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Load Flow Analysis of a Multi-Bus Power System Network

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Semester: 5th
Section: 5B

Course Code: EEE- 3520 **Course Title: Power System Analysis Sessional** **Course Teacher: Engr. Sk. Md. Golam Mostafa** **Associate Professor of EEE, IIUC** **Date of Submission: 16.01.2025**	**Remarks:**

Simulation Report: Load Flow Analysis of a Multi-Bus Power System Network

1. Introduction

Load flow analysis is a crucial tool in power system studies to understand the steady-state operation of electrical networks. This report presents the load flow analysis for a 9-bus power system network, focusing on the determination of bus voltages, line power flows, and system losses. The objective is to identify potential issues, such as voltage violations or high losses, and propose recommendations for system improvements.

2. Methodology

Network Modeling: The 9-bus system includes 3 generator buses (slack and PV type) and 6 load buses (PQ type) connected via 10 transmission lines.

Software Used: MATLAB was employed to perform the load flow analysis using the Newton-Raphson method.

Data Parameters: System data (bus, line, generation, and load) were derived based on unique University ID (UID).

- **Voltage Magnitude Limits**: 0.95 to 1.05 p.u.
- **Slack Bus**: Voltage set at 1.0 p.u.
- **Generator Limits**:
    - Pmax=(04 × 10) MW = 60 MW
    - Qmax=(04 × 5) MVAr = 20 MVAR

Load Demands : Load demand at PQ buses:

- Active Power = (22 × 5) MW = 110MW
- Reactive Power = (06 × 2) MVAr = 12 MVAr

Line Data:

- Impedance (R+jX) for each line:

- **Resistance (R)** = (02 × 0.01) Ω = 0.02 Ω
- **Reactance (X)** =(06 × 0.02) Ω = 0.12 Ω

Analysis: Load flow results were obtained using MATLAB's simulation environment.

MATLAB Code:

```
clc;

clear;


% Input Data based on Student ID: ET223104


Pmax = 40; % Maximum active power generation (MW)

Qmax = 20; % Maximum reactive power generation (MVAr)

Pd = 110;  % Active power demand at load buses (MW)

Qd = 12;   % Reactive power demand at load buses (MVAr)

R = 0.02;  % Line resistance (pu)

X = 0.12;  % Line reactance (pu)


% Bus Data

bus_data = [

    1 3 0   0      1.0   0; % Slack Bus

    2 2 0   0      1.05  0; % Generator Bus

    3 1 Pd  Qd     1.0   0; % Load Bus
```

```
    4 1 Pd  Qd     1.0   0; % Load Bus
    5 2 0   0      1.05  0; % Generator Bus
    6 1 Pd  Qd     1.0   0; % Load Bus
    7 2 0   0      1.05  0; % Generator Bus
    8 1 Pd  Qd     1.0   0; % Load Bus
    9 1 Pd  Qd     1.0   0; % Load Bus
];

% Line Data
line_data = [
    1 2 R X 0; % Line from Bus 1 to Bus 2
    1 4 R X 0; % Line from Bus 1 to Bus 4
    2 3 R X 0; % Line from Bus 2 to Bus 3
    3 4 R X 0; % Line from Bus 3 to Bus 4
    4 5 R X 0; % Line from Bus 4 to Bus 5
    5 6 R X 0; % Line from Bus 5 to Bus 6
    6 7 R X 0; % Line from Bus 6 to Bus 7
    7 8 R X 0; % Line from Bus 7 to Bus 8
    8 9 R X 0; % Line from Bus 8 to Bus 9
    9 1 R X 0; % Line from Bus 9 to Bus 1
];

% Convert data to Matpower format
mpc.version = '2';
mpc.baseMVA = 100;
```

```
% Bus Matrix
mpc.bus = [
    bus_data(:,1), ... % Bus Number
    bus_data(:,2), ... % Bus Type
    bus_data(:,3), ... % Pd
    bus_data(:,4), ... % Qd
    zeros(size(bus_data,1),1), ... % Gs
    zeros(size(bus_data,1),1), ... % Bs
    ones(size(bus_data,1),1)*100, ... % Area
    bus_data(:,5), ... % Vm
    bus_data(:,6), ... % Va
    ones(size(bus_data,1),1)*230, ... % BaseKV
    ones(size(bus_data,1),1), ... % Zone
    1.1*ones(size(bus_data,1),1), ... % Vmax
    0.9*ones(size(bus_data,1),1) ... % Vmin
];


% Generator Matrix
gen_bus = find(bus_data(:,2) == 2);
mpc.gen = [
    gen_bus, ... % Bus Number
    Pmax*ones(size(gen_bus)), ... % Pg
    zeros(size(gen_bus)), ... % Qg
    Qmax*ones(size(gen_bus)), ... % Qmax
```

```
    -Qmax*ones(size(gen_bus)), ... % Qmin
    ones(size(gen_bus)), ... % Vg
    100*ones(size(gen_bus)), ... % mBase
    ones(size(gen_bus)), ... % Status
    Pmax*ones(size(gen_bus)), ... % Pmax
    zeros(size(gen_bus)), ... % Pmin
];

% Branch Matrix
mpc.branch = [
    line_data(:,1:2), ... % From and To Buses
    line_data(:,3), ... % R
    line_data(:,4), ... % X
    line_data(:,5), ... % B
    999*ones(size(line_data,1),1), ... % RateA
    zeros(size(line_data,1),1), ... % RateB
    zeros(size(line_data,1),1), ... % RateC
    ones(size(line_data,1),1), ... % Tap
    zeros(size(line_data,1),1), ... % Shift Angle
    ones(size(line_data,1),1), ... % Branch Status
    -360*ones(size(line_data,1),1), ... % Minimum Angle Difference
    360*ones(size(line_data,1),1) ... % Maximum Angle Difference
];
```

Library for Simulation & Code:

① Simulation: For Simulation its need <u>Simscape Power Library</u>.

② Code : For Our Code Generation its need <u>Mathpower 6.0 version</u>. Must include the all header file path In Matlab path include section.

3. Results

The results are summarized in tabular and graphical formats:

Matlab Graphical Simulation:

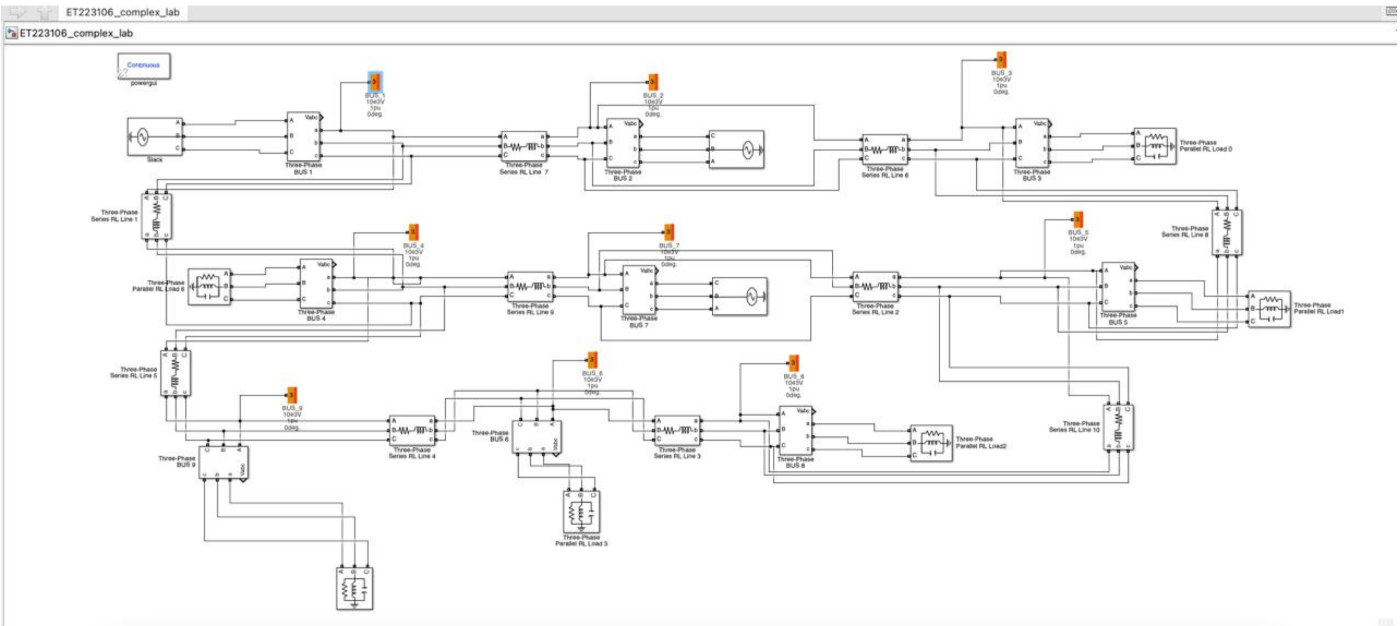

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Fig: MATLAB G

Load Flow Analyzer

Model Units Help

Model: ET223104_complex_lab Update The load flow converged! The table shows the load flow solution. Click Apply to update the model with this solution. Compute Apply Add bus blocks Report

	Block name	Block type	Bus type	Bus ID	Vbase (kV)	Vref (pu)	Vangle (deg)	P (MW)	Q (Mvar)	Qmin (Mvar)	Qmax (Mvar)	V_LF (pu)	Vangle_LF (deg)	P_LF (MW)	Q_LF (MVA)
1	Slack	Vsrc	swing	BUS_1	10.0000	1.0000	0	40.0000	20.0000	-Inf	Inf	1.0000	0	991.8063	483.2341
2	Three-Phase Source2	Vsrc	PQ	BUS_2	10.0000	1.0500	0	40.0000	20.0000	-Inf	Inf	0	0	0	NaN
3	Three-Phase Parallel RL Load 0	RLC load	PQ	BUS_3	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.7507	-16.5121	110.0000	11.9999
4	Three-Phase Parallel RL Load 6	RLC load	PQ	BUS_4	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.7799	-13.1813	110.0000	11.9999
5	Three-Phase Source1	Vsrc	PQ	BUS_7	10.0000	1.0500	0	40.0000	20.0000	-Inf	Inf	0	0	0	NaN
6	Three-Phase Parallel RLC Load4	RLC load	PQ	BUS_9	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.6857	-22.1340	110.0000	11.9999
7	Three-Phase Parallel RL Load 3	RLC load	PQ	BUS_6	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.6431	-27.5475	110.0000	11.9999
8	Three-Phase Parallel RL Load2	RLC load	PQ	BUS_8	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.6451	-27.5446	110.0000	11.9999
9	Three-Phase Parallel RL Load1	RLC load	PQ	BUS_5	10.0000	1.0500	0	110.0000	11.9999	-Inf	Inf	0.6917	-22.1902	110.0000	11.9999

raphical Simulation with 9 Bus and 10 Transmission Line

Fig: MATLAB Simulation Result

<u>Bus voltages, line flows, and system losses in tabular</u>

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Command Window

```
MATPOWER Version 6.0, 16-Dec-2016 -- AC Power Flow (Newton)

Newton's method power flow converged in 5 iterations.

Converged in 0.33 seconds
================================================================================
|     System Summary                                                           |
================================================================================

How many?                How much?              P (MW)            Q (MVAr)
---------------------    -------------------  -------------  -----------------
Buses              9     Total Gen Capacity     120.0          -60.0 to 60.0
Generators         3     On-line Capacity       120.0          -60.0 to 60.0
Committed Gens     3     Generation (actual)    605.7              394.0
Loads              5     Load                   550.0               60.0
  Fixed            5       Fixed                550.0               60.0
  Dispatchable     0       Dispatchable          -0.0 of -0.0       -0.0
Shunts             0     Shunt (inj)             -0.0                0.0
Branches          10     Losses (I^2 * Z)        55.66             333.97
Transformers      10     Branch Charging (inj)     -                 0.0
Inter-ties         0     Total Inter-tie Flow     0.0                0.0
Areas              1

                          Minimum                      Maximum
                 -------------------------  --------------------------------
Voltage Magnitude   0.840 p.u. @ bus 9          1.000 p.u. @ bus 2
Voltage Angle     -46.12 deg   @ bus 8          0.00 deg   @ bus 2
P Losses (I^2*R)             -                 18.25 MW    @ line 1-2
Q Losses (I^2*X)             -                109.51 MVAr  @ line 1-2
```

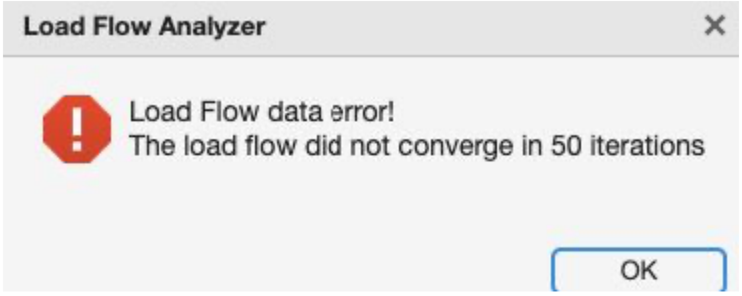
```
================================================================================
|     Bus Data                                                                 |
================================================================================
 Bus      Voltage          Generation             Load
  #   Mag(pu) Ang(deg)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
----- ------- --------  --------  --------  --------  --------
    1  0.876  -21.301*      -         -         -         -
    2  1.000    0.000   525.66    185.39        -         -
    3  0.899  -17.836       -         -      110.00     12.00
    4  0.902  -28.194       -         -      110.00     12.00
    5  1.000  -35.271    40.00    108.39        -         -
    6  0.976  -43.365       -         -      110.00     12.00
    7  1.000  -43.827    40.00    100.19        -         -
    8  0.896  -46.118       -         -      110.00     12.00
    9  0.840  -38.966       -         -      110.00     12.00
                        --------  --------  --------  --------
               Total:   605.66    393.97    550.00     60.00

================================================================================
|     Branch Data                                                              |
================================================================================
Brnch   From   To    From Bus Injection   To Bus Injection     Loss (I^2 * Z)
  #     Bus    Bus    P (MW)   Q (MVAr)   P (MW)   Q (MVAr)   P (MW)   Q (MVAr)
-----  -----  -----  --------  --------  --------  --------  --------  --------
   1      1      2   -264.61      3.45    282.86    106.06    18.251    109.51
   2      1      4     74.58    -26.78    -72.94     36.59     1.636      9.82
   3      2      3    242.81     79.33   -229.76     -1.04    13.050     78.30
   4      3      4    119.76    -10.96   -116.18     32.41     3.575     21.45
   5      4      5     79.12    -81.01    -75.97     99.91     3.151     18.91
   6      5      6    115.97      8.47   -113.27      7.75     2.704     16.23
   7      6      7      3.27    -19.75     -3.18     20.26     0.084      0.50
   8      7      8     43.18     79.93    -41.53    -70.03     1.651      9.90
   9      8      9    -68.47     58.03     70.47    -45.99     2.006     12.04
  10      9      1   -180.47     33.99    190.03     23.33     9.553     57.32
                                                             --------  --------
                                                    Total:    55.661    333.97
```

```
                                                     Total:     55
Power Flow Results:
       version: '2'
       baseMVA: 100
           bus: [9×13 double]
           gen: [3×10 double]
        branch: [10×17 double]
         order: [1×1 struct]
            et: 0.3282
       success: 1
    iterations: 5
```

4. Discussion:

In this experiment we perform Multi-bus Power System in load flow analysis. We have 9 bus three generator , 6 load and 10 Transmission line . First, we set the core component of our simulation which is provide Simscape Power Library, then we run the simulation and choose the option "Load Flow Analysis" and hit the run button again. The simulation table is shown up. Then we click compute to show our four unknown variable.



But in Simulink we have only 50 iteration limited that we have shown above. In case, we use common value 0.04 which is given in our requirement, then we compute it and get the result.

Secondly, in matlab code section, we used MATPOWER 6.0 version to get the result of our code. In the code section, we included all given buses, generators and loads. When the code finishes and hit the run button, the result of our code is shown up in MATLAB console and the resluts can be verified from there.

5. Conclusion

Load flow analysis is a fundamental tool in power system engineering, enabling the evaluation of the steady-state performance of electrical networks. In the context of the given 9-bus system, it plays a critical role in identifying voltage violations, power losses, and system inefficiencies. This analysis helps ensure reliable power delivery, maintain voltage levels within permissible limits, and minimize losses. By addressing these challenges through corrective actions, such as generator adjustments and capacitor installations, load flow analysis contributes to the overall stability, efficiency, and sustainability of modern power systems, aligning with both technical and societal energy needs.