EH2745 Computer Application in Power System

Assignment 2

Labelling Explanation

K-Mean

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Initially it was required to apply the K-Mean algorithm to know the clustering of the different states of the system in different times, then the following step is to tag every cluster according to specific features.

For the project 4 Labels were chosen:

- Generator down
- Line out
- High Load and Low Load

Active Power transfer equation:

$$P=\frac{V_k V_j}{X}\sin(\theta_{kj})$$

Where:

$$\theta_{kj} = \theta_k - \theta_j$$

In degrees

Label: Generator Down

The system consists of 9 buses, 3 of them are classified as Slack bus and PU-bus (Bus 1, Bus 2 and Bus 3), both buses are connected with transmission lines to another buses. When a generator is out of operation, i.e. the machine is not injecting power into the grid, the slack bus or PU bus and their contiguous bus theoretically should be at the same voltage level (as there is no current flowing through the line, there is any voltage drop), in other words the phase shift angle is the same in both buses. Therefore, to classify the state of the system under this label, the following procedure was applied

By analyzing the system, there are three direct connection with any generator bus (1-4, 2-8, 3-6), for this case connection between bus 3 and bus 6 will be used to identify the label. **If the angle difference of these 2 previously mentioned buses is almost**

or equal to zero, then it will be labelled as generator down. By analyzing the equation of active power transfer if $\theta_{kj} = 0$, it means that there is no power transfer in this buses connection as $\sin(\theta)=0$

The following pictures presents the Centroid Location of every bus of every cluster, and it will be used to prove that the arguments for the classification of the labelling are correct. In the highlighted cell with color blue, if we proceed to subtract angle of bus 3 and 6, the value is 0, i.e. the situation is a GENERATOR DOWN.

	BUS #	1	2	3	4	5	6
LABEL	HIGH LOAD	[1.0, 0.0]	[1.0, -20.755663832568146],	[1.0, -25.10339504941667]	[0.8955925545789866, -15.215485536459209]	[0.8498414736878261, -27.51767306701948],	[0.9541909917412981, -28.09571259006436],
	GEN DOWN	[1.0, 0.0]	[1.0, 1.8316977447024525],	[1.0, -9.240636086051088]	[0.9896378813509694, -5.288407125953627]	[0.977373140661007, -9.830518025702451],	[0.9996162738393863, -9.240636086051088],
	LINE OUT	[1.0, 0.0]	[1.0, 18.539964229101237]	[0.9999999999999999, 19.676937078564567],	[0.9722602502842047, -2.699076630267069],	[0.9345093512121824, -1.7357855760904493]	[0.9448944827136893, -7.826847157801757],
	LOW LOAD	[1.0, 0.0]	[1.0, 24.605202152086875],	[1.0, 19.358249435175658],	[0.9905389101373011, 4.218335322673466],	[0.9938286700486392, 7.455135798373066],	[1.0143078478295737, 16.5434691162737],

Labels: High Load and Low Load

By analyzing the active power transfer equation, it can be clearly understood than when the loads are demanding high amount of power, i.e. the whole term $\sin(\theta_{kj})$ will lead to a maximum value of 1 (highest possible value). By the opposite, when the loads demand low power, the power flow coming from Bus 1 to bus 4 will be really low.

By considering the difference between shift angle of bus 1 and bus 4, High Load will occur when the difference is the maximum, while low load occurs when the difference is small.

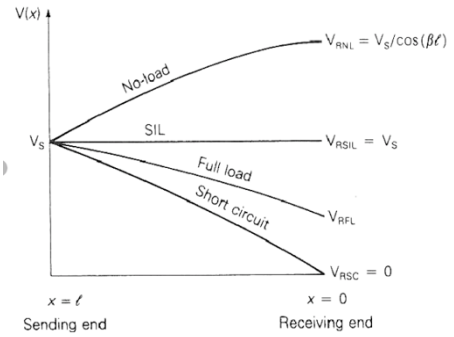
After running K-Mean it can be analyzed in the following picture that High load in fact occurs when the difference of angle of buses 1 and 4 is the maximum (besides the voltage magnitude of the load buses [5,7,9] is low). During a low load situation there are 2 states: load-bus´s voltage level is high and the difference of angle of buses 1 and 4 is small.

High load → Yellow

Low load → Green

BUS #	1	2	3	4	5
HIGH LOAD	[1.0, 0.0]	[1.0, -20.755663832568146],	[1.0, -25.10339504941667]	[0.8955925545789866, -15.215485536459209]	[0.8498414736878261, -27.51767306701948],
GEN DOWN	[1.0, 0.0]	[1.0, 1.8316977447024525],	[1.0, -9.240636086051088]	[0.9896378813509694, -5.288407125953627]	[0.977373140661007, -9.830518025702451],
LINE OUT	[1.0, 0.0]	[1.0, 18.539964229101237]	[0.9999999999999999, 19.676937078564567],	[0.9722602502842047, -2.699076630267069],	[0.9345093512121824, -1.7357855760904493]
LOW LOAD	[1.0, 0.0]	[1.0, 24.605202152086875],	[1.0, 19.358249435175658],	[0.9905389101373011, 4.218335322673466],	[0.9938286700486392, 7.455135798373066],

6	7	8	9
[0.9541909917412981, -28.09571259006436],	[0.9040191409441602, -32.91472659576736],	[0.9382363491732786, -26.989348531298422],	[0.8101955125327271, -29.861274552780998]]
[0.9996162738393863, -9.240636086051088],	[0.9827191230877586, -8.618529722540021],	[0.9954878559224327, -4.042050047455902],	[0.9619362291146679, -8.96799486495894]
[0.9448944827136893, -7.826847157801757],	[1.005710672851973, 16.838078060396022],	[0.981982790747961, 11.98869062614524],	[0.989333342386941, 12.62954643444105],
[1.0143078478295737, 16.5434691162737],	[1.0112967084684366, 17.03572483581089],	[1.0100927817497454, 18.816668217583242],	[0.9829490253508673, 7.720915709355747]



Full load is a similar condition as High load

Label: Line Out

As the three previous clusters have been labelled, the left cluster will be automatically tagged as **line out**.

After performing the K-Mean process the following number of states assigned to each cluster are presented:

Label Class	Number of States
High Load	49
Low Load	51
Generator Down	53
Line Out	47

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Table 1. Set States Classification