Identifying and labelling the power system states.

As a part of Assignment 2 in Computer Applications in Power System a database of measurements been given for a 9-bus system in four different operational states. Also, a set of data of measurement points has been given for 200 different timestamps and a set of data as "analog_values" is given for 20 timestamps. It is required to:

i) Develop a K-means algorithm in java and use it to identify the operational states of measurement database.

ii) Develop a Java application to identify a previously unknown state of the system based on voltage measurements using a k-NN algorithm and validate using Test Set.

This report has to be read in parallel to or after the codes used in java to understand the way the K means is applied and Knn algorithm used.

Averages of Voltages and angles in various clusters are as below:

In cluster one:

Name	**Bus No**	**Voltage (p.u.)**	**Angle**
Amherst	2	1	24.60520215208688
Bowman	4	0.9905389101373009	4.2183353226734654
Clark	1	1	0
Cross	9	0.9829490253508673	7.720915709355744
Grand	7	1.0112967084684366	17.035724835810896
Maple	6	1.0143078478295735	16.5434691162737
Troy	5	0.9938286700486392	7.455135798373064
Wautaga	8	1.0100927817497454	18.81666821758324
Winlock	3	1	19.358249435175658

In cluster two:

Name	**Bus No**	**Voltage (p.u.)**	**Angle**
Amherst	2	0.9999999999999999	20.755663832568146
Bowman	4	0.8955925545789867	-15.21548553645921
Clark	1	1	0
Cross	9	0.8101955125327275	-29.86127455278099
Grand	7	0.9040191409441598	-32.91472659576738
Maple	6	0.9541909917412983	-28.09571259006435
Troy	5	0.8498414736878264	-27.51767306701947
Wautaga	8	0.9382363491732781	26.989348531298415
Winlock	3	0.9999999999999999	-25.10339504941667

In cluster three:

Name	**Bus No**	**Voltage (p.u.)**	**Angle**
Amherst	2	1	1.8316977447024527
Bowman	4	0.9896378813509691	-5.288407125953629
Clark	1	1	0
Cross	9	0.961936229114668	-8.967994864958941

Grand	7	0.9827191230877583	-8.618529722540021
Maple	6	0.9996162738393859	-9.240636086051088
Troy	5	0.9773731406610073	-9.83051802570245
Wautaga	8	0.9954878559224327	-4.042050047455902
Winlock	3	1	-9.240636086051088

In cluster four:

Name	**Bus No**	**Voltage (p.u.)**	**Angle**
Amherst	2	0.9999999999999999	18.539964229101233
Bowman	4	0.9722602502842043	-2.699076630267069
Clark	1	1	0
Cross	9	0.9345093512121824	-1.735785576090448
Grand	7	0.9819827907479612	11.988690626145239
Maple	6	1.0057106728519731	16.838078060396022
Troy	5	0.9448944827136894	-7.826847157801755
Wautaga	8	0.9893333423869416	12.62954643444105
Winlock	3	0.9999999999999999	19.676937078564567

Operational States:

1. High Load:

It is known that by the increase in the load in the system, the voltage at the buses would decrease. The higher the load the lesser is the voltage at the voltage at the buses.

From the obtained clusters, it can be noticed that the cluster two contains the minimum average of voltages compared to rest other clusters. Also using the following equation to see the power of the load at buses 5, 7 and 9 they have higher values in cluster 2, compared to rest other(saw in terms of reactance as a variable which is assumed to be same in all case)

$$P_{kj} = U_k U_j sin\theta_{kj} / X_{kj}$$

Thus, the cluster two belongs to High load operational state. This cluster contains 49 data points and is in cluster2 arraylist in java code and as clustertwodata in mysql.databse.

2. Low Load:

From experience, we know that when the load at the system decreases the voltage the buses increases and on an average, it is higher than 1 p.u. From the observation of the data we see that the values corresponding to cluster one has the average high values of voltages at the buses. Thus, the data in cluster one corresponds to low load operational state. This cluster contains 51 data points and is in cluster1 arraylist in java code and as clusteronedata in mysql.databse.

3. Generator Shut down:

Observing the data in clusters we see that the angle at bus 3 is always larger than at bus 6 except in cluster one where they are equal implying that there is no power flow between bus 3 and 6 due to generator shut down at 3 and hence we get the cluster 3 data is from generator shutdown.

ANG3		ANG6
-9.4300063958...	0	-9.4300063958...
-9.2954129438...	0	-9.2954129438...
-8.8264905217...	0	-8.8264905217...
-9.0794489314...	0	-9.0794489314...
-8.7228566894...	0	-8.7228566894...
-8.7302196018...	0	-8.7302196018...
-9.7027715944...	0	-9.7027715944...
-9.5045642122...	0	-9.5045642122...
-9.3031572450...	0	-9.3031572450...
-8.7971249813...	0	-8.7971249813...
-9.4786193433...	0	-9.4786193433...
-9.1632177627...	0	-9.1632177627...
-8.9565689237...	0	-8.9565689237...
-9.3122742277...	0	-9.3122742277...
-8.7560815876...	0	-8.7560815876...
-8.9443834982...	0	-8.9443834982...
-9.2335771043...	0	-9.2335771043...
-9.4805466323...	0	-9.4805466323...
-8.7408561892...	0	-8.7408561892...
-8.8471820185...	0	-8.8471820185...
-9.0409898456...	0	-9.0409898456...
-9.9566891093...	0	-9.9566891093...
-8.8552638351...	0	-8.8552638351...
-9.1307281295...	0	-9.1307281295...
-9.2912025345...	0	-9.2912025345...
-8.8521603612...	0	-8.8521603612...
-8.8313334197...	0	-8.8313334197...
-9.4236833332...	0	-9.4236833332...
-9.9837690404...	0	-9.9837690404...
-9.4497035410...	0	-9.4497035410...
-8.9243999548...	0	-8.9243999548...
-8.6517955410...	0	-8.6517955410...
-9.8004454221...	0	-9.8004454221...
-8.9506327440...	0	-8.9506327440...
-10.024671754...	0	-10.024671754...
-9.4601116169...	0	-9.4601116169...
-8.6737036080...	0	-8.6737036080...
-8.5666303694...	0	-8.5666303694...
-8.5717694181...	0	-8.5717694181...
-9.6854910886...	0	-9.6854910886...
-9.7404742413...	0	-9.7404742413...
-9.4316783160...	0	-9.4316783160...
-8.9673122916...	0	-8.9673122916...
-9.3249897603...	0	-9.3249897603...
-10.093783156...	0	-10.093783156...
-9.4537643506...	0	-9.4537643506...
-9.1639779216...	0	-9.1639779216...
-9.1673546422...	0	-9.1673546422...
-9.0174874832...	0	-9.0174874832...
-9.6711266679...	0	-9.6711266679...
-10.299745966...	0	-10.299745966...
-9.6037390914...	0	-9.6037390914...
-9.3877435974...	0	-9.3877435974...

4. Line disconnection.

By looking at the differences in lines we see that in cluster 4 has got huge difference in voltage at bus 5 and 6, implying there is a line disconnection between them.

Cluster1	**Bus No**	**Voltage (p.u.)**	**Avg. Voltage angle**	Magnitude of complex Difference
Bowman	6	1.0143078478295735	16.5434691162737	0.02203
Troy	5	0.8498414736878264	7.455135798373064	
Cluster2	**Bus No**	**Voltage (p.u.)**	**Avg. Voltage angle**	
Bowman	6	0.9541909917412983	-28.09571259006435	0.1044
Troy	5	0.8498414736878264	-27.51767306701947	
Cluster3	**Bus No**	**Voltage (p.u.)**	**Avg. Voltage angle**	
Bowman	6	0.9996162738393859	-9.240636086051088	0.0247
Troy	5	0.9773731406610073	-9.83051802570245	
Cluster4	**Bus No**	**Voltage (p.u.)**	**Avg. Voltage angle**	
Bowman	6	1.0057106728519731	16.838078060396022	0.42034
Troy	5	0.9448944827136894	-7.826847157801755	

Thus, cluster 4 corresponds to line disconnection operational state.

The test set data of “analog_values” are assigned to these clusters after Knn algorithm and then from it we can know their operational states too.

For k=20, we get following data classification of “analog_values”.