# States identification

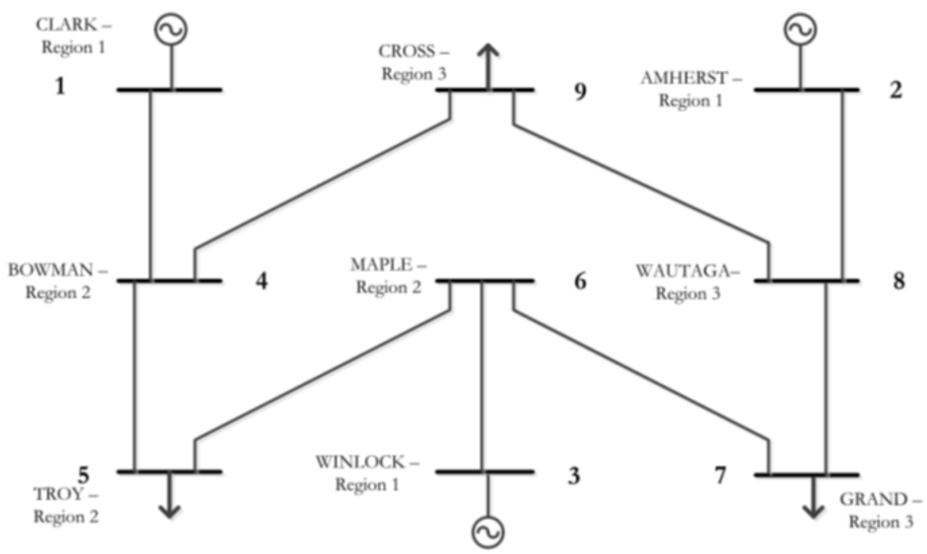
After we classified the training measurements by k-means method, we are going to identify and labelling the clusters to 4 states by analysing and comparing the data in each class.

Since any change in the system can influence the whole system power flow, i.e. all node voltages(angles) are changed, the average values of the 9 buses in the system can shows the general state for a certain training example. The following table shows the average values for each cluster:

| Class.no | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| Size | 48 | 53 | 51 | 49 |
| Average Voltage(pu) | 0.980965654 | 0.989641167 | 1.000334883 | 0.928008447 |
| Average Angle(degree) | 7.490167452 | -5.933008246 | 12.86152229 | -22.93925331 |

Higher loads in general means higher currents and higher voltage drops over the system components, therefore, we can easily identify the low load and high load states by lowest and highest average voltages values separately, i.e. class.no 2 represents “**Low load rate during night**” state and class.no 3 represents “**High load rate during peak hours**” state.

For “**Shut down of generator for maintenance**” state, we will see that if we disconnect a certain generator, generator connected with CLARK for instance, there will be no current flow between bus 1(CLARK) and bus 4(BOWMAN), which means no voltage drop over the line. So that we calculated the average voltage drop over line 1-4, 2-8 and 3-6. Then find out the average values for each cluster, and identify this state with the lowest average value, i.e. class.no 1.



| Class.no | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| average voltage drop (pu) | 0.014705693 | 0.00508645 | 0.01128724 | 0.070660035 |

Now, we just have one cluster left, next we will check if this cluster can represent the "**Disconnection of a line for maintenance**" state. Assume we don't have nonlinear components in the system, we can use the Thévenin equivalent diagram to analyse the influence of the line disconnection.

As is shown in the figure below, the voltage between node k and j after the disconnection $U_{kj}'$ is equal to the Thévenin equivalent voltage $U_{th\text{-}kj}$, which is not smaller than that value $U_{kj}$ before the disconnection, i.e. this disconnection will increase the voltage difference between node k and j, and the influence degree is related to the power flow through that line before the disconnection. Therefore we calculated the average voltage and voltage angle difference between the neighbouring buses.

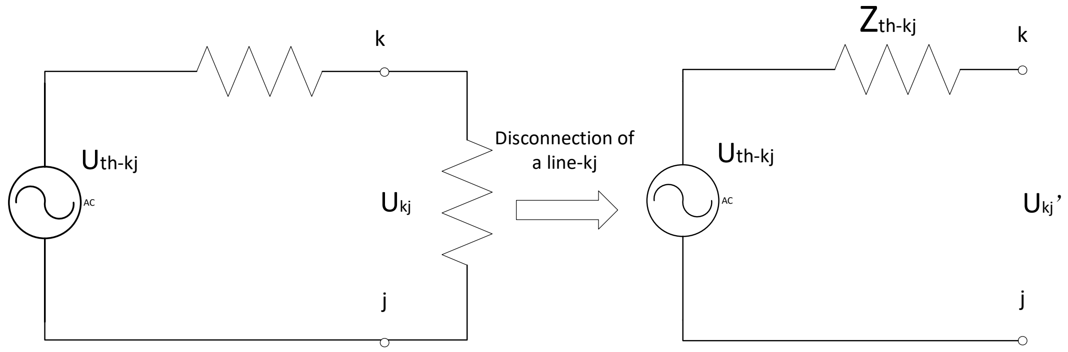



*Figure. Thévenin equivalent seen between node k and j*

According to the calculation results in the below table, both of cluster 0 and 3 shows relatively high average voltage difference. Considering the average voltage and angle again, these values won't be changed too much since just a small line inductance/line shunt capacitance disconnected, the large voltage differences are caused by the high current with high load state as we talked above.

| Class.no | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| average voltage difference (pu) | 0.03530588 | 0.020904506 | 0.01048928 | 0.074654589 |
| average voltage angle difference(degree) | 8.435260342 | 3.156018572 | 4.866110965 | 6.864660938 |

Now we have the labelling results:

| Class.no | 0 | 1 | 2 | 3 |
|---|---|---|---|---|
| label | Disconnection of a line for maintenance | Shut down of generator for maintenance | Low load rate during night | High load rate during peak hours |