Transient Stability Analysis of 11 Bus Systems

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Abstract

Stability of the system is the important parameter for the stable, profitable and proper operation of the power system. The main aim of this research project is to implement the transient stability of the 11 bus power system in power word simulator. Two generators are modeled with different MW ratings. Our system is interconnected system of 11 Buses. The fault is created on different buses and analyzed by bus admittance matrix. Furthermore, the modelling of this system is done on power word simulator. The designing of the electric power system is mandatory to study the small and transient disturbance. The rotor angle variation and bus faults at different buses are studied and also studied its impact on the load. When there is fault or any kind of disturbance on the system, the rotor angle of the generator changes and its frequency also changes. These rotor angle variations can be simulated in the power word simulator. In this research work, it is clearly observed in the simulated graphs that when there is disturbance or fault in the system then the system cannot come back to stability position. As the fault or disturbance is removed then the power system comes to stability. The system that is proposed is universal and generalized system than any other power system. This system has proposed in the aspect that it can be applicable to any power network irrespective of the power generation that how fault affects the stability and rotor angle, how bus admittance matrix changes with the instability of the system. In this system it can be easily analyzed that how voltages vary on different phases when fault occurs on the system.

Key Words:

Transient stability, Fault analysis, Y-Bus, Rotor angle.

1. Introduction

Power system stability is the important parameter for the smooth working of the power system network,When the load on the generator suddenly changes, or disturbance occurs then the rotor angle of the generator changes due to the change in rotor angle the frequency also changes. This research project emphasizes on the importance of the rotor angle and different types of fault in the power system network. When there is fault or disturbance in the power system network then the rotor angle changes, and the system goes to instability. When the fault is removed from the system then rotor angle changes and system comes to stability position.This paper focuses on different types of unsymmetrical faults i-e Line to ground fault, line to line fault and double line to ground fault. These unsymmetrical faults are analyzing through Y-bus.The diagram of the 11 bus power system network is shown in figure 1.

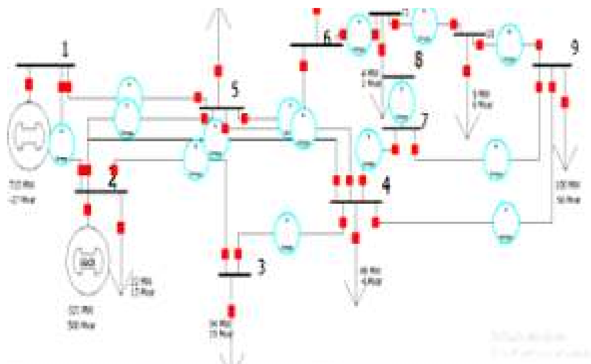

Figure 1: One Line Diagram of 11 Bus Power System

2. Problem Establishment

Power Transient stability deals with the disturbance occur in the system, which occurs due to sudden change in load and generation parameters. Due to sudden change in load and other parameters the system undergoes to instability condition. If this instability goes to long duration the system undergoes a transient instability. In this paper different faults are created (i-e symmetrical and unsymmetrical faults) at different bus to check the instability of the system. When the system undergoes disturbance or fault then the admittance matrix also changes which gives useful information about the data which is useful to study the load flow analysis or load changes, so the admittance matrix for different fault condition can be observed and also the rotor angle under steady state and fault conditions can be analyzed.

In the previous papers the transient stability analysis is done using power flow study methods (i-e Newton Raphson method) and the previously proposed systems are limited to specific generation system but in this paper problem is analyzed by creating faults at different buses and check the admittance matrix and rotor angle stability using power world simulator. This system is universal that can be applied to any power network for transient stability analysis.In this research work transient stability can be improved by using FACT devices (i-e STATCOM and SVC devices). The remaining papers that are discussed in the literature review explains the fault analysis or transient stability analysis about the specific power system like wind power system, micro grids, diesel generators and renewable energy resources.

Some research works focus on the wind energy system that is wind causes different electrical and mechanical distrubance due to the change in size of wind turbines and other factors. This is more related with the control system in which pole zero study is done for the transient and steady state analysis.[1].Some research papers discuss about the fault that occurs in the micro grids and the micro grid stability using electrical transient analyzer program(ETAP). Micro grids are connected with the grids, for the proper operation of the micro grid during fault in grid an islanding operation is adopted. Islanding is a technique in which grid continues to supply power.[2]. Another research shows that different fault calculations like three phase fault, line to ground fault and the fault occur due to sudden removal of generator are discussed in the combined cycle power plant that include conventional and non- convention energy sources, using the ETAP software.[3]. Some research papers discuss about the transient stability i-e when there is variation in wind pressure or frequency varies then instability occurs and the system is no more stable during peak and off peak hours.[4]

The drawback of the above discussed research works and the systems is that they are limited to specific power system. Therefore, a generalized and universal system about the transient stability analysis is proposed that covers the all types of generation systems.

Sr. No	Time	Gen 1#1 Rotor Angle	Gen2#1 Rotor Angle
1	0	96.928	-24.65
2	0.008	96.928	-24.65
3	0.017	96.928	-24.65
4	0.025	96.928	-24.65
5	0.033	96.928	-24.65
6	0.042	96.928	-24.65
7	0.05	96.928	-24.65
8	0.058	96.928	-24.65
9	0.067	96.928	-24.65
10	0.075	96.928	-24.65
11	0.083	96.928	-24.65
12	0.092	96.928	-24.65
13	0.1	96.928	-24.65
14	0.108	96.928	-24.65
15	0.117	96.928	-24.65
16	0.125	96.928	-24.65
17	0.133	96.928	-24.65

Table 1: Rotor angle Gen 1 and Gen 2

In the table 1 it is shown that after simulation in power word simulator, two different rotor angles at generator 1 and generator 2 are obtained at different time intervals. After simulation process, the graph of rotor angle Gen 1 is obtained. In the graph shown in figure 2 it can be seen that the system is stable up to 1.5 time scale axis and after that there is disturbance in the system and graph is going towards instability.

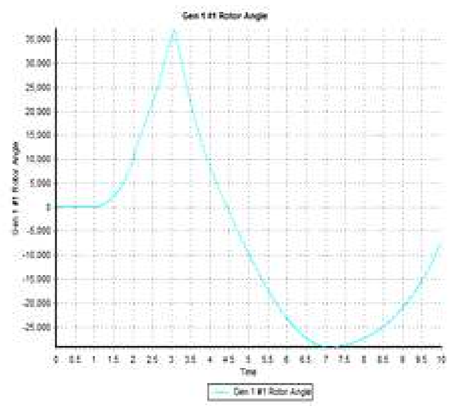

Figure 2: Rotor angle of Gen 1

In the Second graph which is shown in figure 3, it is shown that after simulation process when there is disturbance at rotor angle Gen 1 then there is also effect on rotor angle Gen 2. So the instability at Gen rotor angle 2 also occurs.

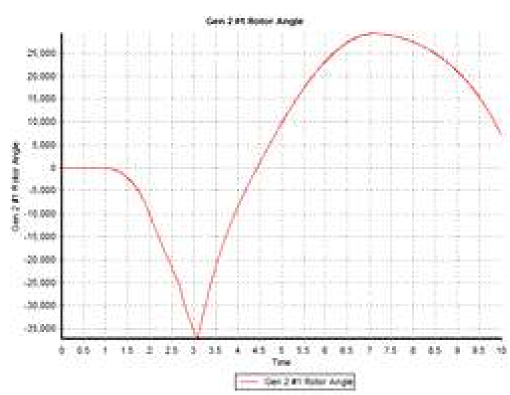

Figure 3: Rotor angle of Gen 2

3. Importance of Y-bus and Sequence components

Y-bus is also called admittance matrix, Y-bus is useful in load flow studies and fault calculations. In any power system network there are different number of buses that are link with each other through transmission lines. In any admittance matrix the diagonal elements are positive and off diagonal elements are negative. When fault occurs i-e unsymmetrical faults in the power network then the voltage and current values in the three phase network do not remain same. To solve these kind of faults, symmetrical components are used. The phenomena of symmetrical components are to resolve the phasor vectors into three sets of balanced phasors. One has positive rotation, negative rotation and zero rotation. When data is simulated in the software, Y-bus matrix of the overall network of 11 bus system is obtained and then resolve the network into positive, negative and zero sequence bus admittance matrix as shown in following tables 2,3,4 and 5.

Sr.No	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9
1	1	1	6.03-j2.500	-5+j15.26			1.03+j4.23				
2	2	2	-5+j15.26	9.74-j35.95	-1.14+j4.74	-1.69+j5.12	-1.70+j5.19				
3	3	3		-1.14+j4.74	4.42-j10.08	-1.99+j5.07					
4	4	4		-1.69+j5.12	-1.99+j5.07	11.22-j38.26	-6.84+j21.58				
5	5	5	1.03+j4.23	-1.70+j5.19		-6.84+j21.58	9.64-j34.95	-0.00+j3.97			
6	6	6					-0.00+j3.97	2.16-j8.20			
7	7	7				-0.00+j4.78			0.00-j19.55	-0.00+j5.68	-0.00+j9.09
8	8	8							-0.00+j5.68	0.00-j5.68	
9	9	9				-0.00+j1.80			-0.00+j9.09		6.93-j22.96
10	10	10									-3.90+j10.37
11	11	11						-1.96+j4.09			

Table 2: Y-Bus Matrix of overall Power system

	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9
1	1	1	6.03-j25.00	-5.00+j15.26			-1.03+j4.23				
2	2	2	-5.00+j15.26	9.74-j35.95	-1.14+j4.78	-1.69+j5.12	-1.70+j5.19				
3	3	3		-1.14+j4.78	4.42-j10.08	-1.99+j5.07					
4	4	4		-1.69+j5.12	-1.99+j5.07	11.22-j38.26	-6.84+j21.58		-0.00+j4.78		-0.00+j1.80
5	5	5	-1.03+j4.23	-1.70+j5.19		-6.84+j21.58	9.67-j34.95	-0.00+j3.97			
6	6	6					-0.00+j3.97	2.16-j8.20			
7	7	7				-0.00+j4.78			0.00-j19.55	-0.00+j5.68	-0.00+j9.09
8	8	8							-0.00+j5.68	0.00-j5.68	
9	9	9				-0.00+j1.80			-0.00+j9.09		6.93-j22.96
10	10	10									-3.90+j10.37
11	11	11						-1.96+j4.09			

Table 3: Positive Sequence Y-bus Matrix

Sr.No	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9
1	1	1	6.03-j25.00	-5.00+j15.26			-1.03+j4.23				
2	2	2	-5.00+j15.26	9.74-j35.95	-1.14+j4.78	-1.69+j5.12	-1.70+j5.19				
3	3	3		-1.14+j4.78	4.42-j10.08	-1.99+j5.07					
4	4	4		-1.69+j5.12	-1.99+j5.07	11.22-j38.26	-6.84+j21.58		-0.00+j4.78		-0.00+j1.80
5	5	5	-1.03+j4.23	-1.70+j5.19		-6.84+j21.58	9.67-j34.95	-0.00+j3.97			
6	6	6					-0.00+j3.97	2.16-j8.20			
7	7	7				-0.00+j4.78			0.00-j19.55	-0.00+j5.68	-0.00+j9.09
8	8	8							-0.00+j5.68	0.00-j5.68	
9	9	9				-0.00+j1.80			-0.00+j9.09		6.93-j22.96
10	10	10									-3.90+j10.37
11	11	11						-1.96+j4.09			

Table 4: Negative Sequence Y-Bus Matrix

Sr.No	Number	Name	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9
1	1	1	6.03-j25.00	-5.00+j15.26			-1.03+j4.23				
2	2	2	-5.00+j15.26	9.74-j35.95	-1.14+j4.78	-1.69+j5.12	-1.70+j5.19				
3	3	3		-1.14+j4.78	4.42-j10.08	-1.99+j5.07					
4	4	4		-1.69+j5.12	-1.99+j5.07	11.22-j38.26	-6.84+j21.58		-0.00+j4.78		-0.00+j1.80
5	5	5	-1.03+j4.23	-1.70+j5.19		-6.84+j21.58	9.67-j34.95	-0.00+j3.97			
6	6	6					-0.00+j3.97	2.16-j8.20			
7	7	7				-0.00+j4.78			0.00-j19.55	-0.00+j5.68	-0.00+j9.09
8	8	8							-0.00+j5.68	0.00-j5.68	
9	9	9				-0.00+j1.80			-0.00+j9.09		6.93-j22.96
10	10	10									-3.90+j10.37
11	11	11						-1.96+j4.09			

***Table 5**: Zero Sequence Y-Bus Matrix*

4. Fault Analysis and Calculations

Fault analysis is an important parameter in the power system network for the selection of circuit breaker, setting of digital relays. When Fault occurs in the power network the rotor angle of the generator changes and frequency also changes. In studying the load flow studies, it is important that the system is working under balanced conditions. There are symmetrical and unsymmetrical faults in the power network. Unsymmetrical faults include line to line fault, line to ground fault and double line to ground fault. Fault on different buses and lines are created and then analyze the admittance matrix. When the fault occurs on the phase "A" of bus 1 then the phase "A" voltages and the phase "A" angle goes to zero as shown in table 6.

Sr.No	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Angle A	Phase Angle B	Phase Angle C
1	1	1	0.00000	1.09351	1.00485	0.00	-119.52	129.22
2	2	2	0.34655	1.06342	0.94833	-9.41	-118.73	122.59
3	3	3	0.26416	0.98792	0.81584	-28.05	-127.28	117.70
4	4	4	0.21212	0.95951	0.80010	-28.52	-126.74	120.34
5	5	5	0.19804	0.98213	0.83487	-25.34	-125.21	121.69
6	6	6	0.19355	0.92582	0.71532	-48.74	-133.23	115.72
7	7	7	0.18668	0.85611	0.62453	-61.04	-136.96	114.72
8	8	8	0.18668	0.85611	0.62453	-61.04	-136.96	114.72
9	9	9	0.19999	0.81466	0.53578	-78.49	-143.27	110.30
10	10	10	0.19423	0.82173	0.55301	-75.92	-141.96	111.44
11	11	11	0.18723	0.86502	0.62581	-63.69	-137.66	113.84

Table 6: Fault at phase A of Bus 1

When the line to line fault occurs between line 11 and line 12 then the phase angle “A” and “B” goes to zero value as shown in table 7.

Sr.No	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Angle A	Phase Angle B	Phase Angle C
1	1	1	1.00001	0.77190	0.80569	3.16	-124.66	133.98
2	2	2	1.00000	0.72717	0.76587	0.00	-130.38	133.68
3	3	3	0.88001	0.44370	0.45202	-8.26	-177.42	161.09
4	4	4	0.84831	0.51844	0.55219	-6.64	-147.73	137.52
5	5	5	0.87651	0.56620	0.60968	-4.83	-141.09	135.23
6	6	6	0.78415	0.49986	0.53830	-13.79	-150.97	127.07
7	7	7	0.69741	0.42617	0.45800	-17.57	-158.00	126.09
8	8	8	0.69741	0.42617	0.45800	-17.57	-158.00	126.09
9	9	9	0.63182	0.38686	0.41280	-25.26	-165.17	118.17
10	10	10	0.64308	0.39614	0.42962	-23.55	-162.79	119.43
11	11	11	0.66683	0.40387	0.26296	0.00	180.00	180.00
12	12	Faultpt	0.86537	0.43268	0.43268	0.00	180.00	180.00

***Table** 7: Line to Line Fault Created Between Line 11 and 12*

In the table 8 it is shown that when single line to ground fault occurs at phase "A" of bus 12 then the phase angle and phase voltage of "A" and phase angle of "B" goes to zero value.

Sr.No	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Angle A	Phase Angle B	Phase Angle C
1	1	1	0.10608	1.08415	0.99300	-3.97	-118.71	128. 36
2	2	2	0.31551	1.07180	0.95930	-9.96	-119.59	123.49
3	3	3	0.24895	0.99602	0.82298	-29.62	-127.94	118.55
4	4	4	0.20948	0.96544	0.80540	-29.47	-127.22	120.95
5	5	5	0.20438	0.98651	0.83887	-25.39	-125.57	122.13
6	6	6	0.19787	0.93108	0.71894	-48.96	-133 .59	116.27
7	7	7	0.18679	0.86245	0.62887	-62.40	-137.40	115.45
8	8	8	0.18679	0.86245	0.62887	-62.40	-137.40	115.45
9	9	9	0.20166	0.82118	0.53949	-79.68	-143.67	111.14
10	10	10	0.19611	0.82801	0.55674	-76.91	-142.36	112.22
11	11	11	0.08260	0.64754	0.26 102	0.00	180.00	180.00
12	12	Faultpt	0.00000	0.57162	064785	0.00	180.00	180.00

Table 8 *: Single Line to Ground Fault at Phase A of bus 12*

Table 9 describes when the double line to ground fault occurs at phase A, B and C of bus 12 then it is clear that all three phase voltages and phase angles of bus 12 are zero

Sr.No	Number	Name	Phase Volt A	Phase Volt B	Phase Volt C	Phase Angle A	Phase Angle B	Phase Angle C
1	1	1	0.70472	0.70472	0.70472	5.66	-114.34	125.66
2	2	2	0.64049	0.64049	0.64049	2.99	-117.01	122.99
3	3	3	0.09655	0.09655	0.09655	-5.36	-125.36	114.64
4	4	4	0.37434	0.37434	0.37434	-2.49	-122.49	117.51
5	5	5	0.45325	0.45325	0.45325	-0.56	-120.56	119.44
6	6	6	0.39344	0.39344	0.39344	-9.51	-129.51	110.49
7	7	7	0.31431	0.31431	0.31431	-13.32	-133.32	106.68
8	8	8	0.31431	0.31431	0.31431	-13.32	-133.32	106.68
9	9	9	0.28862	0.28862	0.28862	-20.68	-140.68	99.32
10	10	10	0.29970	0.29970	0.29970	-18.80	-138.80	101.20
11	11	11	0.33148	0.33148	0.33148	0.00	180.00	180.00
12	12	Faultpt	0.00000	0.00000	0.00000	0.00	0.00	0.00

Table 9*: Double Line to Ground Fault at phase A,B and C of Bus 12*

5. Conclusion

In this research work,the transient stability of 11 bus system in electric power system is analyzed using power world simulator.This is clarifying from the graph of the rotor angles that is shown in figure 4that the rotor angle of generator 1 is unstable up-to 4.5 times scale value. When system becomes normal which means there is no fault in the power network, then rotor angle become stable after 5 times scale value. The figure 5 clarifies that when there is fault on power network, the rotor angle of generator 2 becomes unstable up-to 4.5 times scale value and system becomes stable (no fault in system) after 5 times scale value. This research paper clearly explains how the proposed system is more universal and generalized than the remaining system that have been studied for the reference.

Transient stability analysis of 11 bus system focuses on the fault calculations, rotor angle, Admittance matrix of any power system network, irrespective of the power generation mechanism because this system emphasizes on the universal power system network. The research work proposes a system that is easier to understand, reliable and generalized method that can be applied on any kind of power system. Such kind of proposal is not discussed using the Power word simulator. In this research work, faults at different buses and transmission lines can be calculated and the bus admittance matrix under normal and fault conditions can be analyzed. Moreover rotor angles are analyzed in the software under normal and transient conditions.In future, transient stability problem can also be improved by using Fact devices (i-e STATCOM and SVC devices)

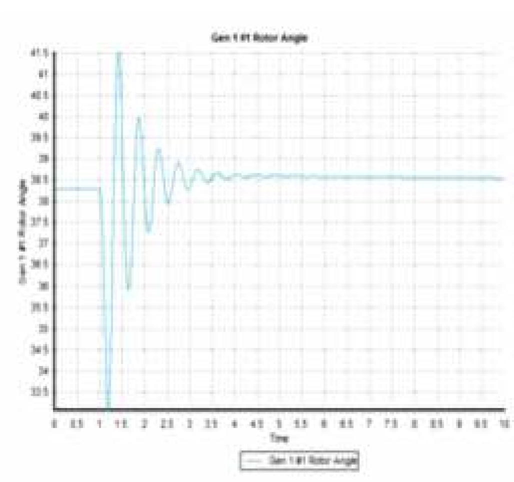

Figure 4: Rotor angle of Gen 1 after stability

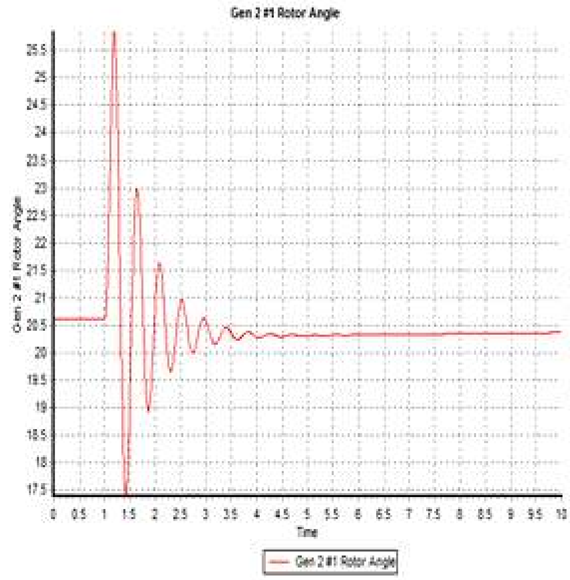

Figure 5: Rotor angle of Gen 2 after stability

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