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ETAP Load Flow Result Validation with Stevenson Textbook Example

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***Abstract*: Electrical Transient Analyzer Program (ETAP) is the user-friendly software which is used in power system studies through worldwide consultancy companies. This research paper deals with the simulation of Stevenson textbook load flow example in ETAP software and to validate the ETAP simulated load flow results.**

***Keywords*: ETAP, Load flow.**

1. Introduction

Power companies use very elaborate programs for making load-flow studies. A typical program is capable of handling systems of more than 2000 buses, 3000 lines, and 500 transformers. Of course programs can be expanded to even greater size provided the available computer facilities are sufficiently large.

Load flow analysis using software is effective and efficient with highly reliable results. This research makes effective use of Electrical Transient Analyzer Program (ETAP) to carry out load flow analysis of 138 kV 5 bus system, as shown in figure 1. The actual ratings of buses, generators and impedances are taken from the Stevenson book “Elements of Power System Analysis, fourth edition, Chapter 8”, [2] and modelled accordingly in ETAP. The five bus system comprises of two generators, five buses, six impedances forming loop between all the buses of 138 kV and lumped load connected to each bus.

The main aim is to validate the results given in the Stevenson textbook example 8.1 with the ETAP Load Flow Analysis Module [2].

Table 1
Details of Components

Component		kV	Rating		Mode
Generator	Gen 1	138	300 MW		Swing mode
	Gen 2	138	200 MW		PQ mode
Loads	Load 1	138	65 MW	30 Mvar	
	Load 2	138	115 MW	60 Mvar	
	Load 3	138	70 MW	40 Mvar	
	Load 4	138	70 MW	30 Mvar	
	Load 5	138	85 MW	40 Mvar	
Impedances		kV	R+jX (pu)	Charging Mvar	Length (kM)
	Z1 (Bus1 to Bus2)	138	0.042+j0.168	4.1	64.4
	Z2 (Bus1 to Bus5)	138	0.031+j0.126	3.1	48.3
	Z3 (Bus3 to Bus5)	138	0.053+j0.21	5.1	80.5
	Z4 (Bus2 to Bus3)	138	0.031+j0.126	3.1	48.3
	Z5 (Bus4 to Bus5)	138	0.063+j0.252	6.1	96.5
	Z6 (Bus3 to Bus4)	138	0.084+j0.336	8.2	128.7

Table 2
Calculated data

LOAD ID	Active Power P (MW)	Reactive Power Q (MVAR)	TAN PHI (=Q/P)	PHI=ATAN (Q/P)	Power Factor (=COS PHI)
L1	65	30	0.4615	0.4324	0.9080
L2	115	60	0.5217	0.4809	0.8866
L3	70	40	0.5714	0.5191	0.8682
L4	70	30	0.4286	0.4049	0.9191
L5	85	40	0.4706	0.4398	0.9048

Table 3

Impedances ID	From bus - to bus	Charging MVAR	Y act (mho)	Ybase (mho)	Y (pu)
Z1	1 to 2	4.1	0.0002	0.0053	0.041
Z2	1 to 5	3.1	0.0002	0.0053	0.031
Z3	3 to 5	5.1	0.0003	0.0053	0.051
Z4	2 to 3	3.1	0.0002	0.0053	0.031
Z5	4 to 5	6.1	0.0003	0.0053	0.061
Z6	3 to 4	8.2	0.0004	0.0053	0.082

2. Simulation of Example in ETAP Software

Fig. 1 show the two generators which supplies power to the 138 kV buses through the various connection of branch impedances. These impedances represents that two buses can be connected to each other through cables or transmission lines. The loop system is formed by interconnecting these impedances to generators.

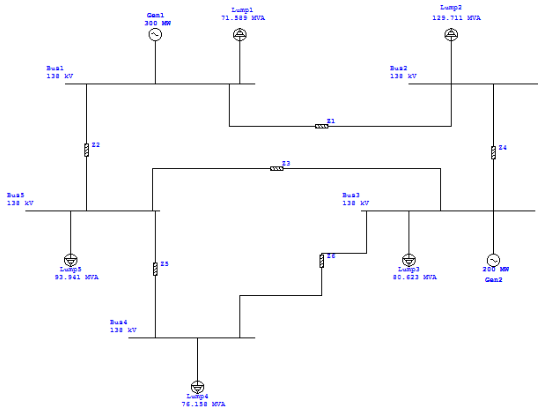


Fig. 1. Simulated diagram of 138 kV loop connected system using ETAP

3. Load Flow Analysis

Fig. 2 shows the Load Flow Analysis of the 138 kV substation carried out using ETAP in which Newton-Raphson method is used. It is observed that at the bus 4 there is under voltage which can be clearly seen from the Fig. 2. The voltage level at bus 4 is 92.03%. The permissible voltage at each 138 kV bus is ± 5 % i.e. (95 % to 105 %).

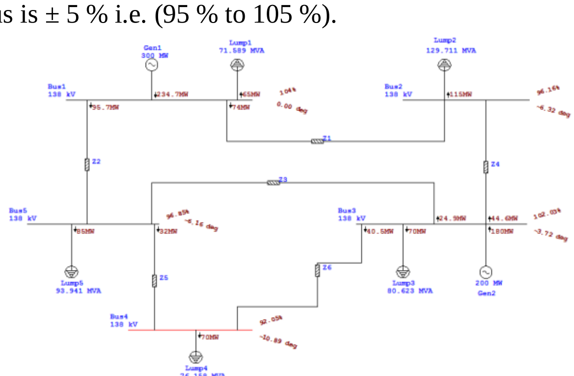


Fig. 2. Load flow results

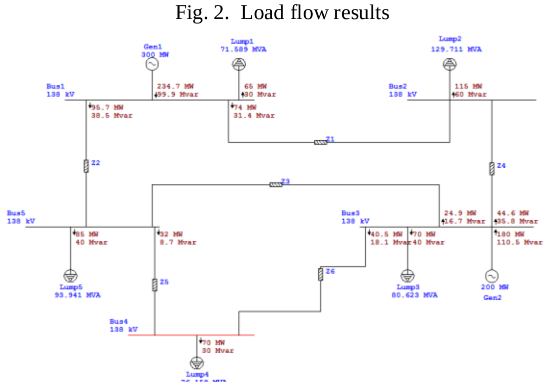


Fig. 3. Active and reactive power flow

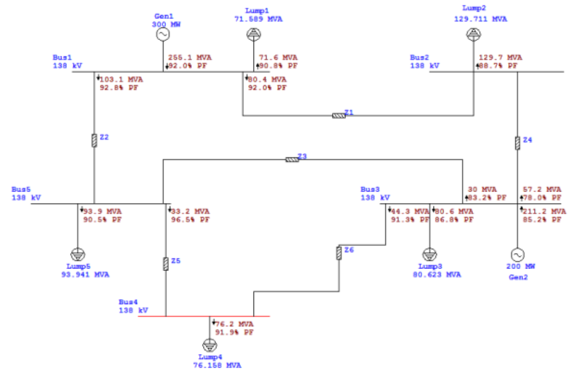


Fig. 4. Apparent power and power factor flow

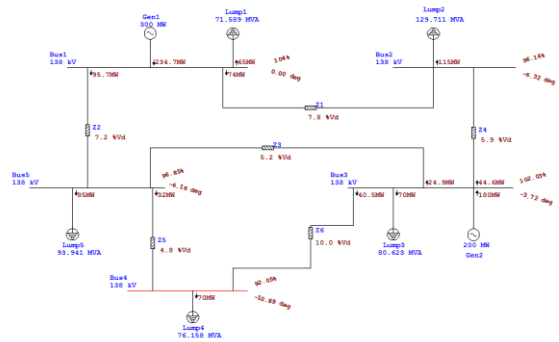


Fig. 5. Voltage and delta angle at each bus

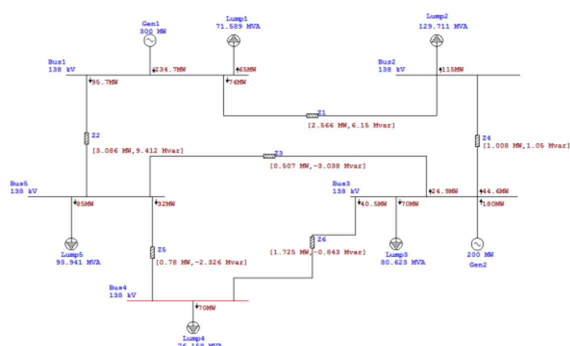


Fig. 6. Losses through each branch

Table 4 shows that the real power on swing bus i.e. at BUS 1 is 234.7 MW and the reactive power is 99.9 Mvar and the power factor is 92 %.

Table 4

Bus ID	KV	MW	MVAR	PF (%)
BUS 1	138	234.7	99.9	92
BUS 2	138	115	60	88.7
BUS 3	138	180	110.5	85.2
BUS 4	138	70	30	91.9
BUS 5	138	85	40	90.5

Below table 5 shows the ETAP calculated results for voltage and voltage angle (delta) available at various buses.

Table 6 shows the demand and losses summary report which tells us about the total demand of the system and also about the losses that occurs in a system.

Table 5

Bus ID	Voltage (pu)	Angle (degree)
BUS 1	1.04	0
BUS 2	0.961	-6.32
BUS 3	1.02	-3.72
BUS 4	0.92	-10.89
BUS 5	0.96	-6.16

Table 6

Type	MW	MVAR	MVA	% PF
Source (Swing Bus)	234.67	99.90	255.05	92.01
Source (Non-Swing Bus)	180	110.5	211.21	85.2
Total Demand	**414.67**	**210.4**	464.99	89.1
Total Motor load	**405**	**200**	451.69	89.6
Apparent losses	**9.67**	**10.40**		

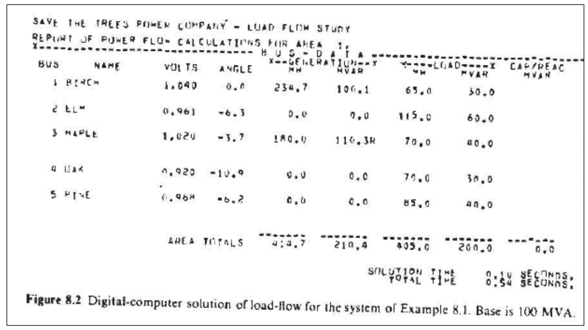
4. ETAP Alerts During Load Flow Analysis

After carrying out load flow analysis using ETAP software, an alert summary report is generated which tells that which part of the system needs immediate attention and it can be clearly seen from the Table 7 that the Bus 4 is operating at an under voltage.

Table 7

Device ID	Condition	Rated Voltage (kV)	Operating Voltage (kV)	Operating Voltage (%)
Bus 4	Under Voltage	138	127.03	92.1

5. Load Flow Results Given in Stevenson Textbook


SAVE THE TREES POWER COMPANY - LOAD FLOW STUDY
REPORT OF POWER FLOW CALCULATIONS FOR AREA 1,
B U S - D A T A

BUS	NAME	VOLTS	ANGLE	GENERATION MW	GENERATION MVAR	LOAD MW	LOAD MVAR	CAP/REAC MVAR
1	BIRCH	1.040	0.0	234.7	106.1	65.0	30.0	
2	ELM	0.961	-6.3	0.0	0.0	115.0	60.0	
3	MAPLE	1.020	-3.7	180.0	110.3R	70.0	40.0	
4	OAK	0.920	-10.9	0.0	0.0	70.0	30.0	
5	PINE	0.968	-6.2	0.0	0.0	85.0	40.0	
	AREA TOTALS			414.7	210.4	405.0	200.0	0.0

SOLUTION TIME 0.10 SECONDS.
TOTAL TIME 0.54 SECONDS.

Figure 8.2 Digital-computer solution of load-flow for the system of Example 8.1. Base is 100 MVA.

Fig.7. Load Flow Results given in Stevenson Textbook

Table 8

Bus ID	Voltage (pu)	Angle (degree)	P MW	Q MVAR	Load demand	
					MW	MVAR
BUS 1	1.04	0	234.7	100.1	65	30
BUS 2	0.961	-6.3			115	60
BUS 3	1.02	-3.7	180	110.38	70	40
BUS 4	0.92	-10.9			70	30
BUS 5	0.96	-6.2			85	40
		TOTAL	**414.7**	**210.48**	**405**	**200**

6. Conclusion

In this paper the validation of the load flow results carried out using ETAP Load Flow Analysis Module with Stevenson textbook example 8.1 is performed.

From Table 5, Table 6 and Table 8 it is found that the ETAP software results exactly matches with the results obtained through the Stevenson textbook example.

References

[1] Rohit Kapahi, “Load Flow Analysis of 132 kV substation using ETAP Software,” International Journal of Scientific & Engineering Research Volume 4, Issue 2, February 2013.

[2] William D. Stevenson, “Textbook for “Elements of Power System Analysis,” Fourth edition.