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Analysis of Transient Stability Using Power World Simulator

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***Abstract:** System stability study is the important parameter of economic, reliable and secure power system planning and operation. The fault is created on different buses and transient stability is analyzed for different load and generation condition. The load flow studies will perform to determine pre-fault conditions in the system using the Newton-Raphson method. With the help of three phase's balanced fault, the variation in power angle and frequency of the system will be studied. In this paper, transient stability analysis of nine bus system will perform using power world simulator.*

***Keyword:** Transient Stability, Load Flow, Three Phase Balanced fault, NINE Bus System.*

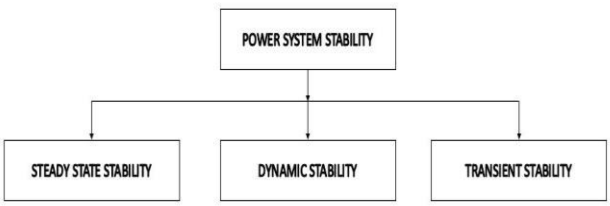
I. INTRODUCTION

Now-a-days it has become a necessity to maintain synchronism because the system is expanding day-by-day and these results in the installation of larger machines. Due to this, transient disturbances are increasing continuously in power system. The transient disturbances are caused by a change in load, switching operation, faults and loss excitation. Thus, it is very important to regain synchronism or equilibrium after disturbances in the electrical utilities. Hence, analysis of transient stability is required to reduce problems such as blackouts, loss of synchronism, etc. critical clearing time (CCT) is employed as a transient stability index to evaluate test system. Critical clearing time is defined as "The maximum time between the fault initiation and its clearing such that the power system is transiently stable.

Power system stability is the property of power system that enables it to remains in a state of equilibrium under normal condition and to regain equilibrium after being subjected to disturbances. Power system stability is defined as the capability of a system to maintain an operating equilibrium point after being subjected to a disturbance for given initial operating conditions. The power system is categorized based on the following considerations:

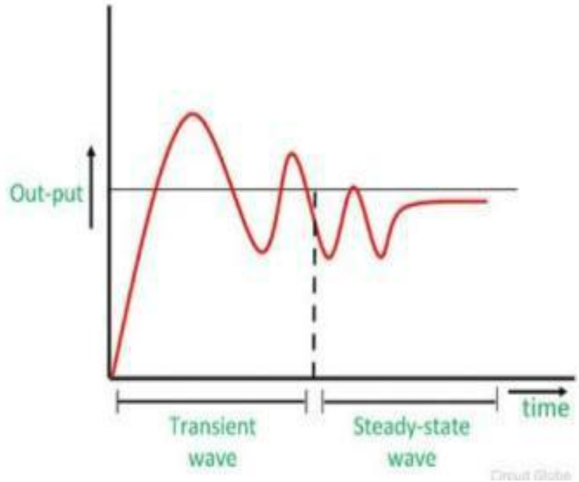
i. The nature of the resulting instability mode indicated by the observed instability on certain system variables
ii. The size of the disturbance which consequently influences the tool used to assess the system stability
iii. The time margin needed to assess system stability

Power system stability can be broadly grouped into steady state stability, transient stability, and dynamic stability.



Steady state stability is the capability of an electric power system to maintain synchronism between machines when small slow disturbance occurs. Increase in load is a kind of disturbance. If the increase in loading takes place gradually and in small steps and the system withstand this change and perform satisfactorily, then the system is said to be in steady state stability. Dynamic stability is the ability of a power system to remain in synchronism after the initial swing until the system has settled down to the new steady state equilibrium conditions. Transient stability is the ability of the system to remain in synchronism during the period of disturbance and prior to the time, that governor can act. The transient stability analysis is carried out for short time period that will be equal to the time of one swing.

Transient stability depends on both initial operating state of system and state when disturbance occurs. Instability is in the form of a periodic drift due to insufficient synchronizing torque and is refer to as first swing stability. Transient stability analysis is performed with the help of three phase balance fault. A fault which gives rise to equal fault current in the lines with 120-degree displacement is known as three-phase fault or symmetrical fault. The fault could happen when a phase establishes a connection with another phase, lighting, insulation deterioration, wind damage, trees falling across lines, etc. transient stability is conducted when new transmitting and generating system are planned. The behavior of synchronous machine during transient disturbances is described by swing equation. The transient and steady-state disturbance occur in power system are shown in the graph below. These disturbances reduce the synchronism of machine, and the system becomes unstable.



Power flow analysis is called the backbone of power system analysis. Power system fault analysis is one of the basic problems in power system engineering.

The single line diagram of IEEE 9 bus model is shown in the figure.

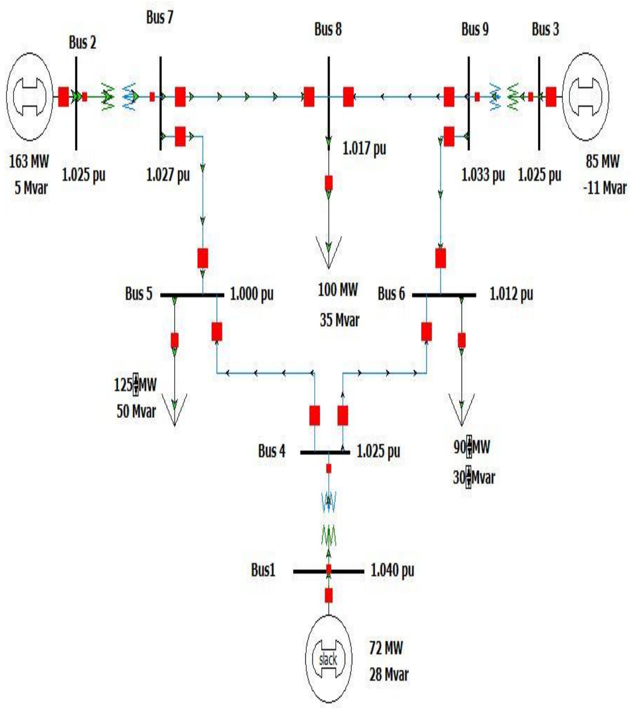


Figure IEEE 9 BUS MODEL in power word simulator

II. PROBLEM FORMULATION

A. Power flow studies:

In transient stability studies, it is necessary to have the knowledge of pre-fault voltages magnitudes. The main information obtained from the power flow study comprises of magnitudes and phase angles of bus voltages, real and reactive power on transmission lines, real and reactive power at generator buses, other variables being specified. The pre-fault conditions can be obtained from results of load flow studies by Newton-Raphson iteration method.

The Newton-Raphson method is the practical method of load flow solution of large power networks. Convergence is not affected by the choice of slack bus. This method begins with initial guesses of all unknown variable such as voltage magnitude and the angle at load buses and voltage angle at generator buses. Next, a Taylor Series is written, with the higher order terms ignored, each of the power balance equation included in the system of equations.

We first consider the presence of PQ buses only apart from a slack bus.

For an i^{th} bus,

Pi = $\sum_{=1}$| || || | cos(+ −) (| |,)

(1)

Qi=$\sum_{=1}$| || || | sin(↑ + −) (| |,)

(2)

i.e., both real and reactive power are function of (|V|,),

Where,

|V| = (|V1|,….,|Vn|^T) = (1, … , 2)^T

We write

Pi (|V|,) = Pi(x)

Qi (|V|,) = Qi(x)

Where,

x = [| |]

Let Pi and Qi be the scheduled power at the load buses.In the course of iteration, x should tend to that value which makes

Pi–Pi(x) = 0 and Qi – Qi(x) = 0

(3)

Writing equation (3) for all load buses, we get its matrix form

f (x) =

[(h) − ( )] = [$^{\Delta ( )}$] = 0

(h) − ( ) Δ ( )

(4)

At the slack bus, P1 and Q1 are unspecified. Therefore, the value P1 (x) and Q1(x) do not enter into the equation (3) and hence (4). Thus, x is a 2(n-1) vector (n-1 load buses), with each element function of (n-1) variables given by the vector x =[| |]

We can write,

f (x) = [$^{\Delta ( )}$] = [− 11( ) − 12( )] [Δ]

Δ ( ) − 21( ) − 22( ) Δ| |

(5)

Where, Δ = (Δ 2, , , , , Δ

)^T,

Δ| | = (Δ| 2| … Δ| |)^T

J(x) = [− 11( ) − 12( )]

− 21( ) − 22( )

J(x) is the jacobia matrix, each J11, J12, J21,J22 are (n-1) × (n-1) matrices.

-J11(x) = ( )

-J12(x) = ( ) | |

-J21(x) = ( )

-J22(x) = ( ) | |

The elements of –J11, -J12, -J21, -J22 are ( ), ( )||, ( ), ,
| |

Where i = 2…n; k =2…n.

From equation (1) and (2), we have
( ) = -| || || | sin(+ −)(=)
=∑ =1| || || | sin(+ −)(=)
≠

(7)
( ) = | || | cos(+ −)(≠)
| |

(8)
= 2| || | cos + ∑ =1| || | cos(+
≠
−)(=)
( ) = | || || | sin(+ −)(≠)
= ∑ =1| | | || | cos(+ −) (=)
≠

(9)
( ) = | || | sin(+ −)(≠)
| |
= 2| || | sin( ) + ∑ =1| || | sin(+
≠
−)(=) (10)

An important observation can be made with respect to elements of the Jacobian matrix. If there is no connection between i^{th} and k^{th} bus, then Yik = 0. The process continues until a stopping condition is met.

B. Standard parameters

TABLE 1: LINE PARAMETERS OF 9 BUS SYSTEM

Line	Resistance(P.U.)	Reactance(PU)	Susceptence(PU)
1-4	0.0000	0.0576	0.0000
4-5	0.0170	0.0920	0.1580
4-6	0.0390	0.1700	0.3580
3-9	0.0000	0.0586	0.0000
5-7	0.0119	0.1008	0.2090
7-8	0.0085	0.0720	0.1490
7-2	0.0000	0.0625	0.0000
8-9	0.0320	0.1610	0.3060
9-6	0.0100	0.0850	0.1760

TABLE 2: MACHINE DATA OF 9 BUS SYSTEM

Parameter	M/C 1	M/C 2	M/C 3
H(sec)	23.64	6.4	3.01
Xd(PU)	0.146	0.8958	1.3125
X’d(PU)	0.0608	0.1198	0.1813
Xq(PU)	0.0969	0.8645	1.2578
X’q(PU)	0.0969	0.1969	0.25
T’d0(PU)	8.96	6.0	5.89
T’q0(PU)	0.31	0.535	0.6

TABLE 3: EXCITER DATA OF 9 BUS SYSTEM

Parameters	Exciter 1	Exciter 2	Exciter 3
KA	20	20	20
TA(sec)	0.2	0.2	0.2
KE	1.0	1.0	1.0
TE(sec)	0.314	0.314	0.314
KF	0.063	0.063	0.063
TF(sec)	0.35	0.35	0.35

III. RESULT AND DISCUSSION

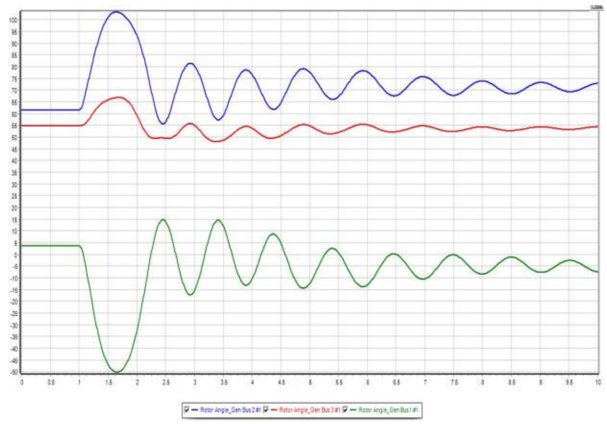
The load flow analysis and transient stability for standard IEEE-9 bus system are performed. The standard IEEE-9 bus system consists of 9 buses, 3 generators, 3 loads and 3 transformers.

TABLE 4: POWER FLOW LIST OF SIMULATED MODEL USING NEWTON-RAPHSON METHOD

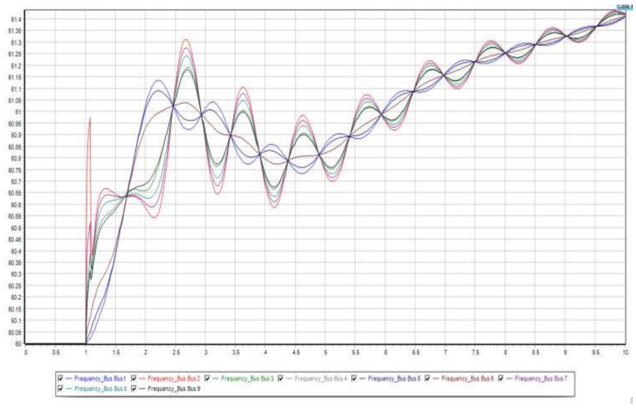
From bus	To bus	Branch Device Type	MW form	Mvar form	MVA form	MW Loss	Mvar Loss
4	1	Transformer1	-72	-24.8	75.8	0	3.15
2	7	Transformer2	163	4.9	163	0	15.8
9	3	Transformer3	-85	15.6	86.4	0	4.1
5	4	Line	-43	-39.6	58.5	0.3	-16
6	4	Line	-28	-16.9	32.9	0.1	-16
7	5	Line	84.2	-10.1	84.8	2.2	-21
9	6	Line	63.3	-17.8	65.7	1.5	-31
7	8	Line	78.8	-0.8	78.9	0.5	-12
8	9	Line	-22	-23.6	32.1	0.1	-21

TABLE 5: BUS DATA OF IEEE 9 BUS MODEL

Name	Nom. KV	PU Volt	Volt (KV)	Angle (Deg)	Load MW	Load Mvar	Gen MW	Gen Mvar
1	16.5	1.04	17.16	0			71.63	27.91
2	18	1.03	18.45	9.35			163	4.9
3	13.8	1.03	14.15	5.14			85	-11.45
4	230	1.03	235.8	-2.22				
5	230	1	229.9	-3.68	125	50		
6	230	1.01	232.8	-3.57	90	30		
7	230	1.03	236.2	3.8				
8	230	1.02	234	1.34	100	35		
9	230	1.03	237.5	2.44				



Graph I: Power angel v/s Time



Graph II: Bus Frequency v/s Time

CONCLUSION

It is concluded that power system should have very low critical clearing time to operate the relays if we isolate the faulty section within very short time, thus the system can obtain the stability otherwise, and it will go out of synchronism. In this research work, load studies are performed to analysis the transient stability of the system. The behavior of three-phase balanced fault and impact of load switching is also investigated. Thus the protection system provided for the system should have fast response. According to this analysis, fast fault clearing and load shedding methodologies can be adopted for system stability.

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