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**FACULTY OF ELECTRICAL ENGINEERING**

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**Lab 4 -** **Voltage and reactive power regulation**

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# 1 Project aim

The aim of this project is to determine voltage and reactive power regulation using MATLAB. Different techniques will be used to compensate for the line drop to keep the receiving end voltage constant. Some of the techniques that will be used in this lab are on-load tap-changing transformers and voltage control by injection of reactive power.

# 2. Scheme of analyzed power system for a=61

Diagram, schematic

Description automatically generated

3. input data file

function [bus,line,transf,Sbase]=net61dat

% Input data for load flow in Test Power System

Sbase = 484; % base power, MVA

%Input data should be expressed in per unit

%relative Sbase and Un - nominal voltage at a given bus

bus=[

% Pd(+) - active demand at bus, Pd(-) - active injection at bus

% Qd(+) - reactive demand at bus, Qd(-) -reactive injection at bus

% Pg(+) - active generation at bus, Pg(-) - active load at bus

% Qg(+) - reactive generation at bus, Qg(-) - reactive load at bus

% Psh(+) - active load at bus modeled as constant shunt conductance

% Qsh(-) - reactive load at bus modeled as constant shunt susceptance

% Qsh(+) - capacitive load at bus modeled as constant shunt susceptance

%BusName type Un\_kV Um angle Pd Qd Pg Qg Psh Qsh

% 1 2 3 4 5 6 7 8 9 10 11

2 3 220 1.10 0.00 0.0 0.0 0.0 0.0 0.0 0.0

1 1 220 1.00 0.00 0.0 0.0 0.0 0.0 0.0 0.0

61 5 6 1.05 0.00 0.042 0.02 0.0 0.0 0.0 0.0

62 5 6 1.05 0.00 0.042 0.02 0.0 0.0 0.0 0.0

110 1 110 1.00 0.00 0.21 0.15 0.0 0.0 0.0 0.0

];

line=[

% B means total shunt susceptance positive (+) for line.

% It is used B, and not B/2

% Smax means line thermal rated power

% st means status=1 - switch on, status=0 - switch off

% From bus To bus R X G B Smax st

% 1 2 3 4 5 6 7 8

2 1 0.1 0.2 0.0 0.0 1.2 1

];

transf=[

% B means total shunt susceptance negative (-), it is used B, not B/2

% Smax means transformer thermal rated power

% st means status=1 - switch on, status=0 - switch off

% "From bus" should be high voltage side of transformer

% "To bus" should be low voltage side of transformer

% Only "To bus" can be the bus of type 5, when tap regulation

% tm - transformer ratio relative tn = Uhigh/Ulow

% angle - in gradius

% dt - tap step

% From bus To bus R X G B Smax tm angle tmin tmax dt st

% 1 2 3 4 5 6 7 8 9 10 11 12 13

1 61 0.0242 1.21 0 0 0.25 1 0 0.82 1.18 0.018 1

1 62 0.0242 1.21 0 0 0.25 1 0 0.82 1.18 0.018 1

1 110 0.0086 0.3602 0 0 0.50 1 0 0.80 1.20 0.020 1

];

return;

4. Results

## 4.1. Results for the first strategy without shunt capacitors Qsh=0.0 pu

>> lf

Input data have been read from the file net61dat.m

There is a slack bus with the numerical bus name 2

Iteration process of Netwon-Raphson method

IT= 1, SignDetJ= 1, Unbalance= 0.4826 - bus with Max. Unbal. 110: Um=0.9884, dpmax= -0.21

IT= 2, SignDetJ= 1, Unbalance= 0.02682 - bus with Max. Unbal. 1: Um=1.0280, dpmax= -0.02682

IT= 3, SignDetJ= 1, Unbalance=0.0006176 - bus with Max. Unbal. 1: Um=1.0278, dpmax=-0.000301

IT= 4, SignDetJ= 1, Unbalance=3.569e-07 - bus with Max. Unbal. 1: Um=1.0278, dpmax=-6.947e-08

\*\*\*\*\*\*\* Under-load tap regulation - approach 1 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.001, t=0.982, tmin=0.820, tmax=1.180, tap=12, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.001, t=0.982, tmin=0.820, tmax=1.180, tap=12, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 2 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.021, t=0.964, tmin=0.820, tmax=1.180, tap=13, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.021, t=0.964, tmin=0.820, tmax=1.180, tap=13, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 3 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.041, t=0.964, tmin=0.820, tmax=1.180, tap=13, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.041, t=0.964, tmin=0.820, tmax=1.180, tap=13, dt=0.0180

Bus Voltages and Powers obtained from Load Flow Solution

===========================================================================================

BUS VOLTAGE GENERATION LOAD

Name type Um angle Un\_kV Pg(MW) Qg(MVAR) Pd(MW) Qd(MVAR Psh(MW) Qsh(MVAR)

===========================================================================================

2 3 1.1000 0.0 220.0 148.86 119.33 - - - -

1 1 1.0278 -1.9 220.0 0.00 -0.00 - - - -

61 5 1.0409 -4.5 6.0 0.00 0.00 20.33 9.68 0.00 0.00

62 5 1.0409 -4.5 6.0 0.00 0.00 20.33 9.68 0.00 0.00

110 1 0.9672 -6.2 110.0 0.00 0.00 101.64 72.60 0.00 0.00

----- ----- ----- ----- ----- -----

Total: 148.86 119.33 142.30 91.96 0.00 0.00

Active - P and Reactive - Q Branch Flows

Effective load coefficients: pSF = Sfrom/Smax\*100%, pST = Sto/Smax\*100%

=========================================================================================

FROM To FLOW at begin FLOW at end SMAX Ifrom LOSS

BUS BUS P(MW) Q(MVAR) pSF P(MW) Q(MVAR) pST MVA kA dP(MW)

=========================================================================================

2 1 148.845 119.122 32.8 -142.639 -106.710 30.7 580.80 0.4548 6.2060

1 61 20.351 10.850 19.1 -20.328 -9.680 18.6 121.00 0.0589 0.0234

1 62 20.351 10.850 19.1 -20.328 -9.680 18.6 121.00 0.0589 0.0234

1 110 101.936 85.011 54.8 -101.640 -72.600 51.6 242.00 0.3389 0.2963

------

TOTAL LOSSES 6.5491

## 4.2. Results for case 2 with shunt capacitors Qsh=0.06 for bus 61 and 0.05 pu for bus 62

## 

>> lf

Input data have been read from the file net61dat.m

There is a slack bus with the numerical bus name 2

Iteration process of Netwon-Raphson method

IT= 1, SignDetJ= 1, Unbalance= 0.4826 - bus with Max. Unbal. 110: Um=1.0173, dpmax= -0.21

IT= 2, SignDetJ= 1, Unbalance= 0.03999 - bus with Max. Unbal. 1: Um=1.0546, dpmax= -0.03999

IT= 3, SignDetJ= 1, Unbalance=0.0006253 - bus with Max. Unbal. 1: Um=1.0543, dpmax=-0.0004933

IT= 4, SignDetJ= 1, Unbalance= 3.45e-07 - bus with Max. Unbal. 1: Um=1.0543, dpmax=-1.182e-07

\*\*\*\*\*\*\* Under-load tap regulation - approach 1 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.111, t=1.036, tmin=0.820, tmax=1.180, tap= 9, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.097, t=1.018, tmin=0.820, tmax=1.180, tap=10, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 2 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.069, t=1.054, tmin=0.820, tmax=1.180, tap= 8, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.075, t=1.036, tmin=0.820, tmax=1.180, tap= 9, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 3 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.049, t=1.054, tmin=0.820, tmax=1.180, tap= 8, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.054, t=1.036, tmin=0.820, tmax=1.180, tap= 9, dt=0.0180

Bus Voltages and Powers obtained from Load Flow Solution

===========================================================================================

BUS VOLTAGE GENERATION LOAD

Name type Um angle Un\_kV Pg(MW) Qg(MVAR) Pd(MW) Qd(MVAR Psh(MW) Qsh(MVAR)

===========================================================================================

2 3 1.1000 0.0 220.0 146.77 50.82 - - - -

1 1 1.0519 -2.4 220.0 0.00 -0.00 - - - -

61 5 1.0489 -5.3 6.0 0.00 0.00 20.33 9.68 0.00 31.95

62 5 1.0540 -5.2 6.0 0.00 0.00 20.33 9.68 0.00 26.89

110 1 0.9930 -6.5 110.0 0.00 0.00 101.64 72.60 0.00 0.00

----- ----- ----- ----- ----- -----

Total: 146.77 50.82 142.30 91.96 0.00 58.84

Active - P and Reactive - Q Branch Flows

Effective load coefficients: pSF = Sfrom/Smax\*100%, pST = Sto/Smax\*100%

=========================================================================================

FROM To FLOW at begin FLOW at end SMAX Ifrom LOSS

BUS BUS P(MW) Q(MVAR) pSF P(MW) Q(MVAR) pST MVA kA dP(MW)

=========================================================================================

2 1 146.890 57.040 27.1 -142.650 -48.561 25.9 580.80 0.3759 4.2399

1 61 20.369 -20.204 23.7 -20.328 22.270 24.9 121.00 0.0716 0.0413

1 62 20.360 -15.610 21.2 -20.328 17.206 22.0 121.00 0.0640 0.0319

1 110 101.921 84.374 54.7 -101.640 -72.600 51.6 242.00 0.3301 0.2811

------

TOTAL LOSSES 4.5942

## 

## 4.3. Results for third case with shunt capacitors Qsh=0.09 and 0.08 pu for bus 61 and 62 respectively

>> lf

Input data have been read from the file net61dat.m

There is a slack bus with the numerical bus name 2

Iteration process of Netwon-Raphson method

IT= 1, SignDetJ= 1, Unbalance= 0.4826 - bus with Max. Unbal. 110: Um=1.0387, dpmax= -0.21

IT= 2, SignDetJ= 1, Unbalance= 0.05032 - bus with Max. Unbal. 1: Um=1.0714, dpmax= -0.05032

IT= 3, SignDetJ= 1, Unbalance=0.0008046 - bus with Max. Unbal. 1: Um=1.0710, dpmax=-0.0008046

IT= 4, SignDetJ= 1, Unbalance= 5.51e-07 - bus with Max. Unbal. 1: Um=1.0710, dpmax=-3.07e-07

\*\*\*\*\*\*\* Under-load tap regulation - approach 1 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.177, t=1.072, tmin=0.820, tmax=1.180, tap= 7, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.161, t=1.054, tmin=0.820, tmax=1.180, tap= 8, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 2 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.088, t=1.090, tmin=0.820, tmax=1.180, tap= 6, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.093, t=1.072, tmin=0.820, tmax=1.180, tap= 7, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 3 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.068, t=1.108, tmin=0.820, tmax=1.180, tap= 5, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.072, t=1.090, tmin=0.820, tmax=1.180, tap= 6, dt=0.0180

\*\*\*\*\*\*\* Under-load tap regulation - approach 4 \*\*\*\*\*\*\*\*\*

From 1 To 61: Ureg=1.050, Uact=1.048, t=1.108, tmin=0.820, tmax=1.180, tap= 5, dt=0.0180

From 1 To 62: Ureg=1.050, Uact=1.052, t=1.090, tmin=0.820, tmax=1.180, tap= 6, dt=0.0180

Bus Voltages and Powers obtained from Load Flow Solution

===========================================================================================

BUS VOLTAGE GENERATION LOAD

Name type Um angle Un\_kV Pg(MW) Qg(MVAR) Pd(MW) Qd(MVAR Psh(MW) Qsh(MVAR)

===========================================================================================

2 3 1.1000 0.0 220.0 146.43 7.63 - - - -

1 1 1.0631 -2.7 220.0 0.00 0.00 - - - -

61 5 1.0483 -5.7 6.0 0.00 0.00 20.33 9.68 0.00 47.87

62 5 1.0519 -5.6 6.0 0.00 0.00 20.33 9.68 0.00 42.84

110 1 1.0050 -6.7 110.0 0.00 0.00 101.64 72.60 0.00 0.00

----- ----- ----- ----- ----- -----

Total: 146.43 7.63 142.30 91.96 0.00 90.71

Active - P and Reactive - Q Branch Flows

Effective load coefficients: pSF = Sfrom/Smax\*100%, pST = Sto/Smax\*100%

=========================================================================================

FROM To FLOW at begin FLOW at end SMAX Ifrom LOSS

BUS BUS P(MW) Q(MVAR) pSF P(MW) Q(MVAR) pST MVA kA dP(MW)

=========================================================================================

2 1 146.524 28.020 25.7 -142.724 -20.420 24.8 580.80 0.3559 3.8000

1 61 20.413 -33.930 32.7 -20.328 38.187 35.8 121.00 0.0977 0.0852

1 62 20.396 -29.746 29.8 -20.328 33.165 32.1 121.00 0.0890 0.0684

1 110 101.914 84.096 54.6 -101.640 -72.600 51.6 242.00 0.3262 0.2745

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TOTAL LOSSES 4.2280

5. Conclusion

* Reactive power can cause voltage to rise or to fall depending on which elements are being  
  used for **reactive power compensation**. So, to maintain voltage stability, decreasing the  
  reactive power causes the voltage to fall and increasing it causes the voltage to rise. Inductive  
  elements are used to absorb reactive power when there is an over-voltage and capacitive  
  elements are used to increase reactive power when there is an under-voltage.
* As can be seen in the results all the voltages are inside the deviation limit of  
  +/- 10% of the nominal voltage. More especially, in the third case with shunt capacitance (Qsh=  
  0.09 and 0.08 pu) has the closest value to the nominal voltage and this also has small active  
  power loss than the other strategies. The actual tap of the transformer decreases as the shunt  
  capacitor value included to the system increases until the permissible value. The actual tap of T1 and T2 is 13 for the case with no shunt capacitor. And then for the second case where the sunt capacitor values are 0.05 and 0.06 tap T1 and T2 become 8 and 9 respectively. And finally for the third case where the shunt capacitor values are 0.08 and 0.09 the tap values of T! and T2 become 5 and 6 respectively.
* As the shunt capacitor value increases the power loss also decreases.