Cluster Operational State Labeling

The state labeling procedure were conducted through analyzing the system topology then it was executed within the program then shown to the user through GUI.

1. High Load and Low Load

This state was identified through taking the system average buses voltages. Ideally, the system average bus voltage should be close to 1. However, it is known that in case of high load the buses voltages tend to go lower meanwhile it goes higher in case of low voltage. On the table below, the system average bus voltage can be shown for each cluster:

Cluster	Size	Volt(pu)	Ang(Deg)	Given Label
0	49	0.928008	-22.9393	High Load
1	47	0.980966	7.490167	?
2	53	0.989641	-5.93301	?
3	51	1.000335	12.86152	Low Load

According to table 1 above, the lowest voltage is 0.928 which can represent the High Load case meanwhile the highest voltage is 1.0003 which can represent the Low Load case.

2. Generator Down and Line Down

When a generator is out, there will be no injected current to the grid forcing the average voltage across the lines connecting the generator buses (slack bus and PV buses) to other busses to be close to zero i.e. U_{14} , U_{28} and U_{36}. This implies the following formula:

$$U_{GenBusDiff} = \frac{|U_1 - U_4| + |U_2 - U_8| + |U_3 - U_6|}{3}$$

By applying this formula, the following table is obtained:

Cluster	Size	Volt(pu)	Ang(Deg)	$U_{GenBusDiff}$	Given Label
0	49	0.928008	-22.9393	0.07066	High Load
1	47	0.980966	7.490167	0.01470	Line Down
2	53	0.989641	-5.93301	0.00508	Generator Down
3	51	1.000335	12.86152	0.01128	Low Load

It can be observed that $U_{GenBusDiff}$ has a minimal voltage of 0.00508 which can represent generator down. However, it can also be concluded that cluster 1 will be Line Out since it is the

only remaining unlabeled state. Alternatively, line down state can be identified by taking the second highest average voltage difference between all the lines.

General Labeling Rule

To drive a general labeling rule, a 2D plot were constructed for the system average angle (x-axis) versus system average voltage (y-axis) as shown in figure 1 below:
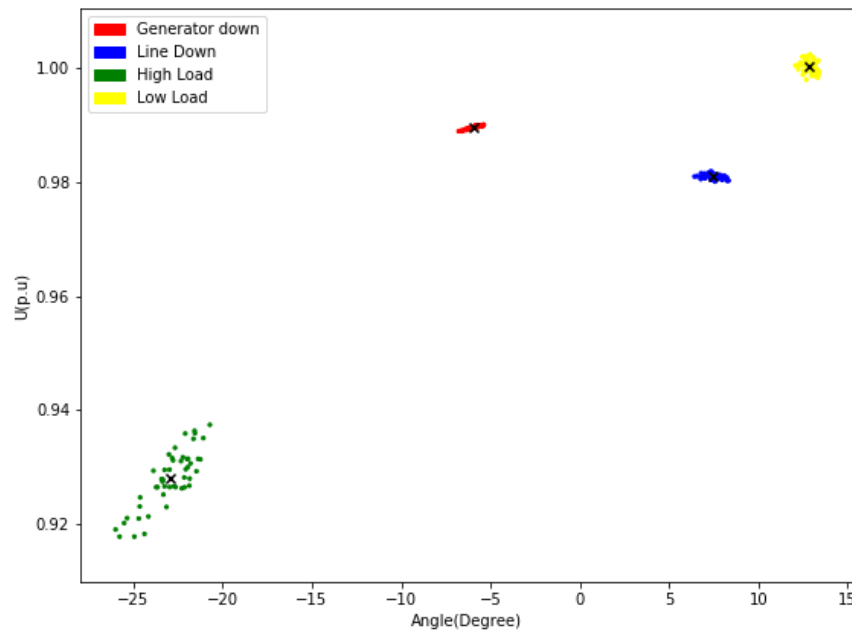

Figure 1 System Average Angle Versus Voltage

Based on the plot above clusters was grouped according to the following:

1. Low Load label were given to cluster 4 according to the highest average voltage and it has the size of 51 points.

2. High Load label were given to cluster 0 according to the lowest average voltage and it has the size of 49 points.

For the two remaining clusters:

3. Line Down label were given to cluster 1 with the highest average angle after Low Load has been assigned and it has the size of 47 points.

4. Generator Down label were given to cluster 2 with the lowest average angle after High Load has been assigned and it has the size of 53 points.