```
1 clc; clear;
 2 %% Standardizing generator sub-transient reactances
 3 \text{ s new} = 100; % MVA
 4 s old = [250; 100; 80; 50; 50;]; % MVA
 6 \times 1 = 15/100;
 7 \times 2 = 12/100;
 8 \times 3 = 10/100;
 9 \times 4 = 9/100;
10 \times 5 = 8/100;
11 x = [1 x1; 2 x2; 3 x3; 4 x4; 5 x5];
13 % converting xolds to xnews
14 \times (:,2) = (\times (:,2)./s \text{ old}) *s \text{ new};
15 [r x, \sim] = size(x);
16 %% Y bus calculation
17
18 % import data as table
19 linedata = readmatrix("line data.xlsx");
20 for k=1:r x
21
       linedata(end+1,1) = x(k,1);
22
       linedata(end,2) = x(k,1);
23
       linedata(end,4) = x(k,2);
24 end
25 [r_data, \sim] = size(linedata);
27 % Preprocessing
28 number of buses = max(max(linedata(:,1:2))); % picking the highest numbered bus
29 y bus = zeros(number of buses);
30 [length y bus, \sim] = size(y bus);
32 % formatting the impedances
33 R = linedata(:,3);
34 X = linedata(:,4);
35 B = linedata(:,5);
36 impedances = [R X.*1i B*1i./2];
37
38 % calculating the diagonal elements
39 for m=1:length y bus % m is the index of the y bus (row)
        z = zeros(1,3); % initialize 3 columns (R,X,B)
40
41
        for n=1:r data % n is the index of the linedata (row)
42
            if linedata(n,1) == m \mid | \text{linedata}(n,2) == m
43
                z = [z; linedata(n,3:5)]; % collecting all the impedances
44
            end
45
       end
46
       [r z, \sim] = size(z);
47
       for impedance=1:r z
48
           R = z(impedance, 1);
49
            X = z(impedance, 2);
```

```
50
            B = z (impedance, 3);
            if R~=0 || X~=0
 51
 52
                y bus(m,m) = y bus(m,m) + 1./(R+X.*1i) + B.*1i/2;
 53
 54
        end
 55 end
 56
 57 % calculating off diagonal elements
 58 for m=1:length y bus % first index of Y element
        for n=1:length y bus % second index of Y element
            current nodes = [m n]
 60
            if m~=n
 61
 62
                 for k=1:r_data
 63
                     if linedata(k,1) == m && linedata(k,2) == n
                         R = linedata(k,3);
 64
 65
                         X = linedata(k, 4);
                         B = linedata(k, 5);
 66
 67
                         current z = [R X B]
                         y bus (m, n) = -1/(R+1i*X)+B*1i/2;
 68
 69
                         y bus(n,m) = y bus(m,n);
 70
                     end
71
                 end
72
            end
73
        end
 74 end
75
 76
77
 78
 79 %% z bus calculation
80 z bus = y bus^-1;
 81
 82
83 %% prefault voltages
85 v = readmatrix('voltages.xlsx'); % prefault voltages
 86 v magnitudes = v(:,1);
87 v angles = deg2rad(v(:,2));
88
 89 % converting to rectangular
 90 vx = v magnitudes.*cos(v angles);
 91 vy = v magnitudes.*sin(v angles);
 92 v = vx+vy*1i;
 93
 94 %% q1: sags
 95
 96 %Calculate the voltage sag at bus 4 and bus 13 when a three-phase-fault occurs at {f v}
each bus
97 %in the system
```

```
98 sag 4 q1 = zeros(14,1);
 99 sag 13 q1 = zeros(14,1);
100 for bus=1:14
        %if bus~=4|bus~=13
101
102
             sag 4 q1(bus) = (1-z bus(4,bus)/z bus(bus,bus))*v(bus);
103
             sag 13 q1(bus) = (1-z bus(13,bus)/z bus(bus,bus))*v(bus);
104
105 end
106
107 % sag magnitudes
108 sag 4 q1 = abs(sag 4 q1);
109 sag 13 q1 = abs(sag 13 q1);
110 %% q2a: sags (lines 4-5 and 6-13 are open)
111
112 % forming the y,z buses
113 [y_bus_q2, linedata_q2, z_bus_q2] = find_y_z_bus('line data q2.\boldsymbol{\nu}
xlsx','gen reactances.xlsx');
114
115 %faults
116 sag 4 q2 = zeros(14,1);
117 sag 13 g2 = zeros(14,1);
118 for bus=1:14
119
        %if bus~=4|bus~=13
120
             sag 4 q2(bus) = (1-z bus q2(4,bus)/z bus q2(bus,bus))*v(bus);
121
             sag 13 q2(bus) = (1-z bus q2(13,bus)/z bus q2(bus,bus))*v(bus);
122
123 end
124 % sag magnitudes
125 \text{ sag } 4 \text{ q2} = \text{abs(sag 4 q2)};
126 sag 13 q2 = abs(sag 13 q2);
127 %% q2b: sags (no x3 and x5)
128
129 [y bus q3, linedata q3, z bus q3] = find y z bus('line data. 🗸
xlsx','gen reactances q2');
130
131 % faults
132 sag 4 q3 = zeros(14,1);
133 sag 13 q3 = zeros(14,1);
134 for bus=1:14
       %if bus~=4|bus~=13
135
136
             sag 4 q3(bus) = (1-z bus q3(4,bus)/z bus q3(bus,bus))*v(bus);
             sag 13 q3(bus) = (1-z bus q3(13,bus)/z bus q3(bus,bus))*v(bus);
137
138
        %end
139 end
140 % sag magnitudes
141 \text{ sag } 4 \text{ q3} = \text{abs}(\text{sag } 4 \text{ q3});
142 sag 13 q3 = abs(sag 13 q3);
143 %% q4: no of sags
144
```

```
145 d = linedata(:,6); %line distance
146 frequency 100 = linedata(:,7); % faults/100km/yr
148 frequency d = frequency 100.*d./100;
149 nodes = linedata(:,1:2);
150 [r,c] = size(nodes);
151 % calculating average sags
152 average sags 4 = zeros(r,3); % will be of the same size as the nodes matrix
153 average sags 4(:,1:2) = nodes;
154 average sags 13 = zeros(r,3); % will be of the same size as the nodes matrix
155 average sags 13(:,1:2) = nodes;
156
157 % sags at lines for bus 4
158 for k=1:r
       from node = linedata(k,1)
159
160
      to node = linedata(k, 2)
      sag 4 q1(linedata(k,1))
161
162
      sag 4 q1(linedata(k,2))
      sag1 = sag 4 q1(from node);
163
      sag2 = sag 4 q1(to node);
164
        average sags 4(k,3) = 0.5*(sag1+sag2);
165
166 end
167
168 % sags at lines for bus 13
169 for k=1:r
170
        sag1 = sag 13 \ q1 (nodes(k, 1));
171
        sag2 = sag 13 q1 (nodes(k, 2));
        average sags 13(k,3) = 0.5*(sag1+sag2);
172
173 end
174
175 frequency table = [nodes average sags 4(:,3) average sags 13(:,3) frequency d];
176 f sag 4 = 0;
177 f sag 13 = 0;
178 % frequency of sag under 40%=0.4 pu
179 [r, \sim] = size(frequency table);
180 for k=1:r
181
        current ave sag 4 = frequency table(k, 3)
        if current ave sag 4<0.4
182
183
            frequency = frequency table (k, 5)
            f sag 4 = f sag 4 + frequency
184
185
        end
186
        current ave sag 13 = frequency table(k, 4)
187
        if current ave sag 13<0.4
            frequency = frequency table (k, 5)
188
            f sag 13 = f sag 13 + frequency table(k, 5)
189
190
        end
191 end
192
193 %% q4: Bar chart
```

```
194 clc;
195
196 % creating chart
197 chart intervals = 0:0.1:1; % each number represents an upper bound for an ✔
interval
198 chart intervals = chart intervals';
199 chart = [chart intervals zeros(length(chart intervals),2)];
200 [r, \sim] = size(chart);
201
202 % filling the chart
203 % sags at bus 4
204 for k=1:length(sag 4 q1)
205
      for index=2:r
206
            l bound = chart(index-1,1)
            u bound = chart(index,1)
207
208
            current sag = sag 4 q1(k)
            if 1 bound < sag 4 q1(k) && sag 4 q1(k) < u bound
209
210
                chart(index, 2) = chart(index, 2) + 1;
211
212
            end
213
        end
214 end
215 % sags at bus 13
216 for k=1:length(sag 13 q1)
217
       for index=2:r
218
            if chart(index-1,1) < sag 13 q1(k) && sag 13 q1(k) < chart(index,1)</pre>
219
                chart(index, 3) = chart(index, 3) + 1;
220
            end
221
        end
222 end
223 clc;
224 chart = chart(2:end,:);
225
226 % barplots
227 figure (1)
228 bar(chart(:,1),chart(:,2))
229 alpha(.3)
230
231 hold on
232 bar(chart(:,1),chart(:,3))
233 alpha(.3)
234
235 legend('Bus 4 sags', 'Bus 13 sags')
236
237 %% q6 new generators
238 clc;
239 [y bus q6, linedata q6, z bus q6] = find y z bus('line data. 🗸
xlsx','gen reactances q6.xlsx');
240 % faults
```

```
241 sag 4 q6 = zeros(14,1);
242 sag 13 q6 = zeros(14,1);
243 for bus=1:14
        %if bus~=4|bus~=13
244
             sag_4_q6(bus) = (1-z_bus_q6(4,bus)/z_bus_q6(bus,bus))*v(bus);
245
246
             sag 13 q6(bus) = (1-z bus q6(13,bus)/z bus q6(bus,bus))*v(bus);
247
         %end
248 end
249 % sag magnitudes
250 \text{ sag } 4 \text{ q6} = \text{abs(sag } 4 \text{ q6)};
251 \text{ sag } 13 \text{ q6} = \text{abs(sag } 13 \text{ q6)};
252 %% Plots
253
254 % q1
255 figure (2)
256 bar(sag_4_q1)
257 hold on
258 bar(sag 13 q1)
259 alpha(0.4)
260 legend('Bus 4 sags', 'Bus 13 sags')
261
262 % q2a
263 figure (3)
264
265 bar(sag_4_q2)
266 hold on
267 bar(sag 13 q2)
268 alpha(0.4)
269 legend('Bus 4 sags', 'Bus 13 sags')
270 title('lines opened')
271
272 % q2b
273 figure (4)
274
275 bar(sag 4 q3)
276 hold on
277 bar(sag_13_q3)
278 alpha(0.4)
279 title('generators disconnected')
280 legend('Bus 4 sags', 'Bus 13 sags')
281
282 % q6
283 figure (5)
284 bar(sag 4 q6)
285 hold on
286 bar(sag_13_q6)
287 alpha(0.4)
288 title('Sags after addition of generators')
289 legend('Bus 4 sags', 'Bus 13 sags')
```