3.4 Simulation on 10-machine New-England Power System

This section presents typical results of the curve-fitting method tested on the 10-Machine New-England Power System. The time domain simulation method was also run providing a reference for assessment of the test results. Next page, the system configuration is shown in Figure 3.8 and the generator parameters and initial conditions are given in table 3.1.

Table 3.1: Generator Parameters and Initial Conditions for New-England System (100 MW Base)

Unit No.	H pu	X'd pu	E pu	Angle (rad)
1	500	0.006	1.0368	-0.1344
2	30.3	0.0697	1.1966	0.3407
3	35.8	0.0531	1.1491	0.3417
4	38.6	0.0436	1.0808	0.2985
5	26	0.132	1.3971	0.5088
6	34.8	0.05	1.191	0.3376
7	26.4	0.049	1.1394	0.3499
8	24.3	0.057	1.0709	0.307
9	34.5	0.057	1.1368	0.5335
10	42	0.031	1.0929	-0.0087

Four fault locations were considered, namely at the terminals of unit 6, 2, 3 and 9, receptively. A self-cleared fault ($Zf = (1+j)*10^{(-5)}$) is applied respectively to unit 2, 3, 6 and 9. It was found that for a fault on unit 6, both units 6 and 7 were unstable. Under these faults, the system has exhibited a wide range of stability behavior including first swing and second swing instability. The unstable equilibrium points and the corresponding energies for the different simulations using the Curve-Fitting method are given in Table 3.2.

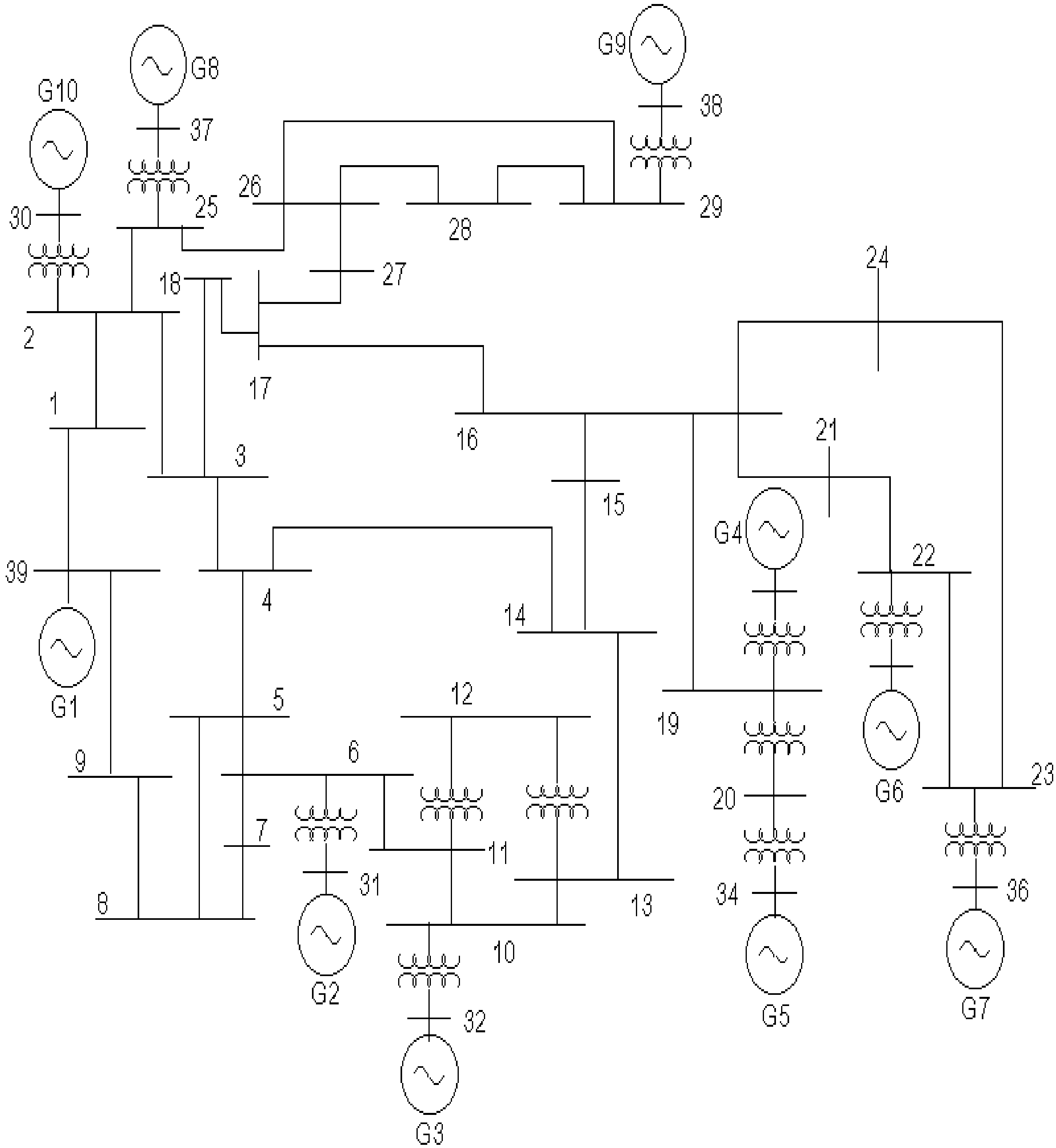

Figure 3.8 : 10-machine, 39-Bus New England Test System

Table 3.2 : Critical Clearing Times and Energies For 10-Unit 39-Bus System
(*) Second swing instability case

Unstable Units	Clearing time stable in seconds	Clearing time unstable in seconds	Total Energy at clearing times in MWrad/MVA	Potential Energy at C.U.E.P. in MWrad/MVA
UNIT 2	0.28	0.30	4.84→5.91	4.96
UNIT 3	0.25	0.26	4.56→4.997	4.96*
UNIT 6	0.31	0.35	9.65→12.809	10.92*
UNIT 9	0.18	0.21	3.54→5.05	3.77

The two first columns of Table 3.2 are obtained performing a time domain simulation. The dynamic equations are integrated using a fourth order Runga-Kutta method. The simulation stops when the system reaches the p.e.b.s. The Ball-Drop method is used to detect when the p.e.b.s. is reached. The fourth column shows two energies. The first energy refers to the stable case and the second one refers to the unstable case. The fifth column represents the potential energy of the c.u.e.p. detected by the curve-fitting method for the clearing times considered in Column 2 and 3. For unit 3 and 6, as signaled by a star in Table 3.2, we are confronted with multiple swing instability cases. In those cases, the fault is cleared such that the system goes unstable at the second swing. Thus, the c.u.e.p.'s found in Column 5 are related to the second swing. Following the results given by Table B2, the approach as defined in this thesis seems to analyze accurately the transient stability for first swing as well as for second swing instability cases. Since the potential energy at the c.u.e.p. is greater than the total energy at the clearing time for stable cases, it is clear that the technique is successful. Similarly, for the cases of an unstable clearing time, the c.u.e.p. potential energy is lower than the system total energy as would be expected. However, the method has shown some slight inaccuracies when it is applied to cases with more than two swings. Typically, for a stable case involving more than two swings, the result tends to be a prediction of instability. The reason for this is due to the algorithm's tendency to track the wrong u.e.p. An explication is that the Curve-Fitting method guarantees stability only for the first two swings and does not assure asymptotic stability in the long run. This limitation is not objectionable since constant voltage behind transient reactance representation is an invalid model for long term stability analysis.

Table 3.3 is comparing the time when the system is crossing the p.e.b.s. using the step-by-step method with the time when the system is assessed to be unstable using the Curve-Fitting method. Here, only unstable cases are considered.

Table 3.3 : Critical Times For 10 Unit 39 Bus System

Unit No.	Clearing Time in seconds	Time of Loss of Synchronism (sec)	Time Necessary to Predict Instability (sec)
Unit 2	0.3	0.680	0.550
Unit 3	0.26	0.940	0.450
Unit 6	0.35	1.07	0.510
Unit 9	0.21	0.600	0.360

The key point in these predictions is to know exactly how much time is available to take action when an instability is predicted. Therefore, the time of interest is the difference between the time the calculations are completed and the time the system actually goes unstable ("available reaction time"). By taking the difference between column three and four of Table 3.3, the average available reaction time to the instability prediction is found to be 350 msec.