INTERNATIONAL JOURNAL FOR SCIENTIFIC AND ENGINEERING RESEARCH VOLUME 3,ISSUE 12,DECEMBER 2012
ISSN 2229-5518

Transient Stability of IEEE-30 bus system using E-TAP Software

Kavitha R

Abstract— The main objective of this paper is to perform transient stability analysis using the electrical power systems design and analysis software namely ETAP. The purpose of performing transient stability on the power system is to study the stability of a system under various disturbances. The stability of the power system is the ability of generators to remain in synchronisation even when subjected to disturbances. In this research work a standard IEEE 30-bus system, subjected to various disturbances is considered. The swing curves for the various generators of IEEE 30-bus system is plotted to comment on the stability of the system. The factors affecting the stability are analysed and methods for obtaining a better stability of the system under the fault conditions are also studied.

Index Terms Transient Stability, Rotor angle, Power Angle, ETAP

1 INTRODUCTION

Transient stability deals with study of the system after a large disturbance. Due to a large disturbance the synchronous alternator the machine power angle changes because of sudden acceleration of the rotor shaft. The ultimate aim of transient stability is to determine if the load angle returns to a steady value after clearance of disturbance. The recovery of a power system subjected to a severe large disturbance is of interest to system planners and operators. System should be designed properly of good quality to supply continuous power to loads and operated such that specified number of credible contingencies does not lead to failure of the system.

Stability is the capability of a system to be able to develop restoring forces equal to or greater than the disturbing forces to maintain equilibrium. If the system is able to overcome the disturbing forces and be able to hold the forces tending to hold the machines in synchronism with one another the system is said to be in equilibrium or stable. The two major stability problems are steady state stability and transient stability. The ability of a power system to regain its synchronism after a disturbance such as gradual power changes is called steady state stability. An extension of steady state stability is the dynamic stability. Dynamic stability deals with small disturbances for a long time.

Transient stability studies deals with the effect of large, sudden disturbances such as effect of large sudden outage of line, occurrence of fault, or the sudden application or removal of loads. To ensure that a system can withstand the transient condition following a disturbance, transient stability analysis should be performed. This analysis can be used to determine other things such as nature of the relaying system, critical clearing time of circuit breakers, voltage level and transfer capability between systems. It also involves determining whether synchronism is maintained after the machine has been adjusted to severe disturbance.

Following the dynamic events the operating limits of equipments shall remain within the normal operating limits or return fast to normal limits.

Classification of Power system stability

The dynamic events can be large disturbances after which the system must be able to continue and service loads without loss of load and quality. The response of the system to large disturbances and its ability to return to normal operating conditions is generally termed transient stability or large signal performance of the system.

Voltage profile is sensitive to the operation point and system structure when the system has multiple voltage levels. Majority of loads are large motors. Even if the system is connected to bulk system it may operate isolated at extremely fault contingency. Now the system faces the requirement of frequency stability and control.

The machine rotor angles are subjected to large excursions due to occurrence of disturbance and there is loss of synchronism among machines. Loss of synchronism can be seen in few seconds of occurrence of disturbance. Transient stability phenomenon is one of the fastest to develop.

Swing equation is the electromechanical equation describing relative motion of the rotor load angle (δ) with respect to the stator field as a function of time is known as Swing equation.

In most disturbances,linearization is not permissible and the nonlinear swing equation must be solved because oscillations are of such magnitude . E*qual-area criterion* is used for a quick prediction of stability. The stability is determined based on the graphical interpretation of the energy stored in the rotating mass as an aid . This is only applicable to a one-machine system connected to infinite bus system.

Software used

The simulation software used here is E-Tap or Electrical Transient Stability Analysis Program by Operation Technology. There are different analyses that can be performed on a bus system using this software. Load flow analysis, short Circuit Analysis, Arc Flash analysis, Harmonic Analysis, Transient stability analysis etc. The one line diagram for IEEE-30 bus system is drawn in the editor of E-Tap Power Station version 4. E-Tap is very user friendly graphical electrical analysis software that can be run in Windows, XP, Microsoft and Vista Operating systems. The results of the analysis on prototype models is used for real time simulation, optimization, advanced monitoring and intelligent load shedding at high speeds. E-Tap allows the user to reduce very large and complex power systems into simple one line diagram and performs operations on it like load the system, subject the system to contingency and study the characteristics of faults. These virtual faults in the simulation model can be compared to the real time system faults. The e tap program is designed on three key concepts. They are Virtual reality operation, Total integration of data and simplicity in data entry.

IEEE 30 bus system

The test system that has been considered here is the IEEE-30 bus system. Using the data referred from Alsac O. & Stott B, "Optimal Load Flow with Steady State Security", and the IEEE 30 bus system is designed in E-Tap software. The bus system is a prototype, and real time systems are designed and developed with reference to such prototype models. Theprototypes are subjected to contingency analysis and results are obtained. The load flow analysis and transient stability for the standard IEEE-30 bus system are performed. The standard IEEE 30 bus system consists of 30 buses, 6 generators, 24 loads and 4 transformers. Generator 1 is in swing Mode. The other Generators are in

Voltage Control Mode.Generators are rated 135kV,Speed 1800 rpm and 4 pole .The 30 buses in the standard IEEE-30 bus System are 135kV and 140 kV.All loads in service in the test Sytem are 3- phase and 135kV.The lines have impedance in Ohms per Kilometer.The transformers are 3-phase and rated for 135 kV-140kV.

The IEEE 30 bus system used for the load flow and transient state analysis is shown as follows along with the ratings of its components.

Load Flow Analysis

Load flow analysis, also called as power flow analysis is an important tool using numerical analysis of a power system. The basic knowledge required to perform load flow analysis of a system is to understand the one line diagram and the representation of the components of the power system in it's per unit values. The one line diagram gives the simplified notation of any three phase power system. It represents the transformers, generators, transmission lines, isolators, switch gears etc in simplified notation and the three phase lines are just represented by a single line. The one line diagram does not give the representation of the exact length of the lines and is used for the purpose of power flow studies. It organises the power system in a specific order like from top to bottom or left to right, to make the system easy for analysis. The per unit system represents all the components of a system with the reference to a base value. This makes the calculations of the analysis process simple and easy.

In a closed power system, the power generated at the generating stations flows through all the componentsof the power systems, like the transformers, lines, buses and the circuit breakers. The study of the flow of active and reactive power through the components of the power system is called as load flow study or power flow study. It helps in determining the steady state operation of the power system. The system characteristics like the power factor, amount of power consumed by the loads, power through the transmission lines etc gives the details about the design of the power system with the appropriate transformers and transmission lines. Any power system before installing, undergoes the load flow analysis with the help of its equivalent one line diagram along with the per unit values of the components, so that they can be designed with the selection of the correct range of components. In this way, it helps in the planning the stages of new networks along with other networks. The effective analysis of the load flow of a system helps to minimize the losses of the power system too. The line flows help in curbing the operation of that line, when it nears the maximum capacity of the line, that is, when it affects the stability or the thermal limits. This keeps the line safe from problems of overloading.

A bus is a node to which transmission lines, generators, loads and transformers are connected. A bus in a power system is associated with four quantities namely, voltage magnitude, phase angle, active and reactive power of the bus. Buses are classified based on the voltage magnitude and phase angle as load bus, generator bus or voltage controlled bus and slack or swing bus.

Load bus

The bus is not connected to any generators. The real and reactive powers are specified and the phase angle and magnitude of voltage are specified from the solution of the load equations.

Generator bus

The voltage magnitude and the real power of the system are specified and it is desired to find the reactive power and phase angle of the bus voltage. *Swing bus*

The magnitude of the voltage of this bus is considered to be a constant value and does not change through the evaluation process. The load flow solutions are used to find the real and reactive power of the bus, while the voltage magnitude and phase angle of voltage are known.

There are three methods to perform load flow analysis.

They are specified as follows.

1. Guass Siedal method
2. Newton Raphson method
3. Fast decoupled method

The load flow analysis is studied by Newton Raphson method in this paper.

Newton Raphson Method

Load flow analysis has to be carried out first for any system to determine the power consumed by each of the loads, pre-fault and post fault currents. So, load flow analysis is done by Newton Raphson algorithm in this pretext.

The number of iterations set for the system in the Newton Raphson algorithm is 10, but the system is found to converge in 3 iterations. The system frequency is assumed to be 60 Hz. Bus 1 is considered to be the swing bus. The bus input data, line/cable data, reactor data, and branch connections are input to the system with reference to the Alsac O. & Stott B, "Optimal Load Flow with Steady State Security". The load flow report is generated which gives the details of the load flows in each of lines connecting the buses, their power factor, operating voltage of the generator buses, loading of the transformers and losses in the transmission lines.

The transient stability analysis of the system is performed in the IEEE 30 bus system. Any of the system components can be chosen for the occurrence of fault. For instance, the fault is considered to be occurring in line 21. The device type selected for transient stability study case is line 21 and the plot type is chosen to be Power angle of Generators. The plot showing the transient stability of the system, when a disturbance occurs in the line is obtained. This graph is as follows.

To add an event to study the transient stability Transient Stability Study Case is opened and the options are chosen. In the Events tab events are added.

The plot type can also be chosen as frequency, which indicates the changes in the frequency of the system from the occurrence of the fault till its clearance.

The fault is occurred in the bus 1 at time 0.010 seconds and is cleared at time 0.060 seconds with 9999 iterations set for transient state analysis. The dynamic stability of the system with fault at line 21

Load Details

BUS NO	LOAD		BUS NO	LOAD	
1	0.0	0.0	16	3.5	1.8
2	21.7	12.7	17	9.5	5.8
3	2.4	1.2	18	3.2	0.9
4	7.6	1.6	19	9.5	3.4
5	94.0	19.0	20	2.2	0.7
6	0.0	0.0	21	27.5	11.2
7	22.8	10.9	22	0.0	0.0
8	30.0	30.0	23	3.2	1.6
9	0.0	0.0	24	8.7	6.7
10	5.8	0.0	25	0.0	0.0
11	0.0	0.0	26	3.5	2.3
12	11.2	7.5	27	0.0	0.0
13	0.0	0.0	28	0.0	0.0
14	6.2	1.6	29	2.4	0.9
15	8.2	2.5	30	10.6	1.9

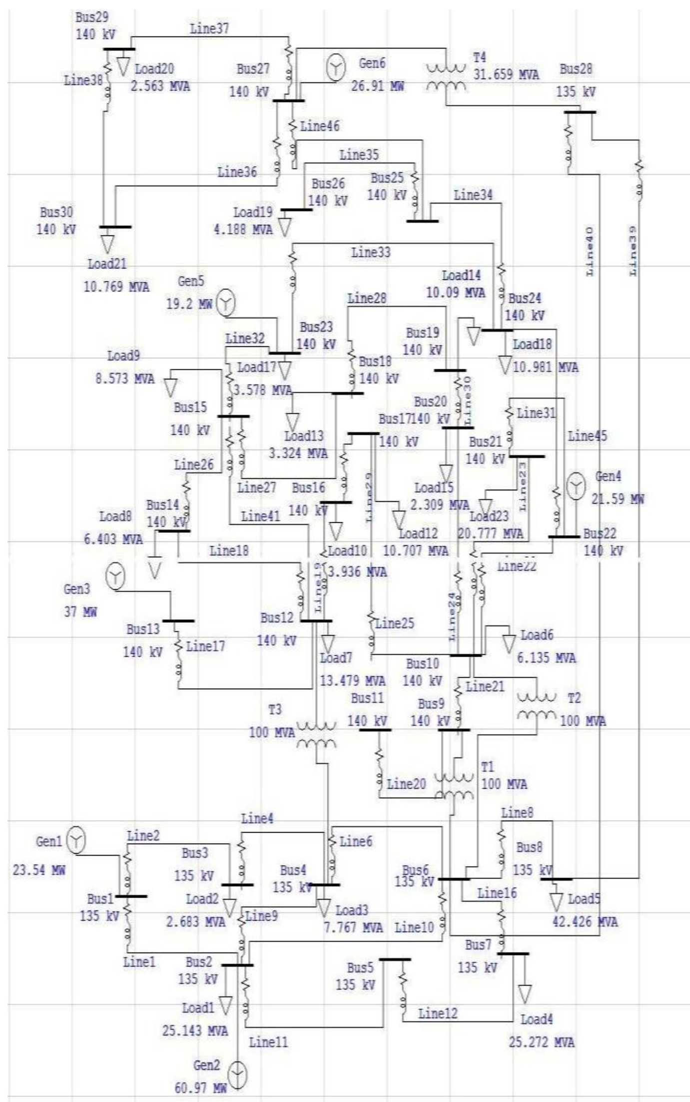
Generator Details

Bus no	Pg min	Pg max	Qg min	Sg max	a	b	C
1	50	200	-20	250	0	2.0	.00375
2	20	80	-20	100	0	1.75	.0175
5	15	50	-15	80	0	1	.0625
8	10	35	-15	60	0	3.25	.00834
11	10	30	-10	50	0	3.0	.025
13	12	40	-15	60	0	3.0	.025

Geneator Power angles

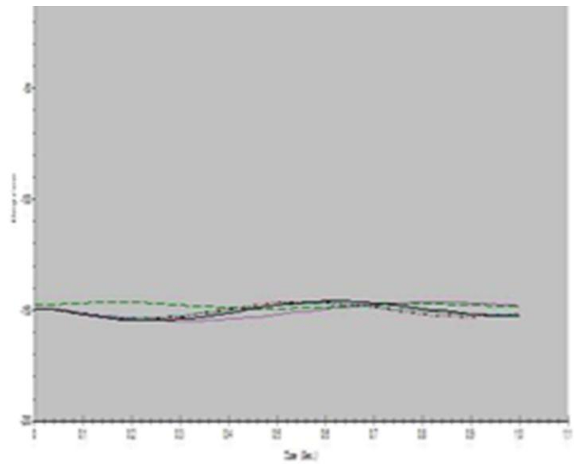
Generators	Power Angles
Generator 1	0 deg
Generator 2	-147.8 deg
Generator 3	-149.4 deg
Generator 4	-149.4 deg
Generator 5	-149.2 deg
Generator 6	-149.4 deg

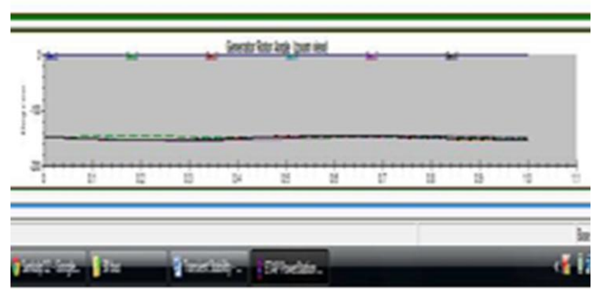
Simulation Of an IEEE-30 bus System in E-Tap Software

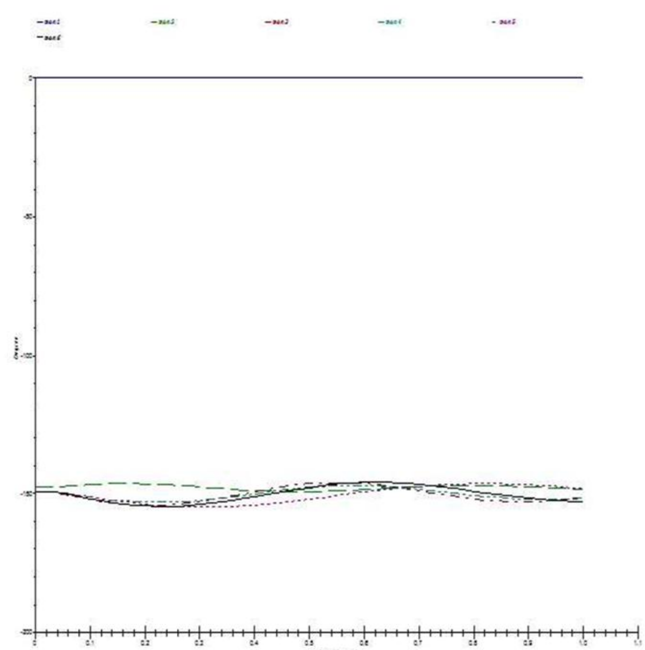


Branch details

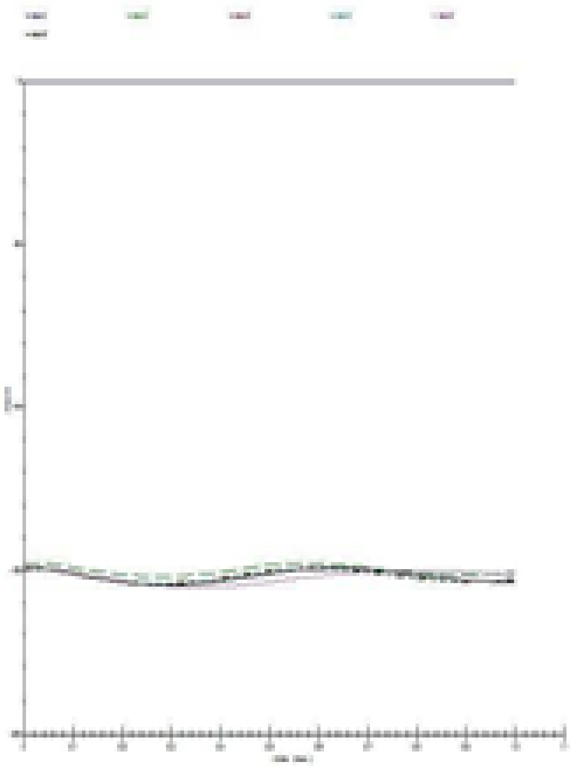
Branch No.	Bus No's	R p.u.	X p.u.	B(total) p.u.	Rating MVA
1	1-2	0.0192	0.0575	0.0264	130
2	1-3	0.0452	0.1852	0.0204	130
3	2-4	0.0570	0.1737	0.0184	65
4	3-4	0.0132	0.0379	0.0042	130
5	2-5	0.0472	0.1983	0.0209	130
6	2-6	0.0581	0.1763	0.0187	65
7	4-6	0.0119	0.0414	0.0045	90
8	5-7	0.0460	0.1160	0.0102	70
9	6-7	0.0267	0.0820	0.0085	130
10	6-8	0.0120	0.0420	0.0045	32
11	6-9	0.0	0.2080	0.0	65
12	6-10	0.0	0.5560	0.0	32
13	9-11	0.0	0.2080	0.0	65
14	9-10	0.0	0.1100	0.0	65
15	4-12	0.0	0.2560	0.0	65
16	12-13	0.0	0.1400	0.0	65
17	12-14	0.1231	0.2559	0.0	32
18	12-15	0.0662	0.1304	0.0	32
19	12-16	0.0945	0.1987	0.0	32
20	14-15	0.2210	0.1997	0.0	16
21	16-17	0.0824	0.1932	0.0	16
22	15-18	0.1070	0.2185	0.0	16
23	18-19	0.0639	0.1292	0.0	16
24	19-20	0.0340	0.0680	0.0	32
25	10-20	0.0936	0.2090	0.0	32
26	10-17	0.0324	0.0845	0.0	32
27	10-21	0.0348	0.0749	0.0	32
28	10-22	0.0727	0.1499	0.0	32
29	21-22	0.0116	0.0236	0.0	32
30	15-23	0.1000	0.2020	0.0	16
31	22-24	0.1150	0.1790	0.0	16
32	23-24	0.1320	0.2700	0.0	16
33	24-25	0.1885	0.3292	0.0	16
34	25-26	0.2544	0.3800	0.0	16
35	25-27	0.1093	0.2087	0.0	16
36	28-27	0.0	0.3960	0.0	65
37	27-29	0.2198	0.4153	0.0	16
38	27-30	0.3202	0.6027	0.0	16
39	29-30	0.2399	0.4533	0.0	16
40	8-28	0.0636	0.2000	0.0214	32
41	6-28	0.0169	0.0599	0.0065	32







Generator Rotor angles for fault at line 9



Generator Rotor angles for fault at line 21

4 Conclusion

The transient stability studies are used to determine speed deviations, system electrical frequency, real and reactive power flows of the machines, the machine power angles as well as the voltage levels of the buses and power flows of lines and transformers in the system. System stability is assessed with these system conditions. Dynamic performance of a power system is critical in the design and operation of the system. The results can be printed or plotted and are displayed on the one- line diagram. The total simulation time for each study case should be long enough to obtain a definite stability conclusion. The power system stability which is an electromechanical phenomenon is defined as the ability of a synchronous machines in a system to remain in synchronism with one after a disturbance such as fault or fault removal in the system.

References

[1] Hadi Saadat,“***Power System Analysis*** ”.Edition 2007

[2] Optimal Load Flow with Steady State Security by 0.Alsac and Scott

[3] H. W. Dommel & W. F. Tinney, "Optimal power flow solutions", IEEE Trans. (Power App. & Syst.), Vol. PAS-87, pp. 1866-1876,October, 1968.

[4] H. D. Limmer, "Techniques and applications of security calculations applied to dispatching computers", paper STY4,Proc. Power Syst. Comp. Conference, Rome, 1969.

[5] E-Tap 7.0.0 Demo Guide by Operation Inc.

[6] Power System Transient Stability Analysis Using ETAP Software Jignesh S. Patel, Manish N. Sinha.

[8] Transaction Analysis in Deregulated Power Systems by R.W.Ferrero, S.M.Shahidehpour, V.C.Ramesh.

[9] Design of Optimal Power System Stabilizer using E-tap by Raja Nivedha.R, Sri Vidhya.L and V Geetha.