345	85.8	-508.43	34.72	509.62	-99.8	5.465	169.8	2.39	26.61
L8	4	14	L8	Line	345	86.5	-327.01	-45.32	330.13	-99.1	3.541	158	0.99	3.96
L9	5	6	L9	Line	345	17.4	-555.72	-57.46	558.68	-99.5	5.983	164.3	0.72	5.5

Line no. 20 is burdened with reactive power flow of more than 200 MVAR. And Line 3, 5, 24 and 27 are having reactive power flow of more than 150 but less than 200 MVAR flowing through them.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SC_2 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SC_2	Line MVAR After Addition of SC_2
10	5	8	273.09	65.57
20	15	16	-259.58	-203
11	6	7	286.49	95.43
13	7	8	195.48	15.17
14	8	9	295.12	-76.79
16	10	11	209.41	78.03
27	21	22	-185.74	-160.61
3	2	3	243.57	169.14
9	5	6	-161.4	-57.46

After addition of second Shunt Capacitor at bus no. 9, we can see line MVAR is reduced in those line mentioned in the table above. The lines L3,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit but their MVAR is greater than 150. The other lines are heavily improved in terms of their MVARs and their value is less than 100.

GENERATOR REPORT

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/V [pu]
G10	30	G10	Generator	1000	16.5	PV	827.22	307.72	882.6	93.7	8.426	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1030.22	559.36	1172.28	87.9	11.381	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	211.25	211.25	0	2.151	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.97	211.06	707.2	95.4	7.194	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.7	84.99	662.18	99.2	6.64	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	546.07	158.16	568.51	96.1	5.616	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.97	262.94	724.38	93.2	6.904	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.62	226.99	626.21	93.2	5.888	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.32	69.6	567.61	99.2	5.522	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.67	79.3	861.33	99.6	8.391	560	-240	38	1.026

No generator is overloaded in the above report table.

SHUNT CAPACITOR TABLE

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	R [MW]	X [MVAR]	Type
SC2_9	9	SC2_9	0	-304.78	304.78	0	0	-296	Shunt Capacitor
SC1_3	3	SC1_3	0	-443.1	443.1	0	0	-456	Shunt Capacitor

Here we used second shunt capacitor of rating 296 MVAR in our second step from our logical intuition. From the above table we see that it works with 304.78 MVAR which is slightly higher. So we can say that our addition of second shunt capacitor is compatible with our system.

TRANSFORMER TABLE:

TXFO ID	Bus From	Bus To	DBase ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed-Tap Xmer	1000	345	16.5	-822.96	-179.2	842.25	-97.7	8.426	153.6	4.26	128.5
T01	12	11	T01	Fixed-Tap Xmer	300	138	345	-14.7	-42.09	44.58	-33	0.484	101.2	0.04	1.02
T11	29	38	T11	Fixed-Tap Xmer	1000	345	16.5	-852.04	30.54	852.58	-99.9	8.391	176.3	5.63	109.84
T02	12	13	T02	Fixed-Tap Xmer	300	138	345	7.2	-45.92	46.48	15.5	0.504	73	0.04	1.11
T12	19	20	T12	Fixed-Tap Xmer	1000	345	230	84.82	2.62	84.86	100	0.862	-7.3	0.05	1.02
T03	6	31	T03	Fixed-Tap Xmer	700	345	16.5	-566.46	-111.65	577.36	-98.1	6.164	160	2.44	95
T04	10	32	T04	Fixed-Tap Xmer	800	345	16.5	-672.38	-107.6	680.94	-98.7	7.194	163.8	2.59	103.46
T05	19	33	T05	Fixed-Tap Xmer	800	345	16.5	-653.62	-22.4	654	-99.9	6.64	172.5	3.09	62.59
T06	20	34	T06	Fixed-Tap Xmer	600	230	16.5	-543.23	-101.4	552.61	-98.3	5.616	163.2	2.84	56.75
T07	22	35	T07	Fixed-Tap Xmer	800	345	16.5	-672.88	-194.8	700.5	-96.1	6.904	159.6	2.09	68.18
T08	23	36	T08	Fixed-Tap Xmer	700	345	16.5	-581.89	-132.7	596.83	-97.5	5.888	162.7	1.73	94.29
T09	25	37	T09	Fixed-Tap Xmer	700	345	16.5	-561.49	1.17	561.49	-100	5.522	167.7	1.83	70.77
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.27	538.56	93.1	5.229	-57.5	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.58	137.22	518.08	-96.4	5.288	-163.4	0.53	19.78

No transformer is overloaded after the SC2 (at 9) annexation.

TRANSFORMER TABLE (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	84.2	1500	56.2	100	100						
T01	12	11	300	14.9	450	9.9	100	100						
T11	29	38	1000	85.3	1500	56.8	100	100						
T02	12	13	300	15.5	450	10.3	100	100						

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T12	19	20	1000	8.5	1500	5.7	100	100						
T03	6	31	700	82.5	1050	55	100	100						
T04	10	32	800	85.1	1200	56.7	100	100						
T05	19	33	800	81.7	1200	54.5	100	100						
T06	**20**	**34**	**600**	**92.1**	**900**	**61.4**	**100**	**100**						
T07	**22**	**35**	**800**	**87.6**	**1200**	**58.4**	**100**	**100**						
T08	**23**	**36**	**700**	**85.3**	**1050**	**56.8**	**100**	**100**						
T09	25	37	700	80.2	1050	53.5	100	100						
Tcul XMer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.8	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	827.22
G3	665	674.97
G4	647	656.7
G5	269	546.07
G6	665	674.97
G7	575	583.62
G8	555	563.32
G9	845	857.67
G1	1015	1030.22

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
4	0	345	0.95	1.05	0.932	-14.1
5	0	345	0.95	1.05	0.934	-9.8
6	0	345	0.95	1.05	0.937	-8.8
7	0	345	0.95	1.05	0.926	-10.1
8	0	345	0.95	1.05	0.925	-10
10	0	345	0.95	1.05	0.947	-7.1
11	0	345	0.95	1.05	0.942	-7.7
12	0	138	0.95	1.05	0.922	-8.1
13	0	345	0.95	1.05	0.943	-8.4
14	0	345	0.95	1.05	0.942	-11.3
36	0	16.5	0.95	1.05	1.064	3.9
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	0.851	4.482		
L20	15	16	2.954	4.482		
L30	25	26	0.298	4.482		
L11	6	7	2.544	4.482		
L31	26	27	2.688	4.482		
L12	6	11	2.28	4.482		
L32	26	28	1.567	4.482		
L13	7	8	0.237	4.482		
L23	16	21	3.686	4.482		
L33	26	29	2.05	4.482		
L24	16	24	1.659	4.482		
L34	28	29	3.568	4.482		
L25	17	18	4.31	4.482		
L16	10	11	2.503	4.482		
L26	17	27	0.837	4.482		

ID						
L28	22	23	0.381	4.482		
L19	14	15	1.564	4.482		
L29	23	24	3.739	4.482		
L4	2	25	3.042	4.482		
L5	3	4	3.95	4.482		
L6	3	18	2.684	4.482		
L8	4	14	3.541	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [MVA]**	**Loading Limit - [MVA]**	**Emergency Loading Limit - [MVA]**	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [MVA]**	**Loading Limit - [MVA]**		
T01	12	11	44.579	150		
T02	12	13	46.476	150		
T12	19	20	84.863	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	**Bus From**	**P Gen - [MW]**	**Q Gen - [MVAR]**	**Q Min - [MVAR]**	**Q Max - [MVAR]**	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	**Bus From**	**Bus To**	**Tap Pos - [%]**	**Min Tap - [%]**	**Max Tap - [%]**	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload but not overload condition exists in the system being analyzed.

Bus no. 36 is a purely generator connected bus; it can be called voltage controlled bus. As we know for load flow solution the magnitude of the voltage of the voltage controlled bus is a known quantity and therefore it must be fixed all the way through load flow analysis. It can alter its value in the case of its reactive limit violation. In that case, bus 36 will behave as PQ bus. But the reactive limit of the generator 7 (G07) is not violated. And therefore bus voltage of 36 is always a fixed quantity and that is 1.064 per unit which is outside the voltage limit of .95 to 1.05.

STEP-3(SC-3 at Bus No. 4 Addition):

After appending SC_2, we have noticed that bus no. 4, 5, 6, 7, 8, 10, 11, 12, 13 and 14 are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into those buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SHUNT CAPACITOR of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	0.922	88
4	0.932	187.54
5	0.934	34.72
6	0.937	57.46
7	0.926	95.43
8	0.925	80.74

From the above table, it is noticed that bus no. 12 has the lowest per unit voltage but the lines associated with it are carrying 88 MVAR reactive powers. But bus no. 4 is not far good than bus no. 12 and additionally the line associated with it is carrying 187.54 MVAR reactive power which is roughly 2 times higher than the case in bus no. 12. This relatively high MVAR is essentially affecting the voltages of adjacent buses of bus no. 4 (i.e. bus no. 5, 6, 7, 8) in an adverse way. So, we have appended a SHUNT CAPACITOR (SC_3) with Q-RATING of 188 MVAR at bus no. 4.

After adding the SC_3 (at 4) at bus no. 4 the modified situation and results are given below.

MODIFIED RESULTS and OUTPUTS after SC3 (at bus 4) ADDITION:

BUS TABLE

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.011	-27.5	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.959	-7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.956	-7.6	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.936	-8	0.95	1.05	0	0	7.5	88	0	0	0	0
13	345	0.958	-8.2	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.96	-11.1	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.965	-12.8	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.983	-11.7	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.985	-14.1	0.95	1.05	0	0	0	0	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
18	345	0.982	-16.2	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.987	-5.2	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.005	-13.7	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.985	-5.9	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.99	-8.9	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.017	-4	0.95	1.05	0	0	0	0	0	0	0	0
23	345	1.016	-4.2	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.991	-11.6	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.021	-12	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.011	-12.5	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.993	-14.5	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.015	-8.4	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.018	-5.4	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.982	-18.2	0.95	1.05	0	0	322	2.4	800	387.46	0	-456
30	16.5	1.048	-5.6	0.95	1.05	826.9	274.91	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	146.63	9.2	4.6	0	0	0	0
32	16.5	0.983	1.2	0.95	1.05	674.71	147.17	0	0	0	0	0	0
33	16.5	0.997	0.2	0.95	1.05	656.45	67.73	0	0	0	0	0	0
34	16.5	1.012	-0.3	0.95	1.05	545.86	150.22	0	0	0	0	0	0
35	16.5	1.049	1.1	0.95	1.05	674.71	243.15	0	0	0	0	0	0
36	16.5	1.064	4.2	0.95	1.05	583.4	215.88	0	0	0	0	0	0
37	16.5	1.028	-4.8	0.95	1.05	563.1	51.16	0	0	0	0	0	0
38	16.5	1.026	2	0.95	1.05	857.34	68.08	0	0	0	0	0	0
39	345	1.03	-35.5	0.95	1.05	1029.82	549.72	1104	250	0	0	0	0
4	345	0.959	-13.8	0.95	1.05	0	0	500	184	0	0	0	-188
5	345	0.952	-9.6	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.953	-8.7	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.944	-9.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.944	-9.9	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1.004	0.9	0.95	1.05	0	0	0	0	0	0	0	-296
B39_REC	100	1.016	-37.4	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	0.996	2.9	0.95	1.05	0	0	0	0	0	0	0	0

Here we can that bus no. 7, 8 and 12 are outside the voltage limit namely under voltage. AND BUS 36 is facing over voltage.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SC_3 ADDITION)

Bus ID	Voltage Before SC_3 Addition(p.u)	Voltage After SC_3 Addition(p.u)
10	0.947	0.959
11	0.942	0.956
12	0.922	0.936
13	0.943	0.958
14	0.942	0.96
15	0.954	0.965
16	0.975	0.983
17	0.976	0.985
18	0.971	0.982
3	0.968	0.982
4	0.932	0.959
5	0.934	0.952
6	0.937	0.953
7	0.926	0.944
8	0.925	0.944
9	0.98	1.004
9_INV	0.972	0.996

The buses highlighted with yellow color are improved in terms of their voltages but are yet to be within specified range of .95 to1.05 per unit.

BRANCH TABLE

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.59	60.83	75.42	59.1	0.792	-63.4	0.06	-12.45
L20	15	16	L20	Line	345	63	-198.09	-170.58	261.41	-75.8	2.71	126.5	0.64	-9.57
L30	25	26	L30	Line	345	216.5	31.72	0.24	31.72	100	0.311	-12.4	0.05	-52.42
L11	6	7	L11	Line	345	61.7	218.32	78.72	232.08	94.1	2.435	-28.5	0.36	-4.62
L21	16	17	L21	Line	345	59.7	452.05	-55.78	455.48	99.2	4.636	-4.7	1.5	6.08
L31	26	27	L31	Line	345	98.5	249.79	95.75	267.52	93.4	2.645	-33.5	1.01	-13.42
L12	6	11	L12	Line	345	55	-209.56	-22.22	210.74	-99.4	2.211	165.3	0.34	-8.67
L22	16	19	L22	Line	345	130.7	-563.09	39.69	564.49	-99.8	5.745	172.3	5.29	35.15
L32	26	28	L32	Line	345	317.7	-154.05	-28.5	156.66	-98.3	1.549	157	1	-69.06
L13	7	8	L13	Line	345	30.8	-15.84	-0.66	15.85	-99.9	0.168	167.7	0	-6.93
L23	16	21	L23	Line	345	90.5	-355.56	-36.93	357.47	-99.5	3.638	162.3	1.05	-7.02
L33	26	29	L33	Line	345	418.9	-203.08	-31.59	205.52	-98.8	2.032	158.7	2.32	-80.44
L14	8	9	L14	Line	345	243.3	-493.31	-96.44	502.65	-98.1	5.326	159.1	6.41	65.61
L24	16	24	L24	Line	345	39.5	-61.13	-140.28	153.02	-39.9	1.557	101.8	0.07	-5.25

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L34	28	29	L34	Line	345	101.2	-361.05	12.96	361.28	-99.9	3.559	173.7	1.78	-6.53
L25	17	18	L25	Line	345	55	418.29	2.63	418.3	100	4.248	-14.5	1.26	2.06
L16	10	11	L16	Line	345	28.8	224.8	52.08	230.75	97.4	2.405	-20.1	0.23	-4.18
L26	17	27	L26	Line	345	116	32.27	-64.49	72.11	44.7	0.732	49.3	0.05	-30.82
L17	10	13	L17	Line	345	28.8	447.45	-3.56	447.46	100	4.664	-6.6	0.87	2.65
L27	21	22	L27	Line	345	93	-630.61	-144.92	647.04	-97.5	6.536	158.1	3.35	33.17
L18	13	14	L18	Line	345	67.7	453.66	-53.57	456.82	99.3	4.769	-1.5	2.04	7.05
L28	22	23	L28	Line	345	64.3	38.71	-1.77	38.75	99.9	0.381	-1.4	0.01	-18.95
L19	14	15	L19	Line	345	145.4	122.22	-47.72	131.21	93.2	1.367	10.2	0.31	-30.14
L29	23	24	L29	Line	345	234.6	372.89	55.42	376.98	98.9	3.709	-12.7	3.09	12.59
L1	1	2	L1	Line	345	275.5	-579.01	98.6	587.35	-98.6	5.811	162.2	12.1	71.15
L2	1	39	L2	Line	345	167.6	579.01	-98.6	587.35	98.6	5.811	-17.8	3.31	4.84
L3	2	3	L3	Line	345	101.2	530.67	117.6	543.54	97.6	5.407	-26.2	3.83	19.23
L4	2	25	L4	Line	345	57.6	-299.04	59.51	304.9	-98.1	3.033	177.6	6.53	-7
L5	3	4	L5	Line	345	142.8	-336.9	130.04	361.12	-93.3	3.678	-177.1	1.8	8.61
L6	3	18	L6	Line	345	89.1	-258.26	18.13	258.9	-99.8	2.637	165.8	0.77	-11.29
L7	4	5	L7	Line	345	85.8	-510.23	94.86	518.97	-98.3	5.413	176.8	2.35	25.42
L8	4	14	L8	Line	345	86.5	-328.46	15.39	328.82	-99.9	3.43	168.9	0.94	2.49
L9	5	6	L9	Line	345	17.4	-557.17	8.6	557.23	-100	5.853	171.3	0.69	4.97

From the above report, we can see that no line is giving the passage of reactive power of more than 200 MVAR and only one line (Line no. 20) is giving gateway for reactive power flow of more than 150 MVAR but less than 200 MVAR.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SC_3 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SC_3	Line MVAR After Addition of SC_3
10	5	8	65.57	60.83
20	15	16	-203	-170.58
11	6	7	95.43	78.72
13	7	8	15.17	-0.66
14	8	9	-76.79	-96.44
16	10	11	78.03	52.08
27	21	22	-160.61	-144.92
3	2	3	169.14	117.6
9	5	6	-57.46	8.6

After addition of third Static VAR Compensator at bus no. 4, we can see line MVAR is reduced in those line mentioned in the table above. The lines L20,L27 which are highlighted with yellow color are improved in terms of their MVAR and they are now within limit. And the other lines which are not highlighted but we are focusing are within limit and their value is less than 150.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/ V [pu]
G10	30	G10	Generator	1000	16.5	PV	826.9	274.91	871.4	94.9	8.319	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1029.82	549.72	1167.36	88.2	11.334	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	146.63	146.63	0	1.493	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.71	147.17	690.57	97.7	7.025	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.45	67.73	659.93	99.5	6.618	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	545.86	150.22	566.15	96.4	5.593	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.71	243.15	717.19	94.1	6.835	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.4	215.88	622.06	93.8	5.849	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.1	51.16	565.42	99.6	5.501	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.34	68.08	860.04	99.7	8.378	560	-240	38	1.026

No generator is overloaded in the above generator table after the addition SC_3.

SHUNT CAPACITOR TABLE

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	R [MW]	X [MVAR]	Type
SC2_9	9	SC2_9	0	-304.78	304.78	0	0	-296	Shunt Capacitor
SC1_3	3	SC1_3	0	-443.1	443.1	0	0	-456	Shunt Capacitor
SC3_4	4	SC3_9	0	-175.38	175.38	0	0	-188	Shunt Capacitor

Here we used third shunt capacitor of rating 188 MVAR in our third step from our logical intuition. From the above table we see that it works with 175.38 MVAR. So we can say that our addition of third shunt capacitor is compatible with our system.

TRANSFORMER TABLE

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed -Tap Xmer	1000	345	16.5	-822.75	-149.66	836.25	-98.4	8.319	156	4.15	125.26
T01	12	11	T01	Fixed -Tap Xmer	300	138	345	-14.63	-41.73	44.22	-33.1	0.472	101.3	0.04	0.97
T11	29	38	T11	Fixed -Tap Xmer	1000	345	16.5	-851.72	41.43	852.73	-99.9	8.378	177.4	5.62	109.51
T02	12	13	T02	Fixed -Tap Xmer	300	138	345	7.13	-46.27	46.81	15.2	0.5	73.3	0.04	1.09
T12	19	20	T12	Fixed -Tap Xmer	1000	345	230	85.01	10.1	85.61	99.3	0.867	-12	0.05	1.04
T03	6	31	T03	Fixed -Tap Xmer	700	345	16.5	-566.61	-52.87	569.07	-99.6	5.971	166	2.29	89.16
T04	10	32	T04	Fixed -Tap Xmer	800	345	16.5	-672.24	-48.51	673.99	-99.7	7.025	168.8	2.47	98.66
T05	19	33	T05	Fixed -Tap Xmer	800	345	16.5	-653.38	-5.56	653.41	-100	6.618	174.3	3.06	62.17
T06	20	34	T06	Fixed -Tap Xmer	600	230	16.5	-543.04	-93.93	551.11	-98.5	5.593	164.3	2.81	56.28
T07	22	35	T07	Fixed -Tap Xmer	800	345	16.5	-672.66	-176.32	695.39	-96.7	6.835	161.3	2.04	66.83
T08	23	36	T08	Fixed -Tap Xmer	700	345	16.5	-581.69	-122.84	594.52	-97.8	5.849	163.9	1.71	93.04
T09	25	37	T09	Fixed -Tap Xmer	700	345	16.5	-561.29	19.07	561.61	-99.9	5.501	170	1.82	70.23
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.28	538.56	93.1	5.229	-56.9	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.72	136.31	517.98	-96.5	5.159	-163.8	0.5	18.83

No transformer is overloaded in the above transformer table after the addition of SC_3.

TRANSFORMER TABLE (% LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	83.6	1500	55.8	100	100						
T01	12	11	300	14.7	450	9.8	100	100						
T11	29	38	1000	85.3	1500	56.8	100	100						
T02	12	13	300	15.6	450	10.4	100	100						
T12	19	20	1000	8.6	1500	5.7	100	100						
T03	6	31	700	81.3	1050	54.2	100	100						
T04	10	32	800	84.2	1200	56.2	100	100						
T05	19	33	800	81.7	1200	54.5	100	100						
T06	20	34	600	91.9	900	61.2	100	100						
T07	22	35	800	86.9	1200	57.9	100	100						
T08	23	36	700	84.9	1050	56.6	100	100						
T09	25	37	700	80.2	1050	53.5	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.7	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	826.9
G3	665	674.71
G4	647	656.45
G5	269	545.86
G6	665	674.71
G7	575	583.4
G8	555	563.1
G9	845	857.34
G1	1015	1029.82

It is obvious from the above chart that the calculated distribution of power about diverse localized zone of the network is slightly higher than the desired ones in order to improve the network bus voltages.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
7	0	345	0.95	1.05	0.944	-9.9
8	0	345	0.95	1.05	0.944	-9.9
12	0	138	0.95	1.05	0.936	-8
36	0	16.5	0.95	1.05	1.064	4.2
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	0.792	4.482		
L20	15	16	2.71	4.482		
L30	25	26	0.311	4.482		
L11	6	7	2.435	4.482		
L31	26	27	2.645	4.482		
L12	6	11	2.211	4.482		
L32	26	28	1.549	4.482		
L13	7	8	0.168	4.482		
L23	16	21	3.638	4.482		
L33	26	29	2.032	4.482		
L24	16	24	1.557	4.482		
L34	28	29	3.559	4.482		
L25	17	18	4.248	4.482		
L16	10	11	2.405	4.482		
L26	17	27	0.732	4.482		
L28	22	23	0.381	4.482		
L19	14	15	1.367	4.482		
L29	23	24	3.709	4.482		
L4	2	25	3.033	4.482		
L5	3	4	3.678	4.482		
L6	3	18	2.637	4.482		

ID						
L8	4	14	3.43	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	44.222	150		
T02	12	13	46.813	150		
T12	19	20	85.609	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload but not overload condition exists in the system being analyzed.

Bus no. 36 is a purely generator connected bus; it can be called voltage controlled bus. As we know for load flow solution the magnitude of the voltage of the voltage controlled bus is a known quantity and therefore it must be fixed all the way through load flow analysis. It can alter its value in the case of its reactive limit violation. In that case, bus 36 will behave as PQ bus. But the reactive limit of the generator 7 (G07) is not violated. And therefore bus voltage of 36 is always a fixed quantity and that is 1.064 per unit which is outside the voltage limit of .95 to 1.05.

STEP-4 (SC-4 at Bus No. 12 Addition):

After appending SC_3, we have noticed that bus no. 7, 8 and 12 are outside the voltage limit namely the lower limit of the voltage has been violated.

If we draw a comparison of the line MVARs running into those buses, we can be able to come to a quick logical conclusion on the selection of next bus to be appended with a SHUNT CAPACITOR of optimal rating.

Bus ID	BUS Voltage (p.u)	LINE MVAR (abs value)
12	.936	88
7	.944	78.12
8	.944	60.17

Here we can observe that bus no. 12 has the lowest voltage in per unit and the lines associated with it are carrying the highest MVAR of 88. So the next target should be bus 12. Therefore, we have decided to append the next SHUNT CAPACITOR SC_4 at bus 12 with Q-RATING of 88 MVAR.

After adding the SC_4 (at 12) at bus no. 12 the modified situation and results are given below.

BUS REPORT

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
1	345	1.011	-27.3	0.95	1.05	0	0	0	0	0	0	0	0
10	345	0.968	-7	0.95	1.05	0	0	0	0	0	0	0	0
11	345	0.966	-7.6	0.95	1.05	0	0	0	0	0	0	0	0
12	138	0.965	-8	0.95	1.05	0	0	7.5	88	0	0	0	-88
13	345	0.968	-8.2	0.95	1.05	0	0	0	0	0	0	0	0
14	345	0.967	-11	0.95	1.05	0	0	0	0	0	0	0	0
15	345	0.969	-12.6	0.95	1.05	0	0	320	153	0	0	0	0
16	345	0.985	-11.6	0.95	1.05	0	0	329	32.3	0	0	0	0
17	345	0.987	-14	0.95	1.05	0	0	0	0	0	0	0	0
18	345	0.985	-16	0.95	1.05	0	0	158	30	0	0	0	0
19	345	0.988	-5.1	0.95	1.05	0	0	0	0	0	0	0	0
2	345	1.007	-13.5	0.95	1.05	0	0	0	0	0	0	0	0
20	230	0.986	-5.7	0.95	1.05	0	0	628	103	0	0	0	0
21	345	0.992	-8.8	0.95	1.05	0	0	274	115	0	0	0	0
22	345	1.018	-3.9	0.95	1.05	0	0	0	0	0	0	0	0

ID	kV Base	V sol [pu]	Ang sol [deg]	Vmin [pu]	Vmax [pu]	P Gen [MW]	Q Gen [MVAR]	P Load [MW]	Q Load [MVAR]	P motor [MW]	Q motor [MVAR]	P shunt [MW]	Q shunt [MVAR]
23	345	1.017	-4.1	0.95	1.05	0	0	247.5	84.6	0	0	0	0
24	345	0.993	-11.4	0.95	1.05	0	0	308.6	-92.2	0	0	0	0
25	345	1.022	-11.8	0.95	1.05	0	0	224	47.2	0	0	0	0
26	345	1.013	-12.3	0.95	1.05	0	0	139	17	0	0	0	0
27	345	0.995	-14.3	0.95	1.05	0	0	281	75.5	0	0	0	0
28	345	1.016	-8.2	0.95	1.05	0	0	206	27.6	0	0	0	0
29	345	1.018	-5.2	0.95	1.05	0	0	283.5	26.9	0	0	0	0
3	345	0.986	-18	0.95	1.05	0	0	322	2.4	800	387.46	0	-456
30	16.5	1.048	-5.4	0.95	1.05	826.78	265.46	0	0	0	0	0	0
31	16.5	0.982	0	0.95	1.05	0	115.86	9.2	4.6	0	0	0	0
32	16.5	0.983	1.1	0.95	1.05	674.61	103.21	0	0	0	0	0	0
33	16.5	0.997	0.3	0.95	1.05	656.35	61.31	0	0	0	0	0	0
34	16.5	1.012	-0.2	0.95	1.05	545.78	147.27	0	0	0	0	0	0
35	16.5	1.049	1.2	0.95	1.05	674.61	235.8	0	0	0	0	0	0
36	16.5	1.064	4.3	0.95	1.05	583.31	211.75	0	0	0	0	0	0
37	16.5	1.028	-4.7	0.95	1.05	563.02	45.74	0	0	0	0	0	0
38	16.5	1.026	2.1	0.95	1.05	857.22	64.48	0	0	0	0	0	0
39	345	1.03	-35.3	0.95	1.05	1029.68	546.97	1104	250	0	0	0	0
4	345	0.966	-13.6	0.95	1.05	0	0	500	184	0	0	0	-188
5	345	0.96	-9.5	0.95	1.05	0	0	0	0	0	0	0	0
6	345	0.961	-8.6	0.95	1.05	0	0	0	0	0	0	0	0
7	345	0.952	-9.9	0.95	1.05	0	0	233.8	84	0	0	0	0
8	345	0.952	-9.8	0.95	1.05	0	0	522	176	0	0	0	0
9	345	1.015	0.8	0.95	1.05	0	0	0	0	0	0	0	-296
B39_REC	100	1.016	-37.2	0.95	1.05	0	0	0	0	0	0	0	0
B9_INV	100	1.007	2.7	0.95	1.05	0	0	0	0	0	0	0	0

From the bus table after SC_4 addition, no bus except bus no 36 is outside of the pre-set voltage limit.

BUS VOLTAGE IMPROVEMENT COMPARISON (AFTER SC_4 ADDITION)

Bus ID	Voltage Before SC_4 Addition(p.u)	Voltage After SC_4 Addition(p.u)
10	**0.959**	**0.968**
11	**0.956**	**0.966**
12	**0.936**	**0.965**
13	**0.958**	**0.968**
14	**0.960**	**0.967**
15	**0.965**	**0.969**

Bus ID	Voltage Before SC_4 Addition(p.u)	Voltage After SC_4 Addition(p.u)
16	**0.983**	**0.985**
17	**0.985**	**0.987**
18	**0.982**	**0.985**
3	**0.982**	**.986**
4	**0.959**	**0.966**
5	**0.952**	**0.96**
6	**0.953**	**0.961**
7	**0.944**	**0.952**
8	**0.944**	**0.952**
9	**1.004**	**1.015**
9_INV	**0.996**	**1.007**

The buses are improved in terms of their voltages and are set to be within specified range of .95 to1.05 per unit.

BRANCH REPORT

ID	Bus From	Bus To	DBase ID	Type	kV Nominal	Length	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	I angle [deg]	P losses [MW]	Q losses [MVAR]
L10	5	8	L10	Line	345	75.1	44.49	55.73	71.31	62.4	0.743	-60.9	0.05	-12.77
L20	15	16	L20	Line	345	63	-198.5	-154.8	251.72	-78.9	2.598	129.4	0.58	-10.22
L30	25	26	L30	Line	345	216.5	32.14	-0.94	32.15	100	0.315	-10.1	0.05	-52.58
L11	6	7	L11	Line	345	61.7	218.27	74.34	230.58	94.7	2.4	-27.4	0.35	-4.96
L21	16	17	L21	Line	345	59.7	451.45	-57.33	455.08	99.2	4.619	-4.4	1.49	5.86
L31	26	27	L31	Line	345	98.5	250.11	91.77	266.41	93.9	2.63	-32.5	1	-13.64
L12	6	11	L12	Line	345	55	-209.41	-45.82	214.36	-97.7	2.231	159	0.34	-8.86
L22	16	19	L22	Line	345	130.7	-562.95	48.48	565.03	-99.6	5.735	173.3	5.27	34.86
L32	26	28	L32	Line	345	317.7	-153.97	-27.01	156.33	-98.5	1.543	157.7	1	-69.27
L13	7	8	L13	Line	345	30.8	-15.88	-4.71	16.56	-95.9	0.174	153.6	0	-7.06
L23	16	21	L23	Line	345	90.5	-355.51	-31.31	356.88	-99.6	3.622	163.4	1.04	-7.27
L33	26	29	L33	Line	345	418.9	-203.05	-30.12	205.27	-98.9	2.026	159.2	2.32	-80.7
L14	8	9	L14	Line	345	243.3	-493.44	-105.15	504.52	-97.8	5.299	158.2	6.34	63.71
L24	16	24	L24	Line	345	39.5	-61.09	-136.71	149.74	-40.8	1.52	102.5	0.07	-5.35
L34	28	29	L34	Line	345	101.2	-360.97	14.66	361.27	-99.9	3.556	174.1	1.77	-6.59
L25	17	18	L25	Line	345	55	418.03	-2.23	418.04	100	4.233	-13.7	1.25	1.87
L16	10	11	L16	Line	345	28.8	224.84	33.12	227.26	98.9	2.347	-15.4	0.22	-4.44
L26	17	27	L26	Line	345	116	31.94	-60.96	68.82	46.4	0.697	48.4	0.04	-31.05
L17	10	13	L17	Line	345	28.8	447.37	-26.26	448.14	99.8	4.628	-3.6	0.86	2.37
L27	21	22	L27	Line	345	93	-630.55	-139.04	645.7	-97.7	6.51	158.8	3.32	32.65
L18	13	14	L18	Line	345	67.7	453.87	-34.17	455.16	99.7	4.703	-3.9	1.99	6.16
L28	22	23	L28	Line	345	64.3	38.71	-2.24	38.78	99.8	0.381	-0.6	0.01	-18.98
L19	14	15	L19	Line	345	145.4	121.79	-32.61	126.08	96.6	1.303	4	0.29	-30.81
L29	23	24	L29	Line	345	234.6	372.82	51.3	376.33	99.1	3.699	-11.9	3.07	12.14
L1	1	2	L1	Line	345	275.5	-579.15	96.04	587.06	-98.7	5.805	162.1	12.07	70.6
L2	1	39	L2	Line	345	167.6	579.15	-96.04	587.06	98.7	5.805	-17.9	3.31	4.65
L3	2	3	L3	Line	345	101.2	529.98	102.95	539.89	98.2	5.362	-24.5	3.76	18.3
L4	2	25	L4	Line	345	57.6	-298.55	63.58	305.24	-97.8	3.032	178.5	6.53	-7.04
L5	3	4	L5	Line	345	142.8	-337.76	115.29	356.9	-94.6	3.621	-179.2	1.74	7.41
L6	3	18	L6	Line	345	89.1	-258.02	22.6	259	-99.6	2.627	167	0.76	-11.49
L7	4	5	L7	Line	345	85.8	-510.33	89.44	518.11	-98.5	5.364	176.3	2.31	24.55
L8	4	14	L8	Line	345	86.5	-329.17	9.82	329.32	-100	3.41	168.1	0.93	2.1
L9	5	6	L9	Line	345	17.4	-557.13	9.16	557.2	-100	5.805	171.4	0.67	4.76

From the above report, we can see that no line is giving the passage of reactive power of more than 200MVAR and only one line (Line no. 20) is giving gateway for reactive power flow of more than 150 MVAR but less than 200 MVAR. L24 and L27 are carrying 136.71 and 139.04 MVAR reactive power.

LINE MVAR IMPROVEMENT COMPARISION (AFTER SC_4 ADDITION)

Line Id	From Bus	To Bus	Line MVAR Before Addition of SC_4	Line MVAR After Addition of SC_4
10	**5**	**8**	**60.83**	**55.73**
20	**15**	**16**	**-170.58**	**-154.8**
11	**6**	**7**	**78.72**	**74.34**
13	**7**	**8**	**-0.66**	**-4.71**
14	**8**	**9**	**-96.44**	**-105.15**
16	**10**	**11**	**52.08**	**33.12**
27	**21**	**22**	**-144.92**	**-139.04**
3	**2**	**3**	**117.6**	**102.95**
9	**5**	**6**	**8.6**	**9.16**

After addition of fourth Shunt Capacitor at bus no. 12, we can see line MVAR is reduced in those line mentioned in the table above. The line L20 which is highlighted with yellow color is improved in terms of its MVAR and it is within limit but greater than 150. And the other lines which are not highlighted but focused are within limit.

GENERATOR TABLE

ID	Bus ID	D Base ID	Type	Rated S [MVA]	kV Nominal	Generator Type	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Q max. [MVAR]	Q min. [MVAR]	Ctrled BusID	Ctrld Bus/ V [pu]
G10	30	G10	Generator	1000	16.5	PV	826.78	265.46	868.36	95.2	8.29	560	-240	30	1.048
G1	39	G1	Generator	10000	345	PV	1029.68	546.97	1165.93	88.3	11.32	5600	-2400	39	1.03
G2	31	G2	Generator	700	16.5	SW	0	115.86	115.86	0	1.18	392	-168	31	0.982
G3	32	G3	Generator	800	16.5	PV	674.61	103.21	682.46	98.8	6.942	448	-192	32	0.983
G4	33	G4	Generator	800	16.5	PV	656.35	61.31	659.21	99.6	6.611	448	-192	33	0.997
G5	34	G5	Generator	600	16.5	PV	545.78	147.27	565.3	96.5	5.584	336	-144	34	1.012
G6	35	G6	Generator	800	16.5	PV	674.61	235.8	714.64	94.4	6.811	448	-192	35	1.049
G7	36	G7	Generator	700	16.5	PV	583.31	211.75	620.56	94	5.835	392	-168	36	1.064
G8	37	G8	Generator	700	16.5	PV	563.02	45.74	564.88	99.7	5.496	392	-168	37	1.028
G9	38	G9	Generator	1000	16.5	PV	857.22	64.48	859.64	99.7	8.375	560	-240	38	1.026

No generator in the above report is operating under overload condition.

SHUNT CAPACITOR TABLE

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	R [MW]	X [MVAR]	Type
SC2_9	9	SC2_9	0	-304.78	304.78	0	0	-296	Shunt Capacitor
SC1_3	3	SC1_3	0	-443.1	443.1	0	0	-456	Shunt Capacitor
SC4_12	12	SC4_12	0	-82.01	82.01	0	0	-88	Shunt Capacitor
SC3_4	4	SC3_9	0	-175.38	175.38	0	0	-188	Shunt Capacitor

Here we used last shunt capacitor of rating 88 MVAR in our last step from our logical intuition. From the above table we see that it works with 82.01 MVAR. So we can say that our addition of last shunt capacitor is compatible with our system.

TRANSFORMER REPORT

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T10	2	30	T10	Fixed -Tap Xmer	1000	345	16.5	-822.66	-141.08	834.67	-98.6	8.29	156.8	4.12	124.38
T01	12	11	T01	Fixed -Tap Xmer	300	138	345	-14.86	-0.49	14.87	-99.9	0.154	170.1	0	0.1
T11	29	38	T11	Fixed -Tap Xmer	1000	345	16.5	-851.61	44.92	852.79	-99.9	8.375	177.8	5.61	109.41
T02	12	13	T02	Fixed -Tap Xmer	300	138	345	7.36	-5.5	9.19	80.1	0.095	28.8	0	0.04
T12	19	20	T12	Fixed -Tap Xmer	1000	345	230	85.08	12.89	86.05	98.9	0.871	-13.7	0.05	1.05
T03	6	31	T03	Fixed -Tap Xmer	700	345	16.5	-566.66	-24.12	567.18	-99.9	5.903	168.9	2.24	87.14
T04	10	32	T04	Fixed -Tap Xmer	800	345	16.5	-672.21	-6.86	672.24	-100	6.942	172.4	2.41	96.35
T05	19	33	T05	Fixed -Tap Xmer	800	345	16.5	-653.3	0.72	653.3	-100	6.611	175	3.06	62.03
T06	20	34	T06	Fixed -Tap Xmer	600	230	16.5	-542.97	-91.15	550.57	-98.6	5.584	164.7	2.81	56.11
T07	22	35	T07	Fixed -Tap Xmer	800	345	16.5	-672.58	-169.44	693.6	-97	6.811	162	2.03	66.36
T08	23	36	T08	Fixed -Tap Xmer	700	345	16.5	-581.61	-119.16	593.69	-98	5.835	164.3	1.7	92.59
T09	25	37	T09	Fixed -Tap Xmer	700	345	16.5	-561.21	24.36	561.74	-99.9	5.496	170.7	1.81	70.1

TXFO ID	Bus From	Bus To	D Base ID	Type	Rated S [MVA]	kV Nominal Primary	kV Nominal Secondary	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]	I [pu]	Iangle [deg]	P losses [MW]	Q losses [MVAR]
T_REC	39	B39_REC	T_REC	Tcul Xmer	800	345	100	501.52	196.28	538.56	93.1	5.229	-56.7	0.52	19.34
T_INV	9	B9_INV	T_INV	Tcul Xmer	800	345	100	-499.78	135.92	517.93	-96.5	5.104	-164	0.49	18.43

No transformer is overloaded after addition of SC_4 at bus no. 12.

TRANSFORMER REPORT (%LOADING in terms of CAPABILITY)

TXFO ID	Bus From	Bus To	Capacity (Norm.) [MVA]	Loading [%] Capacity	Capacity (Emer.) [MVA]	Loading [%] Capacity	Tap Ratio %	Tap Pos [%]	Min	Max	Setpoint Min	Setpoint Max	Ctrld Bus/V [pu]	Ctrled BusID
T10	2	30	1000	83.5	1500	55.6	100	100						
T01	12	11	300	5	450	3.3	100	100						
T11	29	38	1000	85.3	1500	56.9	100	100						
T02	12	13	300	3.1	450	2	100	100						
T12	19	20	1000	8.6	1500	5.7	100	100						
T03	6	31	700	81	1050	54	100	100						
T04	10	32	800	84	1200	56	100	100						
T05	19	33	800	81.7	1200	54.4	100	100						
T06	20	34	600	91.8	900	61.2	100	100						
T07	22	35	800	86.7	1200	57.8	100	100						
T08	23	36	700	84.8	1050	56.5	100	100						
T09	25	37	700	80.2	1050	53.5	100	100						
Tcul Xmer INFO								Tap Pos [%]	Min Tap [%]	Max Tap [%]	Bus Min V [pu]	Bus Max V [pu]		
T_REC	39	B39_REC	800	67.3	1200	44.9	100	100	90	110	1	1	1	B39_REC
T_INV	9	B9_INV	800	64.7	1200	43.2	100	100	90	110	1	1	1	B9_INV

From the above table we can clearly pick up the fact that all the transformers are operating within normal rating set by their design. Here for smooth observation, the transformers operating above or close to 85 percent of the normal rating are highlighted.

DISTRIBUTED SWING TABLE

ID	P Desired [MW]	P calculated [MW]
G10	815	826.78
G3	665	674.61
G4	647	656.35
G5	269	545.78
G6	665	674.61

ID	P Desired [MW]	P calculated [MW]
G7	575	583.31
G8	555	563.02
G9	845	857.22
G1	1015	1029.68

The distributed swing report illustrates that the targeted real power generation and the power calculated through distributed swing mechanism are slightly different. As we have seen before the swing calculated power accounts for the losses of the network.

STATIC LOAD REPORT

ID	Bus ID	DBase ID	P [MW]	Q [MVAR]	S [MVA]	P. Factor [%]
Load8	8	LOAD8	522	176	550.87	94.8
Load18	18	LOAD18	158	30	160.82	98.2
Load28	28	LOAD28	206	27.6	207.84	99.1
Load29	29	LOAD29	283.5	26.9	284.77	99.6
Load39	39	LOAD39	1104	250	1131.95	97.5
Load4	4	LOAD4	500	184	532.78	93.8
Load24	24	LOAD24	308.6	-92.2	322.08	95.8
Load15	15	LOAD15	320	153	354.7	90.2
Load25	25	LOAD25	224	47.2	228.92	97.9
Load16	16	LOAD16	329	32.3	330.58	99.5
Load26	26	LOAD26	139	17	140.04	99.3
Load7	7	LOAD7	233.8	84	248.43	94.1
Load27	27	LOAD27	281	75.5	290.97	96.6
Load20	20	LOAD20	628	103	636.39	98.7
Load21	21	LOAD21	274	115	297.15	92.2
Load31	31	LOAD31	9.2	4.6	10.29	89.4
Load12	12	LOAD12	7.5	88	88.32	8.5
Load3	3	LOAD3	322	2.4	322.01	100
Load23	23	LOAD23	247.5	84.6	261.56	94.6

Here we can see Load 12 at bus no. 12 has power factor of only 8.5 percent lagging. It is not operating at good condition.

INDUCTION MOTOR REPORT

ID	Bus ID	DBase ID	Type	V sol [pu]	S [MVA]	P. Factor [%]	I [pu]
IM1	3	IM1	Induction Motor	0.986	888.89	90	9.017

Our system supports inclusion of 10 induction motor with load flow converging. Here, we can see all the motors are running with 0.9 power factor. Due to heavy lagging reactive power consumption, reactive current component is flowing considerably toward bus no. 03. Therefore the bus voltage of the induction motors was outside the voltage limit namely heavily under voltage. But after adding Shunt Capacitor it is now within limit.

ABNORMAL REPORT

ID						
BUSES OUTSIDE VOLTAGE LIMITS (100 %)						
Bus ID	**Zone**	**kV Base**	**Vmin - [pu]**	**Vmax - [pu]**	**V sol - [pu]**	**Ang sol - [deg]**
36	0	16.5	0.95	1.05	1.064	4.3
OVERLOADED LINES & CABLES (WITHIN 100 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**	
UNDERLOADED LINES & CABLES (WITHIN 50 %)						
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**		
L10	5	8	0.743	4.482		
L20	15	16	2.598	4.482		
L30	25	26	0.315	4.482		
L11	6	7	2.4	4.482		
L31	26	27	2.63	4.482		
L12	6	11	2.231	4.482		
L32	26	28	1.543	4.482		
L13	7	8	0.174	4.482		
L23	16	21	3.622	4.482		

ID						
L33	26	29	2.026	4.482		
L24	16	24	1.52	4.482		
L34	28	29	3.556	4.482		
L25	17	18	4.233	4.482		
L16	10	11	2.347	4.482		
L26	17	27	0.697	4.482		
L28	22	23	0.381	4.482		
L19	14	15	1.303	4.482		
L29	23	24	3.699	4.482		
L4	2	25	3.032	4.482		
L5	3	4	3.621	4.482		
L6	3	18	2.627	4.482		
L8	4	14	3.41	4.482		
OVERLOADED TRANSFORMERS (WITHIN 100 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]	Emergency Loading Limit - [MVA]	
UNDERLOADED TRANSFORMERS (WITHIN 50 %)						
ID	Bus From	Bus To	Power Flow - [MVA]	Loading Limit - [MVA]		
T01	12	11	14.868	150		
T02	12	13	9.188	150		
T12	19	20	86.052	500		
GENERATORS AT REACTIVE LIMITS (WITHIN 0 %)						
ID	Bus From	P Gen - [MW]	Q Gen - [MVAR]	Q Min - [MVAR]	Q Max - [MVAR]	
TRANSFORMERS AT TAP LIMITS (WITHIN 0 %)						
ID	Bus From	Bus To	Tap Pos - [%]	Min Tap - [%]	Max Tap - [%]	

The abnormality report gives information related to the overload or underload condition of the various components of the power system. Here, underload but not overload condition exists in the system being analyzed. Bus no. 36 is over voltage which is outside the voltage limit.

Bus no. 36 is a purely generator connected bus; it can be called voltage controlled bus. As we know for load flow solution the magnitude of the voltage of the voltage controlled bus is a known quantity and therefore it must be fixed all the way through load flow analysis. It can alter its value in the case of its reactive limit violation. In that case, bus 36 will behave as PQ bus. But the reactive limit of the generator 7 (G07) is not violated. And therefore bus voltage of 36 is always a fixed quantity and that is 1.064 per unit which is outside the voltage limit of .95 to 1.05.

SUMMARY REPORT

Summary Data	Active Power	Reactive Power
Total generation	6411.377	1797.859
Spinning reserve	8978.623	
Static Load	6097.1	1408.9
Shunt loads	0	-1005.28
Motor loads	800	387.458
Total load	6897.1	791.077
Line / cable losses	64.792	-91.084
Transformer losses	26.858	803.422
Total losses	92.65	1006.338
Mismatches	-578.373	0.444

In this table, we can observe the power flow in the entire system, such as generated power, load power, line losses, transformers losses. This data gives an overview of the power condition of the system.

Conclusion:

Load flow calculation and abnormality reduction is an integral part of the power system engineering. A power system is an acutely complex and duty-heavy installation which must be dealt with great engineering acumen as the fall-out due to design faltering is severely harsh and highly perilous. Our assigned project has dealt with such big system considered to be the IEEE 39 bus (New England) test system shown below. Nominal frequency is 50 Hz. IEEE 39 bus system is well known as 10-machine New-England Power System. From the inception of our project all the way through the termination we have proceeded with great care and logical thinking along with intuitional reasoning. Firstly we carried out the hackneyed load flow calculation of the 39 bus system which does not demand crucial decision making. The system was in the nominal condition and with some bus voltages outside limits. But no major component was overloaded. It is worth mentioning that, bus 36 was a PV bus and its per unit value is a constant and known quantity in the load flow calculation. Demonstrably, at every step of our project bus 36 maintained a constant per unit voltage as the generator connected to the bus 36 did not transgress its reactive limit. Secondly, after adding HVDC line with correct formation, the bus in the vicinity of bus 9 were heavily affected with under voltage condition due to huge apparent reactive power flow towards that end from the converter which by the way apparently getting reactive power from the rectifier but with absence in the HVDC line. Thirdly, after being capable of adding 10 induction-motor the system health deteriorated drastically with overloaded transformers and generators which represent a very dangerous and loss-infested state of the system. Besides, the system load is way higher than total system generation resulting in an unacceptable increase of power flow from the swing generator. Thus putting pressure on transformer 03 in such a heavy-handed way that its real power is greater than its apparent power rating. To make remedies for that we increased the active generation rating of the generators and made a calculated approach of distributed swing generation. Finally, using our logical reasoning we successfully and efficiently corrected all the abnormalities and uplifted the state or benchmark parameters of the system with SVCs and shunt capacitors. With only four SVCs we have developed the system health to near perfect. Likewise, so is true for the case of shunt capacitors. We think that we have satisfactorily accomplished our project with success and with manipulative engineering in that such large systems are pretty difficult to solve without the help of systematic efficient algorithm.