EXPERIMENT NO.1

AIM: To determine the critical clearing angle, critical clearing time for the system shown in Fig.1 when a 3 phase fault occurs at A, which when cleared leaves both lines intact.

Verify the results by MATLAB command and plot the power angle curve.

The system consists of a 60Hz synchronous generator which has a transient reactance of 0.2 pu and an inertia constant of 5.66 MJ/MVA. It is connected to an infinite bus through a transformer and a double circuit transmission line as shown in Fig.8. Resistances & Reactances are expressed on a common MVA base & marked on the diagram. The generator is delivering a real power of 0.77 pu to bus bar 1. The infinite bus voltage is 1.0 pu, the generator excitation is 1.25 pu.

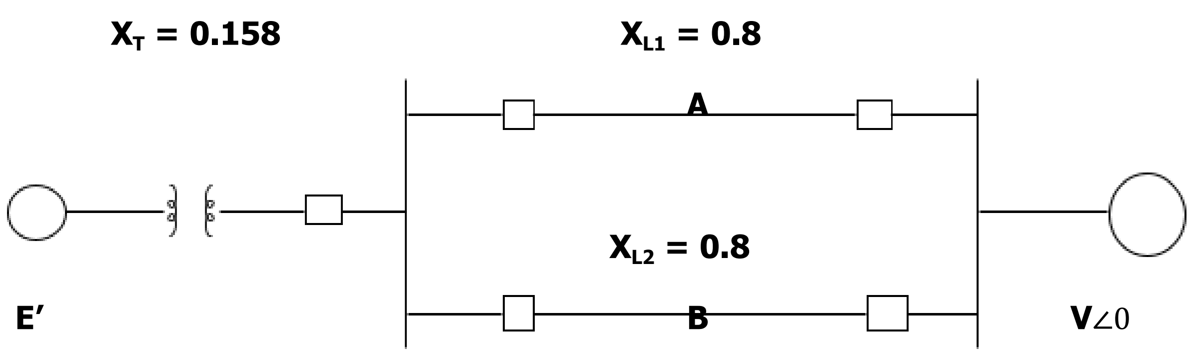


Fig. 1

(i) **By Manual Calculation:**

Max Power that can be transformed P_{max} = lEl lVl /X

Here X = j 0.2+j 0.158+(j0.8//j0.8)=j0.758

lEl = 1.25

lVl = 1.0

P_{max} = 1.25*1.0 /0.758 = 1.649

$P_M = P_{max} \sin \delta_0 = 1.65 \sin \delta_0$

0.77 = 1.65 sin δ_0 = 27.836 or 0.48558 rad

The power angle will be same before and after removed of fault because lines are intact after the fault is cleared.

∂_{max} = 180- $_{\delta 0}$= 180-27.836=152.164 or 2.6544 rad

Since the 3 phase fault is at the beginning of transmission line, the power transfer will be zero.

If we compare

$P_M = P_{max} \sin \delta_0$ in healthy condition

$P_M = r_1 P_{max} \sin \delta_0$ in faulty condition

$P_M = r_2 P_{max} \sin \delta_0$ after fault is cleared

Then $r_1 = 0$, $r_2 = 1$

Now the critical clearing angle

$\partial_c = \cos^{-1}[\{(\delta_m - \delta_0) \sin \delta_0 - r_1 \cos \delta_0 + r_2 \cos \delta_m\}/(r_2 - r_1)]$

$= \cos^{-1}[\{(2.6544-0.48558)*0.46104 - 0 + 1*(0.88426)\}/(1 - 0)]$

$= \cos^{-1} 0.128428 = 82.62^0$

Critical clearing time = $\sqrt{[2H(\delta_c - \delta_0)/\pi f P_M]}$

$=\sqrt{[2*5.66(1.44126-0.4/8558)/3.14*60 *0.77]}$

= 0.273 sec

MATLAB Command

```
Pm=0.77;E=1.25;V=1.0;
X1=0.758;   X2=inf; X3=0.758;
eacfault(Pm,E,V,X1,X2,X3)
```

Result:

For this case tc can be found from analytical formula.

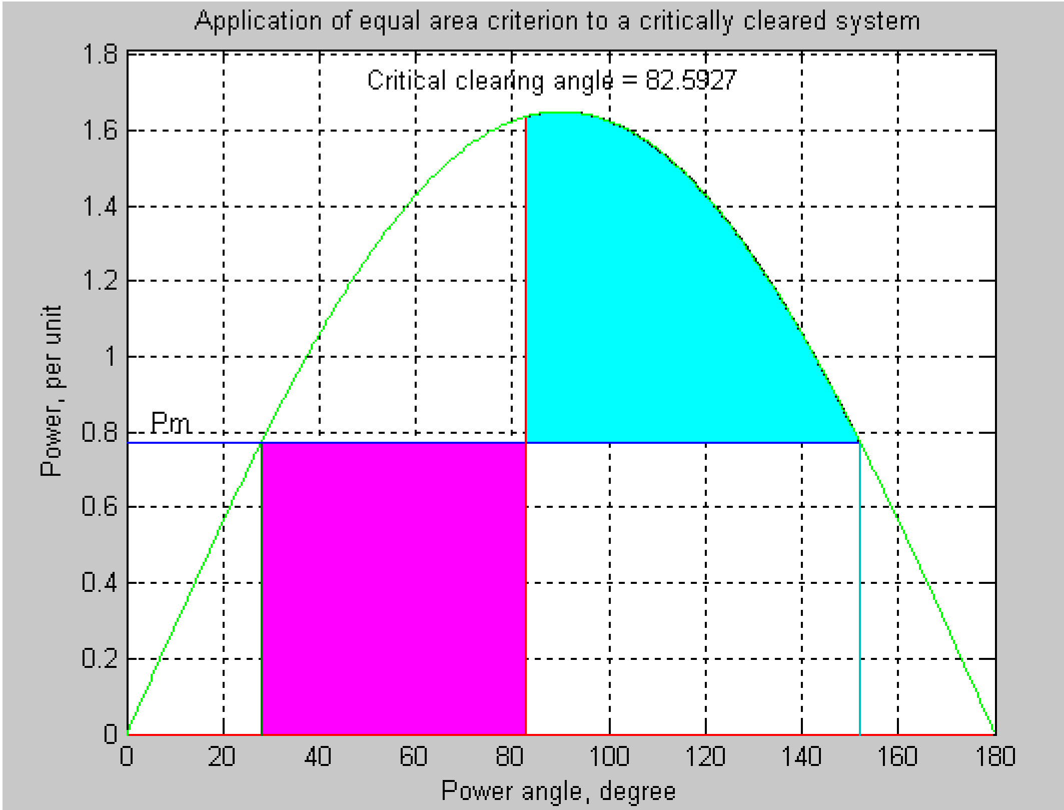
To find tc enter Inertia Constant H, (or 0 to skip) H = 5.66

Initial power angle = 27.835

Maximum angle swing = 152.165

Critical clearing angle = 82.593

Critical clearing time = 0.273 sec.


Application of equal area criterion to a critically cleared system
Critical clearing angle = 82.5927
Pm
Power, per unit
Power angle, degree
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
1.8
0
20
40
60
80
100
120
140
160
180

EXPERIMENT NO. 2

AIM: To determine the critical clearing angle, critical clearing time for the system shown in Fig. 2 when a 3 phase fault occurs at the middle of the one line (line B) which when cleared isolated the faulted line.

Verify the results by MATLAB command and display the power angle curve.

The system consists of a 60Hz synchronous generator which has a transient reactance of 0.2 pu and an inertia constant of 5.66 MJ/MVA. It is connected to an infinite bus through a transformer and a double circuit transmission line as shown in Fig.9. Resistances & Reactances are expressed on a common MVA base & marked on the diagram. The generator is delivering a real power of 0.77 pu to bus bar 1. The infinite bus voltage is 1.0 pu, the generator excitation is 1.25 pu.

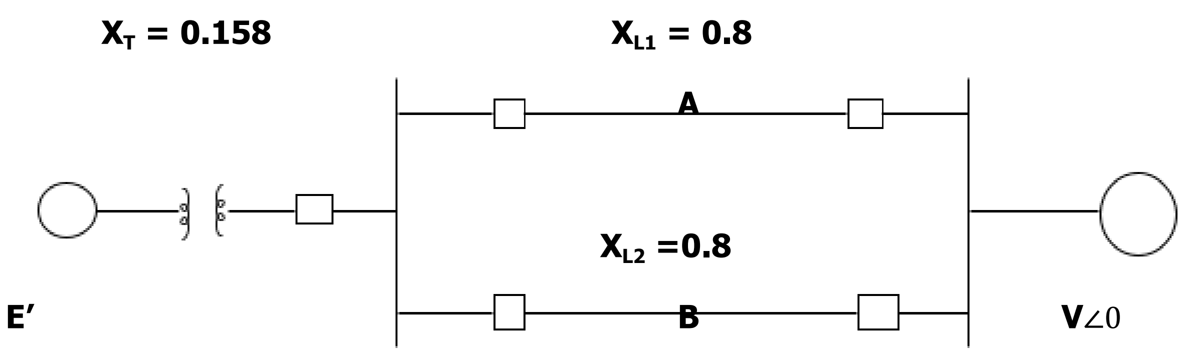


Fig. 2

(i) **By Manual Calculation:**

Under healthy condition X_1 = j0.2+j0.158+j0.8/2=j 0.758

Under faulty condition X_2 = (j0.358*j0.8+j0.358*j0.4+j0.8*j0.4)/j0.4=j1.874

When fault is cleared X_3 = j0.2+j0.158+j0.8= j1.158

POWER TRANSFER:

Under healthy condition $P_{max} = |E|\ |V| / X_1 = 1.25*1/0.758=1.649$

$Pe = P_{max} \sin \delta_0$

$0.77 = 1.649 \sin \delta_0$

$\delta_0 = 27.836$ or 0.48558 rad

Under faulty condition $P_{max1} = |E|\ |V| / X_2 = r_1 P_{max}$

$1.25*1/1.874 = r_1\ 1.649$

$r_1 = 0.4045$

When fault is cleared and faulty line is removed

$P_{max2} = |E|\ |V| / X_3 = r_2 P_{max}$

$1.25*1/1.158 = r_2 * 1.649$

$r_2 = 0.6546$

$\delta_m = 180 - \sin^{-1}[\sin \delta / r_2]$

$= 180 - \sin^{-1}[\sin 27.836 / 0.6546]$

$= 134.4939^0$

$\delta_c = \cos^{-1}[\{(\delta_m - \delta_0) \sin \delta_0 - r_1 \cos \delta_0 + r_2 \cos \delta_m\}/(r_2 - r_1)]$

$= \cos^{-1}[\{(2.3461-0.48558)*0.46104 - 0.4045 \cos 27.836 + 0.6546*\cos 134.4939)\}/(0.6546 - 0.4045)]$

$= 77.916^0$

(ii) MATLAB Command

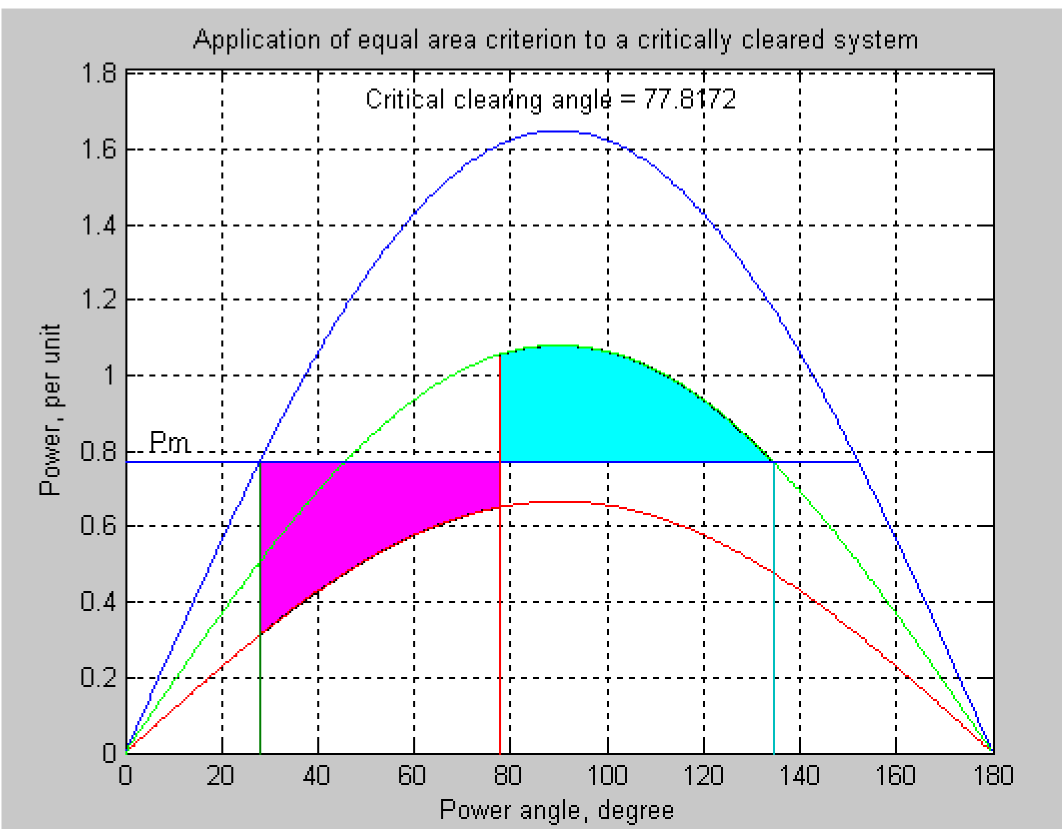
```
Pm=0.77;E=1.25;V=1.0;
X1=0.758;   X2=1.874; X3=1.158;
eacfault(Pm,E,V,X1,X2,X3)
```

Result:

Initial power angle = 27.835

Maximum angle swing = 134.494

Critical clearing angle = 77.817



EXPERIMENT NO.3

AIM: To obtain the swing curve for the system shown in Fig.3 by using Modified Euler's method when a 3 phase fault occurs at the middle of the one line and is cleared by isolating the faulted line. Obtain the numerical solution for 1.5 sec for a step size Δt = 0.01 sec when fault is cleared in

i) 0.2 sec.
ii) 0.3 sec.
iii) 0.4 sec.

Also draw the flow chart of Euler's and Modified Euler's method.

The system consists of a 60Hz synchronous generator which has a transient reactance of 0.2 pu and an inertia constant of 5.66 MJ/MVA. It is connected to an infinite bus through a transformer and a double circuit transmission line as shown in Fig.3. Resistances & Reactances are expressed on a common MVA base & marked on the diagram. The generator is delivering a real power of 0.77 pu to bus bar 1. The infinite bus voltage is 1.0 pu, the generator excitation is 1.25 pu.

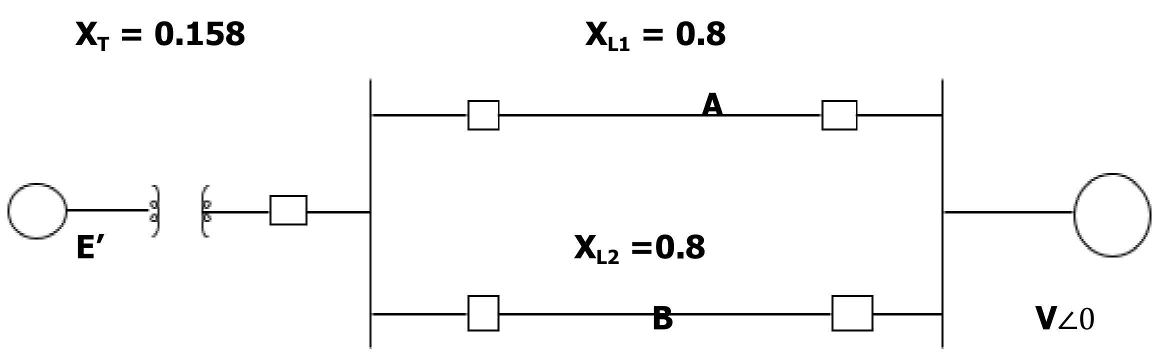


Fig. 3

(i) **By Manual Calculation:**

Under healthy condition X_1 = j0.2+j0.158+j0.8/2=j 0.758

Under faulty condition X_2 =
(j0.358*j0.8+j0.358*j0.4+j0.8*j0.4)/j0.4=j1.874

When fault is cleared X_3 = j0.2+j0.158+j0.8= j1.158

POWER TRANSFER:

Under healthy condition P_{max} = lEl lVl /X_1 = 1.25*1/0.758=1.649

$P_{1max} = P_{max} \sin \delta_0$

$0.77 = 1.649 \sin \delta_0$

$_{\delta 0}$ =27.836 or 0.48558 rad

Under faulty condition P_{2max1} = lEl lVl sin δ_0/X_2

=1.25*1* sin δ/1.874

= 0.667 sin δ_0

Thus accelerating power is given by

$P_a = 0.77 - 0.667 \sin \delta_0$

Applying the Modified Euler's method, the derivatives at beginning of step

$[d\delta/dt]_{\Delta\omega=0} = 0$ and

$[d\Delta\omega/dt]\ \delta_0 = \frac{\pi f Pa}{H}$ =3.14*60(0.77 – 0.667 sin27.836)/5.66 =15.271 rad/sec^2

At the end of first step (t_1 = 0.01 sec), the predicted values are

$\delta_1^p = \delta_r + [d\delta/dt]_{\Delta\omega} * \Delta t$ = 0.48558+0*0.01=0.48558 rad =27.836^0

$\Delta\omega_1^p = \Delta\omega_0 = [d\Delta\omega/dt]\ \delta_0 * \Delta t$ =0+15.271*0.01=0.15271 rad/sec

Using the predicted value of δ_1^p and $\Delta\omega_1^p$, the derivatives at end of internal are determined by

$[d\delta/dt]_{\Delta\omega 1}{}^p = \Delta\omega_1^p$ = 0.15271 rad/sec

$[d\Delta\omega/dt]\ \delta_1^p$ = 3.14*60(0.77 – 0.667 sin27.836)/5.66 =15.271 rad/sec^2

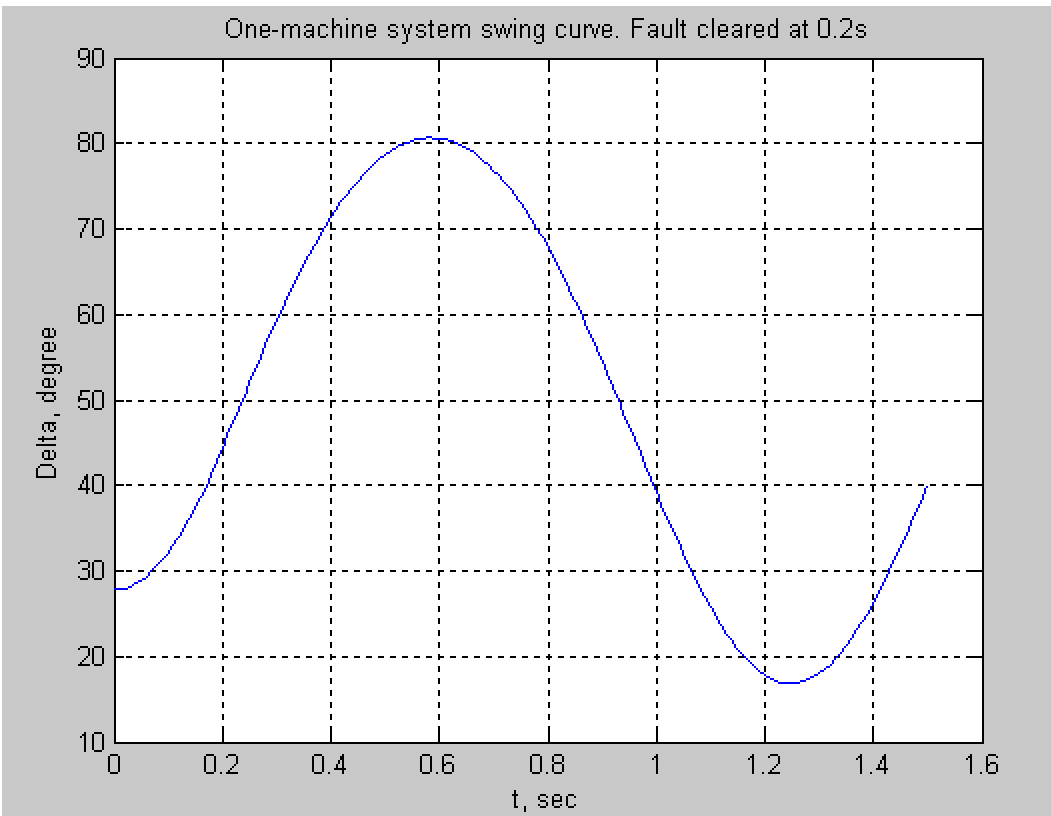
Then the average value of two derivatives is used to find the corrected value

δ_1^c = 0.48558 + (0+0.15271)*0.01/2=0.48634 rad

$\Delta\omega_1^c$ = 0+0.01*(15.271+15.271)/2 = 0.15271 rad/sec

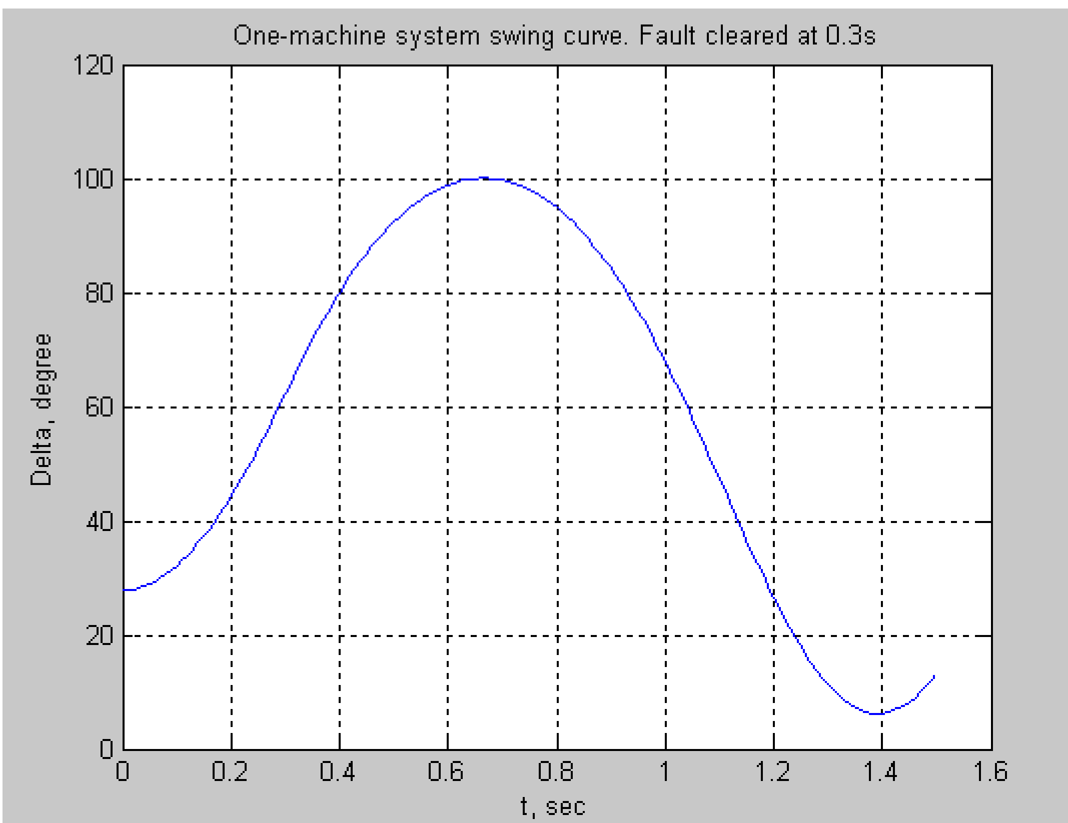
MATLAB Command

```
Pm=0.77;E=1.25;V=1.0;
X1=0.758;    X2=1.874; X3=1.158;
H=5.66;f=60;tc=0.2;ty=1.5;dt=0.01;
swingmeu(Pm,E,V,X1,X2,X3,H,f, tc, ty,dt)
```



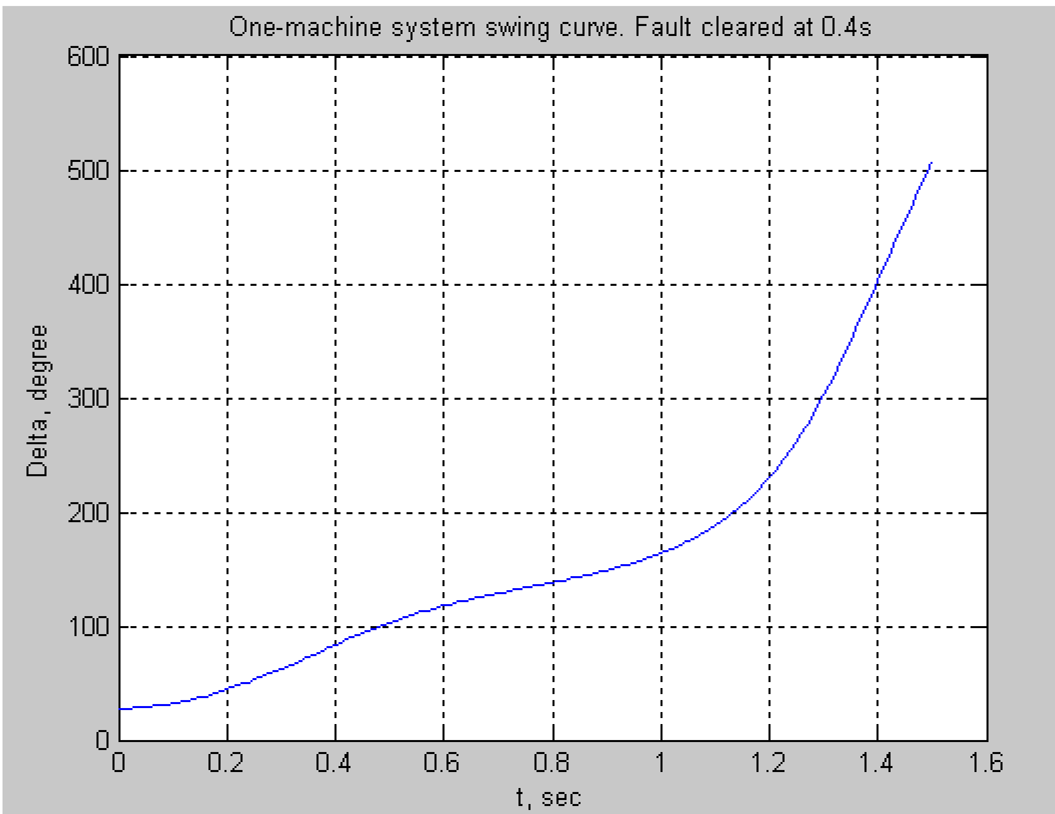
MATLAB Command

```
Pm=0.77;E=1.25;V=1.0;
X1=0.758;   X2=1.874; X3=1.158;
H=5.66;f=60;tc=0.3;ty=1.5;dt=0.01;
swingmeu(Pm,E,V,X1,X2,X3,H,f, tc, ty,dt)
```



MATLAB Command

```
Pm=0.77;E=1.25;V=1.0;
X1=0.758;   X2=1.874; X3=1.158;
H=5.66;f=60;tc=0.4;ty=1.5;dt=0.01;
swingmeu(Pm,E,V,X1,X2,X3,H,f, tc, ty,dt)
```



Fault is cleared at 0.400 Sec.

time	delta	Dw
s	degrees	rad/s
0	27.8351	0
0.0100	27.8788	0.1527
0.0200	28.0100	0.3051
0.0300	28.2284	0.4569
0.0400	28.5336	0.6079
0.0500	28.9249	0.7576
0.0600	29.4017	0.9058
0.0700	29.9629	1.0523
0.0800	30.6075	1.1968
0.0900	31.3343	1.3390
0.1000	32.1419	1.4787
0.1100	33.0287	1.6155
0.1200	33.9931	1.7494
0.1300	35.0333	1.8800
0.1400	36.1474	2.0072
0.1500	37.3334	2.1309
0.1600	38.5892	2.2507
0.1700	39.9125	2.3667
0.1800	41.3012	2.4786
0.1900	42.7527	2.5863
0.2000	44.2649	2.6899
0.2100	45.8351	2.7892
0.2200	47.4610	2.8841
0.2300	49.1400	2.9747
0.2400	50.8698	3.0611
0.2500	52.6477	3.1431
0.2600	54.4714	3.2208
0.2700	56.3385	3.2945
0.2800	58.2466	3.3640
0.2900	60.1934	3.4297
0.3000	62.1767	3.4915
0.3100	64.1944	3.5497
0.3200	66.2444	3.6045
0.3300	68.3248	3.6561
0.3400	70.4339	3.7047
0.3500	72.5701	3.7505
0.3600	74.7317	3.7938
0.3700	76.9174	3.8349
0.3800	79.1261	3.8741
0.3900	81.3568	3.9116
0.4000	83.6085	3.9479
0.4100	85.8416	3.8464
0.4200	88.0162	3.7439
0.4300	90.1319	3.6410
0.4400	92.1885	3.5381
0.4500	94.1862	3.4356
0.4600	96.1254	3.3341
0.4700	98.0068	3.2338
0.4800	99.8311	3.1352
0.4900	101.5994	3.0384
0.5000	103.3129	2.9439
0.5100	104.9729	2.8518
0.5200	106.5808	2.7624
0.5300	108.1383	2.6757
0.5400	109.6470	2.5921
0.5500	111.1086	2.5116
0.5600	112.5250	2.4343
0.5700	113.8981	2.3604
0.5800	115.2299	2.2900
0.5900	116.5222	2.2230
0.6000	117.7772	2.1596
0.6100	118.9969	2.0998
0.6200	120.1834	2.0437
0.6300	121.3388	1.9912
0.6400	122.4652	1.9425
0.6500	123.5647	1.8976
0.6600	124.6396	1.8564
0.6700	125.6920	1.8189
0.6800	126.7240	1.7853
0.6900	127.7378	1.7556
0.7000	128.7357	1.7297
0.7100	129.7199	1.7077
0.7200	130.6925	1.6896
0.7300	131.6560	1.6754
0.7400	132.6124	1.6653
0.7500	133.5642	1.6592
0.7600	134.5137	1.6572
0.7700	135.4633	1.6594
0.7800	136.4153	1.6659
0.7900	137.3722	1.6766
0.8000	138.3366	1.6918
0.8100	139.3109	1.7116
0.8200	140.2979	1.7360
0.8300	141.3003	1.7652
0.8400	142.3207	1.7994
0.8500	143.3622	1.8387
0.8600	144.4277	1.8832
0.8700	145.5203	1.9333
0.8800	146.6431	1.9891
0.8900	147.7997	2.0509
0.9000	148.9933	2.1189
0.9100	150.2278	2.1934
0.9200	151.5069	2.2748
0.9300	152.8346	2.3634
0.9400	154.2151	2.4595
0.9500	155.6529	2.5635
0.9600	157.1527	2.6760
0.9700	158.7194	2.7973
0.9800	160.3583	2.9280
0.9900	162.0747	3.0685
1.0000	163.8746	3.2196
1.0100	165.7642	3.3818
1.0200	167.7499	3.5557
1.0300	169.8388	3.7422
1.0400	172.0382	3.9418
1.0500	174.3559	4.1555
1.0600	176.8002	4.3840
1.0700	179.3797	4.6283
1.0800	182.1039	4.8891
1.0900	184.9824	5.1675
1.1000	188.0255	5.4644
1.1100	191.2442	5.7807
1.1200	194.6499	6.1174
1.1300	198.2544	6.4753
1.1400	202.0702	6.8552
1.1500	206.1101	7.2580
1.1600	210.3874	7.6841
1.1700	214.9156	8.1340
1.1800	219.7085	8.6079
1.1900	224.7797	9.1054
1.2000	230.1427	9.6262
1.2100	235.8107	10.1690
1.2200	241.7957	10.7323
1.2300	248.1091	11.3137
1.2400	254.7604	11.9102
1.2500	261.7572	12.5179
1.2600	269.1048	13.1319
1.2700	276.8053	13.7466
1.2800	284.8573	14.3554
1.2900	293.2553	14.9509
1.3000	301.9896	15.5252
1.3100	311.0458	16.0700
1.3200	320.4043	16.5769
1.3300	330.0413	17.0381
1.3400	339.9283	17.4463
1.3500	350.0331	17.7959
1.3600	360.3207	18.0827
1.3700	370.7542	18.3048
1.3800	381.2963	18.4626
1.3900	391.9107	18.5588
1.4000	402.5631	18.5987
1.4100	413.2232	18.5896
1.4200	423.8652	18.5407
1.4300	434.4692	18.4626
1.4400	445.0217	18.3667
1.4500	455.5160	18.2652
1.4600	465.9521	18.1699
1.4700	476.3371	18.0925
1.4800	486.6845	18.0437
1.4900	497.0137	18.0335
1.5000	507.3494	18.0704