Comparison of Different Simulation Tools for Load Flow Analysis in Power Systems

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Abstract— *The comparative analysis provides valuable insights into the capabilities and limitations of different simulation tools, helping to improve the accuracy and efficiency of load flow studies, ultimately contributing to the reliable and secure operation of modern power systems. In this paper load flow analysis of IEEE 9 bus system is performed on three different software tools i.e. Power world simulator (PWS), MATLAB, MATPOWER. The results of load flow analysis of all three tools are compared. The economic load dispatch problem is also resolved in PWS and MATPOWER software. The results are promising and efficient when compared with latest ones.*

Keywords— *Load Flow Analysis, Power Systems, Power world simulator, DigSILENT.*

I. INTRODUCTION

Load flow analysis is a fundamental tool in power system planning, operation, and control. Various simulation tools have been developed to perform load flow analysis, each with its own unique features and capabilities. The comparative analysis is conducted on a set of standard power system test cases, representing different system configurations and operating conditions. The selected simulation tools include well-established commercial software packages as well as open-source tools. To ensure a comprehensive evaluation, the comparison encompasses both traditional load flow algorithms, such as Newton-Raphson and Gauss-Seidel, as well as advanced techniques like fast decoupled load flow and sparse matrix methods. The strengths and weaknesses of each simulation tool are identified and discussed, along with recommendations for specific applications or scenarios.

This paper compares popular power system analysis software such as PSS/E, ETAP, and DigSILENT Power Factory for load flow analysis. It evaluates various factors including accuracy, computation time, and ease of use. [1] The authors compare different power system analysis software, including PSS/E, DigSILENT Power Factory, and Power World Simulator, for load flow studies. The study focuses on accuracy, convergence characteristics, and computational efficiency. [2] This paper presents a comparative study of various power system simulation software tools, including PSS/E, ETAP, DigSILENTPowerFactory, and PowerWorld Simulator. The comparison is based on load flow analysis accuracy, stability analysis capabilities, and computational efficiency. [3] The authors compare the performance of PSS/E, DIgSILENTPowerFactory, and OpenDSS for load flow analysis. The paper evaluates accuracy, computation time, and stability analysis features. [4] This paper compares PSS/E, DIgSILENTPowerFactory, and MATLAB/Simulink for load flow analysis. The authors evaluate accuracy, convergence behavior, and ease of use. [5] The authors compare PSS/E, DIgSILENTPowerFactory, and MATLAB/Simulink for load flow studies. The study focuses on accuracy, computation time, and robustness under varying system conditions. [6] This paper provides an overview of Power-World Simulator and its capabilities for power system analysis. It discusses the simulation of the IEEE 9-bus system using Power-World Simulator and focuses on power flow analysis, contingency analysis, and voltage stability analysis. The study demonstrates the use of Power-World Simulator as a powerful tool for simulating and analysing the IEEE 9-bus system. [7] This paper investigates the optimal power flow (OPF) analysis of the IEEE 9-bus system using Power-World Simulator. The study aims to optimize the generation and dispatch of

power while considering system constraints. It explores different OPF techniques and discusses their application to the IEEE 9-bus system using Power-World Simulator. **[8]**This paper focuses on contingency analysis of the IEEE 9-bus system using Power-World Simulator. It analyses the system's response to various contingencies such as generator and line outages. The study demonstrates the use of Power-World Simulator's contingency analysis capabilities to assess system reliability and identify critical contingencies. **[9]** This research investigates voltage stability analysis of the IEEE 9-bus system using Power-World Simulator. It examines the system's voltage stability margin and identifies potential voltage collapse scenarios. The study utilizes Power-World Simulator's voltage stability analysis features to assess system voltage stability and propose control strategies for voltage improvement. **[10]** This paper introduces the Power System Analysis Toolbox (PSAT) for MATLAB, which includes various modules for power system analysis. It demonstrates the simulation of the IEEE 9-bus system using PSAT and MATLAB. The study focuses on power flow analysis, transient stability analysis, and optimal power flow using PSAT's functionalities in MATLAB. **[11]** This research paper presents a transient stability analysis of the IEEE 9-bus system using MATLAB/Simulink. The study models the system components and implements stability analysis algorithms in Simulink. It investigates the system's response to disturbances and evaluates stability limits using MATLAB/Simulink simulations. **[12]** This paper focuses on voltage stability analysis of the IEEE 9-bus system using MATLAB. **[13]**It develops a voltage stability index based on the system's load ability margin and performs sensitivity analysis to assess voltage stability limits. The study demonstrates MATLAB's capabilities in analysing and predicting voltage stability in power systems. **[14]** This paper introduces MatPower, a MATLAB-based power system simulation and analysis package. It discusses the simulation of the IEEE 9-bus system using MatPower and highlights its capabilities for power flow analysis, optimal power flow, and contingency analysis. **[15].** This research focuses on voltage stability analysis of the IEEE 9-bus system using MATPOWER. It investigates the system's voltage stability limits, identifies critical buses, and proposes control strategies for voltage improvement. **[16]** This paper explores optimal power flow analysis using MatPower for the IEEE 9-bus system. It formulates the OPF problem and solves it using MatPower's optimization capabilities, considering various system constraints **[17]**

The research Objectives of the works are:

- To perform load flow analysis of IEEE 9 bus system

- To compare the result of load flow analysis of 9 bus system in various simulation tools

II. SOFTWARE TOOLS FOR LOAD FLOW ANALYSIS

Load flow analysis is one of the basic power system analyses in the stage of planning, design and operation of power systems. This is used to calculate the steady state performance of the system under various possible operating conditions and study the effects of changes in equipment configuration.

The three methods for load flow studies mainly

- Gauss siedel method
- Newton raphson method
- Fast decoupled method.

Three software tools are used to simulate the systems.

- Power World Simulator,
- MATLAB and
- MATPOWER

Power World Simulator (PWS)

An effective software programme for simulating and analysing electrical power systems is called Power-World Simulator. It offers a comprehensive platform for modelling, simulating, and optimising many elements of power systems for engineers, researchers, and system operators. Power-World Simulator has grown to be a well-liked option for system analysis, planning, and operation in the power industry because to its user-friendly interface and sophisticated capabilities. Using Power-World Simulator, users can define buses, generators, transmission lines, transformers, loads, and other components to build intricate models of power systems. It enables both steady-state and dynamic modelling, allowing for the analysis of system behavior over a range of timescales and operating circumstances. To faithfully mimic the intricate relationships within the power system, the software incorporates industry-standard methods and solution methodologies. Power flow analysis is one of Power-World Simulator's main features. It computer dispatch, or system designs on the overall system operation by looking at the power flow.es the voltages, currents, and power flows in the system, giving information about how well it is working and spotting potential problems such voltage violations, power losses, and congestion. Engineers can evaluate the effects of adjustments to load demand, generator etc.

MATLAB Simulation

MATLAB is a high-level programming language and software environment used for algorithm creation, data

analysis, and numerical calculation. Its initial purpose was for matrix manipulation and linear algebra operations, and its name stands for "Matrix Laboratory". However, it has since grown to include a variety of features and applications. Here in MATLAB a IEEE-9 Bus system was designed and simulated and the results were verified with the base case results.

MAT Power

The University of Wisconsin-Madison's Power System Engineering Research Centre (PSERC) created MAT-Power, a robust and extensively used MATLAB-based software package. It offers a complete set of features and resources for modelling, analyzing, and improving power systems. As open-source software, MAT-Power is freely available to power systems researchers, engineers, and students. Users can carry out numerous analyses with MAT-Power, such as power flow analysis, optimal power flow (OPF), and contingency analysis. With the use of power flow analysis, it is possible to calculate the steady-state voltages, currents, and power flows in a power system, giving important insights into the operation and behavior of the system. The OPF feature enables generation and dispatch optimization, considering elements like generating costs, transmission losses, and system limits, in order to arrive at an ideal operating point. The impact of component failures or outages on system stability is evaluated using contingency analysis, which also exposes potential weaken.

III. RESULT AND DISCUSSION

The IEEE- 9 bus test system is adopted in this paper to analyze and compare the load flow analysis performed on the three different software as mentioned.

IEEE 9 Bus System

In power system analysis and modelling, the IEEE 9-Bus system is used, as shown in figure 1, as a benchmark. With nine buses, three generators, and numerous transmission lines, it serves as a simplified representation of a power transmission system.
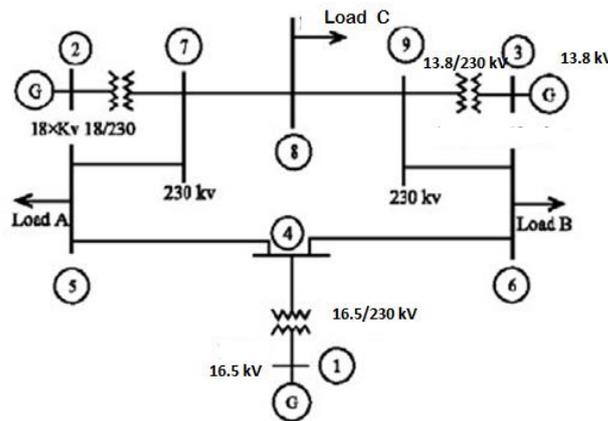

Fig.1: Single Line Diagram of IEEE – 9 Bus System

CASE A: -

IEEE 9 Bus Simulation in Power World Simulator

A sophisticated software programme called PowerWorld Simulator is frequently used for power system analysis, simulation, and optimisation. Engineers, academics, and system operators can analyze and visualize complicated power systems using its user-friendly interface and a variety of strong features. The 9 bus model in PWS software is shown in figure 2. The simulation result of IEEE 9 bus system in PWS software is depicted in table 1.

Table 1: - Load Flow Result of IEEE 9 Bus in Power World Simulator

Sr. No.	Bus No.	Nom. (KV)	p.u. (V)	Volt (KV)	Angle (Deg)	Load (MW)	Load (Mvar)	Gen (MW)	Gen (Mvar)
1	Bus 1	16.50	1.04000	17,160	0.00	0	0	71.63	27.91
2	Bus 2	18.00	1.02500	18.450	9.35	0	0	163.00	4.90
3	Bus 3	13.80	1.02500	14.145	5.14	0	0	85.00	-11.45

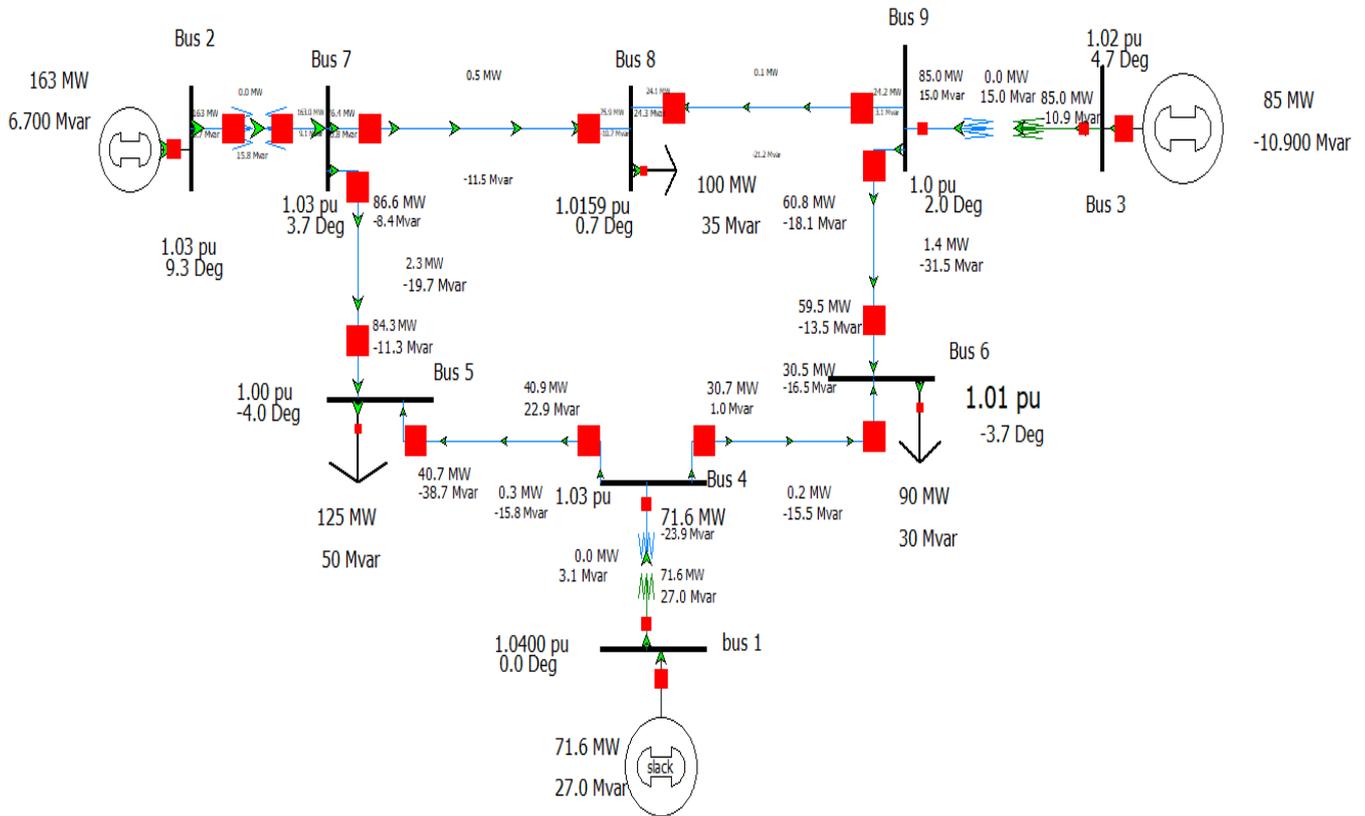| 4	Bus 4	230.00	1.02531	235.821	-2.22	0	0	0	0
5	Bus 5	230.00	0.99972	229.936	-3.68	125.00	50.00	0	0
6	Bus 6	230.00	1.01225	232.819	-3.57	90.00	30.00	0	0
7	Bus 7	230.00	1.02683	236.971	3.80	0	0	0	0
8	Bus 8	230.00	1.01727	133.971	13.4	100.00	35.00	0	0
9	Bus 9	230.00	230.00	1.03269	237.519	2.44	0	0	0

Fig.2: IEEE 9 Bus Simulated Model in PWS

CASE B :-

IEEE 9 Bus Simulation in MATLAB

A well-known benchmark system for power system analysis is the IEEE 9-bus system, and MATLAB offers a potent framework for simulating and analysing this system. The IEEE 9-bus system is simulated in MATLAB using the following overview:

Modelling the IEEE 9-bus system in MATLAB involves specifying its many parts, such as the buses, generators, loads, and transmission lines. The parameters for each component, such as the bus voltages, generator characteristics, load requirements, and line parameters, serve as a representation of that component.

Data Input: The IEEE 9-bus system's data can be entered through an interface provided by MATLAB. Matrix or data structure input can be used to enter the system parameters into MATLAB, including the bus admittance matrix, generator data, load data, and line parameters. As a result, it is simple to alter and manipulate the system data throughout the simulation.

Load Flow Analysis: In order to solve load flow analysis in the IEEE 9-bus system, MATLAB provides built-in functions and toolboxes. The bus voltages, line flows, and power injections in the system are calculated iteratively by these functions, like pf_newton or pf_gauss.

The simulation result of IEEE 9 bus system in MATLAB software is illustrated in table 2.

Table 2 :- Load flow result of IEEE 9 bus in MATLAB

Bus #	Voltage		Generation		Load	
	Mag (pu)	Ang (deg)	P (MW)	Q (MVAr)	P (MW)	Q (MVAr)
1	1.040	0.000	71.64	27.05	-	-
2	1.025	9.280	163.00	6.65	-	-
3	1.025	4.665	85.00	-10.86	-	-
4	1.026	-2.217	-	-	-	-
5	1.013	-3.687	-	-	90.00	30.00
6	1.032	1.967	-	-	-	-
7	1.016	0.728	-	-	100.00	35.00
8	1.026	3.720	-	-	-	-
9	0.996	-3.989	-	-	125.00	50.00
Total:			319.64	22.84	315.00	115.00

IEEE 9 Bus Simulation in MAT Power

The IEEE 9 bus system is simulated in MATPOWER and result are shown in table 3

Table 3: - Load flow result of IEEE 9 bus in MATPOWER

Bus ID	V_{base} (Kv)	V_{ref} (pu)	Vangle (deg)	P(MW)	Q(Mvar)	V_LF(pu)	Vangle_LF(deg)	P_LF(MW)	Q_LF(Mvar)
BUS_1	16.5	1.04	0	0	0	1.04	0	72.1888	26.7986
BUS_4	230	1	0	0	0	1.0261	-2.2265	0	0
BUS_5	230	1	0	125	50	0.9962	-4.0021	125	50
BUS_6	230	1	0	90	30	1.0131	-3.701	90	30
BUS_7	230	1	0	0	0	1.0259	3.6201	0	0
BUS_9	230	1	0	0	0	1.0324	1.8665	0	0
BUS_8	230	1	0	100	35	1.016	0.6336	100	35
BUS_2	18	1.025	0	163	0	1.025	9.1727	163	6.6901
BUS_3	13.8	1.025	0	85	0	1.025	4.5577	85	-10.7842

Economic Load Dispatch

Economic Load Dispatch (ELD) is an optimization problem in power systems that aim to determine the optimal generation schedule for power plants, taking into account various factors such as the system load, generator constraints, and fuel costs. ELD problem is resolved in two software:

- MATPOWER
- Power World Simulator

The results of both software are shown in table 4:

Table 4:- Comparison of ELD Results in PWS and MATPOWER

	PWS	MATPOWER
Real Power Loss (MW)	3.20	3.307
MW Generation	318.20	318.20
Total Hourly Cost	5293.98$/hr	5293.98 $/hr

IV. CONCLUSION

Based on this research, three power simulation tools MATPOWER, MATLAB and Power World are compared

here. By evaluating the performance of the tests through the above mentioned software tools, it is concluded that they all yielded good and fairly reliable results for bus voltage magnitude and its phase angles. It has been determined that the most accurate data for the IEEE 9 bus comes from Powerworld, followed by MATPOWER. ELD was also performed in two softwares namely PWS and MATPOWER and results are compared in which it is found that PWS software gave the minimum value for the economic load dispatch with minimum losses.

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