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Steady state analysis of IEEE-6 Bus System Using PSAT power toolbox

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Abstract- Power companies use very elaborate programs for making load flow studies. The information which is obtained from digital solution of load flow is an indication of the great contribution digital computers have made to the power engineer's ability to obtain operating information about systems not yet built and to analyze the effects of changes on existing system. There are many open source software packages which can be used to study the load flow analysis, PSAT is one among them. PSAT (Power system analysis toolbox) is an open source toolbox which is compatible with MATLAB that makes possible in re-using existing code and merging different software packages into new and less costly applications. This panel paper presents the study of IEEE-6 bus system for steady state analysis with different load level flow methods such as Newton-Raphson, Fast-Decoupled method.

Keywords: Newton- Raphson method ,Power flow, PSAT, Steady state analysis.

I. INTRODUCTION

Power flow analysis is the backbone of power system analysis and design. They are necessary for planning, operation, economic scheduling and exchange of power between utilities. The principle information of power flow analysis is to find the magnitude and phase angle of voltage at each bus and the real and reactive power flowing in each transmission lines. Power flow analysis is an important tool involving numerical analysis applied to a power system [1]. Symmetrical steady state is, in fact the most important mode of operation of a power system. Load flow study in power system parlance is the steady state solution of the power system network. The main information obtained from this study comprises the magnitudes and phase angles of load bus voltages, real and reactive power flow on transmission lines, other variables being specified. This information is essential for the continuous monitoring of the current state of the system and for analyzing the effectiveness of alternative plans for future system expansion to meet the increased load demand.

In the absence of digital computers, the AC calculating board was the only means of carrying out load flow studies. These studies were, therefore, tedious and time consuming [2]. With the availability of fast and large size digital computers, all kinds of power system studies, including load flow, can now be carried out conveniently. Now days there are many software packages are available to perform the load flow analysis. Software packages are of two type's commercial and open source. Commercial software packages available on the market (e.g. PSS/E, Euro Stag, Simpow, and CYME) follow an "all-in-one" philosophy and are typically well-tested and computationally efficient. Despite their completeness, these software's can result cumbersome for educational and research purposes. Even more important, commercial software's are "closed", i.e., do not allow changing the source code or adding new algorithms. For research purposes, the flexibility and the ability of easy prototyping are often more crucial aspects than computational efficiency. On the other hand, there is a variety of open source research tools, which are typically aimed to a specific aspect of power system analysis.

There are several high level languages such as Matlab, Mathematica, and Modelica, have become more and more popular for both research and educational purposes. Any of these languages can lead to good results in the field of power system analysis; however, Matlab proved to be the best user choice. Key features of Matlab are the matrix-oriented programming, excellent plotting capabilities and a graphical environment (Simulink) which highly simplifies control scheme design.

This paper describes a new Matlab-based power system analysis tool (PSAT) which is freely distributed on line [3]. PSAT includes power flow, continuation power flow, optimal power flow, small-signal stability analysis, and time-domain simulation. The toolbox is also provided with a complete graphical interface and a Simulink-based one-line network editor. An important but often missed issue is that the Matlab environment is a commercial and "closed" product, thus Matlab kernel and libraries cannot be modified nor freely distributed. To allow exchanging ideas and effectively improving scientific research, both the toolbox and the platform on which the toolbox runs should be free. At this aim, PSAT can run on GNU/Octave which is a free Matlab clone.



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The paper is organized as follows. Section II illustrates the main PSAT features while Section III and IV describe the models and the algorithms for power system analysis implemented in PSAT. Section V and VI presents a case study based on the IEEE 6-bus test system. Finally, Section VII presents conclusions.

II. PSAT FEATURES

Main features of PSAT are: *power flow; continuation power flow; optimal power flow; small signal stability analysis; time domain simulation*. PSAT is the first free software project in the field of power system analysis. PSAT is also the first power system software which runs on GNU/Octave platforms. Once the power flow has been solved, the user can perform further static and/or dynamic analyses [4]-[6]. These are as follows.

- a) Continuation Power Flow (CPF).
- b) Optimal Power Flow (OPF).
- c) Small-signal stability analysis.
- d) Time-domain simulations.

PSAT deeply exploits Matlab vectorized computations and sparse matrix functions in order to optimize performances. Furthermore, PSAT is provided with the most complete set of algorithms for static and dynamic analyses among currently available Matlab-based power system software's. In order to perform accurate and complete power system analyses, PSAT supports a variety of static and dynamic models. Besides mathematical algorithms and models, PSAT includes a variety of additional tools, as follows.

- a) User-friendly graphical user interfaces.
- b) Simulink library for one-line network diagrams.
- c) Data file conversion to and from other formats.
- d) User defined model editor and installer.
- e) Command line usage.

III. NETWORK MODELLING AND FLOWCHART

The starting point in obtaining the data which must be furnished to the computer is the one line diagram of the system. Values of series impedances and shunt admittances of transmission lines are necessary so that the computer can determine all the Y_{bus} or Z_{bus} elements. Other essential information includes transformer ratings and impedances, shunt capacitor ratings and transformer tap settings. Operating conditions must always be selected for each study [6]. In steady state analysis, the provision is made for the calculation to consider voltage to be maintained constant at a bus only so long as the reactive power generation remains within designated limits [7]. Taylor's series expansion for a function of two or more variables is the basis for the Newton-Raphson method of solving the load flow problem.

FLOWCHART OF POWER CALCULATION WITH PSAT

The power flow computation consists of component-modeling, network establishment, data-reading, equation-solving, simulation calculation, and results output.

PSAT is launched by typing at the Matlab command prompt `>> PSAT`

Which will create all structures required by the toolbox and opens the main GUI [5]. All procedures implemented in PSAT can be launched from this window by means of menus, buttons, and/or short cuts.

The interest of arsenal research in PSAT was born within the renewable energy department, which has been developing strategies for Steady state analysis in power flow solution.

Flowchart gives the detail step by step method followed for ieee-6 bus system data using PSAT power toolbox. Power system data from network utilities for the simulation comes from commercially-available proprietary software like Power Factory [8], the implementation of the complex control algorithms required extensive validation and debugging during development.



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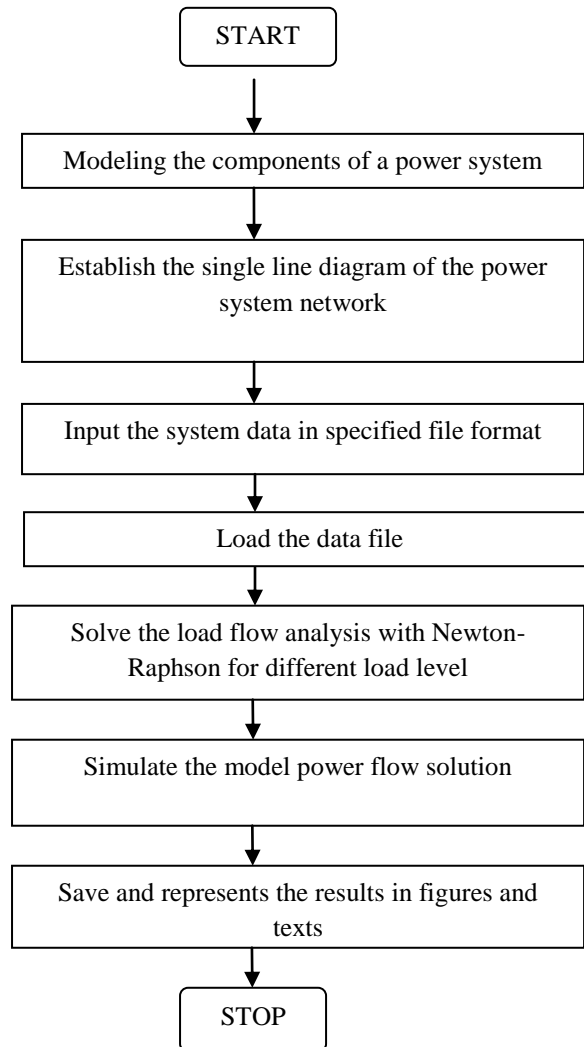


Fig 1. Flowchart for ieee-6 bus system using PSAT toolbox

IV. CASE STUDY

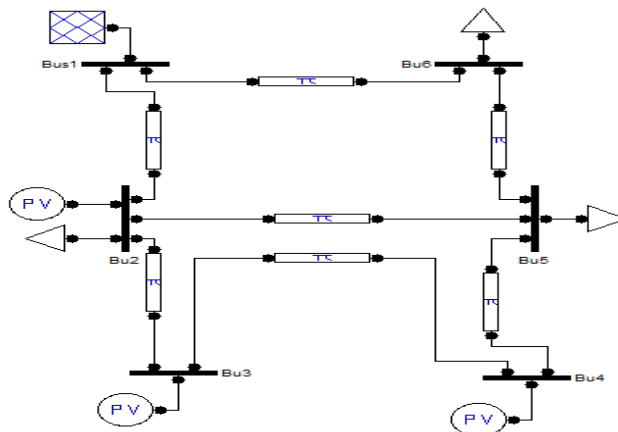


Fig 2. PSAT MODEL



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This section illustrates PSAT features for steady state analysis by means of IEEE-6 bus test system. Fig. 2 depicts the model of the IEEE 6-bus network built using the PSAT Simulink library. Once defined in the Simulink model, one can load the network in PSAT and solve the power flow. PSAT also allows displaying bus voltages and power flows in simulink library for different load levels within simulink model loaded into the system.

A. System Details

IEEE- 6 Bus System Data

MVA Base=100 MVA

System Frequency = 50 Hz

Bus Nominal Voltage =11KV

Bus Maximum Voltage = 11.5 KV

Bus Minimum Voltage = 10.4 KV

Table I: Load Data

Bus	Real Power, Mw	Reactive Power, MVAR
At Bus 2	20	10
At Bus 5	40	15
At Bus 6	30	10

Table II: Line Data

Line No.	Bus Code p-q	Positive Sequence Resistance, p.u	Positive Sequence Reactance, p.u
1	1-2	0.05	0.20
2	2-3	0.10	0.50
3	3-4	0.20	0.80
4	4-5	0.10	0.30
5	5-6	0.20	0.40
6	6-1	0.10	0.15
7	2-5	0.20	0.50

Table III: Generator Data

Generator No.	P+j Q p.u.	V p.u.	MVA	Bus Type
G1	0+j0	1.00	100	Slack
G2	0.1+j0.05	1.041	15	PV
G3	0.30+j0.2	1.0190	40	PV
G4	0.2+j0.1	1.071	30	PV

V. SIMULATION RESULTS

The results obtained from simulation of above system are given in table given below for the various load levels from 60% load level to 120% load level.

Table IV: Total line flows and Total line losses

Load level (p.u)	Line Flow		Line Losses	
	Real Power (p.u)	Reactive Power (p.u)	Real Power (p.u)	Reactive Power (p.u)
0.6	0.55911	0.26322	0.01911	0.05322



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0.8	0.75195	0.36296	0.03195	0.08296
1	0.85028	0.41725	0.04028	0.10225
1.2	0.85028	0.41725	0.04028	0.10225

Table V: Comparison of Scenario with different method

Method	No. of iterations	Time in seconds	Maximum convergence error
Newton-Raphson	3	0.647	2.987e-006
BX Fast decoupled	5	0.206	9.8605e-007
XB Fast Decoupled	6	0.153	3.121e-006

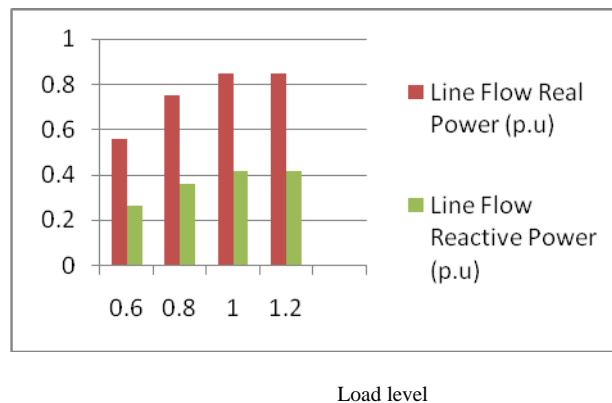


Fig a. Representation of total line flow at different load

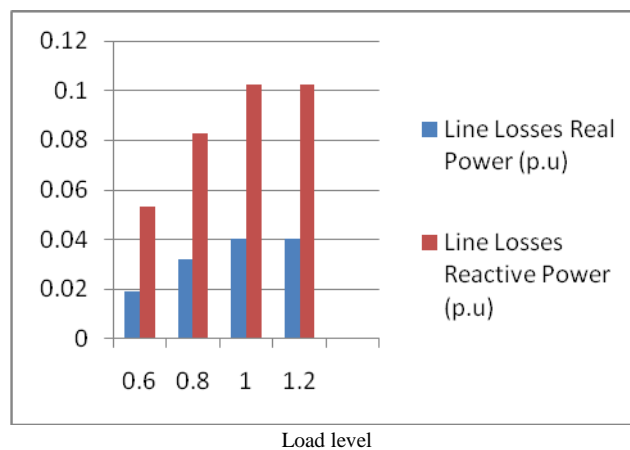


Fig b. Representation of total line losses at different load



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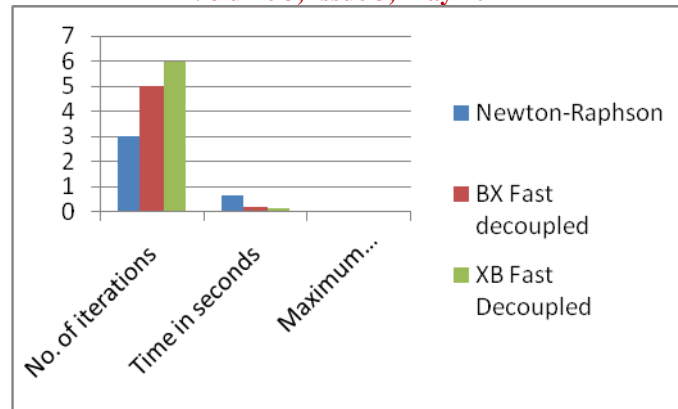


Fig 2. Comparison with different method

The graph shown in Fig a. and Fig b. shown specifies the total line flows vs. load levels and total line losses vs. load levels. The graph in Fig 2. represents the comparison for No. of iterations, Time in seconds, maximum convergence error for different method at different load level... The obtained results, Table 6. Shows the Bus voltage magnitudes and Table 7. The line flows and line losses at different load levels.

VI. CONCLUSIONS

This paper presents the steady state analysis of IEEE-6 bus system using an open source software PSAT. The bus voltage profile remains in the state of equilibrium as the load varies. Also, the line losses slightly increase at different load levels. As compared with other method Newton–Raphson method gives accurate results. Though Fast-Decoupled method takes less time, it gives approximate values. The result shows that the power flow calculation is a fast and a high-precision process, and can meet the need of power simulation. Future work will concentrate on studying power flow solution introducing power system operation arrangement.

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APPENDIX

Table VI. Bus Voltage Magnitudes

Line No.	Bus voltages(p.u)				Phase angles (rad)			
	Load level(p.u)				Load level(p.u)			
	0.6	0.8	1	1.2	0.6	0.8	1	1.2
1	1	1	1	1	0	0	0	0
2	1.041	1.041	1.041	1.041	-0.037	-0.055	-0.064	-0.064
3	1.019	1.019	1.019	1.019	-0.002	-0.026	-0.039	-0.039
4	1.071	1.071	1.071	1.071	-0.058	-0.092	-0.1096	-0.1096
5	1.0113	0.998466	0.9918	0.9918	-0.074	-0.107	-0.124	-0.124
6	0.98156	0.96966	0.96346	0.96346	-0.037	-0.052	-0.059	-0.059

Table VII. Line flows and Line losses

Line No.	Bus code	Line flows(p.u)								Line losses(p.u)							
		Load level(p.u)								Load level(p.u)							
		0.6		0.8		1		1.2		0.6		0.8		1		1.2	
		P flow	Q flow	P flow	Q flow	P flow	Q flow	P flow	Q flow	P flow	Q flow	P flow	Q flow	P flow	Q flow	P flow	Q flow
1	1-2	0.135	-0.235	0.225	-0.253	0.272	-0.262	0.272	-0.262	0.013	0.0147	0.006	0.023	0.007	0.028	0.007	0.028
2	2-3	-0.062	0.059	-0.050	0.056	-0.043	0.055	-0.043	0.055	0.001	0.003	0.001	0.002	0.001	0.002	0.001	0.002
3	3-4	0.057	-0.078	0.069	-0.080	0.075	-0.082	0.075	-0.082	0.001	0.007	0.002	0.008	0.002	0.009	0.002	0.009
4	4-5	0.115	0.179	0.127	0.217	0.133	0.238	0.133	0.238	0.003	0.012	0.006	0.012	0.006	0.019	0.006	0.019
5	5-6	-0.042	0.097	-0.076	0.114	-0.094	0.122	-0.094	0.122	0.002	0.004	0.004	0.008	0.004	0.009	0.004	0.009
6	6-1	-0.224	0.033	-0.320	0.026	-0.368	0.022	-0.368	0.022	0.005	0.007	0.011	0.016	0.014	0.022	0.014	0.022
7	2-5	0.088	0.28	0.125	0.0414	0.143	0.048	0.143	0.048	0.002	0.004	0.003	0.008	0.004	0.010	0.004	0.010