Bangladesh University of Engineering and Technology

EEE412

Power System II Laboratory

<u>PROJECT SUBMISSION</u>

Design of a Zonal-UFLS scheme in IEEE 39-bus network

<u>Submitted by-</u>

<u>Group 11</u>

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Introduction

UFLS:

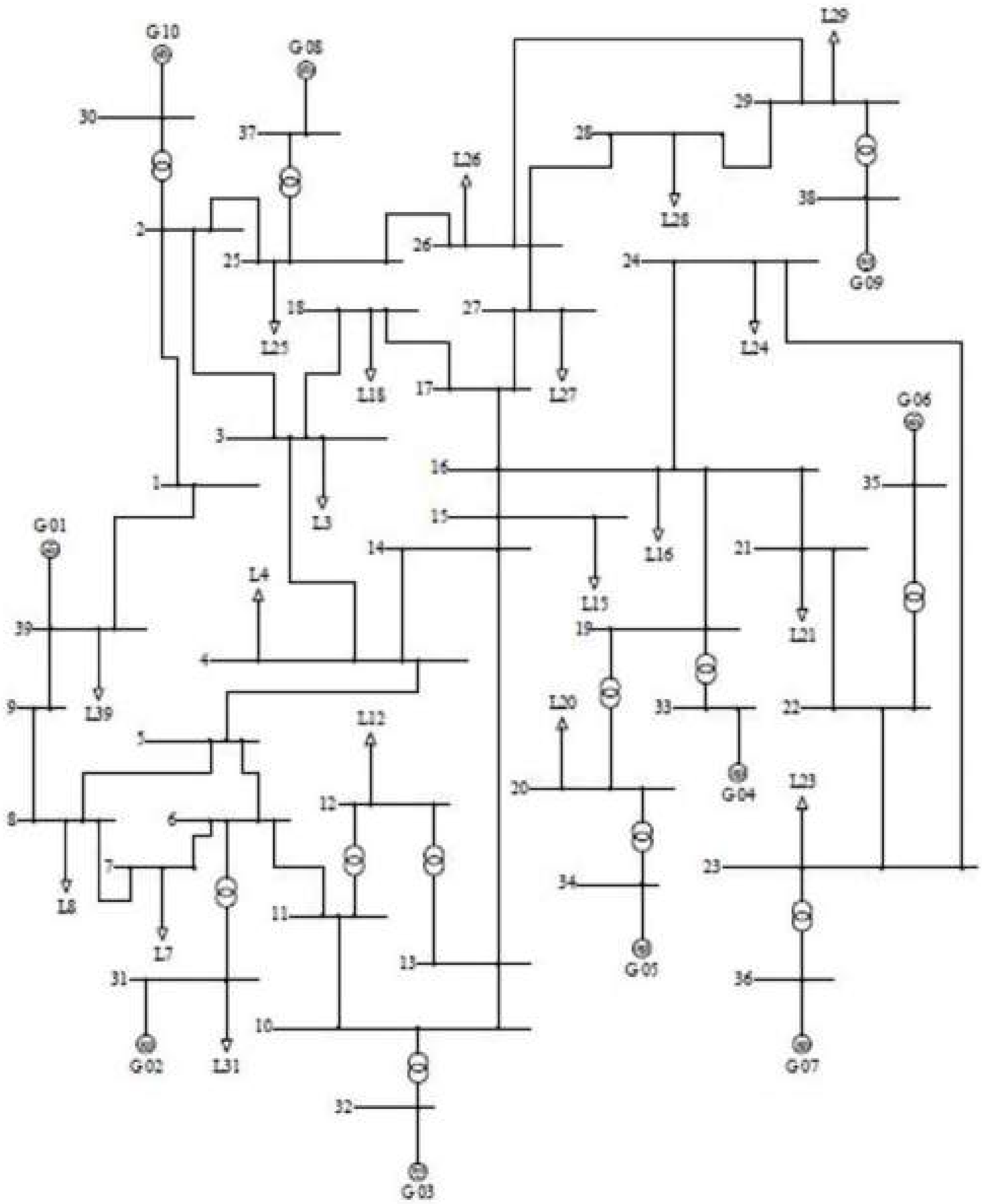
Basically, power system network generation capacity should increase in proportion to the increase of its loads. But, if there are sudden large changes in the system generation capacity through loss of generator or key inter-tie due to line tripping can produce severe generation-load imbalance. In those cases the power generation capacity decreases but the load demand remains constant and causes rapid system frequency decline. If other generators are unable to supply the power needed, then the frequency begins to decline further. To stop further declining of system frequency, which may lead to total system collapse, the fastest way is to temporarily disconnect a portion of electrical load from the system known as under frequency load-shedding.

The main objective of UFLS is to shed an appropriate amount of load for quick recovery of system frequency to its nominal value. UFLS as a coordinated set of possible corrective actions aims at forcing the perturbed system to a new equilibrium state. It is a set of corrective actions to balance between load and generation; thus, maintaining the network system's frequency within nominal range. Load shedding steps are determined by possible (credible) conditions which may lead to frequency decay. Nevertheless, an ideal load shedding program should be able to quickly recognize the generation and load imbalance, to determine accurately the degree of overload and precisely shed only the correct amount of load required to arrest the system frequency back to its nominal condition.

IEEE 39-Bus System

The IEEE 39 bus system is well known as the 10-machine New-England Power System. The IEEE 39-bus system has 10 generators and 46 lines.

Single Line Diagram:

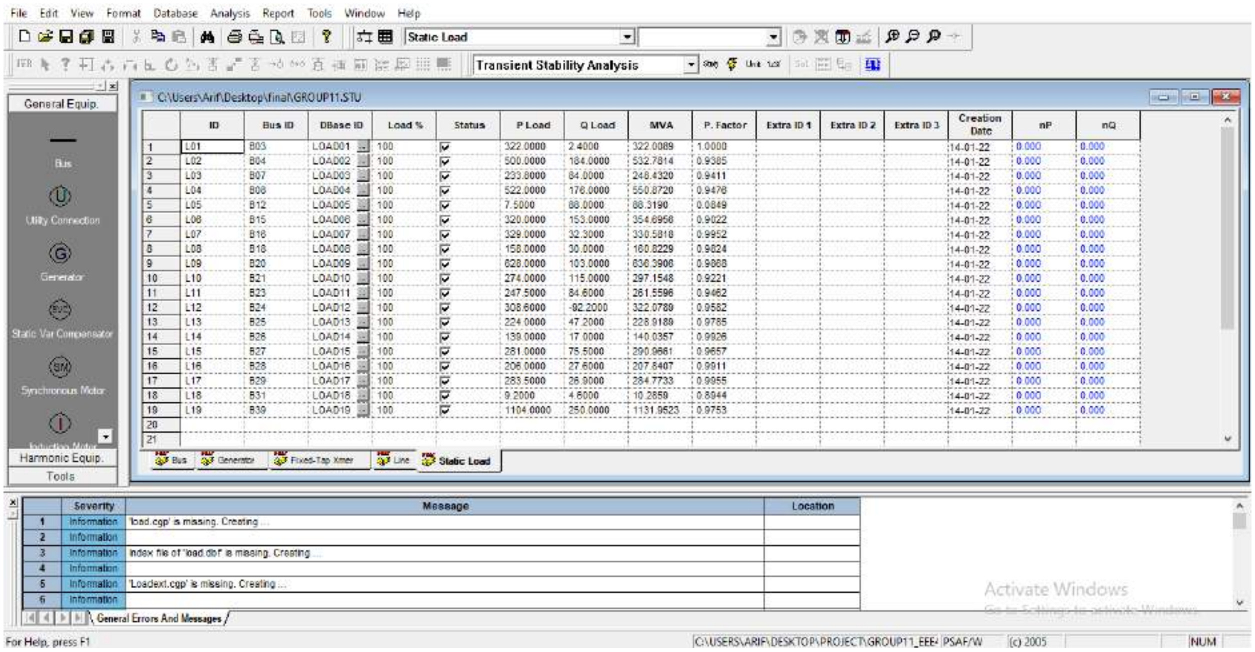


Project Objective:

The objective of this project is to implement a Under-Frequency Load Shedding (UFLS) scheme where the whole network would be divided into multiple zones.IEEE Standard 39-bus system (New England Power System) is the experiment test-bed for the project. The zonal UFLS scheme showed significant improvement in system RoCoF and frequency nadir.

Task01 : <u>Load Flow Analysis:</u>

We were assigned to perform load flow analysis on the given data of IEEE 39 BUS Power System. First of all, we imported all the data manually from the project outline to the PSAF database.



Then we monitor the study of all the buses and solve Newton-Raphson with a flat-start method. From the report section we export the summary report and overall load flow data (with abnormalities) in the excel.

In the summary report , we have total generation, total spinning reserve, total loss, total load etc parameters. From abnormal report, we found some line data (L21-22) from B21 to B22 having overloaded lines and cables.

OVERLOADED LINES & CABLES (WITHIN 100 %)					
ID	**Bus From**	**Bus To**	**Power Flow - [pu]**	**Loading Limit - [pu]**	**Emergency Loading Limit - [pu]**
L21_22	**B21**	**B22**	**6.334**	**5.976**	**7.171**

We also found the Pgen, Qgen for the swing generator(B31)
Pgen = 532.34MW
Qgen = 224.36 MVAR

Summary Report

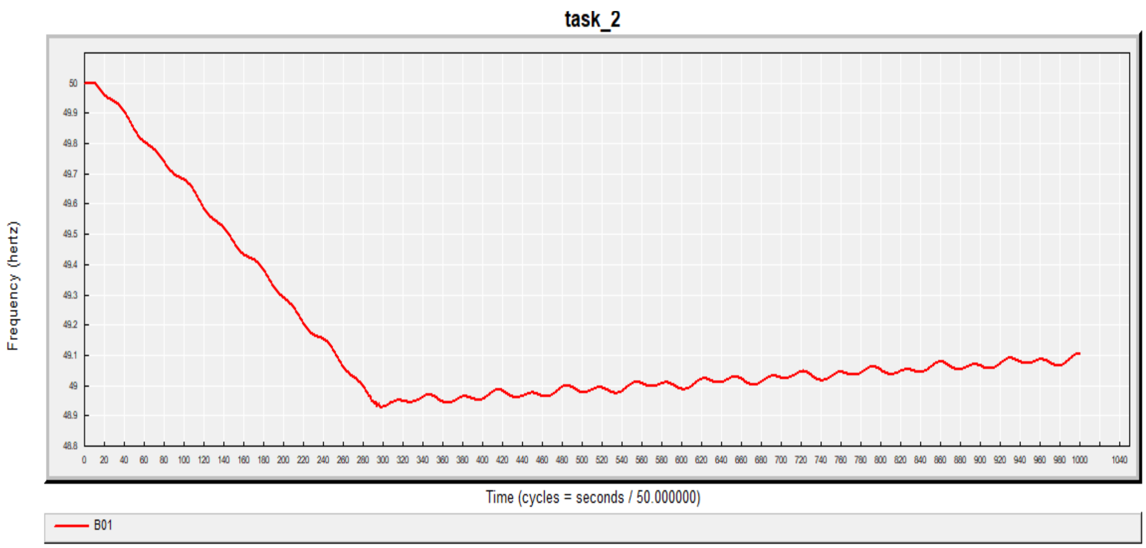
LOAD FLOW STUDY PARAMETERS	
Study :	load_flow_task1
Time :	Fri Feb 18 15h25m51s 2022
Method :	Newton-Raphson
Constraints :	Not applied
Flat start :	Yes
Tcul txfo used as fixed tap :	n\a
Block Q-flow Txfo Adjustment	n\a
Block P-flow Txfo Adjustment :	n\a
Block Switchable Shunt Adjustment :	n\a
Block DC Link Adjustment :	n\a
Base power :	100.00 [MVA]
Tolerance :	0.100 [MVA]

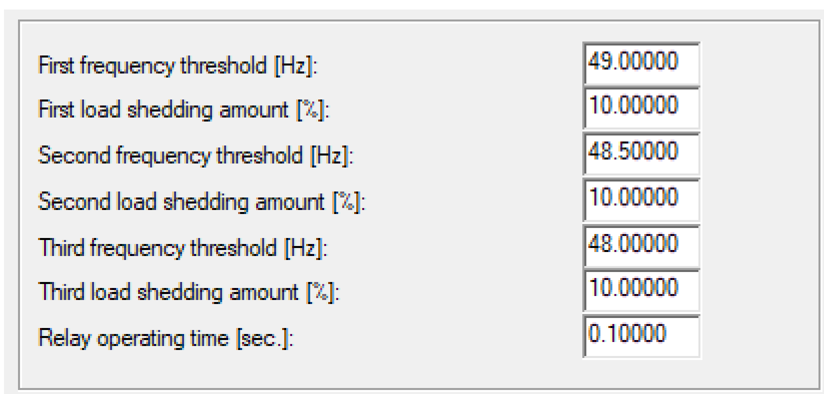
COMPLETE SUMMARY REPORT

Summary Data	**Active Power**	**Reactive Power**
Total generation	**6152.338**	**1450.026**
Spinning reserve	9237.662	
Static Load	6097.100	1408.900
Shunt loads	0.000	0.000
Motor loads	0.000	0.000
Total load	**6097.100**	**1408.900**
Line / cable losses	33.785	-592.866
Transformer losses	21.452	633.994
Total losses	**55.237**	**41.127**
Mismatches	0.001	-0.001

Task 02: <u>Experiment 1 : Random Load Shedding Scheme</u>

The objective of this frequency stability study is to determine the frequency excursion following a loss of generation/ increases in load. In our case, the loss of the G08 bus. We determine the minimum frequency and frequency nadir to compare on the experimentation on various load shedding schemes. For the first, we randomly set (UFLS settings) for IEEE 39 Bus System.





First frequency threshold [Hz]: 49.00000
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

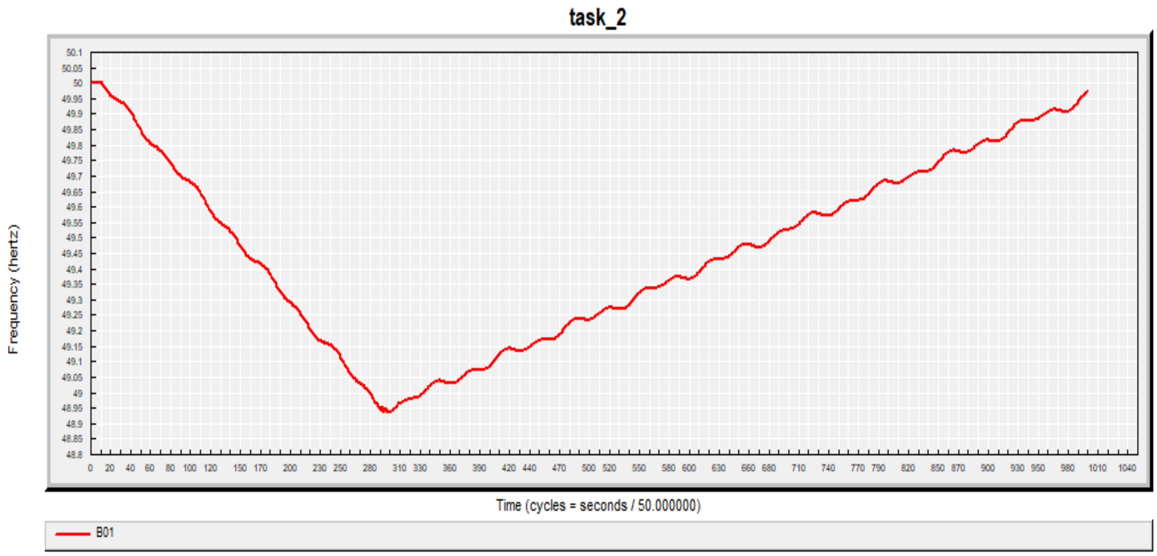
Results :

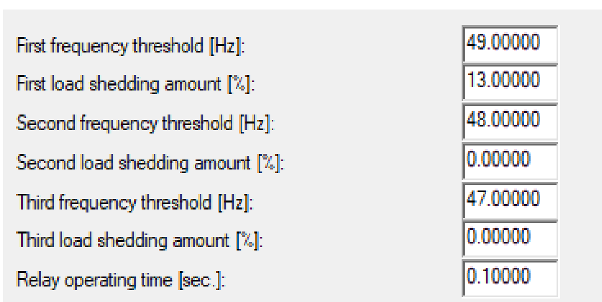
	Freq(nadir)	ROCOF(Hz/cycle)
Random_Exp	48.946322	-0.0030638

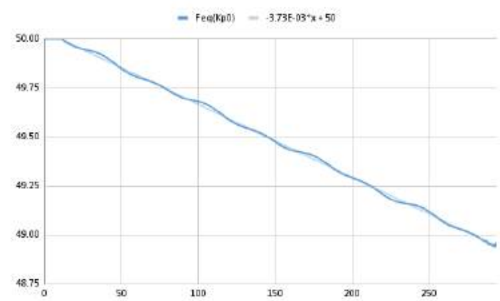
We can see that the frequency excursion wasn't stopped by the random UFLS settings that we took into account. So we did further experimentation on tweaking the settings that would improve our Freq(nadir) and decrease the ROCOF for our task.

Final Experiment : Suitable Load Shedding Scheme

Then we experimented on the suitable UFLS setting for the frequency excursion. We were able to increase Freq(nadir) and decrease the ROCOF for the overall system. We considered B01 as our candidate for comparing results.







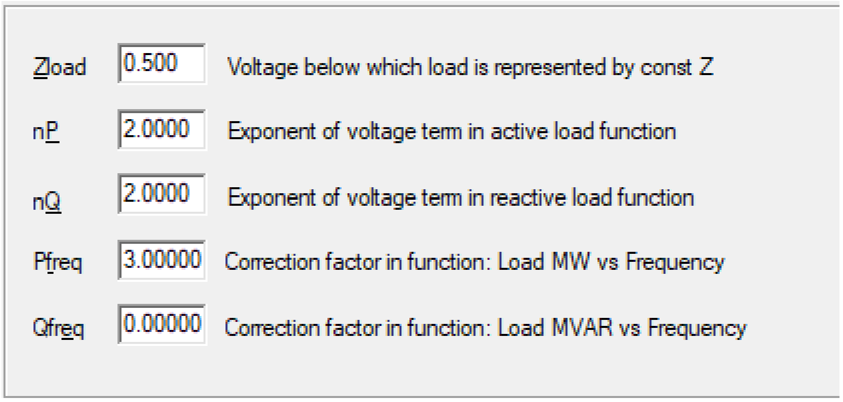
Results:

	Freq(nadir)	ROCOF(Hz/cycle)
Exp_Final	48.934677	-0.003730715348

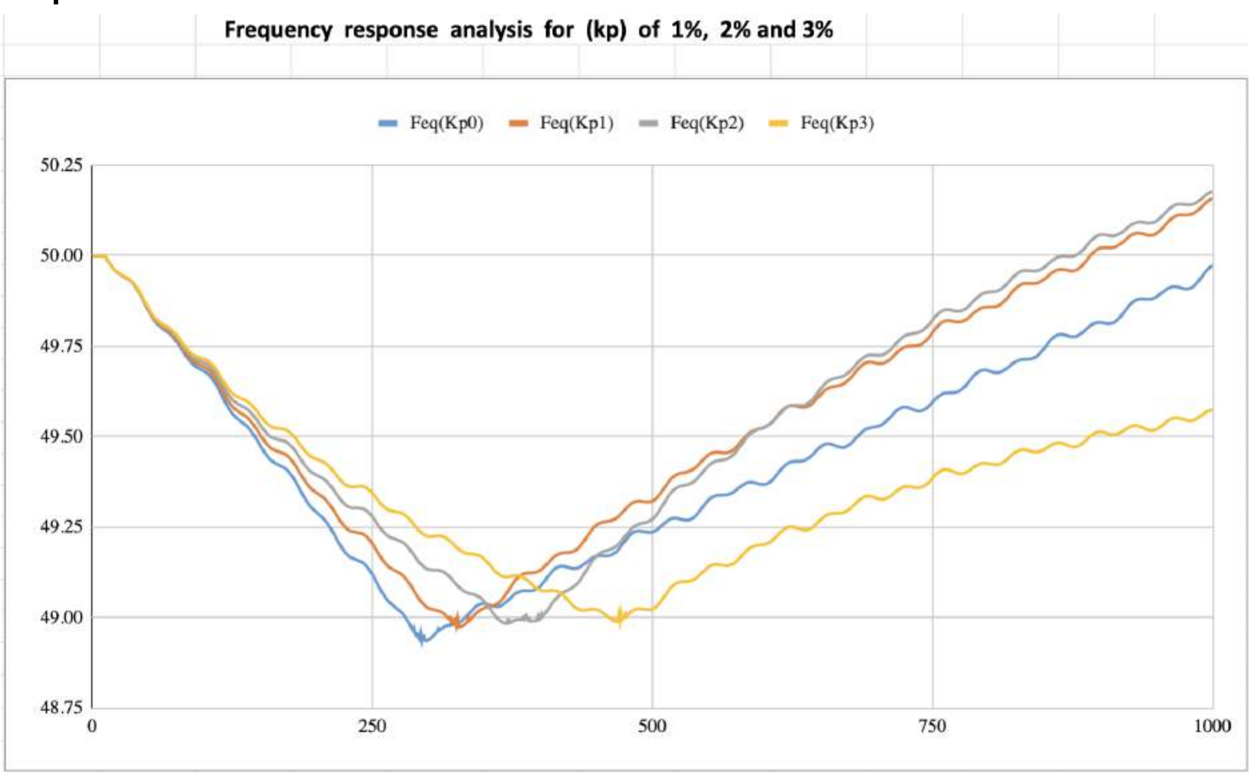
As we can see from the comparison between two experiments, we have improved Freq(nadir) by **0.02%** and ROCOF by **21.77%**.

Task 03:
<u>Frequency Response Analysis varying Kp 1%, 2%, 3% keeping UFLS Settings alike</u>

We apply LFR (Load Frequency Relief) from Study → Global Load → Parameter Pfreq. Setting Pfreq 1%, 2%, 3% we compare the graphs and results. Attaching an image for reference to the changes we have done while doing the study.



Graph:



Results:

kp	Freq(nadir)	ROCOF(Hz/cycle)
0%	48.934677	-0.003730715348
1%	48.973717	-0.003281442325
2%	48.983028	-0.002806643426
3%	48.98885	-0.002179856347

Description :

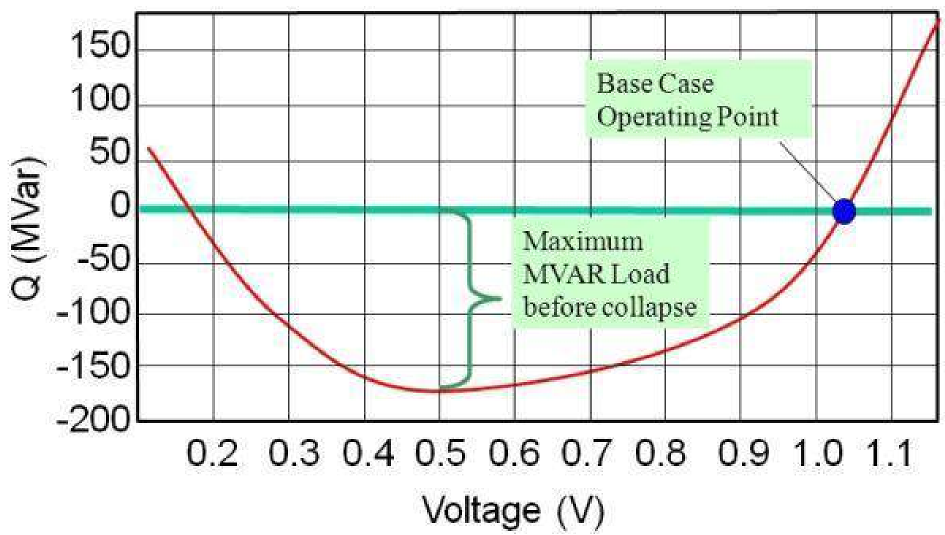
The load frequency relief (LFR) refers to the effect of frequency dependent load on a power system frequency response. As the loads are frequency dependent, the power consumption by these loads decreases when system frequency starts to drop (due to any contingencies – loss of generation). Due to such an effect, the total demand in a system is temporarily decreased when network frequency declines from its nominal value. It eventually helps to reduce load-generation imbalance and slow down the momentum of frequency excursion, this enhances the frequency response of the network.

kp=2% means, the power consumption (load) decreases by 2% for every 1% decrease in the system frequency.

From the results, we can observe that, as we increase kp from 0% to 3% , the Freq(nadir) improves , that means frequency deviation decreases which improves stability. Also ROCOF (rate of change of frequency) is decreasing which ensures the frequency decay rate to be less which also ensures stability in the power system.

TASK 04: QV Curve Method

- QV curves are used to determine the reactive power injection required at a bus in order to vary the bus voltage to the required value and the curve is obtained through a series of power flow calculations.
- Starting with the existing reactive loading at a bus ,the voltage at a bus can be computed for a series of power flows as the reactive load is increased in steps,until the power flow demonstrates convergence difficulties as the system approaches the voltage collapse point.



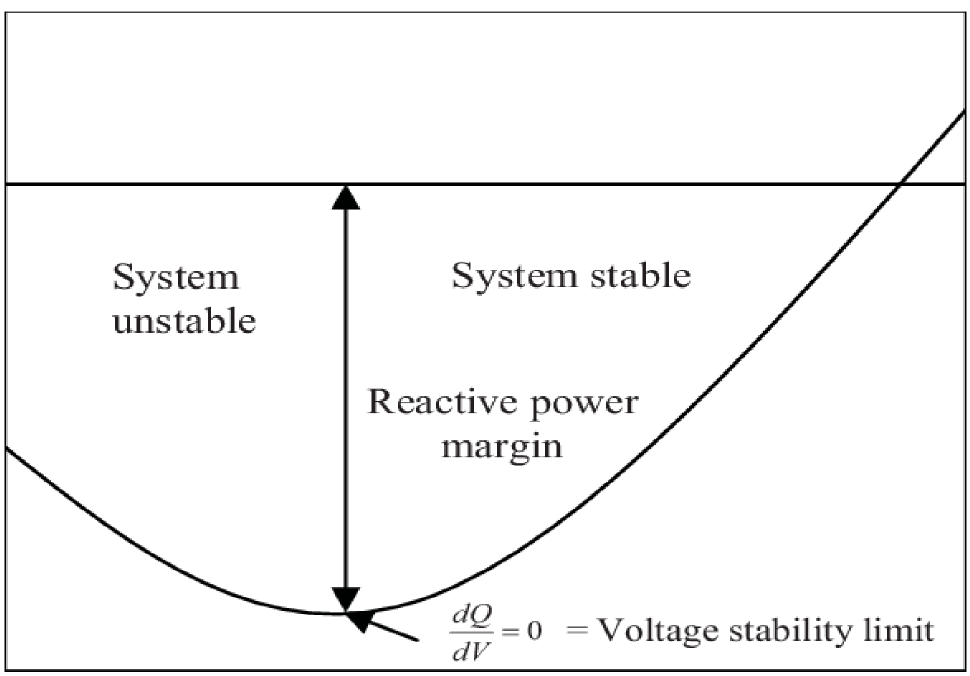


Fig:Typical QV Curve

In order to create a QV curve, a fictitious generator is placed at the bus which is being analyzed. The voltage set- point of this generator is then varied and its VAR output is allowed to be ANY value needed to meet this voltage set- point. At some point, the MVAR value of the generator will stop decreasing and reach the "bottom" of the curve. This point represents the maximum increase in the load MVAR at this bus. Any higher voltage collapse would occur. If the QV curve does not cross the x-axis, this means the system cannot solve this case.

The **V- Q sensitivity** of a bus is the slope of its QV curve at the given operating point. Positive sensitivity indicates a stable system. While small, positive sensitivity indicates a more stable system. And negative sensitivity indicates an unstable system. To maintain stability expect voltage (V) to increase as VARs (Q) are increased.

Procedures followed in PSSE to obtain QV curve:

1.Firstly we used the "QV Analysis"option with the full Newton Raphson Method.

2.Then we had to create the following files:

- Subsystem definition file-.sub
- Monitored Element file -.mon
- Contingency description file-.con
- Distribution factor output file-.dfax

3.Then we used a file name"outputqv.qv" for QV results output

4.After that we plotted QV curves for the load buses and from that we determined the value of Qmin for base cases.

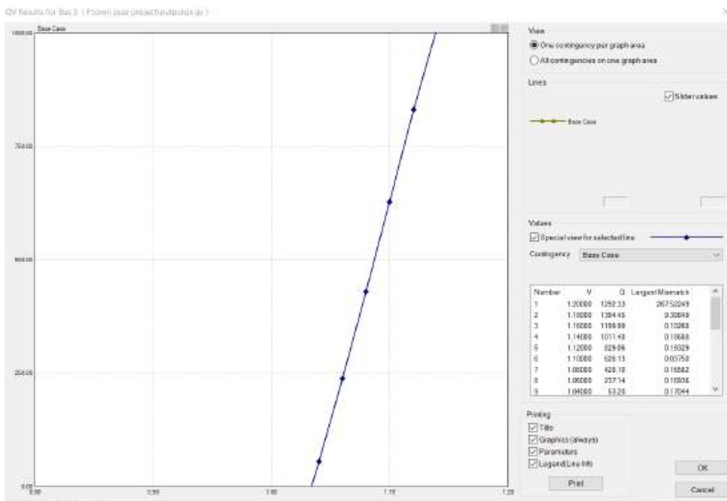
QV Ranking:

BUS	Qmin	Qrated	difference	
16	-1848.41	32.3	-1880.71	zone4
4	-1478.32	184	-1662.32	zone4
20	-1405.12	103	-1508.12	zone4
3	-1457.73	2.4	-1460.13	zone4
15	-1238.91	153	-1391.91	zone4
24	-1436.24	-92.2	-1344.04	zone3
18	-1289.24	30	-1319.24	zone3
21	-1201.88	115	-1316.88	zone3
25	-1241.84	47.2	-1289.04	zone3
8	-1077.2	176	-1253.2	zone3
23	-1149.78	84.6	-1234.38	zone2
26	-1169.92	17	-1186.92	zone2
7	-1048.66	84	-1132.66	zone2
27	-1008.34	75.5	-1083.84	zone2
29	-932.52	26.9	-959.42	zone1
28	-877.42	27.6	-905.02	zone1
12	-493.87	88	-581.87	zone1
39	-305.88	250	-555.88	zone1

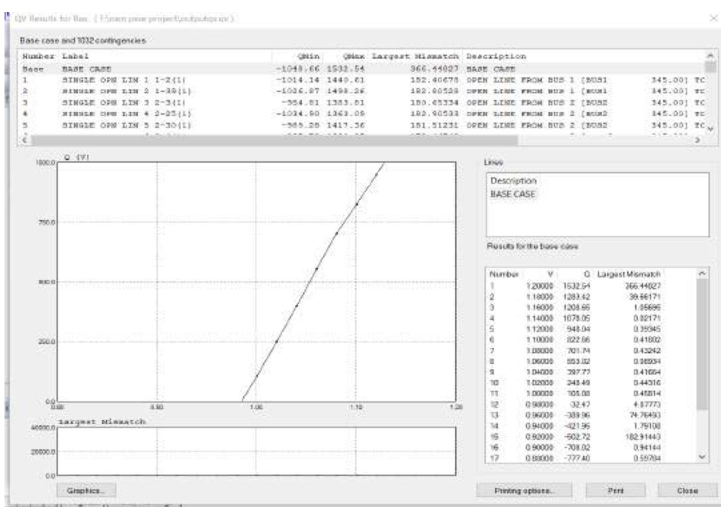
In the table,we determined the difference between Qmin and Qrated for various load buses.The ranking goes from stronger to weaker.From this table,we can see that Bus 16 is the strongest bus and bus 39 is the weakest bus.

QV curves for various load buses:

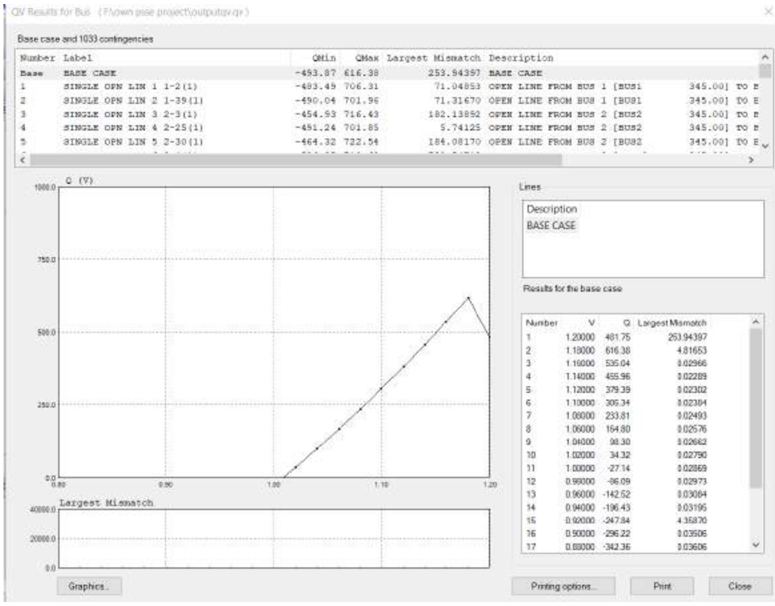
For bus no.3:



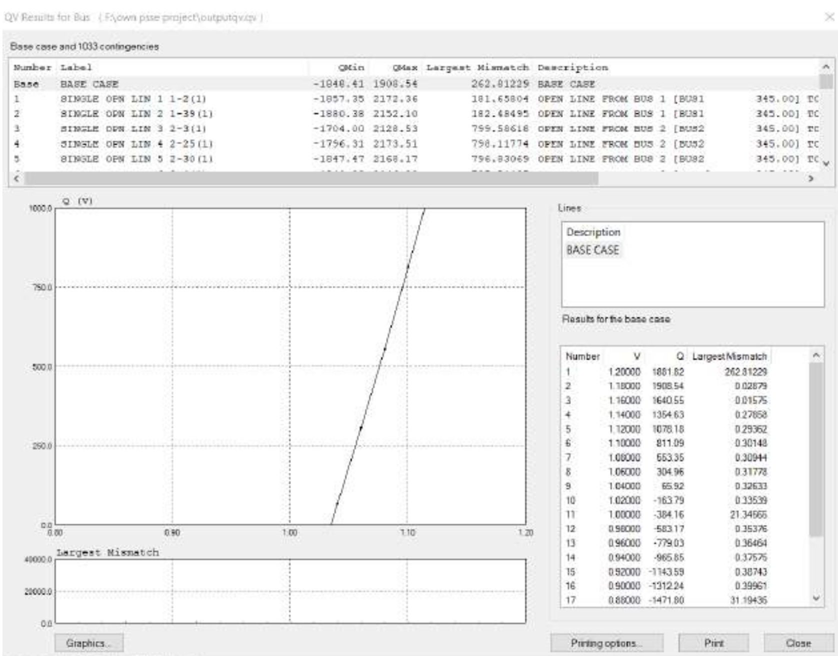
For bus no.7



For Bus no.12:



For Bus no.16:



Thus we have plotted QV curves for various load buses.

5. Answer:

Zone allocation: Here the bus ranking is done from **weaker to stronger** bus.

BUS	Qmin	Qrated	Difference	Rank	Zone Allocation
39	-305.88	250	-555.88	1	zone1
12	-493.87	88	-581.87	2	zone1
28	-877.42	27.6	-905.02	3	zone1
29	-932.52	26.9	-959.42	4	zone1
27	-1008.34	75.5	-1083.84	5	zone2
7	-1048.66	84	-1132.66	6	zone2
26	-1169.92	17	-1186.92	7	zone2
23	-1149.78	84.6	-1234.38	8	zone2
8	-1077.2	176	-1253.2	9	zone3
25	-1241.84	47.2	-1289.04	10	zone3
21	-1201.88	115	-1316.88	11	zone3
18	-1289.24	30	-1319.24	12	zone3
24	-1436.24	-92.2	-1344.04	13	zone3
15	-1238.91	153	-1391.91	14	zone4
3	-1457.73	2.4	-1460.13	15	zone4
20	-1405.12	103	-1508.12	16	zone4
4	-1478.32	184	-1662.32	17	zone4
16	-1848.41	32.3	-1880.71	18	zone4

Zone	Bus
1	**39,12,28,29,** 1,2,5,6,30,36 (Weakest)
2	**27,7,26,23,**17,35,38
3	**8,25,21,18,24,**10,13,14,22,37
4	**15,3,20,4,16,**11,19,31,34,33 (Strongest)

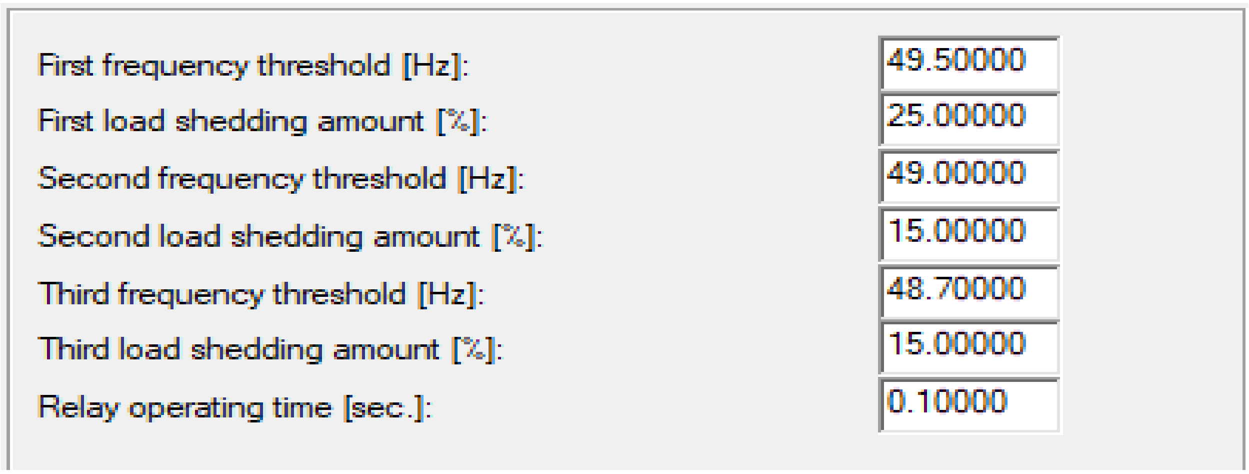
Reasonig behind zoning scheme:

We have devided the buses into four zones keeping the most strongest buses together. As, buses **15,3,20,4,16** are the most strong buses, we kept them into zone 4(most strong zone). Then, into the zone 3(third most strong zone) we kept buses

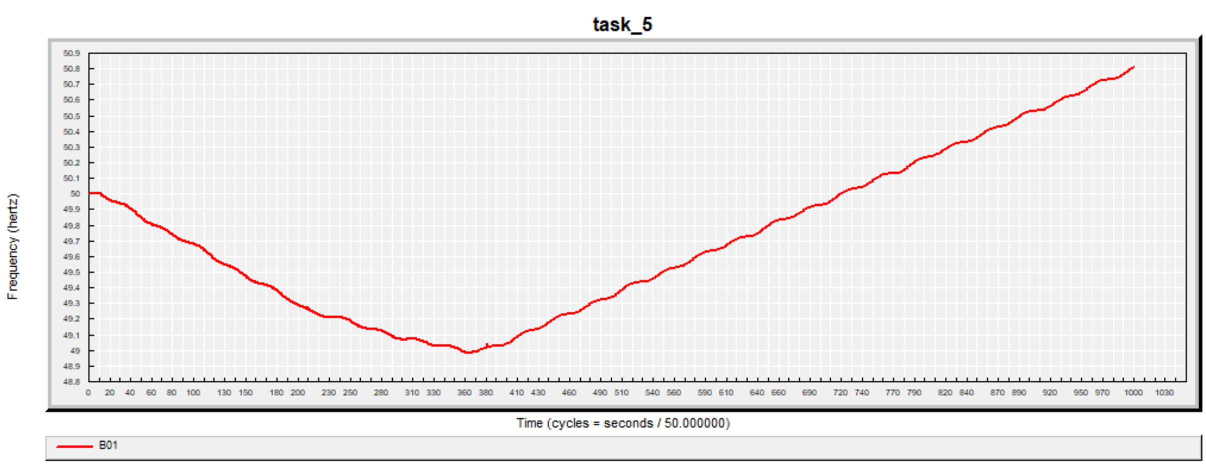
8,25,21,18,24. Thus we have allocated the other buses into zone 2(**27,7,26,23**) and zone 1(**39,12,28,29**). The other buses were allocated using their regional position.

Design of load shedding scheme:

<u>Zone 1</u>

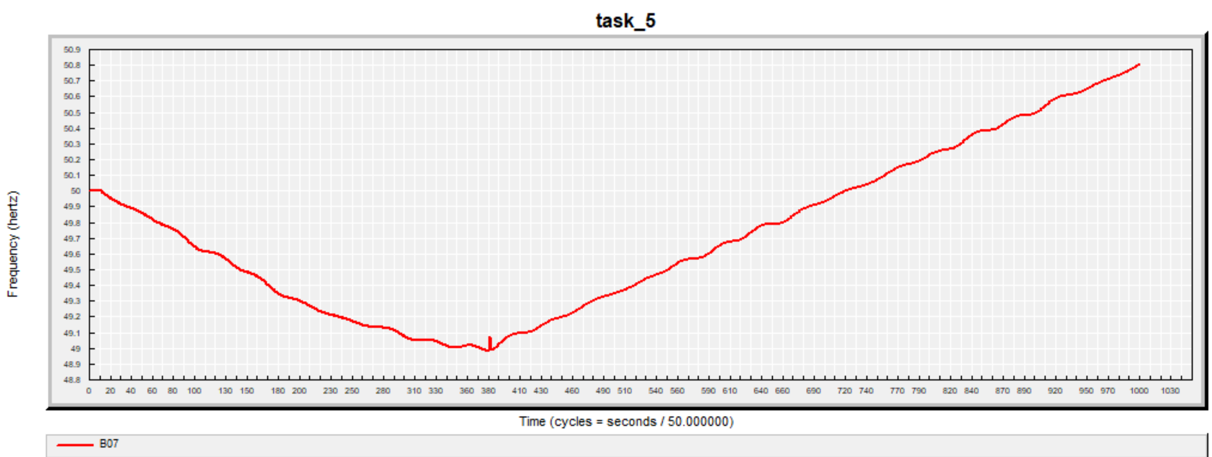


First frequency threshold [Hz]:	49.50000
First load shedding amount [%]:	25.00000
Second frequency threshold [Hz]:	49.00000
Second load shedding amount [%]:	15.00000
Third frequency threshold [Hz]:	48.70000
Third load shedding amount [%]:	15.00000
Relay operating time [sec.]:	0.10000



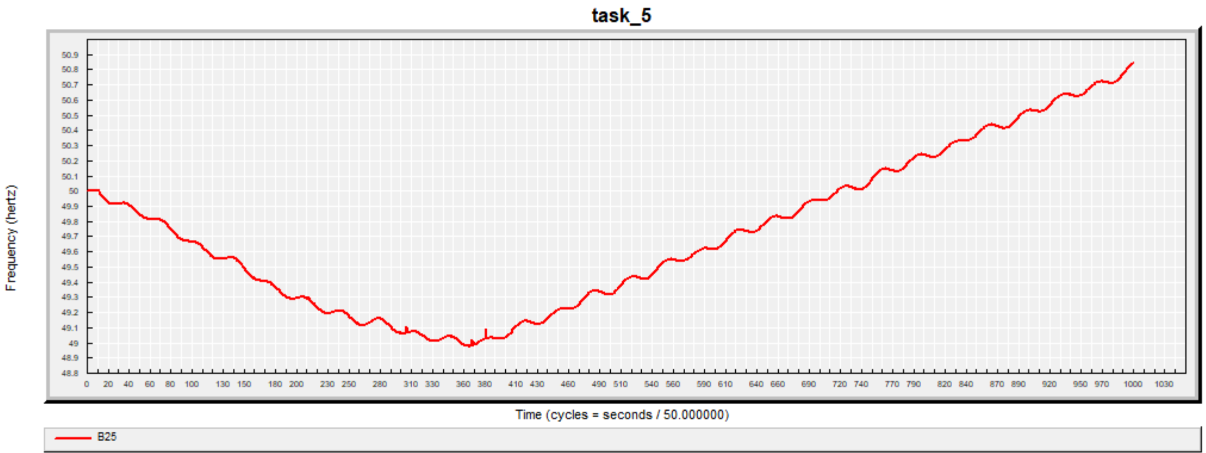
Zone 2:

First frequency threshold [Hz]:	49.30000
First load shedding amount [%]:	25.00000
Second frequency threshold [Hz]:	48.00000
Second load shedding amount [%]:	15.00000
Third frequency threshold [Hz]:	48.50000
Third load shedding amount [%]:	10.00000
Relay operating time [sec.]:	0.10000



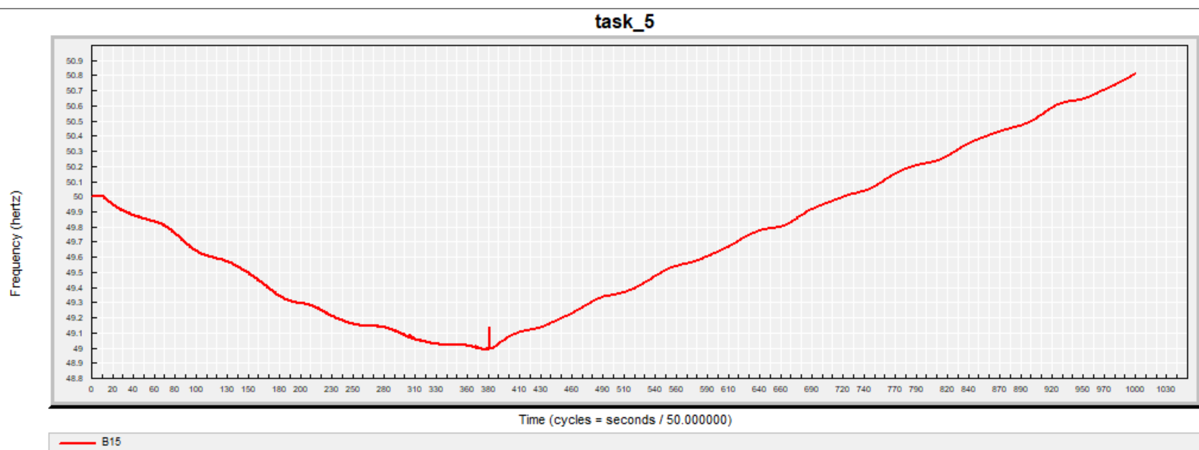
Zone 3:

First frequency threshold [Hz]:	49.10000
First load shedding amount [%]:	20.00000
Second frequency threshold [Hz]:	48.60000
Second load shedding amount [%]:	15.00000
Third frequency threshold [Hz]:	48.30000
Third load shedding amount [%]:	10.00000
Relay operating time [sec.]:	0.10000



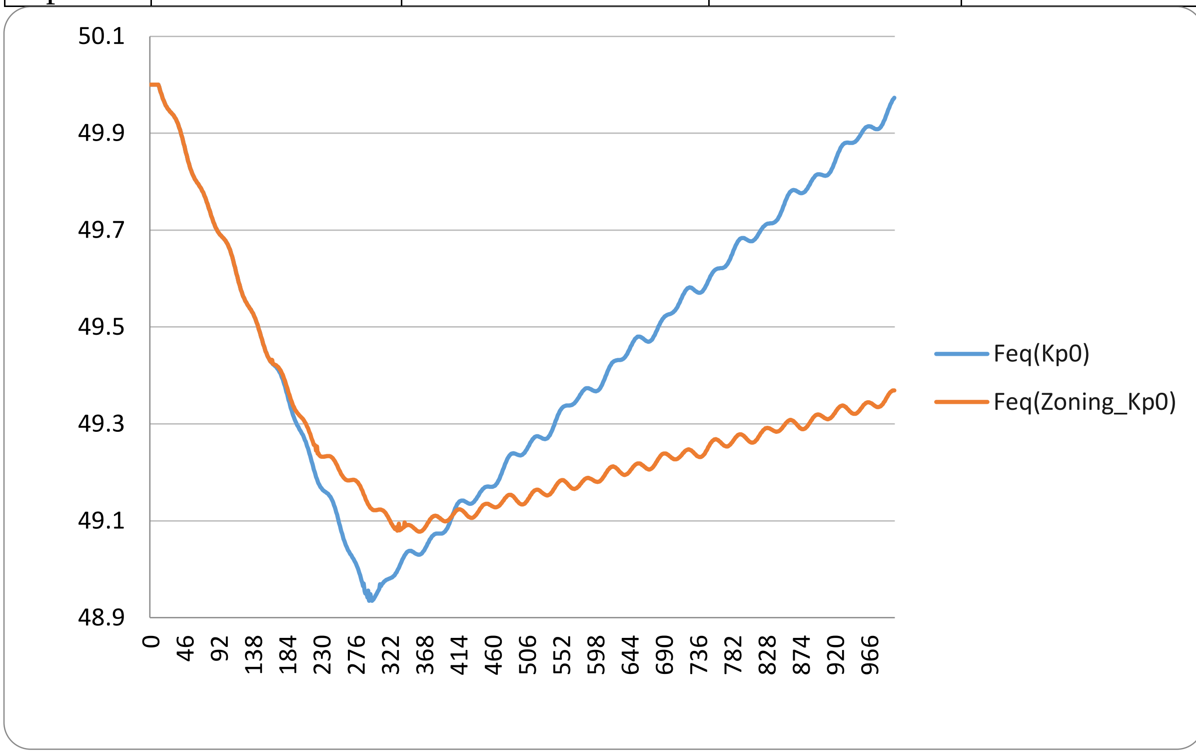
Zone 4:

First frequency threshold [Hz]:	48.90000
First load shedding amount [%]:	15.00000
Second frequency threshold [Hz]:	48.40000
Second load shedding amount [%]:	15.00000
Third frequency threshold [Hz]:	48.10000
Third load shedding amount [%]:	10.00000
Relay operating time [sec.]:	0.10000



For Kp = 0, Zone 1(B01)

	Before Zoning		After Zoning	
	Freq(nadir)	ROCOF	Freq(nadir)	ROCOF
Kp0	48.934677	-0.003730715	49.077545	-0.00279008



Improvement of frequency nadir: 0.14287

Improvement of ROCOF: 0.00094

Task 6:

Investigation the impact of load frequency relief (Kp):

For zone 1: Comparing the frequency/cycle

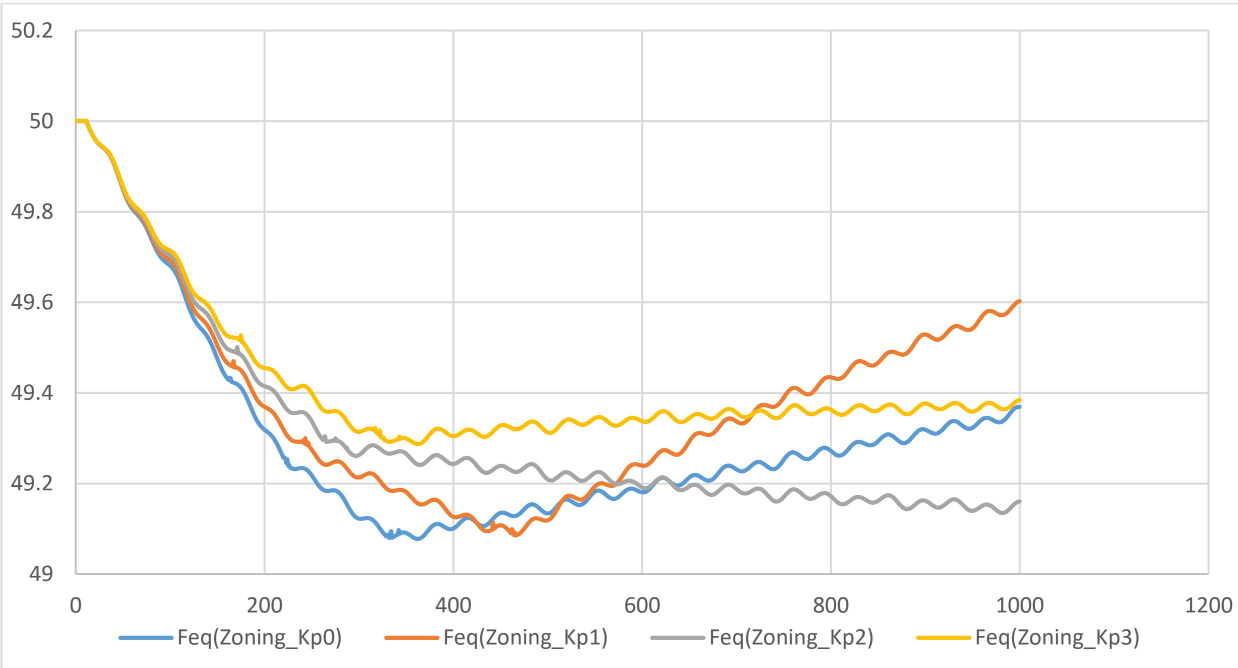
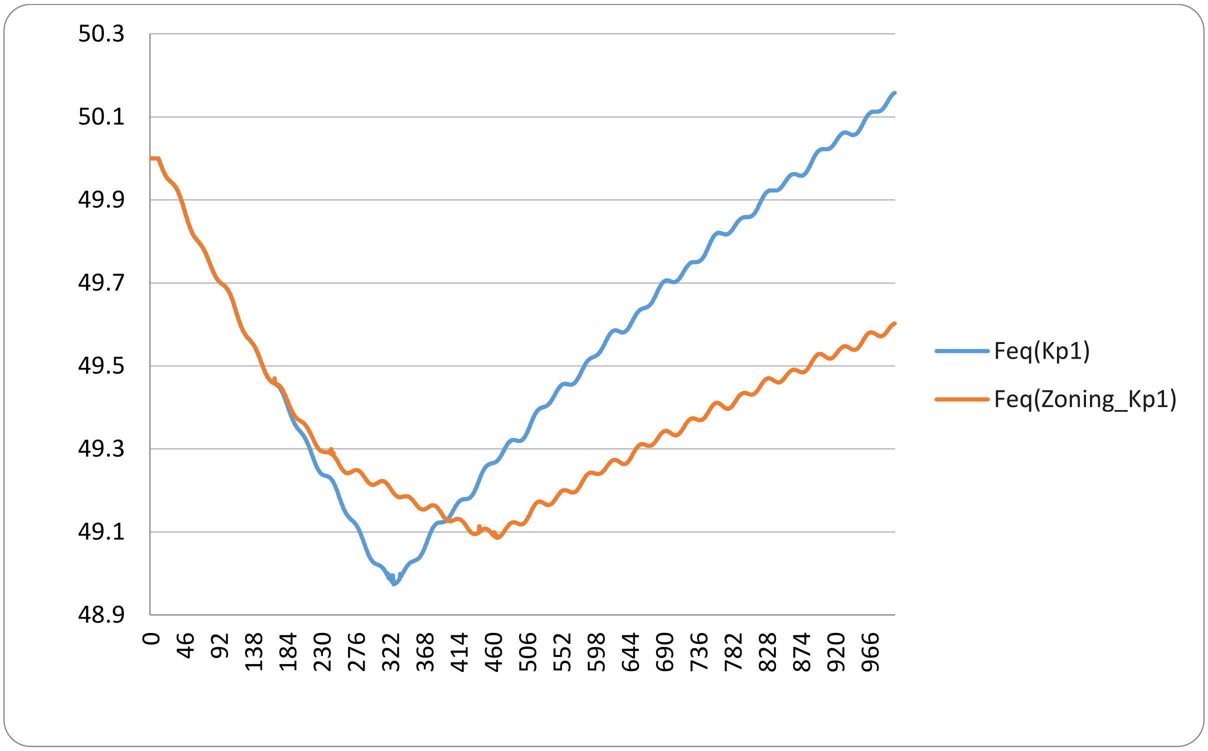


Fig: Frequency response analysis for (kp) of 1%, 2% and 3% after zoning

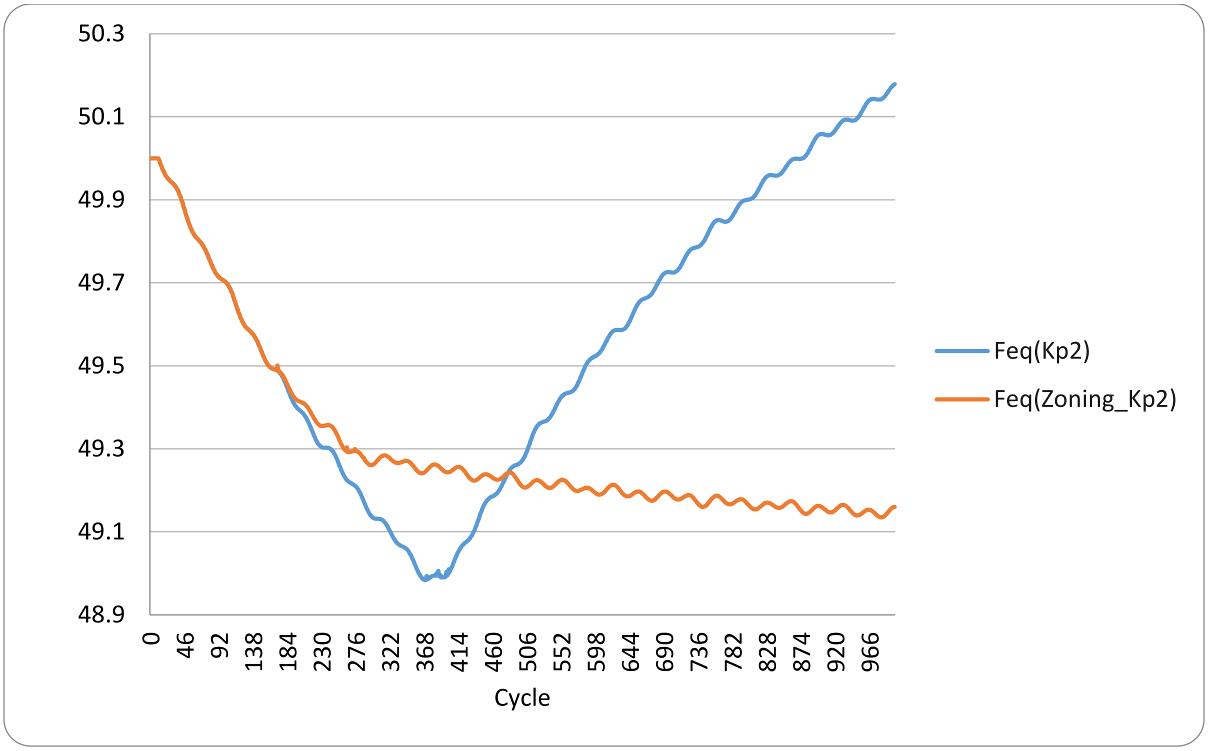
For Kp 1:



Improvement of frequency nadir: 0.11217

Improvement of ROCOF: 0.0013

For Kp 2:

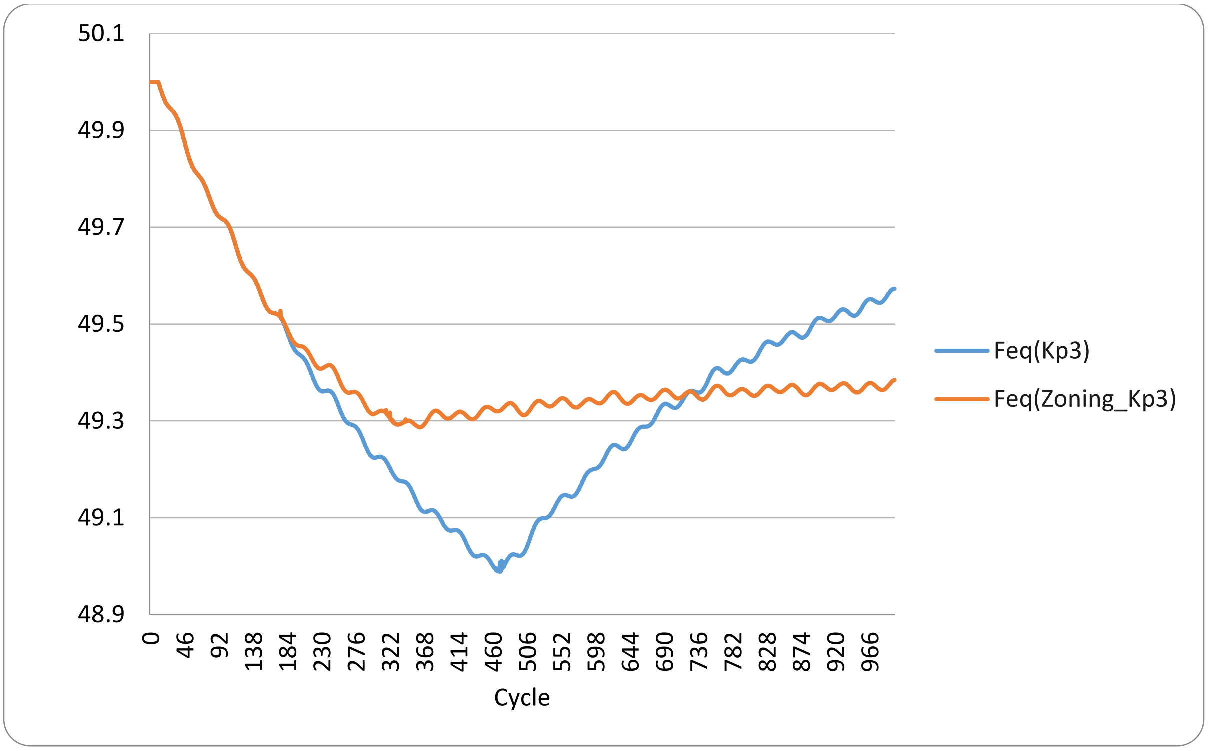


Improvement of frequency nadir: 0.15174

Improvement of ROCOF: 0.00218

We can see frequency excursion here.

<u>For Kp 3:</u>



Improvement of frequency nadir: 0.29819

Improvement of ROCOF: 0.0001

Summary:

	Before Zoning		After Zoning		Improvement	
	Freq(nadir)	ROCOF	Freq(nadir)	ROCOF	Freq(nadir)	ROCOF
Kp0	48.934677	-0.003730715	49.077545	-0.00279008	-0.142868	-0.00094064
Kp1	48.973717	-0.003281442	49.085888	-0.001979913	-0.112171	-0.00130153
Kp2	48.983028	-0.002806643	49.134766	-0.000630157	-0.151738	-0.00217649
Kp3	48.98885	-0.002179856	49.287041	-0.002076487	-0.298191	-0.00010337

From these graph, we can see that, frequency nadir and ROCOF has improved but there is frequency excursion.