```
clc
clear

% Dados:
% IEEE 14 barras
% [       NUM    TIPO    V        TETA     PG    QG      PD         QD       GSH    BSH ]
barras = [
            1   2   1.060 0.0  232.4 -16.9  0.0     0.0     0.0    0.0 0 0
            2   1   1.045 0.0  40.0  42.4  21.70  12.70    0.0    0.0 -40  50
            3   1   1.010 0.0  0.0  23.4  94.20  19.00    0.0    0.0 0    40
            4   0   1.000 0.0  0.0   0.0  47.80   -3.90   0.0    0.0 0    0
            5   0   1.000 0.0  0.0   0.0  7.60   1.600    0.0    0.0 0    0
            6   1   1.070 0.0  0.0   12.2  11.20  7.500    0.0    0.0 -6   24
            7   0   1.000 0.0  0.0   0.0   0.0    0.0     0.0    0.0 0    0
            8   1   1.090 0.0  0.0   17.4   0.0    0.0     0.0    0.0 -6   24
            9   0   1.000 0.0  0.0   0.0  29.50   16.60   0.0   19.0 0    0
            10  0   1.000 0.0  0.0   0.0   9.00   5.800   0.0    0.0 0    0
            11  0   1.000 0.0  0.0   0.0   3.50   1.800   0.0    0.0 0    0
            12  0   1.000 0.0  0.0   0.0   6.10   1.600   0.0    0.0 0    0
            13  0   1.000 0.0  0.0   0.0   13.50  5.800   0.0    0.0 0    0
            14  0   1.000 0.0  0.0   0.0   14.90  5.000   0.0    0.0 0    0 ];

%            [FR    TO         R          X      BSHtotal   Tap  ]
linhas = [
1    2    0.01938  0.05917    0.05280    0
1    5    0.05403  0.22304    0.04920    0
2    3    0.04699  0.19797    0.04380    0
2    4    0.05811  0.17632    0.03400    0
2    5    0.05695  0.17388    0.03460    0
3    4    0.06701  0.17103    0.01280    0
4    5    0.01335  0.04211    0          0
4    7    0.0      0.20912    0          0.978
4    9    0.0      0.55618    0          0.969
5    6    0.0      0.25202    0          0.932
6    11    0.09498  0.19890    0          0
6    12    0.12291  0.25581    0          0
6    13    0.06615  0.13027    0          0
7    8    0.0      0.17615      0          0
7    9    0.0      0.11001    0          0
9    10    0.03181  0.08450    0             0
9    14    0.12711  0.27038    0          0
10    11    0.08205  0.19207    0          0
12    13    0.22092  0.19988    0          0
13    14    0.17093  0.34802    0          0          ];


Custo = [1 1 2 4 4];
MaxP  = [250 40 15 15 15];
MaxQ  = [50  50  50 50 50];
MinP  = [0 0 0 0 0];
```

```
MinQ  = [-50 -50 -50 -50 -50];

Ref= 1;
% ========================
% Leitura dos dados de entrada

[NumBarras,NumBCol] = size(barras);
[NumLinhas,NumLCol] = size(linhas);

% Linhas
% Init das variaveis
de = zeros(NumLinhas,1);
para = zeros(NumLinhas,1);
R = zeros(NumLinhas,1);
X = zeros(NumLinhas,1);
B = zeros(NumLinhas,1);
Tap = zeros(NumLinhas,1);

for i=1:NumLinhas
    de(i) = linhas(i,1);
    para(i) = linhas(i,2);
    R(i) = linhas(i,3);
    X(i) = linhas(i,4);
    B(i) = 1/X(i);
    Tap(i) = linhas(i,6);
end

% Desconsiderando taps
Tap = ones(NumLinhas,1);

% Barras
% Init das variaveis
Tipo = zeros(NumBarras,1);
V = zeros(NumBarras,1);
Teta = zeros(NumBarras,1);
Pg = zeros(NumBarras,1);
Qg = zeros(NumBarras,1);
Pd = zeros(NumBarras,1);
Qd = zeros(NumBarras,1);
Gsh = zeros(NumBarras,1);
Bsh = zeros(NumBarras,1);

for i=1:NumBarras
    Tipo(i) = barras(i,2);
    V(i) = barras(i,3);
    Teta(i) = barras(i,4);
    Pg(i) = barras(i,5);
    Qg(i) = barras(i,6);
    Pd(i) = barras(i,7);
    Qd(i) = barras(i,8);
```

```
    Gsh(i) = barras(i,9);
    Bsh(i) = barras(i,10);
end

% Potencias em PU
Pg = Pg/100;
Qg = Qg/100;
Pd = Pd/100;
Qd = Qd/100;



% ========================
% Matriz B_linha

B_linha = zeros(NumBarras,NumBarras);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    B_linha(K,K) = B_linha(K,K) + B(i)/(Tap(i)^2); % diagonal principal considerando tap
    B_linha(M,M) = B_linha(M,M) + B(i); % diagonal principal
    B_linha(K,M) = B_linha(K,M) - B(i)/Tap(i); % Fora da diagonal principal
    B_linha(M,K) = B_linha(M,K) - B(i)/Tap(i); % Fora da diagonal principal
end

% ========================
% Fluxo de potencia linearizado


B_REF = Ref;
B_linha(B_REF,B_REF) = 10^20; % Infinito
Teta=  B_linha\(-Pd+Pg); % inv
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  4.588513e-21.
```

```

Pkm = zeros(NumLinhas,1);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    Pkm(i) = (Teta(K)-Teta(M))*B(i)/Tap(i); % Pkm = Pk - Pm
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 14 Barras -  Pd = 100%')
```

```
Fluxo de potencia linearizado - IEEE 14 Barras -  Pd = 100%
```

```
disp(Teta)
```

```
    0.0000
   -0.0875
   -0.2262
   -0.1849
   -0.1586
   -0.2647
   -0.2455
   -0.2455
   -0.2774
   -0.2826
   -0.2772
   -0.2840
   -0.2869
   -0.3042
```

```
disp(Pkm)
```

```
    1.4788
    0.7112
    0.7005
    0.5523
    0.4090
   -0.2415
   -0.6234
    0.2899
    0.1663
    0.4208
    0.0630
    0.0755
    0.1703
   -0.0000
    0.2899
    0.0620
    0.0992
   -0.0280
    0.0145
    0.0498
```

```
% Analisando para Pd a 80% ============================
Pd1 = Pd*0.8;
Teta1=  B_linha\(-Pd1+Pg);
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  4.588513e-21.
```

```
Pkm1 = zeros(NumLinhas,1);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    Pkm1(i) = (Teta1(K)-Teta1(M))*B(i)/Tap(i); % Pkm = Pk - Pm
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 14 Barras -  Pd = 80%')
```

```
Fluxo de potencia linearizado - IEEE 14 Barras -  Pd = 80%
```

```
disp(Teta1)
```

```
    0.0000
   -0.0660
   -0.1774
   -0.1447
   -0.1240
   -0.2088
   -0.1933
   -0.1933
   -0.2188
   -0.2230
   -0.2188
   -0.2242
   -0.2265
   -0.2403
```

```
disp(Pkm1)
```

```
    1.1160
    0.5560
    0.5626
    0.4464
    0.3334
   -0.1910
   -0.4923
    0.2321
    0.1332
    0.3363
    0.0502
    0.0603
    0.1362
         0
    0.2321
    0.0498
    0.0795
   -0.0222
    0.0115
    0.0397
```

```
% Analisando para Pd a 120% ============================
Pd2 = Pd*1.2;
Teta2=  B_linha\(-Pd2+Pg);
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  4.588513e-21.
```

```
Pkm2 = zeros(NumLinhas,1);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    Pkm2(i) = (Teta2(K)-Teta2(M))*B(i)/Tap(i); % Pkm = Pk - Pm
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 14 Barras -  Pd = 120%')
```

Fluxo de potencia linearizado - IEEE 14 Barras - Pd = 120%

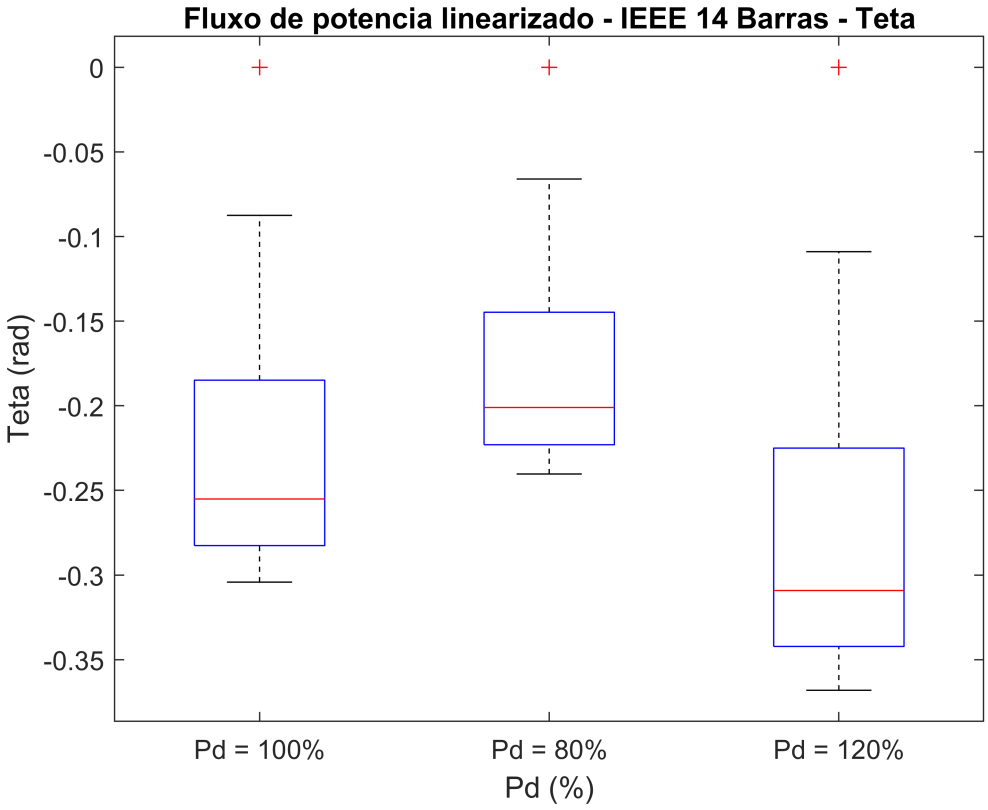
```
disp([Teta2])
```

```
   -0.0000
   -0.1090
   -0.2749
   -0.2250
   -0.1932
   -0.3206
   -0.2977
   -0.2977
   -0.3359
   -0.3422
   -0.3357
   -0.3438
   -0.3472
   -0.3681
```

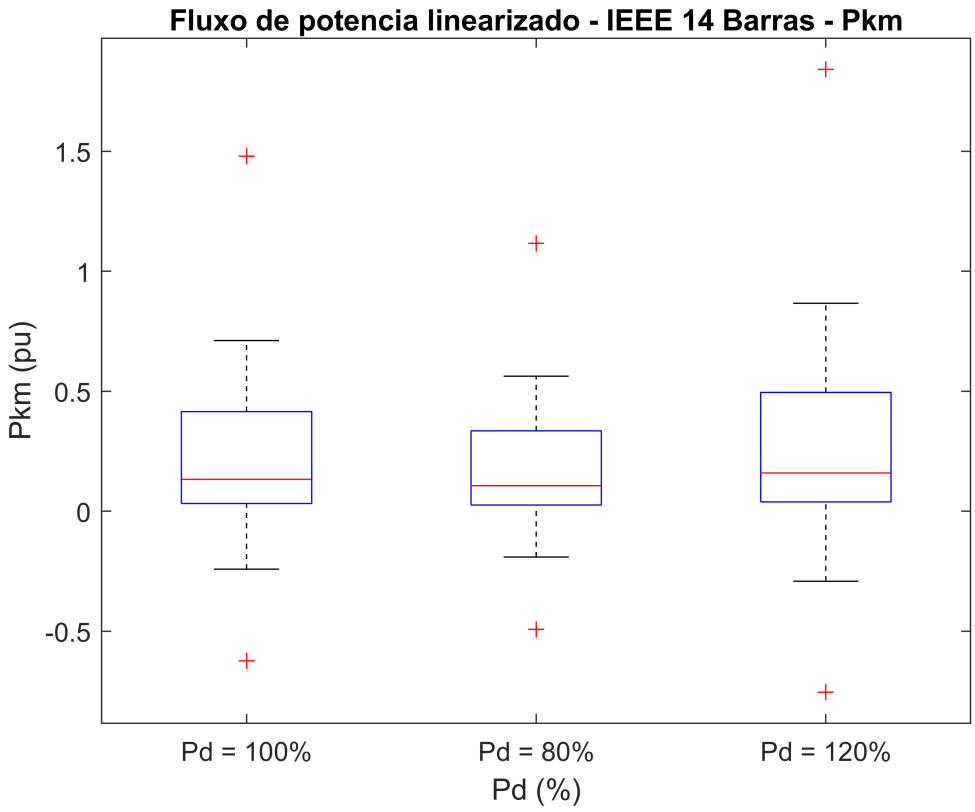
```
disp([Pkm2])
```

```
    1.8416
    0.8664
    0.8384
    0.6581
    0.4847
   -0.2920
   -0.7545
    0.3476
    0.1994
    0.5054
    0.0759
    0.0906
    0.2045
   -0.0000
    0.3476
    0.0741
    0.1189
   -0.0339
    0.0174
    0.0599
```

```
% Box Plot
figure(1)
boxplot([Teta Teta1 Teta2],'Labels',{'Pd = 100%','Pd = 80%','Pd = 120%'})
title('Fluxo de potencia linearizado - IEEE 14 Barras - Teta')
ylabel('Teta (rad)')
xlabel('Pd (%)')
```




```
% Box Plot Pkm
figure(2)
boxplot([Pkm Pkm1 Pkm2],'Labels',{'Pd = 100%','Pd = 80%','Pd = 120%'})
title('Fluxo de potencia linearizado - IEEE 14 Barras - Pkm')
ylabel('Pkm (pu)')
xlabel('Pd (%)')
```



IEEE 33 Barras

```
% Dados:


% [       NUM    TIPO    V        TETA     PG    QG      PD         QD       GSH    BSH ]
barras = [
            1      0     1.0000  0.0000    0      0      100.0      60.0     0.0    0.0;
            2      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
            3      0     1.0000  0.0000    0      0      120.0      80.0     0.0    0.0;
            4      0     1.0000  0.0000    0      0       60.0      30.0     0.0    0.0;
            5      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
            6      0     1.0000  0.0000    0      0      200.0     100.0     0.0    0.0;
            7      0     1.0000  0.0000    0      0      200.0     100.0     0.0    0.0;
            8      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
            9      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
           10      0     1.0000  0.0000    0      0       45.0      30.0     0.0    0.0;
           11      0     1.0000  0.0000    0      0       60.0      35.0     0.0    0.0;
           12      0     1.0000  0.0000    0      0       60.0      35.0     0.0    0.0;
           13      0     1.0000  0.0000    0      0      120.0      80.0     0.0    0.0;
           14      0     1.0000  0.0000    0      0       60.0      10.0     0.0    0.0;
           15      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
           16      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
           17      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
           18      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
```

```
          19      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
          20      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
          21      0     1.0000  0.0000    0      0       90.0      40.0     0.0    0.0;
          22      0     1.0500  0.0000    0      0       90.0      50.0     0.0    0.0;
          23      0     1.0000  0.0000    0      0      420.0     200.0     0.0    0.0;
          24      0     1.0000  0.0000    0      0      420.0     200.0     0.0    0.0;
          25      0     1.0500  0.0000    0      0       60.0      25.0     0.0    0.0;
          26      0     1.0500  0.0000    0      0       60.0      25.0     0.0    0.0;
          27      0     1.0000  0.0000    0      0       60.0      20.0     0.0    0.0;
          28      0     1.0000  0.0000    0      0      120.0      70.0     0.0    0.0;
          29      0     1.0000  0.0000    0      0      200.0     600.0     0.0    0.0;
          30      0     1.0000  0.0000    0      0      150.0      70.0     0.0    0.0;
          31      0     1.0000  0.0000    0      0      210.0     100.0     0.0    0.0;
          32      0     1.0000  0.0000    0      0       60.0      40.0     0.0    0.0;
          33      2     1.0000  0.0000    0      0        0.0       0.0     0.0    0.0
];



%            [FR    TO         R          X      BSHtotal    Tap   Tapmin   Tapmax]
linhas    = [ 33     1      0.0922     0.0470       0        0     0        0;
               1     2      0.4930     0.2511       0        0     0        0;
               2     3      0.3660     0.1864       0        0     0        0;
               3     4      0.3811     0.1941       0        0     0        0;
               4     5      0.8190     0.7070       0        0     0        0;
               5     6      0.1872     0.6188       0        0     0        0;
               6     7      0.7114     0.2351       0        0     0        0;
               7     8      1.0300     0.7400       0        0     0        0;
               8     9      1.0440     0.7400       0        0     0        0;
               9     10     0.1966     0.0650       0        0     0        0;
              10     11     0.3744     0.1238       0        0     0        0;
              11     12     1.4680     1.1550       0        0     0        0;
              12     13     0.5416     0.7129       0        0     0        0;
              13     14     0.5910     0.5260       0        0     0        0;
              14     15     0.7463     0.5450       0        0     0        0;
              15     16     1.2890     1.7210       0        0     0        0;
              16     17     0.7320     0.5740       0        0     0        0;
               1     18     0.1640     0.1565       0        0     0        0;
              18     19     1.5042     1.3554       0        0     0        0;
              19     20     0.4095     0.4784       0        0     0        0;
              20     21     0.7089     0.9373       0        0     0        0;
               2     22     0.4512     0.3083       0        0     0        0;
              22     23     0.8980     0.7091       0        0     0        0;
              23     24     0.8960     0.7011       0        0     0        0;
               5     25     0.2030     0.1034       0        0     0        0;
              25     26     0.2842     0.1447       0        0     0        0;
              26     27     1.0590     0.9337       0        0     0        0;
              27     28     0.8042     0.7006       0        0     0        0;
              28     29     0.5075     0.2585       0        0     0        0;
              29     30     0.9744     0.9630       0        0     0        0;
```

```
             30     31     0.3105     0.3619       0        0     0       0;
             31     32     0.3410     0.5302       0        0     0       0;
            ];

Sb = 1e6;      % Potencia Base
Vb = 12.66e3;  % Tensão Base
Zb = Vb^2/Sb;
linhas(:,3:4) = linhas(:,3:4)/Zb;

barras(:,7:8) = barras(:,7:8)*1e3/Sb;

ref = 1;
% ========================
% Leitura dos dados de entrada

[NumBarras,NumBCol] = size(barras);

[NumLinhas,NumLCol] = size(linhas);

% Linhas
% Init das variaveis
de = zeros(NumLinhas,1);
para = zeros(NumLinhas,1);
R = zeros(NumLinhas,1);
X = zeros(NumLinhas,1);
B = zeros(NumLinhas,1);
Tap = zeros(NumLinhas,1);
TapMin = zeros(NumLinhas,1);
TapMax = zeros(NumLinhas,1);

for i=1:NumLinhas
    de(i) = linhas(i,1);
    para(i) = linhas(i,2);
    R(i) = linhas(i,3);
    X(i) = linhas(i,4);
    B(i) = 1/X(i);
    Tap(i) = linhas(i,6);
    TapMin(i) = linhas(i,7);
    TapMax(i) = linhas(i,8);
end

% Desconsiderando taps
Tap = ones(NumLinhas,1);

% Barras
% Init das variaveis
Tipo = zeros(NumBarras,1);
V = zeros(NumBarras,1);
Teta = zeros(NumBarras,1);
Pg = zeros(NumBarras,1);
```

```
Qg = zeros(NumBarras,1);
Pd = zeros(NumBarras,1);
Qd = zeros(NumBarras,1);
Gsh = zeros(NumBarras,1);
Bsh = zeros(NumBarras,1);

for i=1:NumBarras
    Tipo(i) = barras(i,2);
    V(i) = barras(i,3);
    Teta(i) = barras(i,4);
    Pg(i) = barras(i,5);
    Qg(i) = barras(i,6);
    Pd(i) = barras(i,7);
    Qd(i) = barras(i,8);
    Gsh(i) = barras(i,9);
    Bsh(i) = barras(i,10);
end

% Potencias em PU  - já estão em pu

% ========================
% Matriz B_linha

B_linha = zeros(NumBarras,NumBarras);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    B_linha(K,K) = B_linha(K,K) + B(i)/(Tap(i)^2); % diagonal principal considerando tap
    B_linha(M,M) = B_linha(M,M) + B(i); % diagonal principal
    B_linha(K,M) = B_linha(K,M) - B(i)/Tap(i); % Fora da diagonal principal
    B_linha(M,K) = B_linha(M,K) - B(i)/Tap(i); % Fora da diagonal principal
end

% ========================
% Fluxo de potencia linearizado


B_REF = ref;
B_linha(B_REF,B_REF) = 10^20; % Infinito
Teta=  B_linha\(-Pd+Pg); % inv
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.169055e-20.
```

```

Pkm = zeros(NumLinhas,1);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    Pkm(i) = (Teta(K)-Teta(M))*B(i)/Tap(i); % Pkm = Pk - Pm
```

```
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 100%')
```

```
Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 100%
```

```
disp(Teta)
```

```
   -0.0000
   -0.0051
   -0.0077
   -0.0103
   -0.0193
   -0.0235
   -0.0248
   -0.0279
   -0.0307
   -0.0309
   -0.0313
   -0.0346
   -0.0363
   -0.0372
   -0.0379
   -0.0395
   -0.0398
   -0.0004
   -0.0026
   -0.0032
   -0.0037
   -0.0069
   -0.0106
   -0.0124
   -0.0199
   -0.0207
   -0.0254
   -0.0286
   -0.0296
   -0.0321
   -0.0327
   -0.0329
   -0.0000
```

```
disp(Pkm)
```

```
         0
    3.2550
    2.2350
    2.1150
    2.0550
    1.0750
    0.8750
    0.6750
    0.6150
    0.5550
    0.5100
    0.4500
    0.3900
    0.2700
    0.2100
    0.1500
    0.0900
    0.3600
```

```
    0.2700
    0.1800
    0.0900
    0.9300
    0.8400
    0.4200
    0.9200
    0.8600
    0.8000
    0.7400
    0.6200
    0.4200
    0.2700
    0.0600
```

```
% Analisando para Pd a 90% ============================

Pd1 = Pd*0.9;
Teta1=  B_linha\(-Pd1+Pg);
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.169055e-20.
```

```
Pkm1 = zeros(NumLinhas,1);

for i=1:NumLinhas
    K = de(i);
    M = para(i);
    Pkm1(i) = (Teta1(K)-Teta1(M))*B(i)/Tap(i); % Pkm = Pk - Pm
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 90%')
```

```
Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 90%
```

```
disp(Teta1)
```

```
   -0.0000
   -0.0046
   -0.0069
   -0.0092
   -0.0174
   -0.0211
   -0.0223
   -0.0251
   -0.0276
   -0.0278
   -0.0282
   -0.0311
   -0.0327
   -0.0335
   -0.0341
   -0.0356
   -0.0359
   -0.0003
   -0.0024
   -0.0029
```

```
   -0.0033
   -0.0062
   -0.0095
   -0.0112
   -0.0179
   -0.0186
   -0.0228
   -0.0257
   -0.0266
   -0.0289
   -0.0295
   -0.0296
   -0.0000
```

```
disp(Pkm1)
```

```
    0.0000
    2.9295
    2.0115
    1.9035
    1.8495
    0.9675
    0.7875
    0.6075
    0.5535
    0.4995
    0.4590
    0.4050
    0.3510
    0.2430
    0.1890
    0.1350
    0.0810
    0.3240
    0.2430
    0.1620
    0.0810
    0.8370
    0.7560
    0.3780
    0.8280
    0.7740
    0.7200
    0.6660
    0.5580
    0.3780
    0.2430
    0.0540
```

```
% Analisando para Pd a 110% ============================
Pd2 = Pd*1.1;
Teta2=  B_linha\(-Pd2+Pg);
```

```
Warning: Matrix is close to singular or badly scaled. Results may be inaccurate. RCOND =  2.169055e-20.
```

```
Pkm2 = zeros(NumLinhas,1);

for i=1:NumLinhas
```

```
    K = de(i);
    M = para(i);
    Pkm2(i) = (Teta2(K)-Teta2(M))*B(i)/Tap(i); % Pkm = Pk - Pm
end

% Variaveis de saida
disp('Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 110%')
```

```
Fluxo de potencia linearizado - IEEE 33 Barras -  Pd = 110%
```

```
disp(Teta2)
```

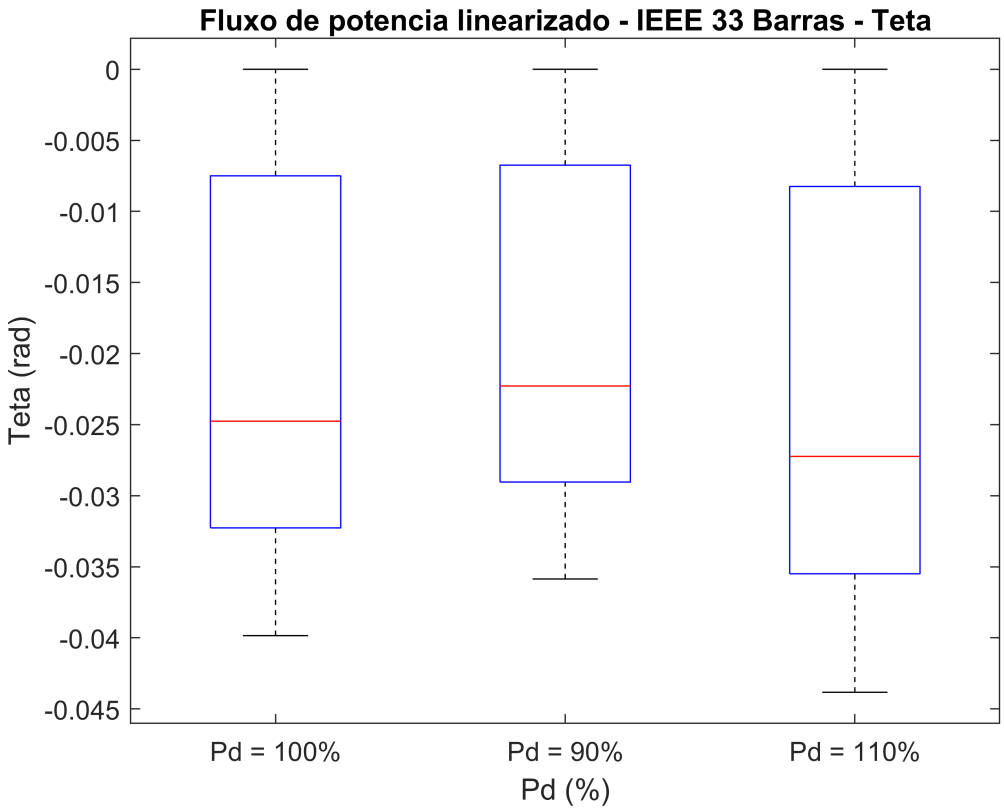
```
   -0.0000
   -0.0056
   -0.0085
   -0.0113
   -0.0213
   -0.0258
   -0.0272
   -0.0307
   -0.0338
   -0.0340
   -0.0345
   -0.0380
   -0.0399
   -0.0409
   -0.0417
   -0.0435
   -0.0438
   -0.0004
   -0.0029
   -0.0035
   -0.0041
   -0.0076
   -0.0117
   -0.0137
   -0.0219
   -0.0228
   -0.0279
   -0.0314
   -0.0325
   -0.0353
   -0.0360
   -0.0362
   -0.0000
```

```
disp(Pkm2)
```

```
         0
    3.5805
    2.4585
    2.3265
    2.2605
    1.1825
    0.9625
    0.7425
    0.6765
    0.6105
    0.5610
    0.4950
    0.4290
    0.2970
```

```
    0.2310
    0.1650
    0.0990
    0.3960
    0.2970
    0.1980
    0.0990
    1.0230
    0.9240
    0.4620
    1.0120
    0.9460
    0.8800
    0.8140
    0.6820
    0.4620
    0.2970
    0.0660
```

```
% Box Plot Teta
figure(3)
boxplot([Teta Teta1 Teta2],'Labels',{'Pd = 100%','Pd = 90%','Pd = 110%'})
title('Fluxo de potencia linearizado - IEEE 33 Barras - Teta')
ylabel('Teta (rad)')
xlabel('Pd (%)')
```




```
% Box Plot Pkm
```

```
figure(4)
boxplot([Pkm Pkm1 Pkm2],'Labels',{'Pd = 100%','Pd = 90%','Pd = 110%'})
title('Fluxo de potencia linearizado - IEEE 33 Barras - Pkm')
ylabel('Pkm (pu)')
xlabel('Pd (%)')
```