Kungliga Tekniska Högskolan

EH2745 Computer Applications in Power Systems

Assignment II

Assignment II: Machine Learning in Power Systems

Group members:
Rebeca Brenes Brenes, 931008-6542
Nick van Dunné, 910124-T777

11th June, 2018

System State Labeling

In the SQL relational database of the power system, for every time step there are nine voltage and angle values for the nine different buses in the power system. When implementing a K-means clustering algorithm, four clusters can be defined which need to be linked to the following four system states:

- High load rate during peak hours
- Shut down of generator for maintenance
- Low load rate during night
- Disconnection of a line for maintenance

In order to link the system states with the clusters, the following criteria per system state was used.

High load rate during peak hours

During peak hours when there is a high load, the busbars which are directly connected to the load present lower voltage levels. For that reason, the sum of voltage levels for the busbars that correspond to the loads (V_5, V_7 and V_7) was obtained. To define if the cluster correspond to high load the sum was compared with a higher and lower bound. These threshold values were obtained after analyzing the cluster centroids. The following mathematical expression was implemented in the algorithm:

$$2.60 < V_5 + V_7 + V_9 < 2.92 \tag{1}$$

Shut down of generator for maintenance

If any of the generators is shut down, there will be no power injected in the bus which is connected to the generator. A way to verify this is by analyzing the power flows between the lines that connect a generator to the rest of the grid (lines 1-4, 2-8 and 3-6). To determine if the generator is shut down, the value of the power flow of the lines is compared with a threshold value of 0.01 rad (obtained by analyzing the cluster centroids data).

The power flow can be obtained using the reduced expression from equation (2), which reduces the problem to finding the difference between bus angles. If the power flow through the line where it is below a 0.01 rad, then the label of *Shut down of generator for maintenance* is applied, as presented in equation (3)

$$P_{ij} = \frac{V_i \cdot V_j}{X_{ij}} \cdot sin\left(\theta_i - \theta_j\right) \approx \theta_i - \theta_j \tag{2}$$

$$\left(P_{14} \approx \theta_1 - \theta_4 < 0.01\right) || \left(P_{28} \approx \theta_2 - \theta_8 < 0.01\right) || \left(P_{36} \approx \theta_3 - \theta_6 < 0.01\right) \tag{3}$$

Low load rate during night

For the low load periods, the opposite applies compared to high load periods. For that reason, the sum of the voltage levels at the load busbars was checked to be higher than a threshold of 2.97 (obtained by analyzing cluster centroid data). Mathematically presented as:

$$V_5 + V_7 + V_9 > 2.97 \tag{4}$$

Disconnection of a line for maintenance

To detect the disconnection of a line is quite simple, the effects of the line disconnection are very noticeable in the network, because when a line is taken out for maintenance the current will use the remaining lines instead causing voltage reduction.

$$V_i < 0.85 \tag{5}$$

Therefore, it can be detected by simply scanning all the voltages, if there is one bus with a very low voltage, then it is most likely a line disconnection case. The threshold value to determine a heavy voltage drop is 0.85, which was obtained by analyzing the cluster centroid data.

Java Method

The previous concepts were adapted in a method in Java, where the attributes of a structure `double[]`. The method compares the four different conditions in order to assign a state.

```
1  public static String kLabel(double[] attributes){
2          String state = null;
3          double sum579 = attributes[8]+attributes[12]+attributes[16];
4          if(sum579<2.92 && sum579>2.6){
5                  state = "High Load";
6          }else if(sum579>2.97){
7                  state = "Low Load";
8          }else if((attributes[1]-attributes[7])<0.01 || (attributes[3]-
               attributes[15])<0.01 || (attributes[5]-attributes[11])
               <0.01){
9                  state = "Shut Down";
10         }else if(minValue(attributes)<0.85){
11                 state = "Disconnect";
12         }
13         return state;
14 }
```

Clustering Result

After running the algorithm, the following results were obtained for the training set, using *k-means* algorithm:

- **High load rate during peak hours** = 47 samples
- **Shut down of generator for maintenance** = 53 samples
- **Low load rate during night** = 51 samples
- **Disconnection of a line for maintenance** = 49 samples

Then the following results were obtained for the test set, using *k-nn* algorithm:

- **High load rate during peak hours** = 5 samples
- **Shut down of generator for maintenance** = 5 samples
- **Low load rate during night** = 5 samples
- **Disconnection of a line for maintenance** = 5 samples