ISLAMIC UNIVERSITY OF TECHNOLOGY (IUT)

ORGANISATION OF ISLAMIC COOPERATION (OIC)

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

Course No: EEE 4632

Course Title: POWER SYSTEM III LAB

Project:

Exploring the stability and resilience of the IEEE 39 bus power system under disturbances.

Group Members:

Name	**Id**
Zerin Yeasmin	200021108
Nahadia Tabassum Oyshi	200021112
Farhan Sharif Rishad	200021136
Rafsan Sayad	200021138
Md. Mehedi Hasan	200021146

Contents

Introduction:

This project explores the stability and resilience of the IEEE 39 bus power system under disturbances. We begin with a load flow analysis using the Newton-Raphson method to confirm system stability. Next, we examine the frequency response to the outage of a major generator, including the impact of different load frequency relief settings. We calculate the Fast Voltage Stability Index (FVSI) for each bus to identify weaker points and design a load shedding scheme that prioritizes these areas to enhance stability. This study highlights the importance of integrated analysis and control strategies for reliable power system performance.

Input Parameters:

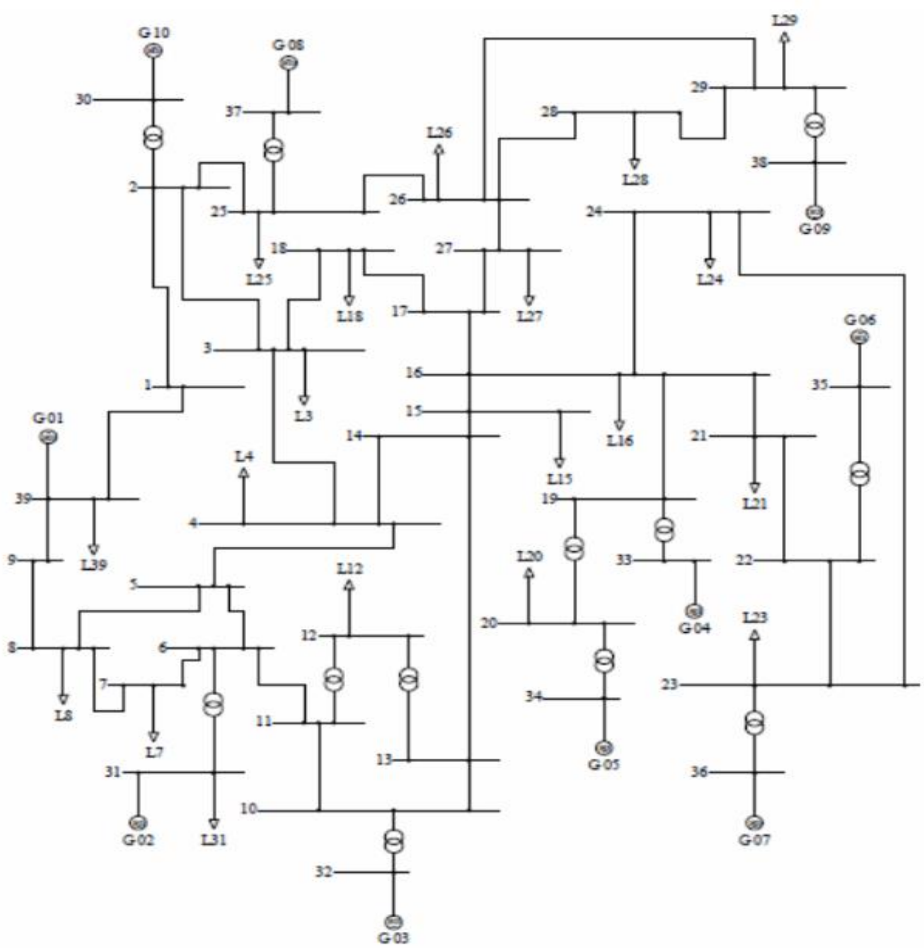


Figure 1: Single line diagram of IEEE 39 bus system

.

Using the information given in the following tables, we created the network shown in Figure.

For bus,

UNTITLED

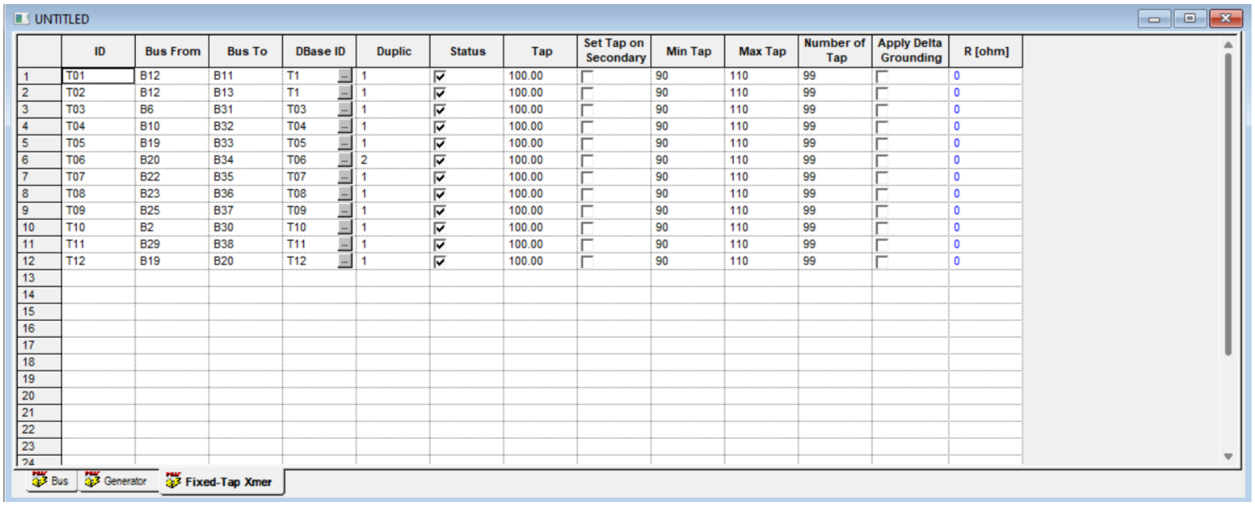
	ID	Extra ID	Zone	Status	Volt Sol	Angle Sol	kV Base	kV Oper	pu Min	pu Max	RQQ1	XQQ1	RQQ0	XQQ0
1	B1		0	☑	1.003517866	2.192557096	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
2	B10		0	☑	0.973115742	3.772673606	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
3	B11		0	☑	0.973279714	2.414514303	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
4	B12		0	☑	0.950242459	2.866640090	138.000	138.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
5	B13		0	☑	0.967666923	3.436872243	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
6	B14		0	☑	0.957258880	2.811717271	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
7	B15		0	☑	0.951832830	6.215657234	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
8	B16		0	☑	0.968287110	9.484937667	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
9	B17		0	☑	0.980299472	6.927950859	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
10	B18		0	☑	0.975832760	5.106091976	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
11	B19		0	☑	0.972841322	21.46045684	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
12	B2		0	☑	0.991034746	6.729355812	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
13	B20		0	☑	0.965237855	24.67361068	230.000	230.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
14	B21		0	☑	0.963181495	12.23052501	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
15	B22		0	☑	0.980267286	17.29824829	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
16	B23		0	☑	0.976465642	17.05236244	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
17	B24		0	☑	0.969367444	9.502398490	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
18	B25		0	☑	0.990541338	8.326059341	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
19	B26		0	☑	0.994171917	8.367235183	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
20	B27		0	☑	0.982465803	6.778510093	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
21	B28		0	☑	0.994798421	12.27365779	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
22	B29		0	☑	0.994230329	15.33893299	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
23	B3		0	☑	0.973347067	3.390926122	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
24	B30		0	☑	1.000000000	9.346354484	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000

Bus | Generator

UNTITLED

	ID	Extra ID	Zone	Status	Volt Sol	Angle Sol	kV Base	kV Oper	pu Min	pu Max	RQQ1	XQQ1	RQQ0	XQQ0
21	B28		0	☑	0.994798421	12.27365779	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
22	B29		0	☑	0.994230329	15.33893299	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
23	B3		0	☑	0.973347067	3.390926122	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
24	B30		0	☑	1.000000000	9.346354484	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
25	B31		0	☑	1.000000000	0.000000000	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
26	B32		0	☑	1.000000000	11.44985771	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
27	B33		0	☑	1.000000000	26.67368888	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
28	B34		0	☑	1.000000000	35.46267700	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
29	B35		0	☑	1.000000000	22.73927116	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
30	B36		0	☑	1.000000000	25.98954391	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
31	B37		0	☑	1.000000000	15.56835460	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
32	B38		0	☑	1.000000000	22.79916763	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
33	B39		0	☑	1.000000000	-0.47046485	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
34	B4		0	☑	0.944488227	-0.02350826	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
35	B5		0	☑	0.943623363	-0.99412930	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
36	B6		0	☑	0.945141196	-0.67922568	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
37	B7		0	☑	0.935582697	-2.82956600	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
38	B8		0	☑	0.936003088	-3.22830319	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
39	B9		0	☑	0.980118095	-1.60142946	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
40														

For Fixed tap transformer,

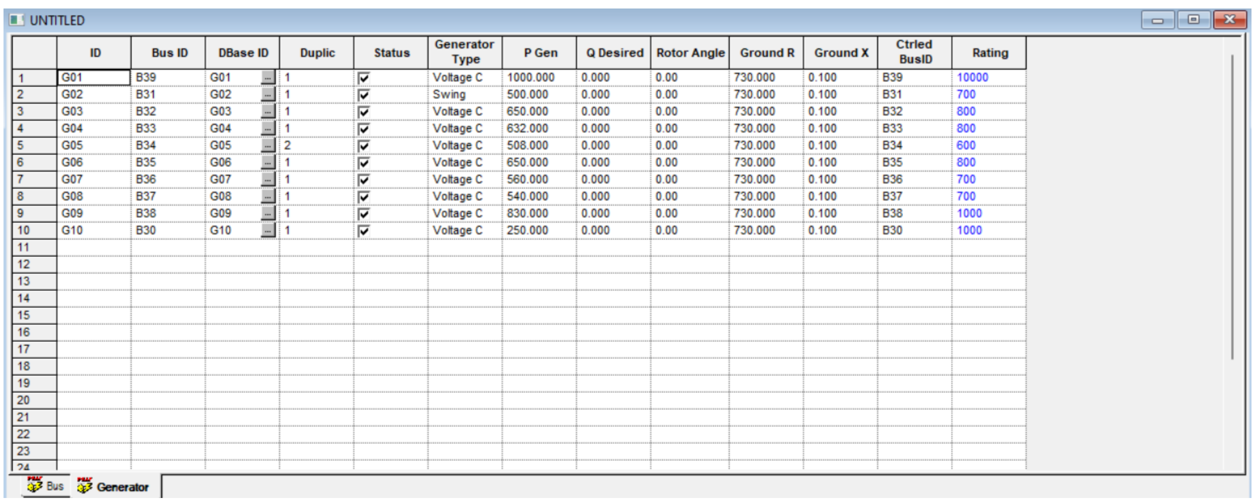


UNTITLED

	ID	Bus From	Bus To	DBase ID	Duplic	Status	Tap	Set Tap on Secondary	Min Tap	Max Tap	Number of Tap	Apply Delta Grounding	R [ohm]
1	T01	B12	B11	T1	1	☑	100.00	☐	90	110	99	☐	0
2	T02	B12	B13	T1	1	☑	100.00	☐	90	110	99	☐	0
3	T03	B6	B31	T03	1	☑	100.00	☐	90	110	99	☐	0
4	T04	B10	B32	T04	1	☑	100.00	☐	90	110	99	☐	0
5	T05	B19	B33	T05	1	☑	100.00	☐	90	110	99	☐	0
6	T06	B20	B34	T06	2	☑	100.00	☐	90	110	99	☐	0
7	T07	B22	B35	T07	1	☑	100.00	☐	90	110	99	☐	0
8	T08	B23	B36	T08	1	☑	100.00	☐	90	110	99	☐	0
9	T09	B25	B37	T09	1	☑	100.00	☐	90	110	99	☐	0
10	T10	B2	B30	T10	1	☑	100.00	☐	90	110	99	☐	0
11	T11	B29	B38	T11	1	☑	100.00	☐	90	110	99	☐	0
12	T12	B19	B20	T12	1	☑	100.00	☐	90	110	99	☐	0

Bus | Generator | Fixed-Tap Xmer

For Generator,



UNTITLED

	ID	Bus ID	DBase ID	Duplic	Status	Generator Type	P Gen	Q Desired	Rotor Angle	Ground R	Ground X	Ctrled BusID	Rating
1	G01	B39	G01	1	☑	Voltage C	1000.000	0.000	0.00	730.000	0.100	B39	10000
2	G02	B31	G02	1	☑	Swing	500.000	0.000	0.00	730.000	0.100	B31	700
3	G03	B32	G03	1	☑	Voltage C	650.000	0.000	0.00	730.000	0.100	B32	800
4	G04	B33	G04	1	☑	Voltage C	632.000	0.000	0.00	730.000	0.100	B33	800
5	G05	B34	G05	2	☑	Voltage C	508.000	0.000	0.00	730.000	0.100	B34	600
6	G06	B35	G06	1	☑	Voltage C	650.000	0.000	0.00	730.000	0.100	B35	800
7	G07	B36	G07	1	☑	Voltage C	560.000	0.000	0.00	730.000	0.100	B36	700
8	G08	B37	G08	1	☑	Voltage C	540.000	0.000	0.00	730.000	0.100	B37	700
9	G09	B38	G09	1	☑	Voltage C	830.000	0.000	0.00	730.000	0.100	B38	1000
10	G10	B30	G10	1	☑	Voltage C	250.000	0.000	0.00	730.000	0.100	B30	1000

Bus | Generator

For line,

UNTITLED

	ID	Bus From	Bus To	DBase ID	Duplic	Status	Series X Compensation	Length
3	L11	B6	B7	L11	1	✓	0.00	61.7000
4	L12	B6	B11	L12	1	✓	0.00	55.0000
5	L13	B7	B8	L13	1	✓	0.00	30.8000
6	L14	B8	B9	L14	1	✓	0.00	243.3000
7	L15	B9	B39	L15	1	✓	0.00	167.6000
8	L16	B10	B11	L16	1	✓	0.00	28.8000
9	L17	B10	B13	L17	1	✓	0.00	28.8000
10	L18	B13	B14	L18	1	✓	0.00	67.7000
11	L19	B14	B15	L19	1	✓	0.00	145.4000
12	L2	B1	B39	L2	1	✓	0.00	167.6000
13	L20	B15	B16	L20	1	✓	0.00	63.0000
14	L21	B16	B17	L21	1	✓	0.00	59.7000
15	L22	B16	B19	L22	1	✓	0.00	130.7000
16	L23	B16	B21	L23	1	✓	0.00	90.5000
17	L24	B16	B24	L24	1	✓	0.00	39.5000
18	L25	B17	B18	L25	1	✓	0.00	55.0000
19	L26	B17	B27	L26	1	✓	0.00	116.0000
20	L27	B21	B22	L27	1	✓	0.00	93.8000
21	L28	B22	B23	L28	1	✓	0.00	64.3000
22	L29	B23	B24	L29	1	✓	0.00	234.6000
23	L3	B2	B3	L3	1	✓	0.00	101.2000
24	L30	B25	B26	L30	1	✓	0.00	216.5000
25	L31	B26	B27	L31	1	✓	0.00	98.5000

Bus | Generator | Fixed-Tap Xmer | Line

UNTITLED

	ID	Bus From	Bus To	DBase ID	Duplic	Status	Series X Compensation	Length
18	L25	B17	B18	L25	1	✓	0.00	55.0000
19	L26	B17	B27	L26	1	✓	0.00	116.0000
20	L27	B21	B22	L27	1	✓	0.00	93.8000
21	L28	B22	B23	L28	1	✓	0.00	64.3000
22	L29	B23	B24	L29	1	✓	0.00	234.6000
23	L3	B2	B3	L3	1	✓	0.00	101.2000
24	L30	B25	B26	L30	1	✓	0.00	216.5000
25	L31	B26	B27	L31	1	✓	0.00	98.5000
26	L32	B26	B28	L32	1	✓	0.00	317.7000
27	L33	B26	B29	L33	1	✓	0.00	418.9000
28	L34	B28	B29	L34	1	✓	0.00	101.2000
29	L4	B2	B25	L4	1	✓	0.00	57.6000
30	L5	B3	B4	L5	1	✓	0.00	142.8000
31	L6	B3	B18	L6	1	✓	0.00	89.1000
32	L7	B4	B5	L7	1	✓	0.00	85.8000
33	L8	B4	B14	L8	1	✓	0.00	86.5000
34	L9	B5	B6	L9	1	✓	0.00	17.4000
35								
36								
37								
38								
39								

Bus | Generator | Fixed-Tap Xmer | Line

For static load,

UNTITLED

	ID	Bus ID	DBase ID	Load %	Status	P Load	Q Load	MVA	P. Factor	Extra ID 1	Extra ID 2	Extra ID 3	Creation Date	nP	nQ
1	L01	B3	L1	100	✓	322.0000	2.4000	322.0089	1.0000				5 / 3 /2024	0.000	0.000
2	L02	B4	L2	100	✓	500.0000	184.0000	532.7814	0.9385				5 / 3 /2024	0.000	0.000
3	L03	B7	L3	100	✓	233.8000	84.0000	248.4320	0.9411				5 / 3 /2024	0.000	0.000
4	L04	B8	L4	100	✓	522.0000	176.0000	550.8720	0.9476				5 / 3 /2024	0.000	0.000
5	L05	B12	L5	100	✓	7.5000	88.0000	88.3190	0.0849				5 / 3 /2024	0.000	0.000
6	L06	B15	L6	100	✓	320.0000	153.0000	354.6956	0.9022				5 / 3 /2024	0.000	0.000
7	L07	B16	L7	100	✓	329.0000	32.3000	330.5818	0.9952				5 / 3 /2024	0.000	0.000
8	L08	B18	L8	100	✓	158.0000	30.0000	160.8229	0.9824				5 / 3 /2024	0.000	0.000
9	L09	B20	L9	100	✓	628.0000	103.0000	636.3906	0.9868				5 / 3 /2024	0.000	0.000
10	L10	B21	L10	100	✓	274.0000	115.0000	297.1548	0.9221				5 / 3 /2024	0.000	0.000
11	L11	B23	L11	100	✓	247.5000	84.6000	261.5596	0.9462				5 / 3 /2024	0.000	0.000
12	L12	B24	L12	100	✓	308.6000	-92.2000	322.0789	0.9582				5 / 3 /2024	0.000	0.000
13	L13	B25	L13	100	✓	224.0000	47.2000	228.9189	0.9785				5 / 3 /2024	0.000	0.000
14	L14	B26	L14	100	✓	139.0000	17.0000	140.0357	0.9926				5 / 3 /2024	0.000	0.000
15	L15	B27	L15	100	✓	281.0000	75.5000	290.9661	0.9657				5 / 3 /2024	0.000	0.000
16	L16	B28	L16	100	✓	206.0000	27.6000	207.8407	0.9911				5 / 3 /2024	0.000	0.000
17	L17	B29	L17	100	✓	283.5000	26.9000	284.7733	0.9955				5 / 3 /2024	0.000	0.000
18	L18	B31	L18	100	✓	9.2000	4.6000	10.2859	0.8944				5 / 3 /2024	0.000	0.000
19	L19	B39	L19	100	✓	1104.0000	250.0000	1131.9523	0.9753				5 / 3 /2024	0.000	0.000
20															
21															
22															
23															
24															

Bus | Generator | Fixed-Tap Xmer | Line | Static Load

Task-1: Performing the load flow analysis

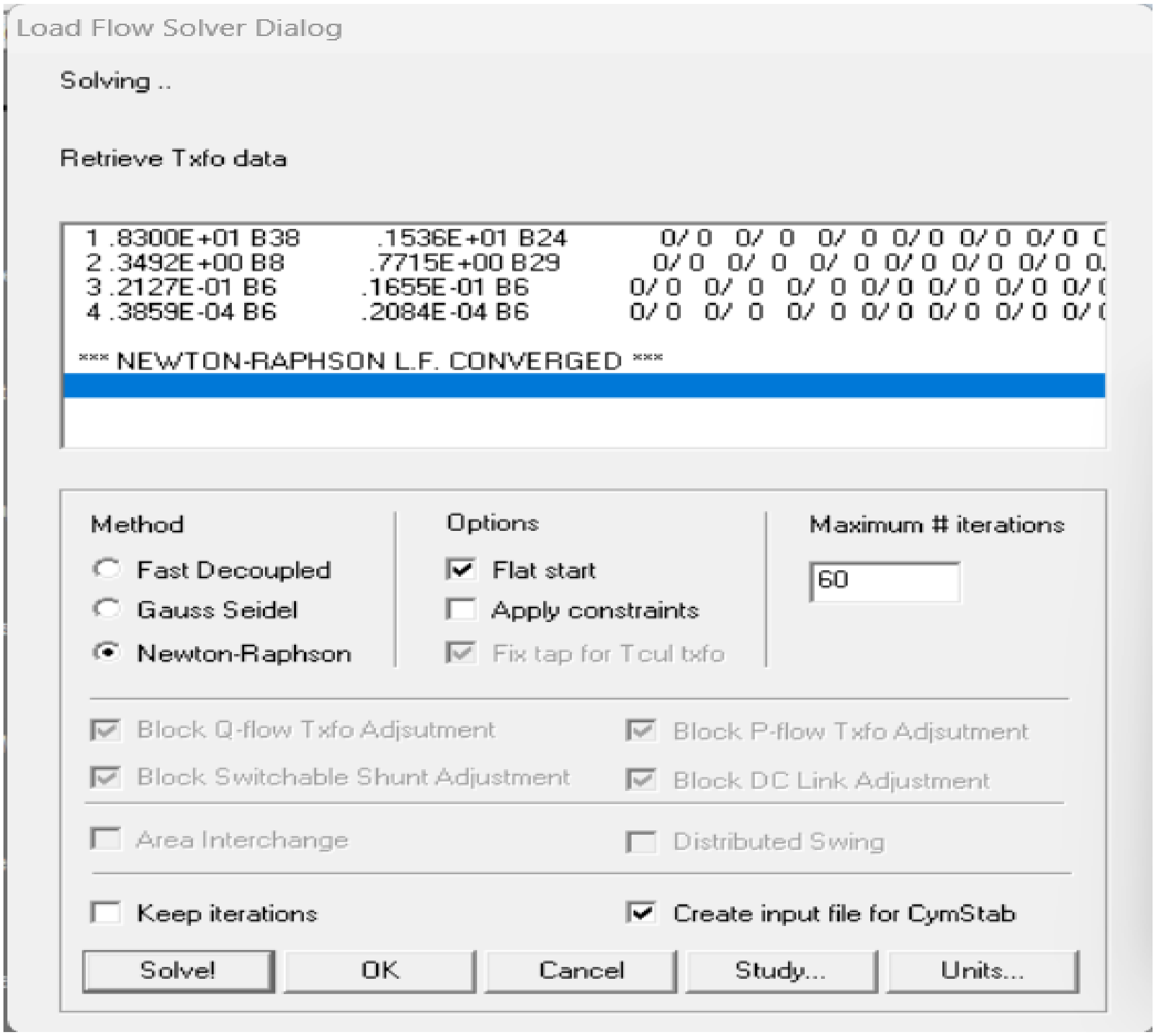


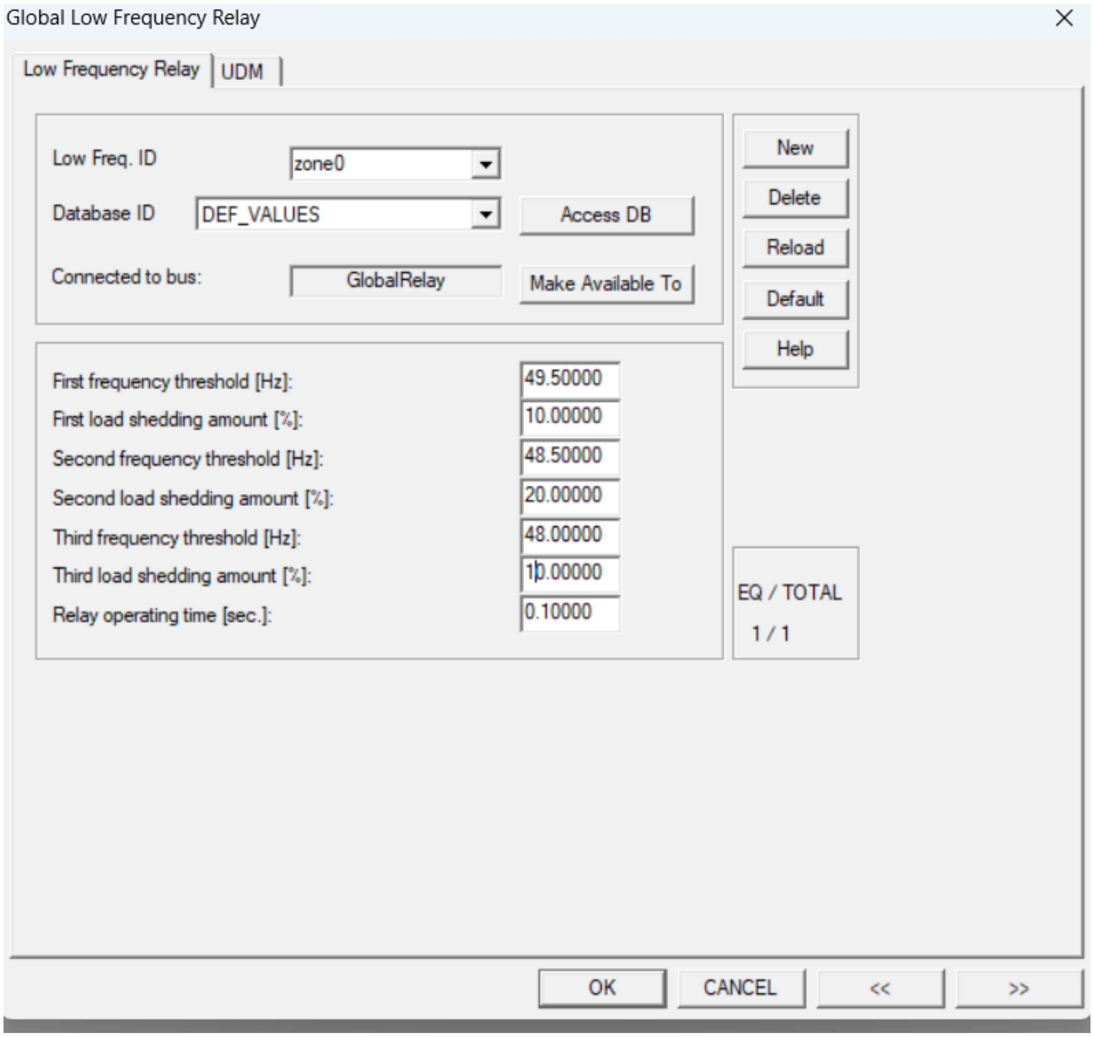
Fig.: load flow solver dialog

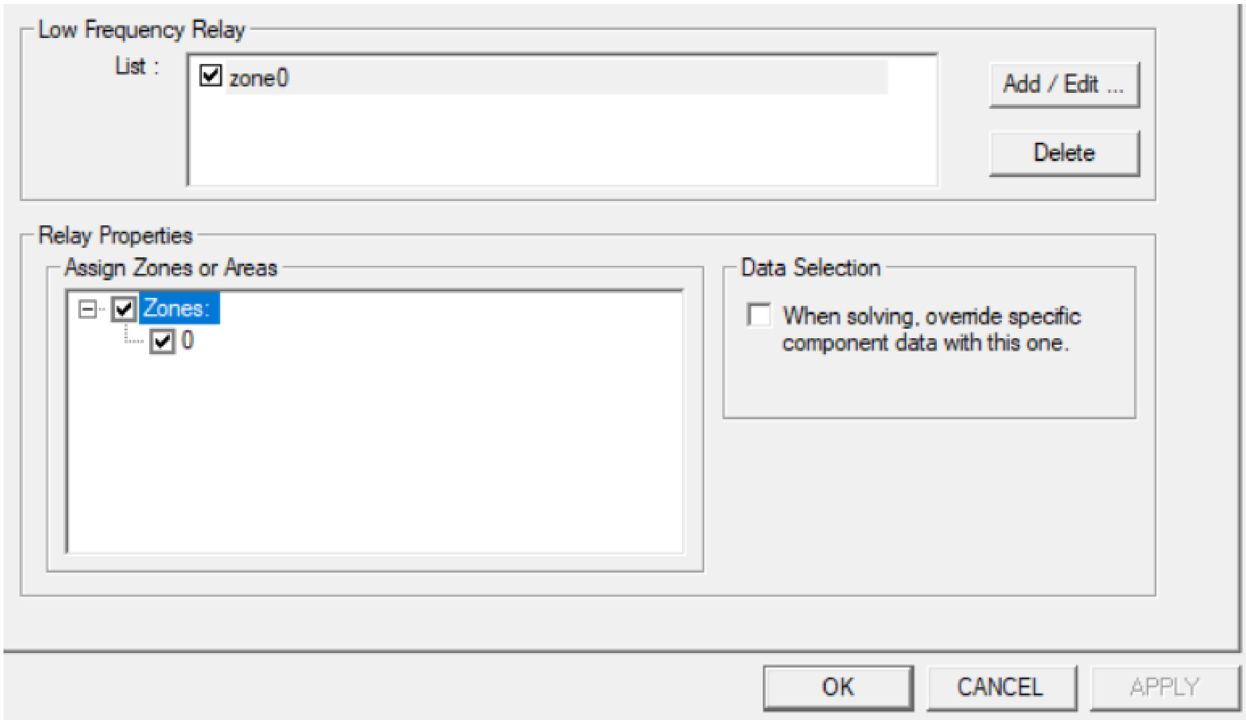
From the load flow analysis, we can see that the system converged which means the system is stable

Task-2: Performing frequency response analysis for the outage of G08

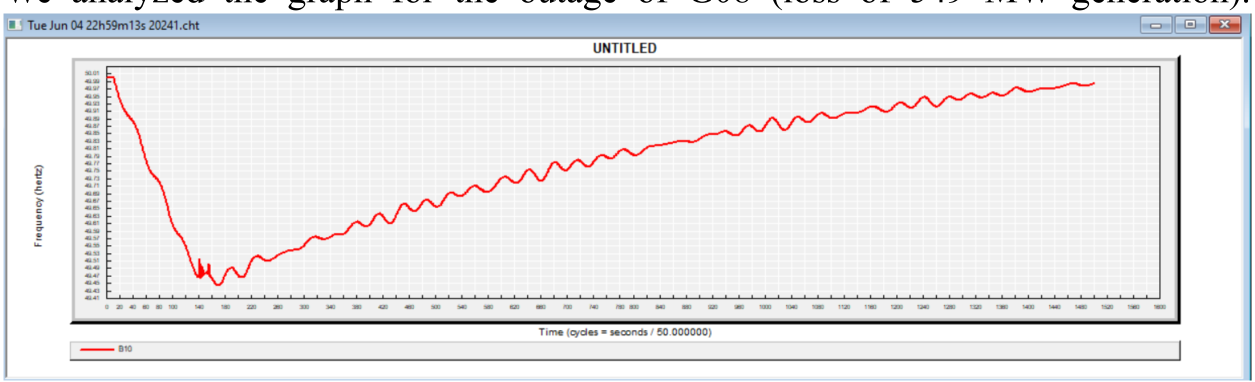
Taking Peak frequency of kp=0 for 1500 cycle under Transient Stability settings. Also, we performed the frequency analysis taking one zone named 'zone0'.

Estimated load shed amount was 10%,20%,10% respectively.





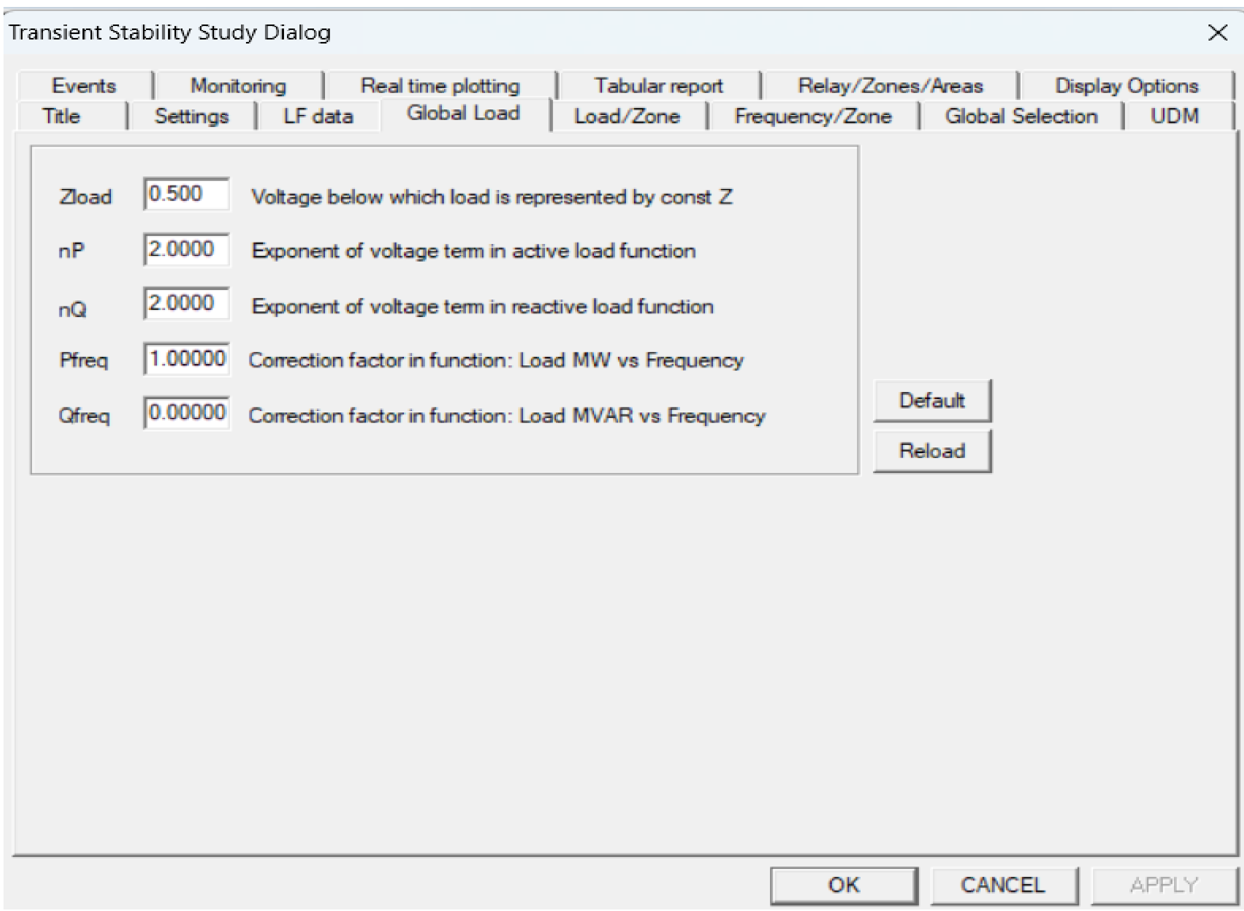
We analyzed the graph for the outage of G08 (loss of 549 MW generation).



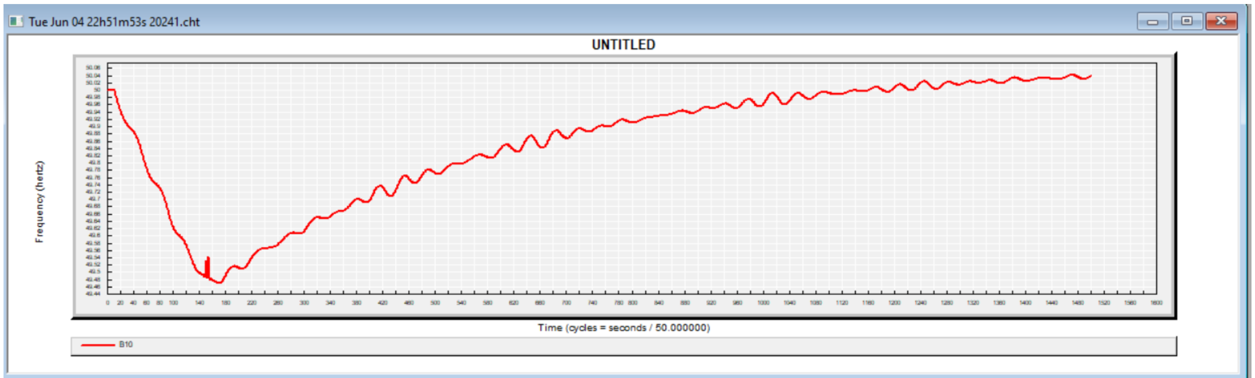
As we can see the frequency is dropping to its lowest point due to increment of load which is the Nadir point and after some time becoming stable that means it is frequency response is again rising.

Task-3: Repeating the frequency response analysis for the load frequency relief (kp) of 1%, 2% and 3%.

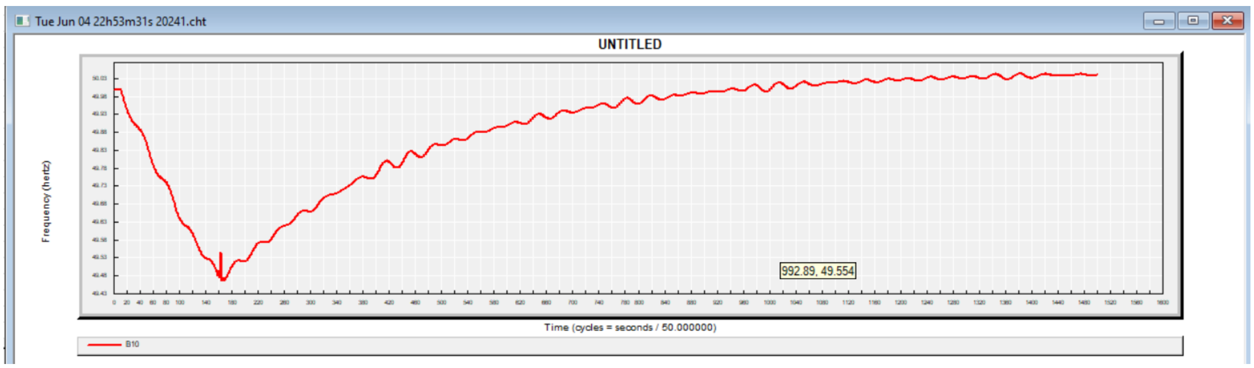
In this case we repeated the same process as Question-2. We chanced the values of Pfreq under load/ Zone in transient stability study dialog. For load frequency relief(kp) of 1%, we set Pfreq= 1, for 2%, we set Pfreq= 2 and for 3%, we set Pfreq= 3. We analyzed frequency vs time graph of kp analysis for the above-mentioned cases.



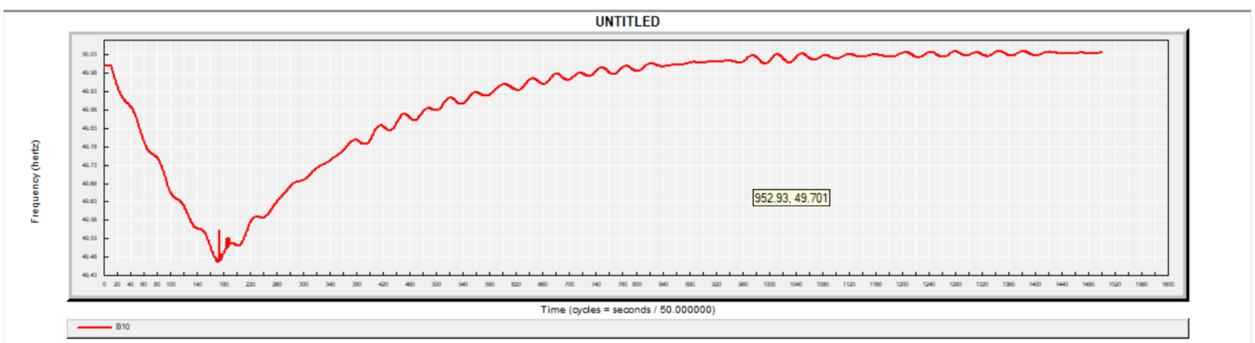
Output graph when kp=1%:



Output graph when kp=2%:



Output graph when kp=3%:



It is visible that with the increment of Kp our frequency response is improving as our Nadir point is increasing. Like when kp increased from 2% to 3% Nadir point improved from 49.554Hz to 49.701Hz.

Task-4: Determining Fast voltage stability index (FVSI) for each load bus and then ranking them.

To determine the FVSI of each bus, at first we need to consider two bus where one is the sending end bus and another is receiving end bus. FVSI of k-th bus can be expressed as

$$FVSI_{zk} = \frac{4Z^2 Q_k}{{V_S}^2 X}$$

FVSI calculation of each bus

$\boxed{\text{FVSI calculation}}$

$$FVSI_{z,k} = \frac{4Z^2 Q_k}{V_s^2 X}$$

$$FVSI_{1,2} = \frac{4(1.27\times10^{-5^2} + 0.000149^2)\times 0}{345^2 (0.000149)}$$

$$= 0$$

$FVSI_{1,39} = 1.256 \times 10^{-6}$

$FVSI_{2,3} = 1.212 \times 10^{-8}$

$FVSI_{2,25} = 3.937 \times 10^{-7}$

$FVSI_{3,4} = 9.259 \times 10^{-9}$

$FVSI_{3,16} = 1.514 \times 10^{-7}$

$FVSI_{4,5} = 0$

$FVSI_{4,14} = 0$

$FVSI_{5,6} = 0$

$FVSI_{6,8} = 8.872 \times 10^{-7}$

$FVSI_{6,7} = 4.227 \times 10^{-7}$

$FVSI_{6,11} = 0$

$FVSI_{7,8} = 8.901 \times 10^{-7}$

$FVSI_{8,9} = 0$

$FVSI_{9,39} = 1.256 \times 10^{-6}$

$FVSI_{10,11} = 0$

$FVSI_{10,13} = 0$

$FVSI_{13,14} = 0$

$FVSI_{14,15} = 7.725 \times 10^{-7}$

$FVSI_{15,16} = 1.6383 \times 10^{-7}$

$FVSI_{16,17} = 0$

$FVSI_{16,19} = 0$

$FVSI_{16,21} = 5.7878 \times 10^{-7}$

$FVSI_{16,24} = 4.64 \times 10^{-7}$

$FVSI_{17,18} = 1.515 \times 10^{-7}$

$FVSI_{17,27} = 3.805 \times 10^{-7}$

$FVSI_{21,22} = 0$

$FVSI_{22,23} = 4.264 \times 10^{-7}$

$FVSI_{23,24} = 4.64 \times 10^{-7}$

$FVSI_{25,26} = 8.612 \times 10^{-8}$

$FVSI_{26,27} = 3.818 \times 10^{-7}$

$FVSI_{26,28} = 1.395 \times 10^{-7}$

$FVSI_{26,29} = 1.3605 \times 10^{-7}$

$FVSI_{27,29} = 1.3605 \times 10^{-7}$

Load shedding should be highest where the Fast Voltage Stability Index (FVSI) is largest because a higher FVSI indicates a system is nearing voltage instability. When the FVSI value is high, it suggests that the power system is operating closer to its voltage stability limits, making it more susceptible to voltage collapse. To prevent voltage collapse and maintain system stability, load shedding is implemented to reduce the demand on the network. This reduction in load helps to bring the system back within stable operating conditions. By shedding load in areas with high FVSI, the system can reduce the risk of widespread voltage instability or blackout. Therefore, targeted load shedding in these vulnerable areas is a preventive measure to maintain overall system reliability and stability.

The buses are divided into four zones based on their FVSI calculations. Bus2-3 are placed into zone 3. Bus 1,9,39 are placed to zone 1. FVSI calculated zero values are placed to zone 0. The rest of the buses are placed to zone 2.

UNTITLED

	ID	Extra ID	Zone	Status	Volt Sol	Angle Sol	kV Base	kV Oper	pu Min	pu Max	RQQ1	XQQ1	RQQ0	XQQ0
1	B1		0	☑	1.003517866	2.192557096	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
2	B10		0	☑	0.973115742	3.772673606	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
3	B11		0	☑	0.973279714	2.414514303	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
4	B12		0	☑	0.950242459	2.866640090	138.000	138.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
5	B13		0	☑	0.967666923	3.436872243	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
6	B14		0	☑	0.957258880	2.811717271	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
7	B15		2	☑	0.951832830	6.215657234	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
8	B16		2	☑	0.968287110	9.484937667	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
9	B17		0	☑	0.980299472	6.927950859	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
10	B18		2	☑	0.975832760	5.106091976	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
11	B19		0	☑	0.972841322	21.46045684	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
12	B2		0	☑	0.991034746	6.729355812	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
13	B20		0	☑	0.965237855	24.67361068	230.000	230.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
14	B21		2	☑	0.963181495	12.23052501	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
15	B22		0	☑	0.980267286	17.29824829	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
16	B23		2	☑	0.976465642	17.05236244	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
17	B24		2	☑	0.969367444	9.502398490	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
18	B25		2	☑	0.990541338	8.326059341	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
19	B26		2	☑	0.994171917	8.367235183	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
20	B27		2	☑	0.982465803	6.778510093	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
21	B28		2	☑	0.994798421	12.27365779	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
22	B29		2	☑	0.994230329	15.33893299	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
23	B3		3	☑	0.973347067	3.390926122	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
24	B30		0	☑	1.000000000	9.346354484	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
25	B31		0	☑	1.000000000	0.000000000	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
26	B32		0	☑	1.000000000	11.44985771	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
27	B33		0	☑	1.000000000	26.67368888	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
28	B34		0	☑	1.000000000	35.46267700	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
29	B35		0	☑	1.000000000	22.73927116	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
30	B36		0	☑	1.000000000	25.98954391	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
31	B37		0	☑	1.000000000	15.56835460	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
32	B38		0	☑	1.000000000	22.79916763	16.500	16.500	0.900	1.100	0.00000	0.00000	0.00000	0.00000
33	B39		1	☑	1.000000000	-0.47046485	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
34	B4		2	☑	0.944488227	-0.02350826	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
35	B5		0	☑	0.943623363	-0.99412930	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
36	B6		3	☑	0.945141196	-0.67922568	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
37	B7		2	☑	0.935582697	-2.82956600	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
38	B8		2	☑	0.936003088	-3.22830319	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000
39	B9		0	☑	0.980118095	-1.60142946	345.000	345.000	0.900	1.100	0.00000	0.00000	0.00000	0.00000

Bus

Task-5: Designing a load shedding scheme to apply more load cut to weaker buses after dividing into 4 zones

Based on FVSI values, we divided the entire system into 4 separate zones naming them as Zone 0, Zone 1, Zone 2, Zone 3 and Zone 4.

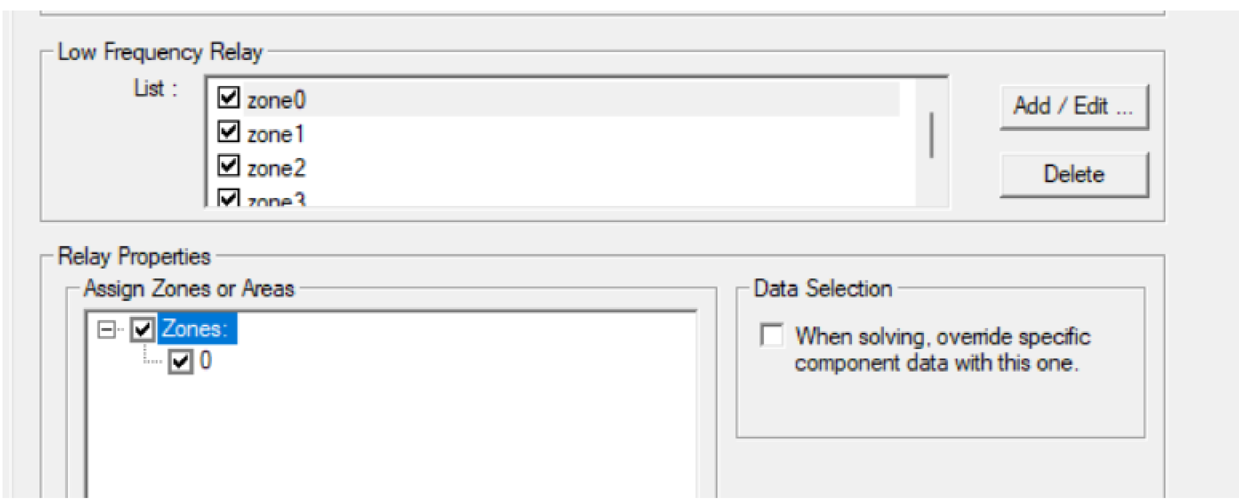
If FVSI value is more, then that bus is weaker which implies we have to shed more load from that bus. We divided into four zones where zone 0 is the strongest since its FVSI value is 0. So we shed less loads from this zone. Likewise ranking our zones from weaker to stronger:

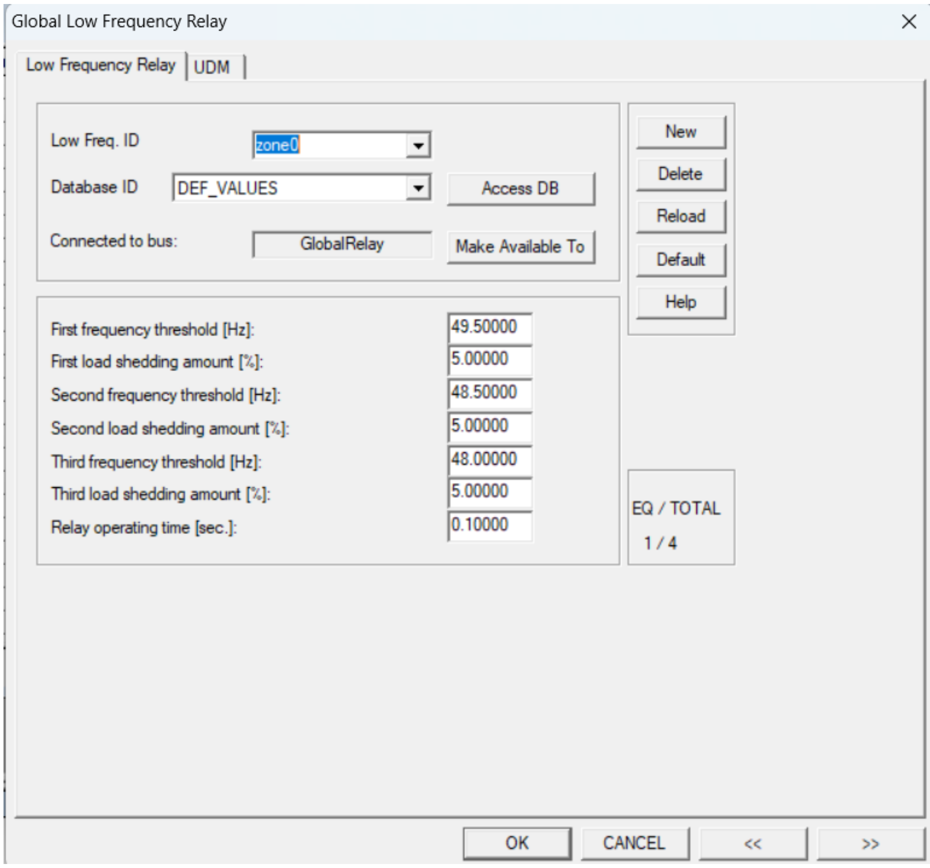
Zone1>Zone2>Zone3> Zone 0.

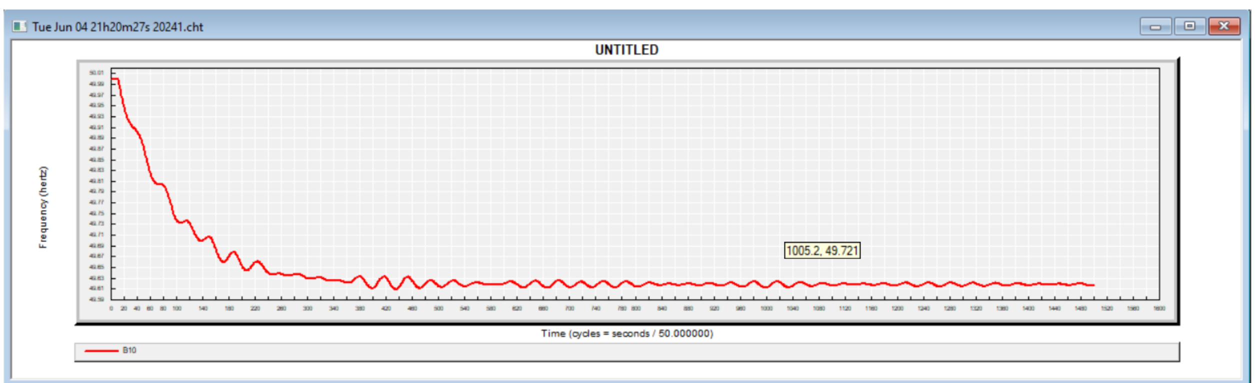
So, the largest amount of loads should be shed from zone 1

Zone 0:

The buses in Zone 0 have an FVSI value of 0, indicating that they are the most stable.Because of this, only 5% of the load was reduced when every frequency threshold was reached.



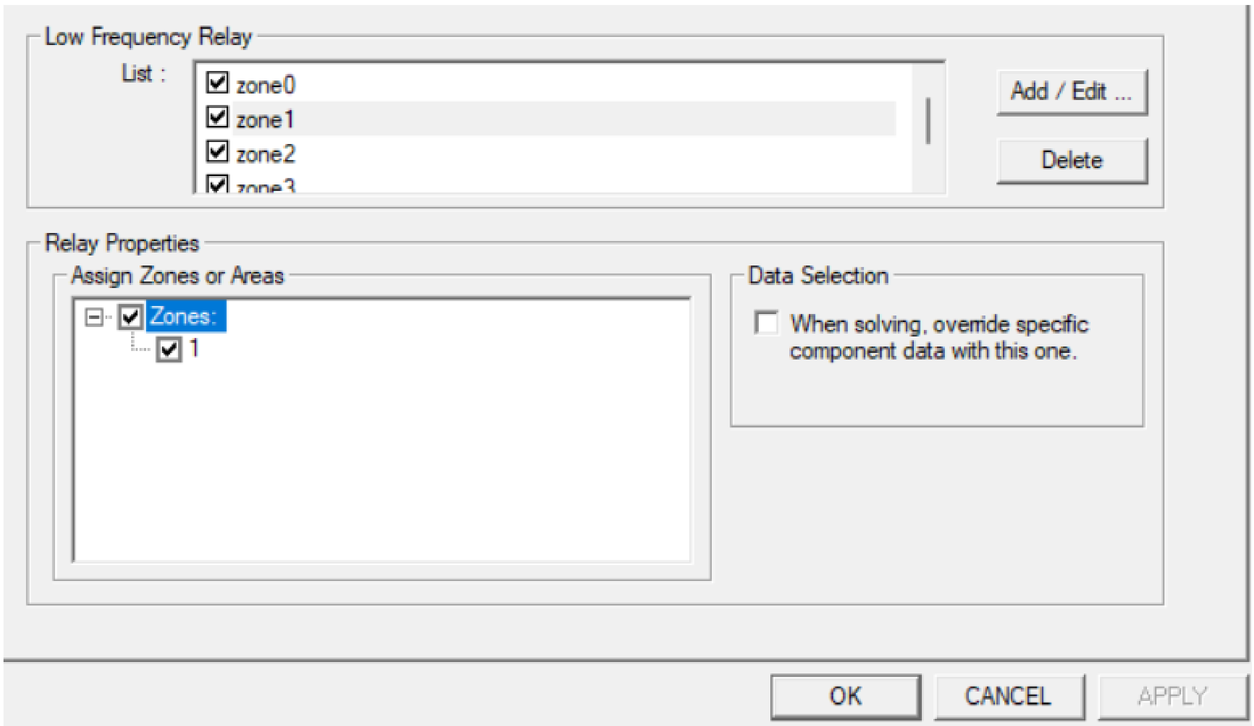


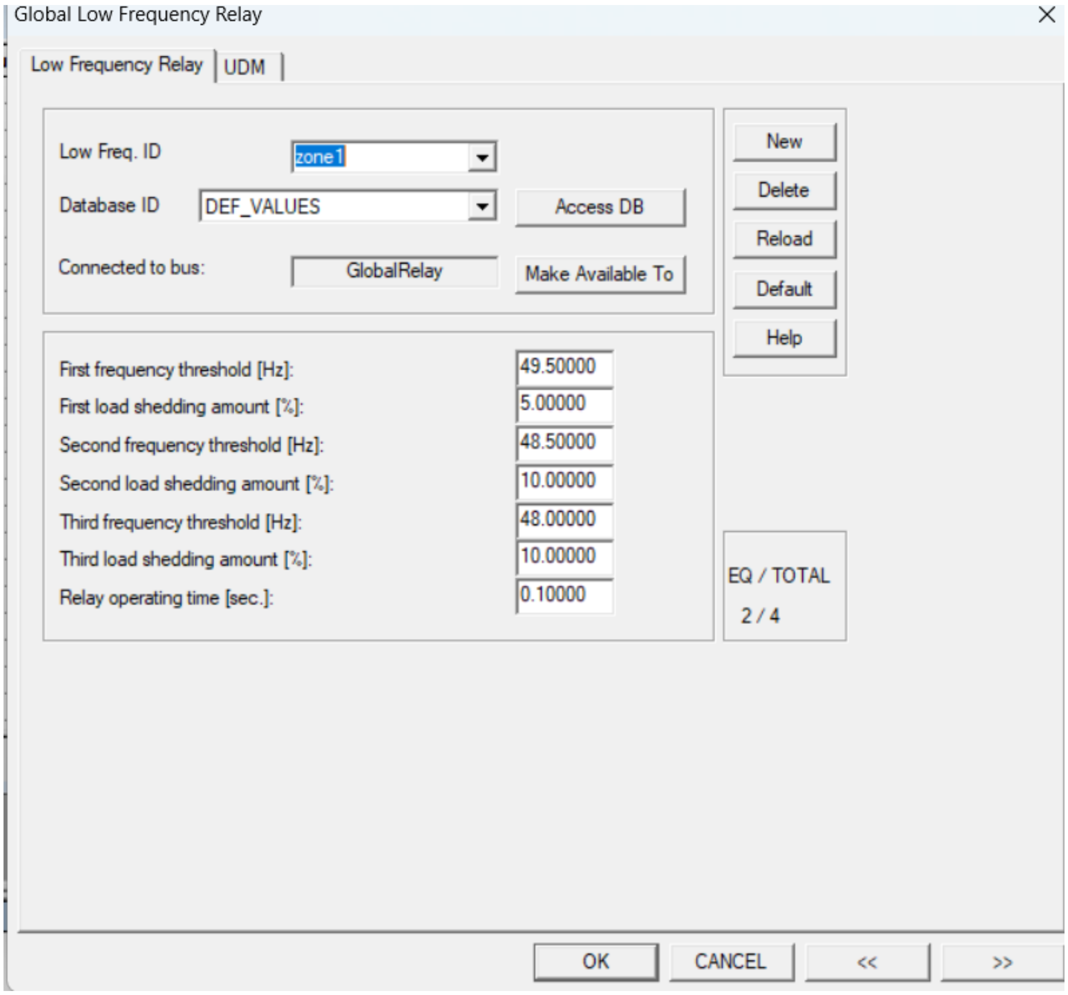


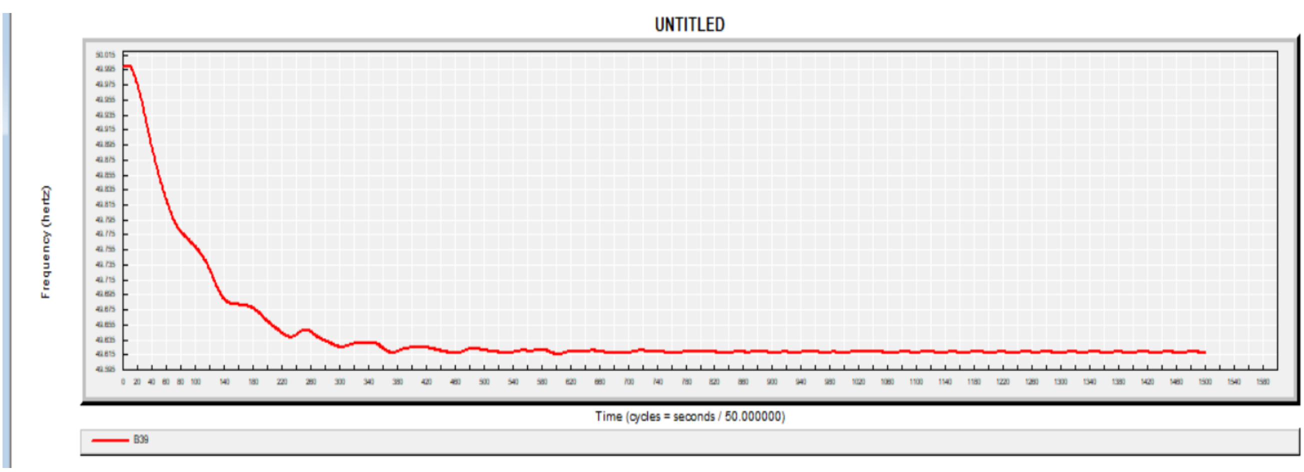
System is becoming stable after reaching a certain frequency.

Zone 1:

The threshold frequencies for Zone 1 were maintained, but this time 10% of the load was shed once each frequency threshold was crossed. Better to note that buses with FVSI values more than 0 and less than 10^{-6} have been classified as Zone 1.

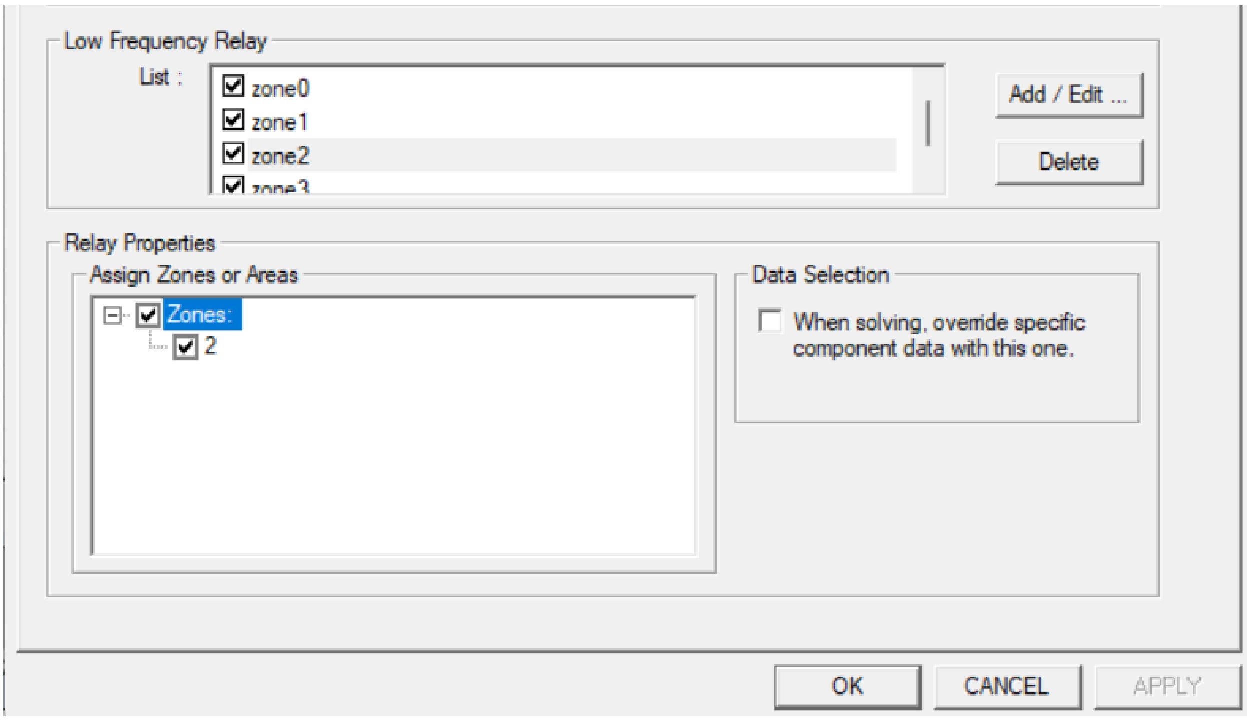


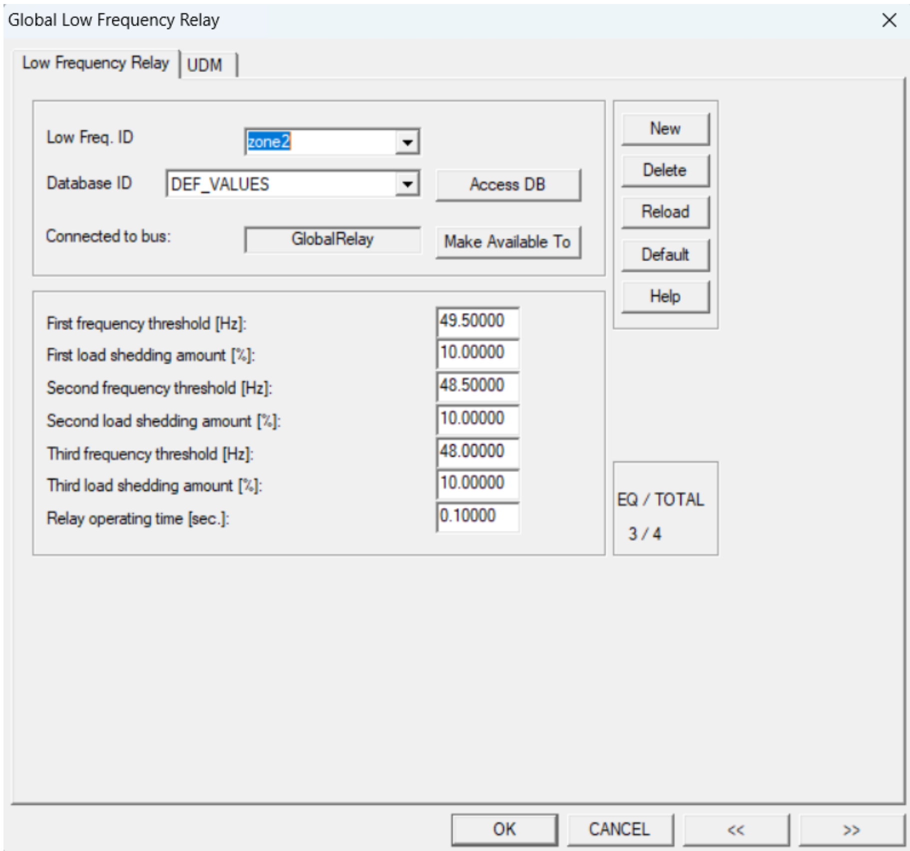

Global Low Frequency Relay
Low Frequency Relay
UDM
Low Freq. ID
zone1
Database ID
DEF_VALUES
Access DB
Connected to bus:
GlobalRelay
Make Available To
New
Delete
Reload
Default
Help
First frequency threshold [Hz]:
49.50000
First load shedding amount [%]:
5.00000
Second frequency threshold [Hz]:
48.50000
Second load shedding amount [%]:
10.00000
Third frequency threshold [Hz]:
48.00000
Third load shedding amount [%]:
10.00000
Relay operating time [sec.]:
0.10000
EQ / TOTAL
2 / 4
OK
CANCEL
<<
>>

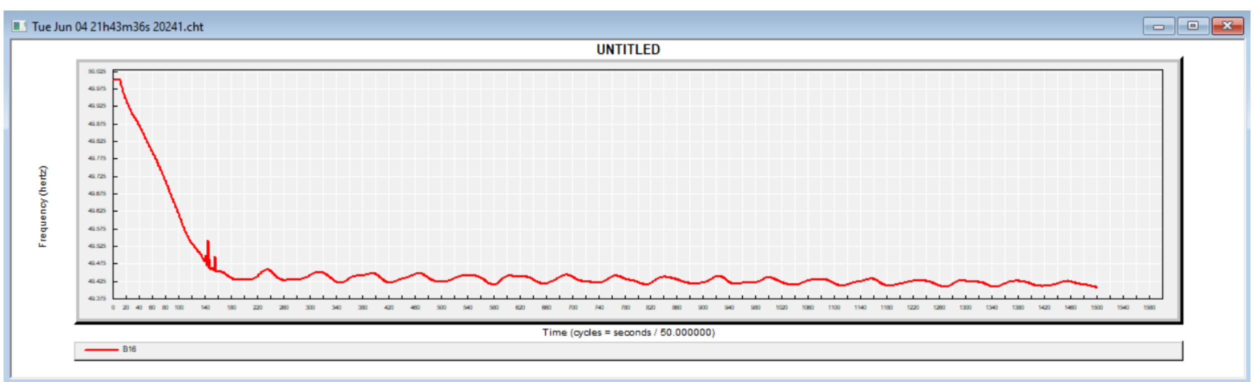

UNTITLED
Frequency (hertz)
Time (cycles = seconds / 50.000000)
B39

Zone-2:

Buses with FVSI values more than 10^{-6} and less than 10^{-7} have been classified as Zone 2.

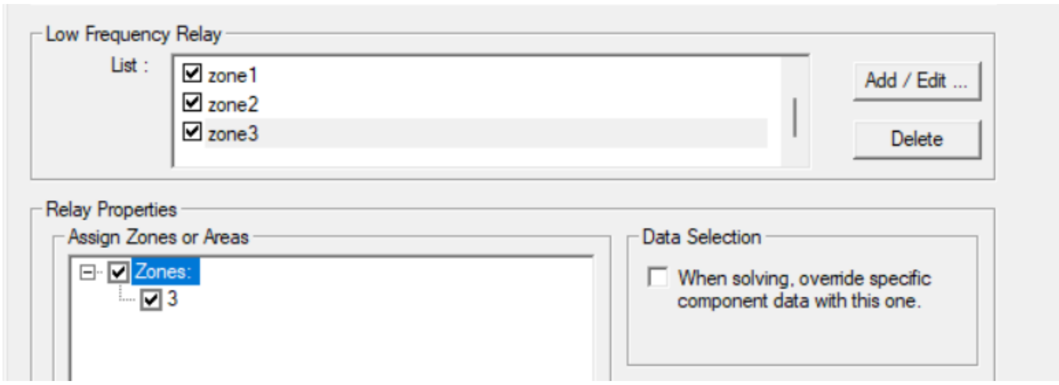


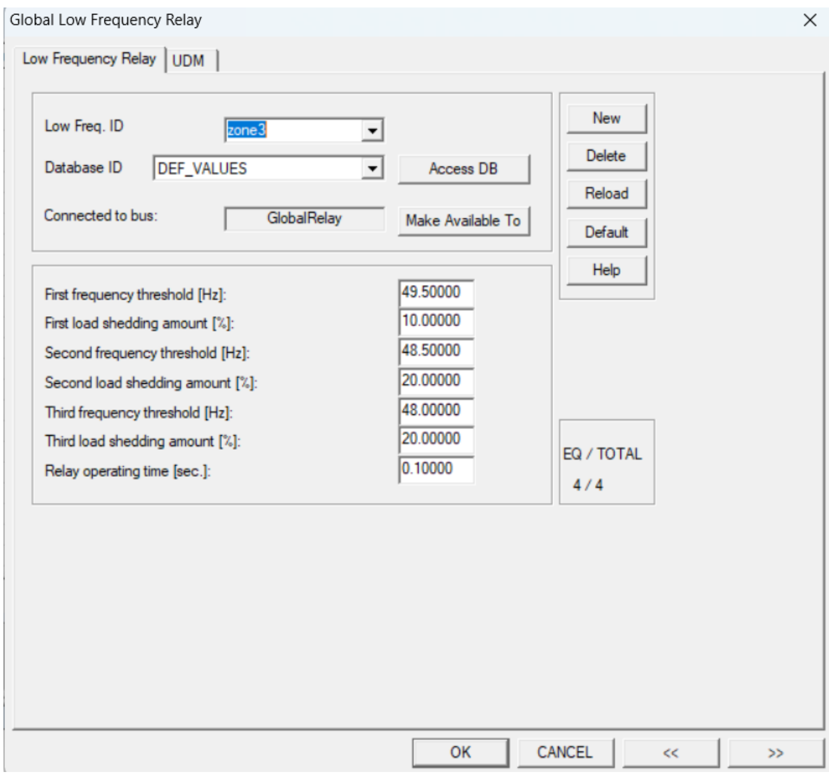

Global Low Frequency Relay
Low Frequency Relay
UDM
Low Freq. ID
zone2
Database ID
DEF_VALUES
Access DB
Connected to bus:
GlobalRelay
Make Available To
New
Delete
Reload
Default
Help
First frequency threshold [Hz]:
49.50000
First load shedding amount [%]:
10.00000
Second frequency threshold [Hz]:
48.50000
Second load shedding amount [%]:
10.00000
Third frequency threshold [Hz]:
48.00000
Third load shedding amount [%]:
10.00000
Relay operating time [sec.]:
0.10000
EQ / TOTAL
3 / 4
OK
CANCEL
<<
>>

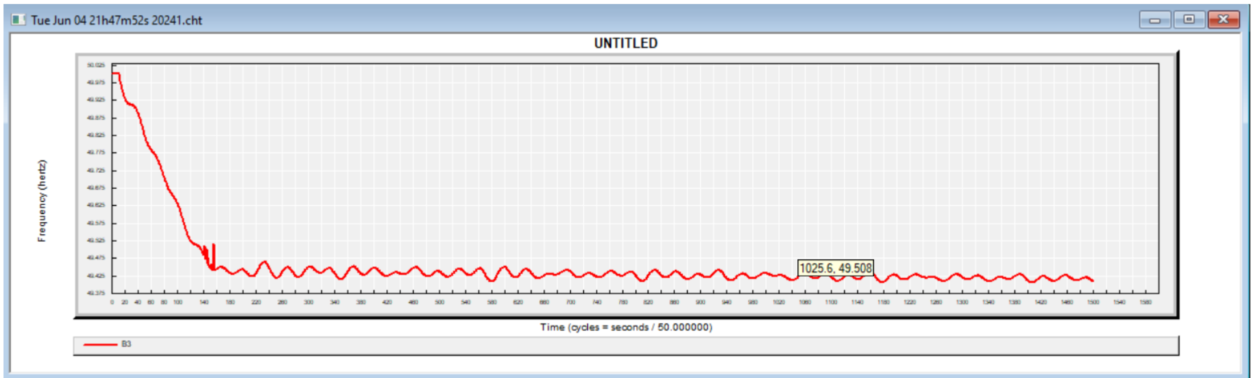

Tue Jun 04 21h43m36s 20241.cht
UNTITLED
Frequency (hertz)
Time (cycles = seconds / 50.000000)
B16

Zone-3:

Buses with FVSI values more than 10^{-7} and less than 10^{-8} have been classified as Zone 3.







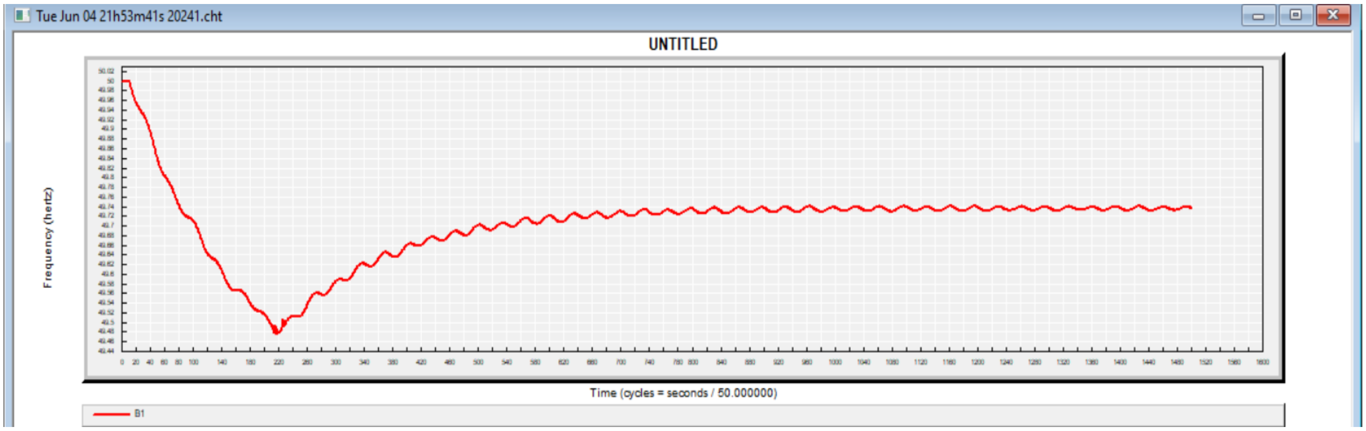
Here, we can see that while the load dropped after each frequency threshold had grown by 5% for each increasing zone as the buses were getting weaker, the threshold frequencies remained constant. Even though the NADIR point did not improve significantly, the system's frequency stability regaining time has been drastically reduced. This indicates a comprehensive improvement due to the implementation of the enhanced load shedding schemes.

Task-6: Investigating the impact of load frequency relief (i.e. use kp = 5%, 8% and 10%) on the load shedding scheme designed in task-5.

In Task 5, we created a load-shedding plan that, in the event of G08's failure, prioritizes removing additional load from the weaker buses. When this method was designed, intrinsic load frequency relief was not taken into consideration ($k\ p$ = 0). Here, we look into the effects of several load frequency relief levels, namely kp = 5%, 8% , and 10% %, on the effectiveness and performance of this load shedding scheme. The main aim is to determine how different levels of kp influence the effectiveness of the load shedding scheme. Higher values of kp imply a more aggressive response to frequency deviations, potentially stabilizing the system more quickly but at the cost of greater load shedding.

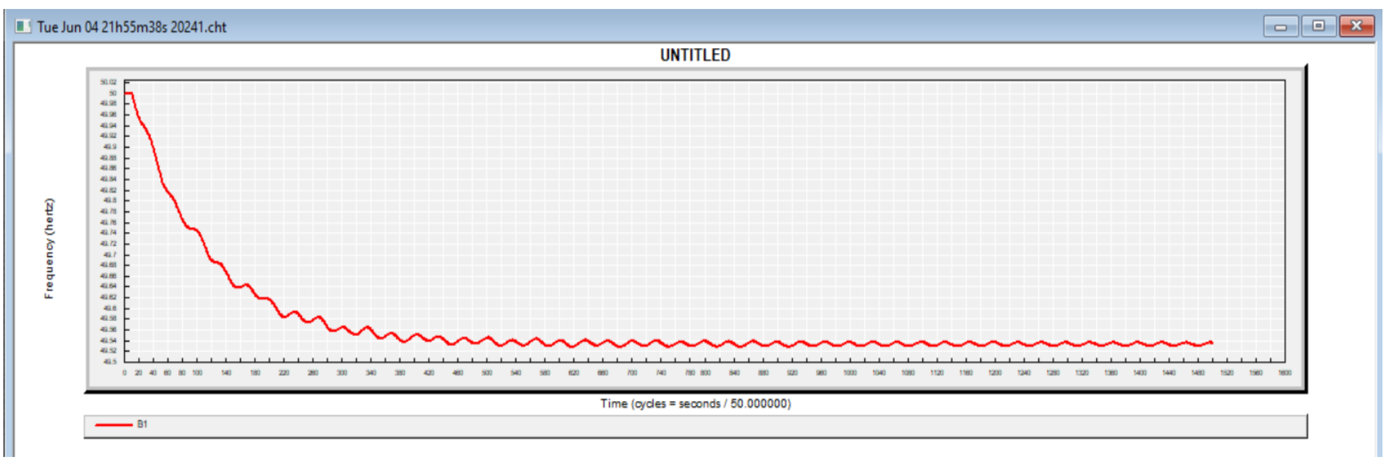
To demonstrate the influence of Kp in the FVSI implemented Frequency Response, we alter the value of the Pfreq parameter in the Global Load tab. We do this task for a cycle of 1500.The task is performed for zone-0 as follows:

Output Frequency Response with (Kp = 5%):



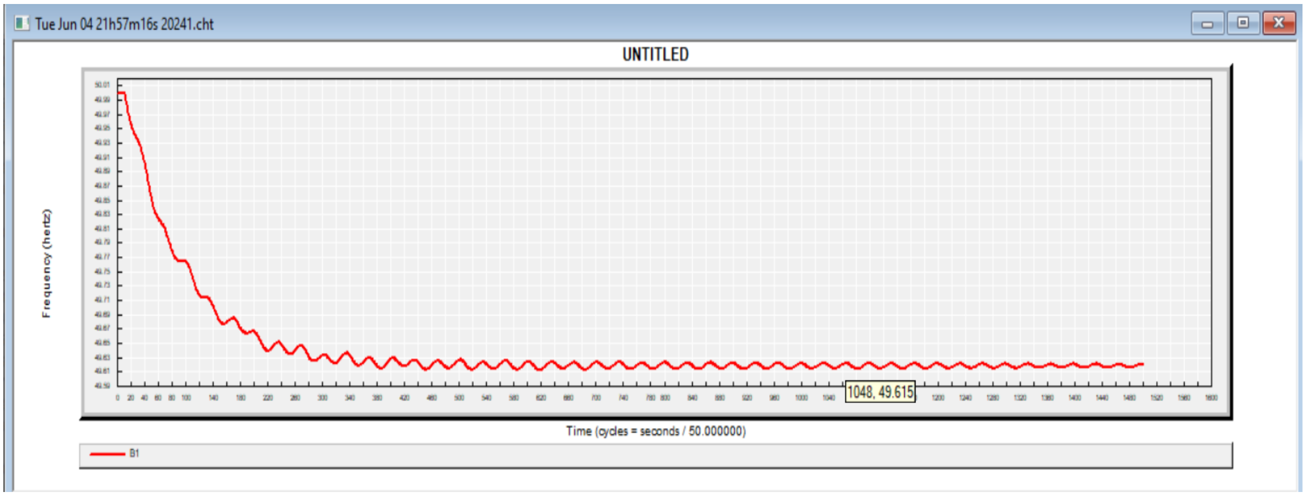
It is evident that even with a higher Kp value, the system was able to stabilize and put an end to the frequency excursion by improving Nadir point.

Output Frequency Response with (Kp = 8%):



Again, we can see, frequency excursion continued. The system frequency keeps oscillating around the lower NADIR. And improving Kp improved Nadir point.

Output Frequency Response with (Kp = 10%):



From the above figures we can see that the nadir point tends to somewhat improve and so does the time taken to attain a stable frequency point when the Frequency Relief (Kp) parameter is tuned, i.e., by increasing the percentage Kp. Therefore, this parameter can be likened to a PID controller's differential operator, which aids in improving transient characteristics.

Likewise, we can perform the frequency response for incremented Kp value on other zones as well. Here we showed only for zone0.

Discussion:

Precise bus voltages and power flows were obtained from our thorough examination of the IEEE 39-bus power system utilizing the Newton-Raphson approach for load flow analysis. The development of a successful load shedding model to control frequency disruptions required this accuracy. We tested the effects of three different frequency relief settings on the nadir point and overall frequency response of the system. As can be shown, higher frequency relief in load shedding models increases nadir points and speeds up stabilization during disturbances. The greatest k p value considerably improved frequency stability. By computing the Fast Voltage Stability Index (FVSI) for each line linked to a bus, we were able to determine the stability conditions and divide them into five zones, which allowed us to further evaluate the dynamics of the system. A customized load shedding plan was created, with the degree of load shedding changing based on the stability of each zone. By ensuring targeted intervention in weaker areas, this zonal strategy optimized the process of load shedding. Understanding the alterations involved was possible by looking at the frequency curves for these zones under two distinct load frequency alleviation settings. Our analysis revealed that frequency response and stability are greatly impacted by different load frequency relief settings.

In the end, our research emphasized how crucial it is to strategically load-shedding and modify frequency relief in order to preserve power system stability, particularly in the event of serious disruptions like the loss of a large generator. This method increased the power system's overall resilience by guaranteeing faster stabilization in addition to improving Nadir point.

Contributions:

We did all the tasks almost altogether. So, each of us had equal contributions in every tasks. Listed below are the main initiatives by each member

Data input- Zerin

Task1- Zerin

Task2- Rafsan

Task3-Rishad

Task4-Rishad

Task5-Mehedi

Task6-Oyshi

Presentation slides-Rafsan

Report-Oyshi, Mehedi