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Load Flow Analysis of Dhaka Grid Using PSAT and ETAP and Performance Comparison with PGCB Data

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***Abstract*— This paper deals with a load flow simulation of existing Dhaka Grid Circle of Bangladesh National Grid by using Power System Analysis Toolbox (PSAT) which is a free and open source software of MATLAB Simulink and Electrical Transient and Analysis Program (ETAP) software designed for simulation, operation, and automation of generation, distribution, and industrial power systems. All the data used to simulate were collected from Power Grid Company of Bangladesh (PGCB) and Load flow analysis was carried out using Newton Raphson method and simulated results were compared with PGCB Base Case Data. The network considered to simulate has 71 buses (400, 230 and 132 kV), 135 interconnecting lines, 32 generators, 47 loads and only 4 shunt capacitors as per the Dhaka grid circle system. Regarding the maximum demand of the load centers, total 5,525 MW load is connected in this system and the average grid generation in September, 2018 was 10,919.57 MW, though only 5988 MW of the total generation is enlisted in the Dhaka grid circle.**

Keywords—PSAT, ETAP, PGCB, HVDC, SVC, Load Flow

I. INTRODUCTION

All across the earth, the use of power system is uninterruptedly extending in size and growing in complexity. To cope with the flow of this expansion, the necessity for various system study, understanding and analyzing is much essential today than ever earlier. As Bangladesh is a developing country, so with the industrial growths in our country, the power system kept on increasing day by day. In such circumstances, load flow analysis may help the continuous assessment of current performance of the power system and analyzing the effectiveness of alternative plans for system expansion to meet raising load demand. Load flow analysis is focused with explaining the operating condition of an entire power system, by which we mean a network of generators, transmission lines, distribution lines and loads that could represent an area as small as a municipality or as large as several states. Considering certain known quantities—like the amount of power generated and consumed at different locations, load flow analysis permits one to determine other quantities. The most predominant of these quantities are the voltages at locations throughout the transmission system, which, for alternating current (AC) consists of both active and reactive power, phase angle or both magnitude and time element and following in each line [1], [2]. Load flow analysis are of great significance in planning and executing by designing the future expansion of power systems as well as in determining the best operation of existing systems [3], [4]. There was a time when it was a challenge to simulate and examine the load flow study of power system. But with the invention of modern technologies and introduction of computer aided load flow analysis, it is much simpler and reliable to accomplish these operations. Now-a-days different types of free simulation software are accessible online for load flow analysis. Among them PSAT, ETAP, MATPOWER, UWPFLOW etc. are noteworthy. Different circumstances need different techniques and algorithms used by the different software.

In this paper, a simulation model of electrical network system for Dhaka Grid circle is developed and the performance of this grid circle is analyzed. The simulation model has been developed by using the PSAT software which is a highly reliable free Power System Analysis toolbox for MATLAB Simulink as well as EPAT software which is a high impact commercial software used worldwide for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. The total network consists of 71 buses (400, 230 and 132 kV), 135 interconnecting lines, 32 generators, 47 loads and only 4 shunt capacitors as per the Dhaka grid circle system. The load flow study can be done by using the developed simulation model. To justify the developed simulation model the output of this software has been observed and compare with PGCB data of 20 September, 2018. On that day the generation is 11,623 MW which is largest generation till now on 20 September 2018. In the existing model of PGCB, only the real values are provided in the PGCB website but in this paper that model was simulated using the two software PSAT and ETAP and load flow was obtained so that it can be improved in the future as well as if a new load or generator is introduced in the system, the real data can be measured very easily and accurately.

The paper is arranged in the following order: Section II describes about the simulation software, PSAT and ETAP briefly. Section III gives us the overall idea of the network for performing the simulation. Section IV compares the simulation results and performance of the software with that of the PGCB base case data. Lastly, Section V consists of the findings and conclusion.

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II. About The Software

A. About PSAT

PSAT is a comparatively brand new and up to date software (developed around 2004-2005) appointing the outstanding matrix-oriented computation techniques of MATLAB. This toolbox (MATLAB) or software-package is designed for control & electric power system analysis. To grant flexibility to the user, it utilizes Simulink library as a graphical tool, which allows drawing of pictorial or schematic blocks to represent different components of a power system [5]. One distinctive point about PSAT is that, it can also run in GNU/ Octave environment- free software for performing numerical experiments using a language that is mostly compatible with MATLAB. It also reflects as one of the active FOSS (Free and Open-Source Software) projects for power systems [6]. Apart from fundamental power flow analysis, PSAT proposes various other static/dynamic analyses like CPF (Continuation Power Flow), OPF (Optimal Power Flow), Small-signal stability analysis, Time-domain simulations etc. For the simulation design of this work, only the power flow feature is explored. Newton-Raphson (NR) method, Runge-Kutta method, Fast decoupled methods (both BX and XB), Simple robust method are the available algorithmic options provided by PSAT to conduct power flow analysis. Both theoretically and practically Newton-Raphson (NR) algorithm converges faster to the solutions than the others, which is why we applied it to our system.PSAT allocates a set of parameters, consisting of the corresponding state variables, to each component. After the standard models (inter-related non-linear differential equations) are all established, Jacobians are formed in a common function. As soon as the necessary functions are organized, the iterative process begins and it continues until the best results regarding the tolerance limits are found. The results are output as a static report and further conversion into other formats can also be done.

B. About ETAP

ETAP is a full fetched electrical engineering software invented by Operation Technology Inc. (OTI) which specializes in the analysis, simulation, monitoring, control, optimization, and automation of electrical power systems. Starting from modeling to operation, everything related to power system enterprise is offered by the compact suite of ETAP. An excellent interface for performing severe analysis on electrical power systems is one of the special characteristics of ETAP. Not only that, it can also perform Electrical Transient analysis accurately. It also includes the integration of utility software such as Microsoft Excel. The ETAP software is designed with an excellent human friendly interface which is very easy to understand. The user manual which comes with it is also written in a very simple and easy manner which is efficient in solving a problem encountered during simulation. The toolbars of ETAP are arranged in a very organized way based on their respective functions. This arrangement comes in handy while designing a single line diagram. Different types of analysis can be performed by using the respective study modes such as Load Flow, Unbalanced Load Flow, ANSI Short Circuit Analysis, Motor Starting Analysis, Harmonic Analysis, Transient Analysis, Star Protection Coordination, Optimal Load Flow, Reliability Analysis, Optimal Capacitor Placement, DC Load Flow, DC Short Circuit Analysis and Battery Sizing Analysis. [7]

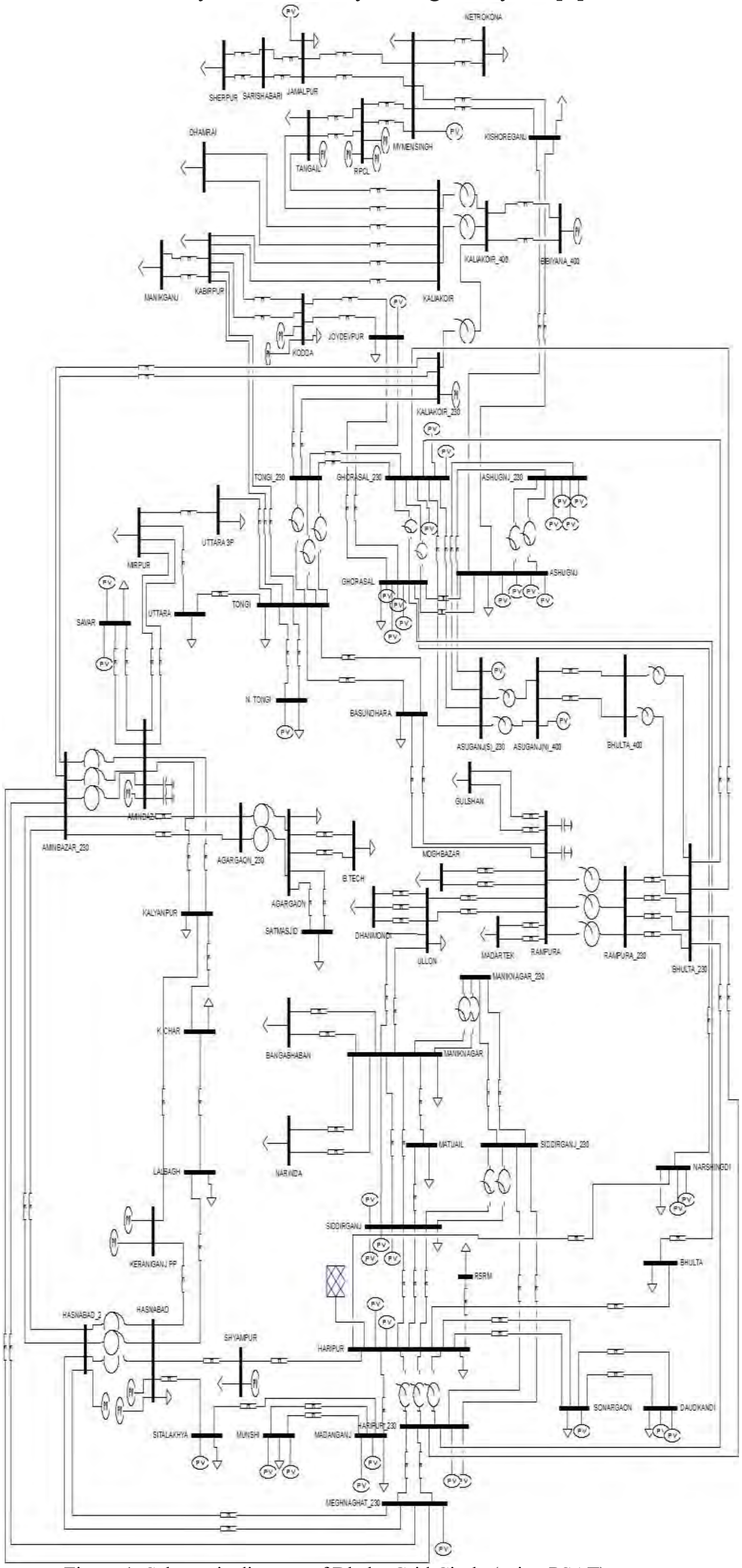

Figure 1. Schematic diagram of Dhaka Grid Circle (using PSAT)

III. OVERALL SYSTEM TAKEN UNDER CONSIDERATION

Bangladesh has a very large distribution network with over 128 grid substations and total transmission line of around 6,251.234 km among which generating stations of 11 kV, 11.5 kV or 15.75 kV are present. These are then stepped up to 400 kV, 230 kV or 132 kV and transmission lines are also designed as such. These are then stepped down in the substations and supplied to the required users.

The general block diagram of the Power System of Bangladesh is given below in figure 2:

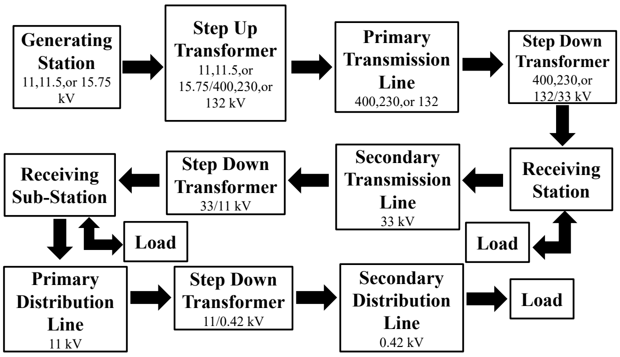

Figure 2. Block Diagram of Bangladesh Power System

The highest grid generation is 11,623 MW till now on 20 September 2018. The system was considered for the day (20 September 2018). Regarding the maximum demand of the load centers, total 5,525 MW load is connected in this system and the average grid generation in September, 2018 was 10,919.57 MW, though only 5988 MW of the total generation is enlisted in the Dhaka grid circle.[8,9] Here, HARIPUR is defined as the slack bus for simulating the system under consideration. The lines are modeled with the π- model for cables depicted in PSAT library. The network we are considering to simulate has 71 buses (400, 230 and 132 kV), 135 interconnecting lines, 32 generators, 47 loads and only 4 shunt capacitors as per the Dhaka grid circle system are modeled with PSAT in figure 1 and ETAP in figure 3.

In the software PSAT and ETAP, HARIPUR is considered for defining the slack bus of our system and the model used in the transmission lines are considered π- model for cable as shown in the PSAT library and cable for the ETAP library. Table I demonstrates all the working generators along with their bus connections. Table II shows the parameters considered for the line conductors. Even though the parameters in PSAT such as per unit (p.u.) data (resistance, reactance and susceptance) for each line were taken from the table, parameters such as the specifications for other components like generators or transformers were kept as the default settings.

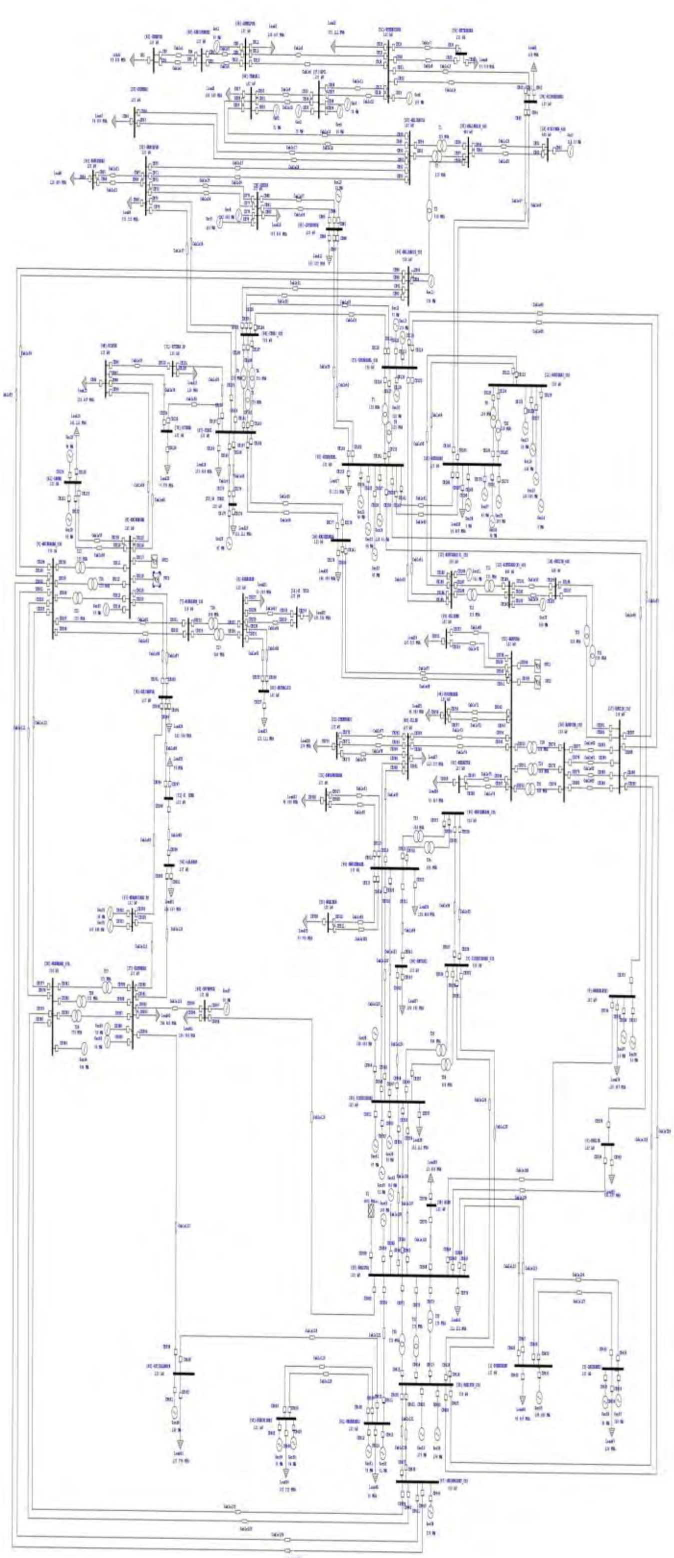

Figure 3. Schematic diagram of Dhaka Grid Circle (using ETAP)

TABLE I. GENERATION DATA

BUS NAME	ACTIVE POWER (p.u.)	BUS NAME	ACTIVE POWER (p.u.)
JAMALPUR	0.87	SAVAR : UNIT-1	0.49
TANGAIL	0.22	SAVAR : UNIT-2	0.55
RPCL : UNIT-1	0.20	AMINBAZAR	0.68
RPCL : UNIT-2	0.20	SIDDIRGANJ : UNIT-1	1.00
RPCL : UNIT-3	0.38	SIDDIRGANJ : UNIT-2	0.97
MYMENSINGH	1.85	SIDDIRGANJ : UNIT-3	0.51
BIBIYANA_400	3.10	SIDDIRGANJ : UNIT-4	0.50
JOYDEVPUR	0.33	NARSHINGDI : UNIT-1	0.19
KODDA : UNIT-1	1.33	NARSHINGDI : UNIT-2	0.33
KODDA : UNIT-2	1.08	KERANIGANJ PP : UNIT-1	0.90
KALIAKOIR_230	2.00	KERANIGANJ PP : UNIT-2	1.00
GHORASHAL_230 : UNIT-1	0.75	HARIPUR : UNIT-1	1.05
GHORASHAL_230 : UNIT-2	1.20	HARIPUR : UNIT-2	3.86
GHORASHAL_230 : UNIT-3	2.10	DAUDKANDI : UNIT-1	0.48
ASHUGANJ_230 : UNIT-1	0.68	DAUDKANDI : UNIT-2	2.00
ASHUGANJ_230 : UNIT-2	1.00	SONARGAON	1
ASHUGANJ_230 : UNIT-3	1.30	MADANGANJ : UNIT-1	0.55
ASHUGANJ_230 : UNIT-4	0.05	MADANGANJ : UNIT-2	0.81
GHORASHAL : UNIT-1	0.40	MEGHNAGHAT_230	2.25
GHORASHAL : UNIT-2	0.34	MUNSHI : UNIT-1	0.35
GHORASHAL : UNIT-3	0.45	MUNSHI : UNIT-2	0.54
GHORASHAL : UNIT-4	1.10	SITALAKHYA	1.02
ASHUGANJ : UNIT-1	0.05	HASNABAD : UNIT-1	0.55
ASHUGANJ : UNIT-2	0.42	HASNABAD : UNIT-2	0.96
ASHUGANJ : UNIT-3	0.34	SHYAMPUR	0.5
ASHUGANJ : UNIT-4	1.50	HASNABAD_230	3.08
ASUGANJ(S)_230	3.01	HARIPUR_230 : UNIT-1	1.75
ASUGANJ(N)_400	3.60	HARIPUR_230 : UNIT-2	1.74
N. TONGI	0.42	Total Active Power Generation	59.88

TABLE II. LINE DATA

SL No.	Conductor Name	Size	Volt	Positive Sequence Parameter		
				Resistance Ohm/km	Reactance H/km	Susceptance F/km
1	GROSBEAK	636	132	0.000555	0.002357	0.000493
2	AAAC	37/4.176 MM	132	0.000555	0.002348	0.000493
3	XLPE	800 MM SQ	132	0.000143	0.000634	0.012376
4	MALLARD	795	230	0.000145	0.000145	0.000146
5	TWIN MALLARD	2×795	230	0.000072	0.000586	0.001981
6	TWIN AAAC	37/4.176 MM	230	0.000073	0.000658	0.001772
7	TWIN FINCH	1113	400	0.000018	0.000206	0.005629
8	QUAD EGRET	636	400	0.000045	0.000527	0.002226

This table demonstrates the different types of conductors used in Bangladesh Grid Network.

IV. SIMULATION RESULTS

Simulation results have been obtained using PSAT 2.1.10 run in MATLAB R2016a and ETAP 16.0.0. All simulations have been done in a computer with Core i5-9400F 2.90GHz processor, 8.00GB RAM, Windows 10 Pro operating system. Due to the shortage of space it is not possible to accommodate all the data in tabular form. But the necessary data can be recognized from the related graphs.

A. POWER FLOW REPORT FROM PSAT

Buses:71
Lines: 135
Transformers: 32
Generators: 32
Loads:47
SOLUTION STATISTICS
Number of Iterations: 4
Maximum P mismatch [p.u.] 0
Maximum Q mismatch [p.u.] 0
Power rate [MVA] 100

TABLE III. POWER FLOW RESULTS OF SOME RANDOMLY SELECTED BUSES OF DHAKA GRID CIRCLE USING NEWTON RAPHSON METHOD (PSAT)

Bus Name	Voltage (kV)	Phase (deg.)	$P_{Generation}$ MW	$Q_{Generation}$ MVAr	P_{Load} MW	Q_{Load} MVAr
[1]-SONARGAON	132	3.4576	100	13.9501	42	20.342
[2]-BHULTA	127.3417	-5.1127	0	0	186	90.084
[30]-JOYDEVPUR	138.996	-9.117	33	134.9714	236	114.3
[32]-KABIRPUR	132.905	-9.6798	0	0	209	101.223
[50]-MUNSHIGANJ	134.9964	0.48673	89	-630.9082	119	57.634
[51]-MYMENSINGH	130.02	-23.8682	185	-160.3155	253	122.533
[57]-RPCL	132	-23.5182	78	352.8198	0	0
[58]-RSRM	131.8853	-0.10245	0	0	14	6.781
[60]-SATMASJID	118.4504	-6.2664	0	0	109	52.791
[61]-SAVAR	142.56	-3.305	104	318.5838	127	61.509

This table contains the details of total 10 buses out of 71 buses.

Global Summary Report
Total Generation
Real Power [P.U.] 55.432
Reactive Power [P.U.] 33.2171
Total Load
Real Power [P.U.] 55.25
Reactive Power [P.U.] 25.3128
Total Losses
Real Power [P.U.] 0.18204
Reactive Power [P.U.] 7.9043

B. POWER FLOW REPORT FROM ETAP

Study Case ID	:	LF
Date Revision	:	Base
Configuration	:	Normal
Loading Cat	:	Design
Generation Cat	:	Design
Diversity Factor	:	Normal Loading
Buses	:	71
Branches	:	167
Generators	:	56
Power Grids	:	1
Loads	:	47
Mismatch-MW	:	0
Mismatch-Mvar	:	0

TABLE IV. POWER FLOW RESULTS OF SOME RANDOMLY SELECTED BUSES OF DHAKA GRID CIRCLE USING ADAPTIVE NEWTON RAPHSON METHOD (ETAP)

Bus Name	Voltage (kV)	Phase (deg.)	$P_{Generation}$ MW	$Q_{Generation}$ MVAr	P_{Load} MW	Q_{Load} MVAr
[1]-SONARGAON	132	0.5	100	-8.967	42	20.342
[2]-BHULTA	127.3417	-0.3	0	0	182.930	88.597
[30]-JOYDEVPUR	138.996	-0.5	33	50	230.103	111.444
[32]-KABIRPUR	132	-0.5	0	0	203.105	98.378
[50]-MUNSHIGANJ	132	0	89	74.299	119	57.634
[51]-MYMENSINGH	132	-1.7	185	70	243.466	117.916
[57]-RPCL	132	-1.7	78	170	0	0
[58]-RSRM	132	0	0	0	13.995	6.778
[60]-SATMASJID	132	-0.5	0	0	106.604	51.631
[61]-SAVAR	132	-0.5	104	160	125.961	61.006

This table contains the details of total 10 buses out of 71 buses.

Global Summary Report
Total Generation
Generation-MW : 5455.118
Generation-Mvar : 2723.603
Total Load
Load-MW : 5455.118
Load-Mvar : 2723.603
Total Losses
Loss-MW : 31.668
Loss-Mvar : 63.823

C. COMPARISON OF SIMULATION RESULTS WITH PGCB BASE CASE DATA

The simulated results of the voltage magnitudes and phases of the 71 buses in the network were tabulated. In this section we compared the simulated results with PGCB Base Case Data and they are shown in Table V. Table V compares the bus voltage magnitudes obtained from PSAT and ETAP to Base Case data from PGCB, Graphical comparison for all the 71 buses data is shown in Fig. 4.

TABLE V. COMPARISON OF VOLTAGE MAGNITUDES BETWEEN PSAT, ETAP AND PGCB DATA OF SOME RANDOMLY SELECTED BUSES

Bus Name	Voltage Magnitude from PSAT (kV)	Voltage Magnitude from ETAP (kV)	Base Case Data from PGCB (kV)
[1]- SONARGAON	132	132	132
[2]- BHULTA	127.3417	130.906	130
[30]-JOYDEVPUR	138.996	130.319	139
[31]-K. CHAR	128.1551	130.187	134
[32]-KABIRPUR	132.905	130.096	137
[50]-MUNSHI	134.9964	132	135
[51]-MYMENSINGH	130.02	129.468	130
[52]-N. TONGI	132.99	131.014	133
[57]-RPCL	132	129.597	132
[58]-RSRM	131.8853	131.975	132
[59]-SARISHABARI	133.8082	127.979	132
[60]-SATMASJID	118.4504	130.437	135
[61]-SAVAR	142.56	131.346	133

This table contains the details of total 10 buses out of 71 buses.

The voltages of all the buses can be observed from the following graph in figure 4.

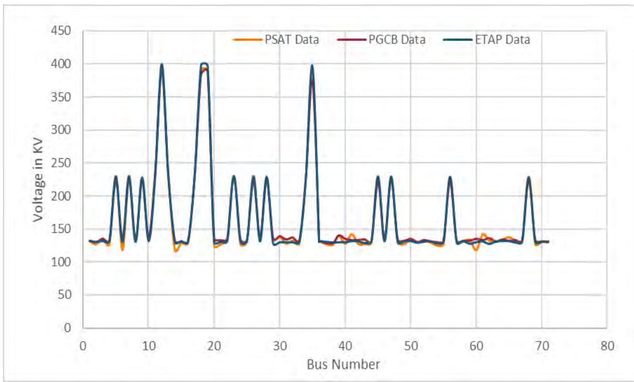

Figure 4. Comparison of Voltages between PSAT, PGCB and ETAP Data.

In this graphical diagram, the voltages of the buses are plotted in the X axis and the Bus numbers along the Y axis. It can be observed that the voltages of the simulation results obtained from PSAT and ETAP are very close to that of the PGCB data.

V. CONCLUSION

This paper contains the load flow simulation of Dhaka Circle by using the PSAT software is which is an open source toolbox for MATLAB and EPAT software which is a high impact commercial software used worldwide for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. The power flow took a total of 0.39 seconds to complete the simulation for PSAT. The PSAT simulation shows a deviation of around 0.476% to the Bus Voltages from that of PGCB and the ETAP simulation shows a deviation of about 0.221% to the Bus Voltages from that of PGCB data due to the reason that the PGCB data is taken for the whole of Bangladesh whereas the data from PSAT and ETAP is only considered for the Dhaka Circle. Moreover, there is a difference of 0.256% between the voltages of PSAT and ETAP This paper should act as a guideline for the future improvement of power quality as well as introducing a new generator or a new load to the existing model of the Dhaka Grid Circle.

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