

Transient and Harmonic Analysis of IEEE 9-Bus System using ETAP

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Abstract - This research paper presents a transient analysis of a 9-bus power system using ETAP software. The simulation results obtained from ETAP are analyzed in terms of voltage and current waveforms, fault current magnitudes. However, the system experiences voltage and current fluctuations during fault conditions, which can lead to instability if not properly addressed.

Key Words: ETAP, Frequency Stability, Harmonic Analysis, IEEE-9 Bus Test System, Load Flow Study, Transient Stability.

1.INTRODUCTION

The use of transient analysis utilizing ETAP software can be used to address the serious power quality issues that modern power system is now experiencing[1]. This modeling approach is used to examine how the power system responds to various transient situations, such as voltage sags, swells, and other disturbances. Analysis of the voltage and current waveforms, fault current magnitudes, and relay coordination of the simulation results from ETAP is possible. The main reason for significant power system problems is undervoltage, as voltage variations cause reactive power (VARs) to flow. Stability studies are used to assess the stability state of the power system. For the IEEE-9 Bus test system that is simulated using ETAP, the Load Flow study and Transient Stability study are described and carried out.

1.1 Swing Equation

The swing equation governs the motion of the machine rotor relating the inertia torque to the resultant of the mechanical and electrical torques on the rotor.

$$M_i \frac{d^2 \delta_i}{dt^2} = P_{m_i} - P_{e_i}, i=1,2,3, 4, \dots, n \quad \text{-----}(1)$$

With:

δ_i = rotor angle of the i-th machine;

M_i = inertia coefficient of the i-th machine;

P_{m_i}, P_{e_i} = mechanical and electrical power of the i-th machine;

E_i = voltage behind the direct axis transient reactance;

G_{ij}, B_{ij} = real and imaginary part of the ij-th element of the nodal admittance matrix reduced at the nodes which are connected to generators

1.2 Transient stability

Transient stability is essential when building an electric power system, as it evaluates the power system's ability to withstand or sustain disturbances and make it through a changeover to a regular operational condition. System variables such as transmission line short circuits, generator loss, drop in

load, rotor angle excursions, bus voltages, and power flows can lead to disruptions[2]. Power quality is a variety of electromagnetic phenomena that specify voltage and current at a certain time and location.

1.3 Load Flow

Depending on the stipulated quantity, the buses are divided into 3 groups: Load Bus, Voltage-controlled Bus, and Swing Bus / Slack Bus[3]. Knowledge of pre-fault voltage magnitudes and transient stability is required, as well as real and reactive powers on transmission lines, bus voltage magnitudes and phase angles, real and reactive powers at generator buses, and other required variables. By using the Newton-Raphson (N-R) iteration approach, the findings of load flow studies may be used to determine the prior fault (pre-fault) conditions.

1.4 Harmonic Analysis

Harmonics are caused by nonlinear loads on electronic equipment drawing incurrent in sharp, brief pulses, which recirculate distorted current waveforms into other components of the power system. They can lead to issues such as overloading neutral conductors, overheating transformers, annoying breaker trips, overloading capacitor banks, and skin effect. Total Harmonic Distortion (THD) is the proportion of the total power of all harmonic components to the fundamental frequency.

1.5 IEEE Nine Bus System

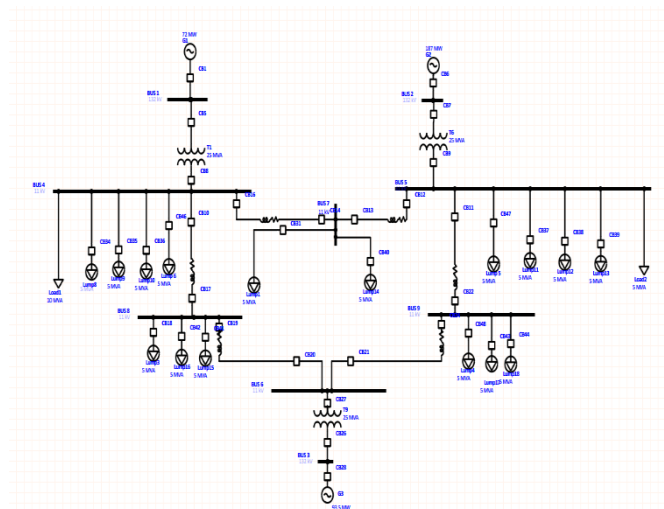


Fig -1: Single Line Diagram of IEEE Nine Bus System

Three generators, three transformers, and Eighteen loads make up this paper. In this system, generators, transformers, and loads are listed in the appendix. Generators G2 and G3 are linked to PV-bus, whereas generator G1 is connected to slack bus 1. Bus bars 5, 6, and 8 are used to link loads A, B, and C, correspondingly. There are 313MW of total generation and 347.5MW of total load. We have looked at two cases. The first instance was thought of without a three-phase defect, while the second case was thought of with a three-phase.

2. Methodology

The most important details in this work are the steps required to use ETAP to do a transient study of a 9-bus system. This includes choosing the "Transient Stability" option when building a new project, creating a one-line diagram, providing system parameters, specifying fault circumstances, setting up simulation settings, running the simulation, and examining the outcomes. Verifying the data used in the simulation, using suitable models for the generators, transformers, transmission lines, and loads, and doing sensitivity analysis are all advised to increase the accuracy of the simulation findings. With the help of ETAP, precise and trustworthy findings can be obtained.

3. System Simulation and Load Flow Analysis

This paper simulates an IEEE 9 bus system on ETAP 19.0.1. The load parameters and system generator are listed in the appendix. The total generation is 313MW and the total load is 347.5MW. It is good practice to have periodic and updated load flow study for every installation. Many load flow solution techniques, including Gauss-Seidel, Newton-Raphson, and current injection, are employed in industry. The network must include at least one swing bus.

Table -1: Values provided to the system

Bus No.	Bus KV	Voltage (Magnitude)	Voltage (Angle)	Generation (MW)	Generation (Mvar)	Total Bus Load		
						MVA	%PF	Amp
1	132	132.00	0.0	-39.839	69.392	80.015	49.8	350.0
2	132	132.00	61.3	40.00	0.813	40.008	100.0	175.0
3	132	132.00	61.3	40.00	0.808	40.008	100.0	175.0
4	11	9.215	7.3	0	0	67.030	60.4	4199.7
5	11	10.986	55.6	0	0	39.958	99.7	2099.9
6	11	10.986	55.6	0	0	39.963	99.7	2100.1
7	11	9.226	33.7	0	0	33.551	89.5	2099.6
8	11	9.226	33.7	0	0	33.560	89.5	2100.1
9	11	10.986	55.6	0	0	0.006	70.7	0.3

4. Result and Conclusion

For Transient Analysis, Bus 1 and Bus 2 were faulted At T = 1.0 sec Line to Ground Fault occurred at bus 1 and fault cleared at 1.2 sec , the Circuit Breaker 1 and 5 are operated.

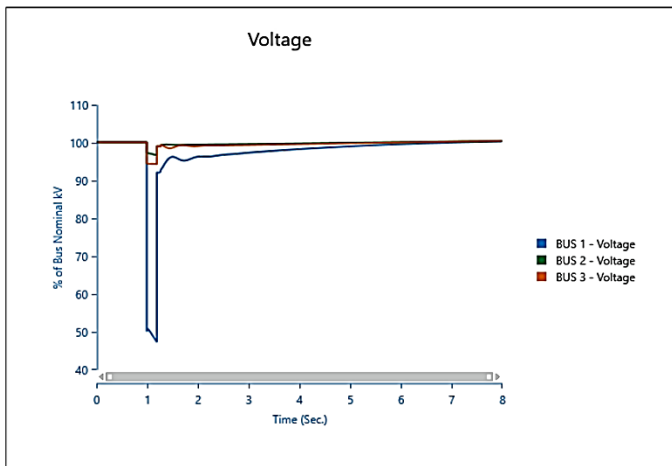


Fig-2: Bus Voltages when fault occurred at bus 1

At T = 1.0 sec Line to Ground Fault occurred at bus 2, the Circuit Breaker 6 and 7 are operated.

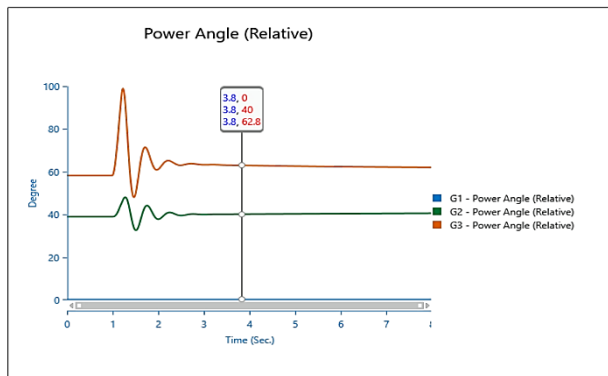


Fig-3: Bus Voltages when fault occurred at bus 2

Similarly, When Line to Ground Fault occurred at Bus 1,Bus 2, the relative power angle for Gen 1, Gen 2, Gen 3 were simulated through plot manager.

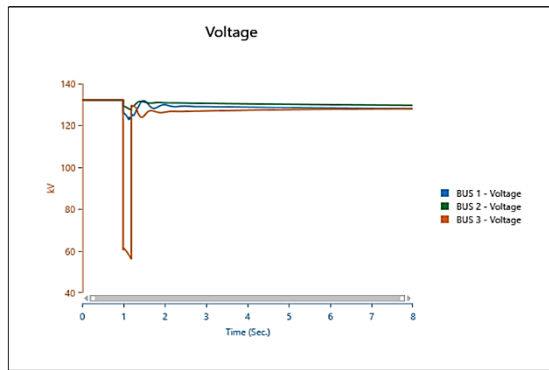


Fig-4: Relative power angles when fault occurred at bus 1

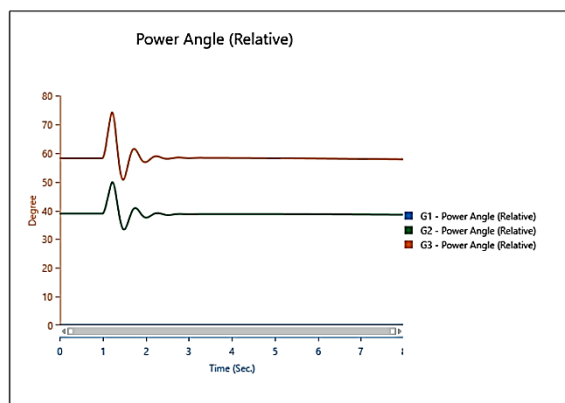


Fig-5: Relative power angles when fault occurred at bus 2

Now moving towards Harmonic Analysis, We need to connect a static load at Bus 4 and Bus 5. So Two static loads of 10 MVA and 5 MVA were connected to Bus 4 and Bus 5.

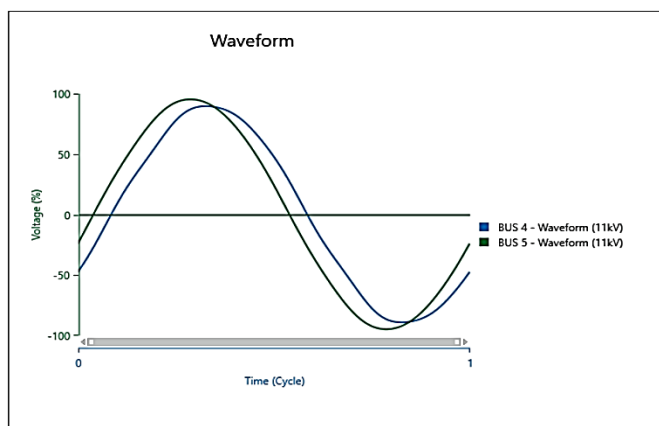
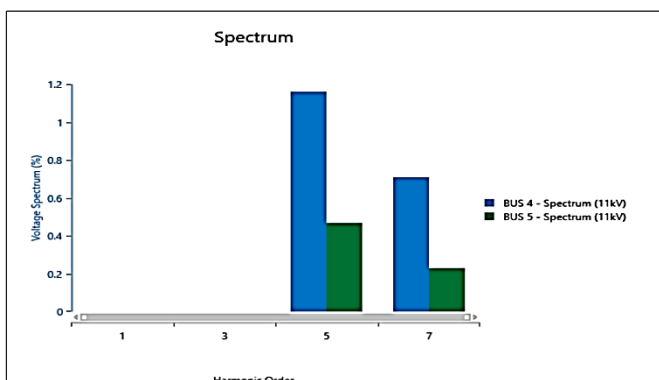


Fig-6: Waveform of Bus 4 and Bus 5 after Harmonic Analysis

Chart-1: Spectrum Chart of Bus 4 and Bus 5 after Harmonic Analysis



3. CONCLUSIONS

This study investigated the stability of the IEEE 9-Bus Electrical Power System. Transient stability analysis was performed on ETAP software, system frequency and voltage was analyzed for different loading conditions, and harmonic analysis was done attaching two static loads. Results showed that before a fault, the system took a few seconds to stabilize,

while following a malfunction, the system needed significantly longer time to stabilize and even rapid changes in the system were seen.

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BIOGRAPHIES



I am an electrical engineer from Hetauda, Nepal who graduated from Tribhuvan University with a Bachelor of Engineering degree. I have excelled in technical and soft skills, including Microsoft PowerPoint, Adobe Illustrator, Photoshop, Python, Object-Oriented Programming, Domestic Wiring, and MATLAB programming