Department of Electric Power and Energy Systems

EH2745 – Computer Applications in Power Systems

Assignment II

Power System State Labeling & Results

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Labeling

High Load

In order to assess if a given power system state can be classified as *"High Load"*, it is precise to verify the voltage magnitudes at buses 5, 7 and 9 (the buses with connected loads). If the sum of all these three voltages if beneath a certain threshold (in our case we selected 2.93 p.u.) then we can establish that the present scenario is one of high load.

$$|V_5| + |V_7| + |V_9| < 2.93\, p.u. => State = High\ Load$$

Shut Down

To determine if any of the generators is shut down, we need to verify the injected power into the buses where the generators are located. A generator will be labeled as *"Shut-Down"* if the power flow through the line where it is connected is very small (beneath 0.02 rad).

$$P_{ij} = \frac{V_i \cdot V_j}{X_{ij}} \cdot \sin(\theta_i - \theta_j) \approx \theta_i - \theta_j$$

$$P_{14} \approx \theta_1 - \theta_4\ and\ P_{28} \approx \theta_2 - \theta_8\ and\ P_{36} \approx \theta_3 - \theta_6$$

If one of these power flows is too low, it means that the generator is offline.

$$if\ (P_{14} < 0.02)\ or\ (P_{28} < 0.02)\ \ or\ (P_{36} < 0.02)\ \ =>\ State = Shut\ Down$$

Low Load

In order to assess if a given power system state can be classified as *"Low Load"*, it is precise to verify the voltage magnitudes in buses 6, 7 and 8. Whenever a low load condition takes place in bus 7, it affects the most nearby buses (6 and 8) in such a way that all these buses exhibit voltage magnitudes above 1.01 p.u. We can establish a criteria where, if the sum of the all these three voltages is above a certain threshold (in our case we selected 3.02 p.u.) then we can establish that the present scenario is one of low load.

$$|V_6| + |V_7| + |V_8| > 3.02\, p.u. => State = Low\ Load$$

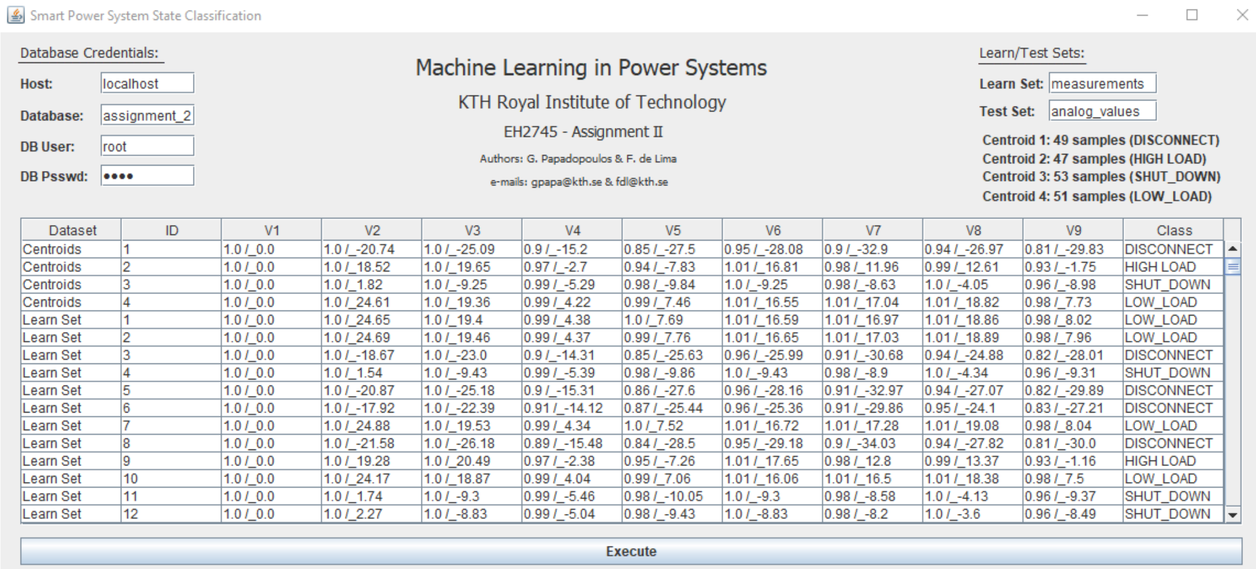
Disconnect

A straight-forward way to determine if a line disconnection has taken place in the power system is to use the voltage magnitudes of the buses. Consider that, if a failure (or maintenance) occurs, and the line has to be tripped, the current will have to find alternate ways to reach the loads, which means that voltage drops will heavily increase in the remaining lines, which in turn means that one or more buses will have very low voltages (we consider this to be beneath 0.85 p.u.)

$$|V_i| < 0.85\ for\ at\ least\ one\ i \in \{1, \dots, 9\}\ \ => State = Disconnection$$

Results

Figure 1 shows the execution results of the program.



Dataset	ID	V1	V2	V3	V4	V5	V6	V7	V8	V9	Class
Centroids	1	1.0 /_0.0	1.0 /_-20.74	1.0 /_-25.09	0.9 /_-15.2	0.85 /_-27.5	0.95 /_-28.08	0.9 /_-32.9	0.94 /_-26.97	0.81 /_-29.83	DISCONNECT
Centroids	2	1.0 /_0.0	1.0 /_18.52	1.0 /_19.65	0.97 /_-2.7	0.94 /_-7.83	1.01 /_16.81	0.98 /_11.96	0.99 /_12.61	0.93 /_-1.75	HIGH LOAD
Centroids	3	1.0 /_0.0	1.0 /_1.82	1.0 /_-9.25	0.99 /_-5.29	0.98 /_-9.84	1.0 /_-9.25	0.98 /_-8.63	1.0 /_-4.05	0.96 /_-8.98	SHUT_DOWN
Centroids	4	1.0 /_0.0	1.0 /_24.61	1.0 /_19.36	0.99 /_4.22	0.99 /_7.46	1.01 /_16.55	1.01 /_17.04	1.01 /_18.82	0.98 /_7.73	LOW_LOAD
Learn Set	1	1.0 /_0.0	1.0 /_24.65	1.0 /_19.4	0.99 /_4.38	1.0 /_7.69	1.01 /_16.59	1.01 /_16.97	1.01 /_18.86	0.98 /_8.02	LOW_LOAD
Learn Set	2	1.0 /_0.0	1.0 /_24.69	1.0 /_19.46	0.99 /_4.37	0.99 /_7.76	1.01 /_16.65	1.01 /_17.03	1.01 /_18.89	0.98 /_7.96	LOW_LOAD
Learn Set	3	1.0 /_0.0	1.0 /_-18.67	1.0 /_-23.0	0.9 /_-14.31	0.85 /_-25.63	0.96 /_-25.99	0.91 /_-30.68	0.94 /_-24.88	0.82 /_-28.01	DISCONNECT
Learn Set	4	1.0 /_0.0	1.0 /_1.54	1.0 /_-9.43	0.99 /_-5.39	0.98 /_-9.86	1.0 /_-9.43	0.98 /_-8.9	1.0 /_-4.34	0.96 /_-9.31	SHUT_DOWN
Learn Set	5	1.0 /_0.0	1.0 /_-20.87	1.0 /_-25.18	0.9 /_-15.31	0.86 /_-27.6	0.96 /_-28.16	0.91 /_-32.97	0.94 /_-27.07	0.82 /_-29.89	DISCONNECT
Learn Set	6	1.0 /_0.0	1.0 /_-17.92	1.0 /_-22.39	0.91 /_-14.12	0.87 /_-25.44	0.96 /_-25.36	0.91 /_-29.86	0.95 /_-24.1	0.83 /_-27.21	DISCONNECT
Learn Set	7	1.0 /_0.0	1.0 /_24.88	1.0 /_19.53	0.99 /_4.34	1.0 /_7.52	1.01 /_16.72	1.01 /_17.28	1.01 /_19.08	0.98 /_8.04	LOW_LOAD
Learn Set	8	1.0 /_0.0	1.0 /_-21.58	1.0 /_-26.18	0.89 /_-15.48	0.84 /_-28.5	0.95 /_-29.18	0.9 /_-34.03	0.94 /_-27.82	0.81 /_-30.0	DISCONNECT
Learn Set	9	1.0 /_0.0	1.0 /_19.28	1.0 /_20.49	0.97 /_-2.38	0.95 /_-7.26	1.01 /_17.65	0.98 /_12.8	0.99 /_13.37	0.93 /_-1.16	HIGH LOAD
Learn Set	10	1.0 /_0.0	1.0 /_24.17	1.0 /_18.87	0.99 /_4.04	0.99 /_7.06	1.01 /_16.06	1.01 /_16.5	1.01 /_18.38	0.98 /_7.5	LOW_LOAD
Learn Set	11	1.0 /_0.0	1.0 /_1.74	1.0 /_-9.3	0.99 /_-5.46	0.98 /_-10.05	1.0 /_-9.3	0.98 /_-8.58	1.0 /_-4.13	0.96 /_-9.37	SHUT_DOWN
Learn Set	12	1.0 /_0.0	1.0 /_2.27	1.0 /_-8.83	0.99 /_-5.04	0.98 /_-9.43	1.0 /_-8.83	0.98 /_-8.2	1.0 /_-3.6	0.96 /_-8.49	SHUT_DOWN

Figure 1 Execution Results

The solution obtained from the program shows the following results.

Table 1 Learn Set Samples Classification

Class	Number of Samples (out of 200)
High Load	47
Shut Down	53
Low Load	51
Disconnect	49

The performed *kNN* classification algorithm shows the following results.
The query: `SELECT * FROM assignment_2.test_set;` was executed so as to acquire the test set classification results.

ID	V1	O1	V2	O2	V3	O3	V4	O4	V5	O5	V6	O6	V7	O7	V8	O8	V9	O9	Class
1	1.0000	0.0000	1.0000	24.9339	1.0000	19.6416	0.9901	4.2670	0.9911	7.4969	1.0139	16.8257	1.0117	17.4514	1.0104	19.1474	0.9842	7.8639	LOW LOAD
2	1.0000	0.0000	1.0000	-22.1619	1.0000	-26.3902	0.8868	-15.7221	0.8358	-28.4055	0.9510	-29.3926	0.9023	-34.3716	0.9356	-28.4132	0.7987	-31.2219	DISCONNECT
3	1.0000	0.0000	1.0000	-20.2853	1.0000	-24.5325	0.8999	-15.1860	0.8560	-27.1859	0.9555	-27.5207	0.9043	-32.2356	0.9400	-26.5073	0.8186	-29.8711	DISCONNECT
4	1.0000	0.0000	1.0000	-19.5877	1.0000	-24.1075	0.8987	-14.9877	0.8477	-27.2122	0.9554	-27.0960	0.9081	-31.5123	0.9417	-25.7985	0.8201	-29.1323	DISCONNECT
5	1.0000	0.0000	1.0000	18.0896	1.0000	19.1913	0.9725	-2.8302	0.9453	-7.9359	1.0057	16.3524	0.9820	11.5028	0.9894	12.1796	0.9347	-2.0965	HIGH LOAD
6	1.0000	0.0000	1.0000	24.6016	1.0000	19.3989	0.9918	4.1730	0.9954	7.4407	1.0144	16.5845	1.0108	17.1110	1.0103	18.8142	0.9855	7.5524	LOW LOAD
7	1.0000	0.0000	1.0000	25.3900	1.0000	20.1341	0.9877	4.5183	0.9920	8.0785	1.0127	17.3150	1.0073	17.8957	1.0075	19.5868	0.9775	8.2208	LOW LOAD
8	1.0000	0.0000	1.0000	24.3268	1.0000	19.1401	0.9896	4.0941	0.9909	7.3351	1.0139	16.3243	1.0117	16.7562	1.0100	18.5379	0.9817	7.4375	LOW LOAD
9	1.0000	0.0000	1.0000	24.4801	1.0000	19.2533	0.9894	4.0852	0.9904	7.3002	1.0129	16.4346	1.0087	16.9530	1.0087	18.6838	0.9813	7.4454	LOW LOAD
10	1.0000	0.0000	1.0000	-18.6957	1.0000	-22.9680	0.8986	-14.4050	0.8565	-25.7348	0.9538	-25.9614	0.8984	-30.6456	0.9357	-24.9461	0.8070	-28.4851	DISCONNECT
11	1.0000	0.0000	1.0000	1.6302	1.0000	-9.4155	0.9892	-5.4321	0.9768	-10.0344	0.9995	-9.4155	0.9827	-8.7742	0.9954	-4.2444	0.9610	-9.2788	SHUT DOWN
12	1.0000	0.0000	1.0000	18.4096	1.0000	19.6096	0.9718	-2.8472	0.9440	-8.0617	1.0057	16.7706	0.9819	11.9211	0.9890	12.4974	0.9335	-2.0356	HIGH LOAD
13	1.0000	0.0000	1.0000	1.8547	1.0000	-9.1752	0.9894	-5.3284	0.9773	-9.8220	0.9997	-9.1752	0.9829	-8.5208	0.9955	-4.0191	0.9612	-9.1157	SHUT DOWN
14	1.0000	0.0000	1.0000	18.6703	1.0000	19.9062	0.9719	-2.7461	0.9445	-7.8619	1.0057	17.0673	0.9819	12.2178	0.9890	12.7578	0.9333	-1.8649	HIGH LOAD
15	1.0000	0.0000	1.0000	19.4354	1.0000	20.7191	0.9722	-2.4005	0.9461	-7.2557	1.0057	17.8803	0.9820	13.0311	0.9890	13.5231	0.9336	-1.2124	HIGH LOAD
16	1.0000	0.0000	1.0000	19.3079	1.0000	20.6334	0.9709	-2.6668	0.9425	-7.9889	1.0057	17.7944	0.9818	12.9453	0.9887	13.3935	0.9323	-1.4637	HIGH LOAD
17	1.0000	0.0000	1.0000	1.5115	1.0000	-9.5094	0.9894	-5.4259	0.9772	-10.0015	0.9995	-9.5094	0.9825	-8.9420	0.9953	-4.3634	0.9613	-9.2876	SHUT DOWN
18	1.0000	0.0000	1.0000	2.1824	1.0000	-8.9529	0.9895	-5.2341	0.9768	-9.8006	0.9997	-8.9529	0.9832	-8.1819	0.9957	-3.6902	0.9618	-8.8063	SHUT DOWN
19	1.0000	0.0000	1.0000	-21.7935	1.0000	-26.1154	0.8866	-15.7346	0.8352	-28.4906	0.9491	-29.1237	0.8958	-33.9396	0.9331	-28.0616	0.7984	-31.1970	DISCONNECT
20	1.0000	0.0000	1.0000	2.5458	1.0000	-8.4798	0.9901	-4.9781	0.9787	-9.1904	1.0001	-8.4798	0.9834	-7.7968	0.9959	-3.3256	0.9624	-8.4854	SHUT DOWN

Figure 2 Execution Results

It has been found that there are 5 samples of each class among the test set objects.

Table 2 Learn Set Samples Classification

Class	**Number of Samples (out of 20)**	**Executed Query**
High Load	5	`SELECT COUNT(*) FROM assignment_2.test_set WHERE Class='HIGH LOAD';`
Shut Down	5	`SELECT COUNT(*) FROM assignment_2.test_set WHERE Class='SHUT_DOWN';`
Low Load	5	`SELECT COUNT(*) FROM assignment_2.test_set WHERE Class='LOW_LOAD';`
Disconnect	5	`SELECT COUNT(*) FROM assignment_2.test_set WHERE Class='DISCONNECT';`

Appendix

The next algorithm shows the *KLabel* class implemented in the *Java* program to label the different power system states.

```
package assignment2;

import java.util.ArrayList;

public class KLabel {

	//*** LABEL CENTROIDS ***
	public static void LabelCentroids(ArrayList<Sample> centroids) {
		for (Sample centroid : centroids) {
			isHighLoad(centroid);
			isShutDown(centroid);
			isLowLoad(centroid);
			isDisconnect(centroid);
			centroids.set(centroid.cluster, centroid);
		}
	}

	//*** DETERMINE IF CENTROID IS HIGH LOAD ***
	private static void isHighLoad(Sample centroid) {
		int Nbus = centroid.attribute.length/2;
		double[] v = new double[Nbus];

		for (int n=0; n < Nbus; n++) {
			v[n] = centroid.attribute[2*n];
		}

		if (v[4] + v[6] + v[8] < 2.93) {
			//buses 5, 7 and 9 have low voltages
			centroid.state = Sample.HIGH_LOAD;
		}
	}

	//*** DETERMINE IF CENTROID IS SHUT DOWN ***
	private static void isShutDown(Sample centroid) {
		int Nbus = centroid.attribute.length/2;
		double[] o = new double[Nbus];

		for (int n=0; n < Nbus; n++) {
			o[n] = centroid.attribute[2*n+1]*Math.PI/180;
		}

		double pmin = 0.02; //minimum power to assume generator is online
		double p14 = Math.abs(o[0]-o[3]); //flow through line 1-4
		double p28 = Math.abs(o[1]-o[7]); //flow through line 2-8
		double p36 = Math.abs(o[2]-o[5]); //flow through line 3-6

		if (p14 < pmin || p28 < pmin || p36 < pmin) {
			//if one of these flows is too low, it means that the generator is
offline
			centroid.state = Sample.SHUT_DOWN;
		}
	}

	//*** DETERMINE IF CENTROID IS LOW LOAD ***
	private static void isLowLoad(Sample centroid) {
		int Nbus = centroid.attribute.length/2;
```

```
            double[] v = new double[Nbus];

            for (int n=0; n < Nbus; n++) {
                  v[n] = centroid.attribute[2*n];
            }

            if (v[5] + v[6] + v[7] > 3.02) {
                  //buses 6, 7 and 8 have high voltages
                  centroid.state = Sample.LOW_LOAD;
            }
      }

      //*** DETERMINE IF CENTROID IS DISCONNECT ***
      private static void isDisconnect(Sample centroid) {
            int Nbus = centroid.attribute.length/2;
            double[] v = new double[Nbus];

            for (int n=0; n < Nbus; n++) {
                  v[n] = centroid.attribute[2*n];
            }

            for (int i=0; i < Nbus; i++) {
                  if (v[i] < 0.85) {
                        //if one of the voltages is too low, it is because of line
disconnection
                        centroid.state = Sample.DISCONNECT;
                        break;
                  }
            }
      }

      //*** LABEL SAMPLES BASED ON CENTROIDS ***
      public static void LabelSamples(ArrayList<Sample> centroids, ArrayList<Sample>
samples) {
            for (int m=0; m < samples.size(); m++) {
                  Sample sample = samples.get(m);
                  for (Sample centroid : centroids) {
                        if (sample.cluster == centroid.cluster) {
                              sample.state = centroid.state;
                        }
                  }
                  samples.set(m, sample);
            }
      }
}
```