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Matlab Applications for Power Flow Analysis

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ABSTRACT
In this paper a brief review has been done on MATLAB Applications for power flow analysis with realistic loads . The classical algorithms for power flow Gauss Seidel and Newton Raphson method has been implemented under MATLAB codes, Simpower, simulink ,and fuzzy logic environment. Simscape™ Electrical™ can perform a power-flow, or load-flow, analysis for an AC, DC, or mixed AC and DC electrical power transmission system modeled using the Simscape three-phase electrical domain. A load-flow analysis allows to determine the voltage magnitudes, voltage phase angles, active power, and reactive power of the electrical system in steady-state operation. For a given steady-state operating point, the load-flow data reveals the:Voltage magnitude and voltage phase angle at each bus,Active and reactive power generation for each generator that supplies the grid,Active and reactive power that flows to each load that places demand on the grid , the data is used to determine ideal operating conditions or estimate the response of your system to hypothetical situations.
Key words - Matab , Simpower , Simulink , Fuzzy logic.

I. Introduction

The Power Flow Analysis Toolbox like, Fuzzy logic controller, Simpower ,Simulink ,Power flow analyser has been implemented with MATLAB programming codes and functions in stages to research power flow analysis which is useful for the practicing scientists and engineers. All the routines in the toolbox are to facilitate in solving power flow problems, but its most biggest feature is to visualize computations insteps. Because they are remarkably concise and lucid to be applied and then to be revised forward user's decisions. These are also useful in advanced algorithms such as genetic algorithm, particle swarm optimization algorithm and so forth to solve economical dispatch and optimal power flow in large-scale power system.

II - MATLAB Applications for Power flow analysis

a. Modeling
b. Simulation
c. Data analysis
d. Visualization.

III -Methodology and Steps for modeling & simulation under Simulink environment

1: Input Raw Data.
Input the electrical grid data, with containing bus data, transmission line data and transformer data. To make the computation more signifificant.
2: Execute Algorithms.
The power flow algorithms are normally including Gauss-Seidel algorithm, Newton-Raphson algorithm, P-Q Decoupling algorithm and so forth .
3: Output Solution.
After the power flow evaluation, we can get the results, that is to say, the final voltage magnitude and phase angle at each bus under balanced three-phase steady state conditions. Additionally, as a

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by-product of this solution, real and reactive power flows in equipments such as transmission lines and transformers, as well as equipment losses, can also be computed using simpower GUI and load flow analyzer .

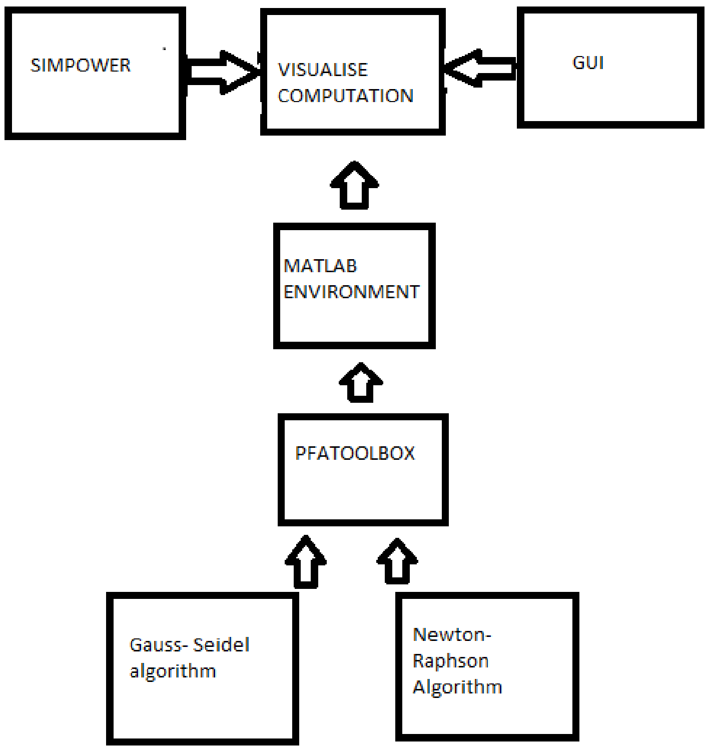

Fig 1- flow chart for power flow computation

IV- DATA ANALYSIS

Load flow analyzer report
The Load Flow converged in 5 iterations !
SUMMARY for subnetwork No 1

Total generation : P= 219.83 MW Q= 210.58 Mvar
Total PQ load : P= 210.00 MW Q= 210.00 Mvar
Total Zshunt load : P= -0.00 MW Q= -28.87 Mvar
Total ASM load : P= 0.00 MW Q= 0.00 Mvar
Total losses : P= 9.83 MW Q= 29.45 Mvar

1 : BUS_1 V= 1.050 pu/10kV 0.00 deg ; Swing bus
Generation : P= 109.83 MW Q= 18.86 Mvar

PQ_load : P= 0.00 MW Q= 0.00 Mvar
Z_shunt : P= -0.00 MW Q= -4.41 Mvar

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--> BUS_2 : P= 34.50 MW Q= -15.38 Mvar
--> BUS_4 : P= 35.28 MW Q= 18.07 Mvar
--> BUS_5 : P= 40.05 MW Q= 20.58 Mvar

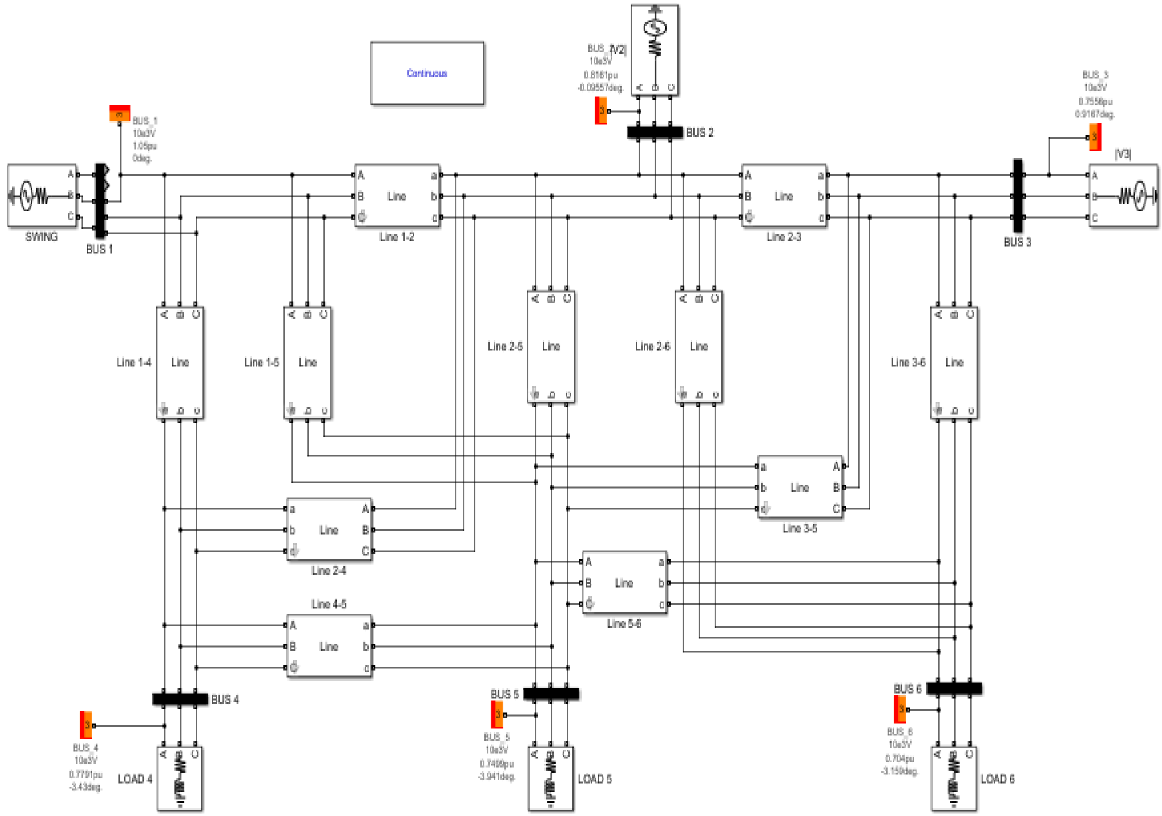

Fig 2- IEEE 6 BUS SIMULINK MODEL

2 : BUS_2 V= 1.050 pu/10kV -4.39 deg ; Qmax limit reached on PV voltage source (100.00 Mvar)
Generation : P= 50.00 MW Q= 100.00 Mvar

PQ_load : P= 0.00 MW Q= 0.00 Mvar
Z_shunt : P= 0.00 MW Q= -6.33 Mvar
--> BUS_1 : P= -33.21 MW Q= 17.97 Mvar
--> BUS_3 : P= -0.14 MW Q= -10.71 Mvar
--> BUS_4 : P= 41.54 MW Q= 57.11 Mvar
--> BUS_5 : P= 16.66 MW Q= 23.86 Mvar
--> BUS_6 : P= 25.16 MW Q= 18.10 Mvar

3 : BUS_3 V= 1.070 pu/10kV -4.65 deg
Generation : P= 60.00 MW Q= 91.72 Mvar

PQ_load : P= 0.00 MW Q= 0.00 Mvar
Z_shunt : P= -0.00 MW Q= -4.36 Mvar
--> BUS_2 : P= 0.20 MW Q= 10.92 Mvar
--> BUS_5 : P= 12.81 MW Q= 17.96 Mvar
--> BUS_6 : P= 47.00 MW Q= 67.21 Mvar

4 : BUS_4 V= 0.975 pu/10kV -5.12 deg
Generation : P= 0.00 MW Q= 0.00 Mvar

PQ_load : P= 70.00 MW Q= 70.00 Mvar
Z_shunt : P= -0.00 MW Q= -4.28 Mvar
--> BUS_1 : P= -34.14 MW Q= -13.80 Mvar
--> BUS_2 : P= -39.28 MW Q= -52.59 Mvar
--> BUS_5 : P= 3.41 MW Q= 0.66 Mvar

5 : BUS_5 V= 0.966 pu/10kV -5.87 deg
Generation : P= 0.00 MW Q= 0.00 Mvar

PQ_load : P= 70.00 MW Q= 70.00 Mvar
Z_shunt : P= 0.00 MW Q= -6.24 Mvar
--> BUS_1 : P= -38.57 MW Q= -15.06 Mvar
--> BUS_2 : P= -15.89 MW Q= -21.56 Mvar
--> BUS_3 : P= -11.90 MW Q= -15.96 Mvar
--> BUS_4 : P= -3.39 MW Q= -0.61 Mvar
--> BUS_6 : P= -0.26 MW Q= -10.57 Mvar

6 : BUS_6 V= 0.999 pu/10kV -6.45 deg
Generation : P= 0.00 MW Q= 0.00 Mvar

PQ_load : P= 70.00 MW Q= 70.00 Mvar
Z_shunt : P= -0.00 MW Q= -3.24 Mvar
--> BUS_2 : P= -24.55 MW Q= -16.35 Mvar
--> BUS_3 : P= -45.83 MW Q= -61.33 Mvar
--> BUS_5 : P= 0.38 MW Q= 10.93 Mvar

V -GAUSS-SEIDEL AND NEWTON RAPHSON ALGORITHM

```
basemva = 100; accuracy = 0.001; maxite= 50;
% IEEE 6-BUS TEST SYSTEM (American Electric Power)
% Bus  Bus    Voltage   Angle---Load---- Generator---- Injected
% No  code  Mag.    Degree  MW Mvar  MW Mvar  Qmin Qmax  Mvar
busdata=
[1 1      1.06 0.0 0.0 0.0 0.0 0.0 0 0 0
  2 2      1.043 0.0 21.70 12.7 40.0 0.0 -40 50 0
  3 0      1.0 0.0 2.4 1.2 0.0 0.0 0 0 0
  4 0      1.06 0.0 7.6 1.6 0.0 0.0 0 0 0
  5 2      1.01 0.0 94.2 19.0 0.0 0.0 -40 40 0
  6 0      1.0 0.0 0.0 0.0 0.0 0.0 0 0 0 ];

%                                                   Line code
% Bus bus          R            X        1/2 B          =1 for lines
% nl     nr          p.u         p.u.       p.u.       >1 or < 1 tr. tap at bus nl
linedata=
```

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```
[1  2    0.0192 0.0575 0.02640 1
  1  3    0.0452 0.1852 0.02040 1
  2  4    0.0570 0.1737 0.01840 1
  3  4    0.0132 0.0379 0.00420 1
  2  5    0.0472 0.1983 0.02090 1
  2  6    0.0581 0.1763 0.01870 1
  4  6    0.0119 0.0414 0.00450 1];
```

```
lfybus % form the bus admittance matrix
lfgauss or lfnewton % Load flow solution by gauss seidel method or newton raphson method
busout % Prints the power flow solution on the screen
lineflow % computes and displays the line flow and losses
```

VI-Power Flow Solution by Newton-Raphson Method

Maximum Power Mismatch = 3.42751e-07

No. of Iterations = 4

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.060	0.000	0.000	0.000	91.221	3.244	0.000
2	1.043	-2.135	21.700	12.700	40.000	-3.987	0.000
3	1.052	-1.601	2.400	1.200	0.000	0.000	0.000
4	1.050	-1.873	7.600	1.600	0.000	0.000	0.000
5	1.010	-12.732	94.200	19.000	0.000	31.542	0.000
6	1.049	-1.938	0.000	0.000	0.000	0.000	0.000
Total			125.900	34.500	131.221	30.799	0.000

Line Flow and Losses

Line from	Line to	Power at bus & line flow MW	Mvar	MVA	Line loss MW	Line loss Mvar	Transformer tap
1		91.221	3.244	91.278			
	2	74.250	4.914	74.412	0.953	-2.985	
	3	16.971	-1.670	17.053	0.116	-4.075	
2		18.300	-16.687	24.766			
	1	-73.297	-7.899	73.721	0.953	-2.985	
	4	-3.782	-4.767	6.085	0.012	-3.994	
	5	98.405	0.721	98.408	4.205	13.263	
	6	-3.027	-4.741	5.625	0.009	-4.066	
3		-2.400	-1.200	2.683			
	1	-16.855	-2.405	17.026	0.116	-4.075	
	4	14.455	1.205	14.505	0.025	-0.855	

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```
4        -7.600   -1.600    7.767
     2    3.793    0.773    3.871    0.012   -3.994
     3  -14.430   -2.060   14.576    0.025   -0.855
     6    3.036   -0.313    3.053    0.001   -0.988

5       -94.200   12.542   95.031
     2  -94.200   12.542   95.031    4.205   13.263

6         0.000    0.000    0.000
     2    3.035    0.675    3.110    0.009   -4.066
     4   -3.035   -0.675    3.110    0.001   -0.988
```

Total loss 5.321 -3.701

VII- Power Flow Solution by Gauss-Seidel Method

Maximum Power Mismatch = 0.000694865

No. of Iterations = 17

Bus No.	Voltage Mag.	Angle Degree	Load MW	Load Mvar	Generation MW	Generation Mvar	Injected Mvar
1	1.060	0.000	0.000	0.000	91.147	3.265	0.000
2	1.043	-2.134	21.700	12.700	40.000	-3.996	0.000
3	1.052	-1.599	2.400	1.200	0.000	0.000	0.000
4	1.050	-1.872	7.600	1.600	0.000	0.000	0.000
5	1.010	-12.731	94.200	19.000	0.000	31.540	0.000
6	1.049	-1.936	0.000	0.000	0.000	0.000	0.000
Total			125.900	34.500	131.147	30.809	0.00

VIII- Line Flow and Losses

```
  --Line--  Power at bus & line flow    --Line loss--  Transformer
  from  to    MW      Mvar     MVA       MW      Mvar      tap
==============================================================
1           91.147    3.265   91.206
     2     74.221    4.923   74.384    0.952   -2.987
     3     16.952   -1.665   17.034    0.116   -4.076

2          18.300  -16.696   24.772
     1    -73.269   -7.910   73.695    0.952   -2.987
     4     -3.789   -4.764    6.087    0.012   -3.994
     5     98.406    0.721   98.409    4.206   13.263
     6     -3.031   -4.739    5.626    0.009   -4.066

3          -2.400   -1.200    2.683
     1    -16.836   -2.411   17.008    0.116   -4.076
     4     14.465    1.200   14.515    0.025   -0.855
```

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4		-7.600	-1.600	7.767		
	2	3.801	0.770	3.878	0.012	-3.994
	3	-14.440	-2.055	14.585	0.025	-0.855
	6	3.050	-0.318	3.066	0.001	-0.988
5		-94.200	12.540	95.031		
	2	-94.200	12.542	95.032	4.206	13.263
6		0.000	0.000	0.000		
	2	3.040	0.673	3.113	0.009	-4.066
	4	-3.049	-0.670	3.122	0.001	-0.988
Total loss					**5.320**	**-3.703**

IX- FUZZY APPROACH TO POWER FLOW

All values of Pk and Qk are fuzzy numbers in the proposed algorithm and their intervals/fuzzy values for example are calculated by using their respective membership functions. A typical membership function has been shown in Fig.3. The deviation in values for example has been fixed for all membership functions with +- 0.2 p.u. only. Also an appropriate value of α may be selected (example 0.9 ,0.8).

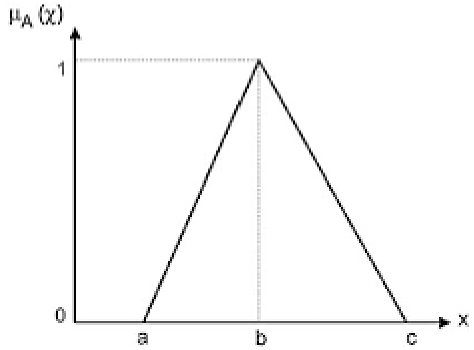

Figure 3. Triangular membership function

Using the fuzzy rules of after each iteration,depending on the error obtained a new value of acceleration factor α is calculated. This value of α is used for the next iteration. Note that in this method the range of α has been taken from 0 to1, in all the calculations the base MVA has been taken as 100MVA. The tolerance value ε has been taken as 0.001 .

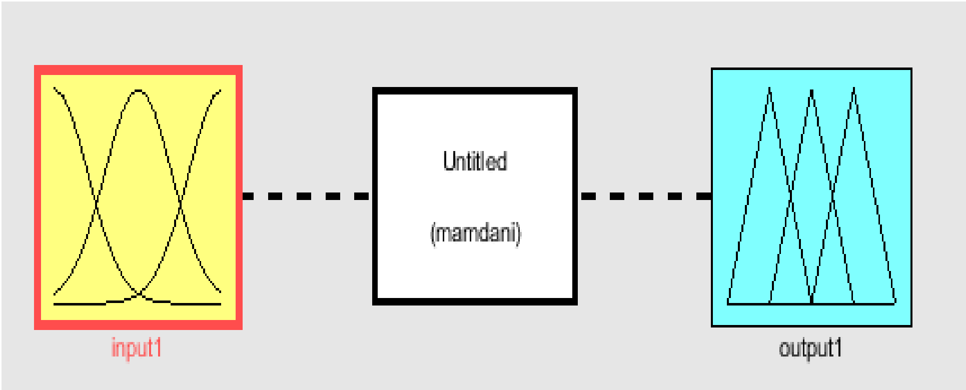

Fig 4 fuzzy logic controler model

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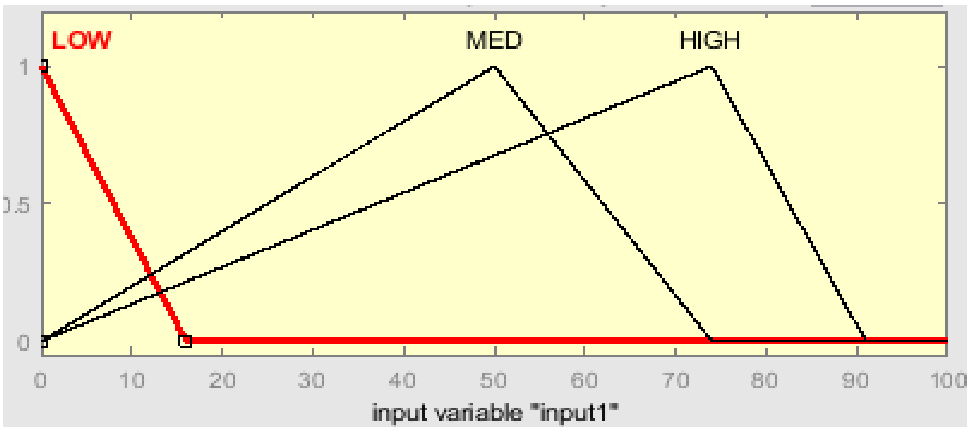

Fig 5 Input variables

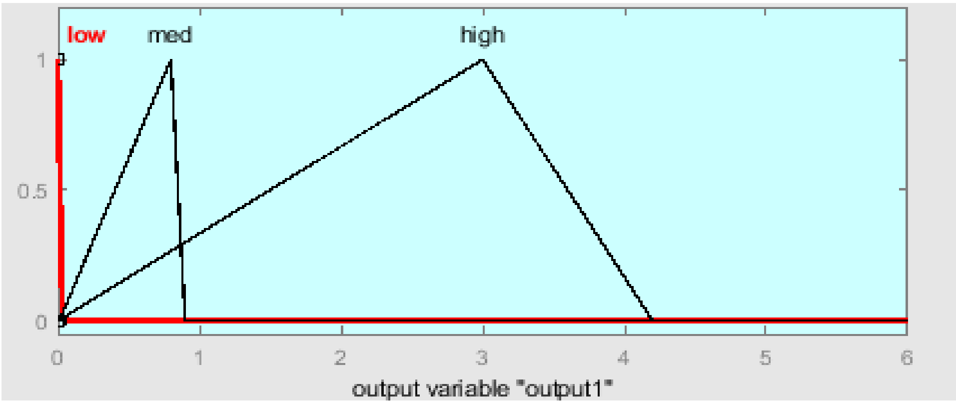

Fig 6 Output variables

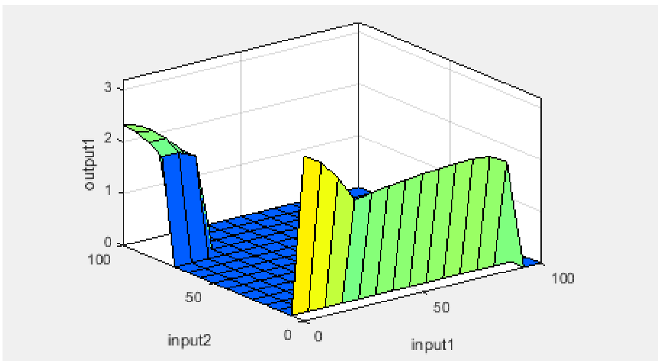

Fig 7 3-D Visualization of input and line loss output

To validate the proposed model the IEEE standard 6-bus test system shown has been considered. and fuzzy version of Newton-Raphson algorithm were carried out for 5 and 4 iterations respectively.

Bus no	Line loss range 1	Line loss range 2
1	1.0200	1.0600
2	$0.9944 - 0.0624i$	$1.0285 - 0.0585i$
3	$1.0038 - 0.0743i$	$1.0522 - 0.0698i$

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4	$0.9849 - 0.0753i$	$0.9954 - 0.0652i$
5	$0.9213 - 0.0803i$	$0.9854 - 0.0807i$
6	$0.9315 - 0.0803i$	$1.0039 - 0.0924i$

X- Conclusion -
The results obtained in this paper proves that application simpower simulink, load flow analyser , matlab codes and fuzzy logic concept helps in minimizing computation time and the number of iteration. It also provides the 3-D visualization of the power system model and results, which saves the computation time and improves the efficiency of the method.

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