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APPENDIX 1

DERIVATION OF INDUCTION MOTOR STEADY STATE CHARACTERISTIC

In steady state condition, the electrical torque Te and mechanical torque Tm is equal. Thus we can write

$$Te - Tm = 0 \qquad (A1.1)$$

where

$$T_e = \frac{\frac{\omega_e}{\omega_b} X_M^2 r_r s |V_s|^2}{\left[r_s r_r + s\left(\frac{\omega_e}{\omega_b}\right)^2 (X_M^2 - X_{ss}X_{rr})\right]^2 + \left(\frac{\omega_e}{\omega_b}\right)^2 (r_r X_{ss} + s r_s X_{rr})^2} \qquad (A1.2)$$

$$Tm = a + b*w_r + c*w_r**2 \qquad (A1.3)$$

or in terms of slip

$$Tm = a + b*(1-s) + c*(1-s)**2 \qquad (A1.4)$$

Substitute (A1.2) and (A1.4) into (A1.1) and solving (A1.1) we can derive operating slip at given voltage and frequency. The method used here for solving (A1.1) is False Position Method. This method is used to find a real root of an equation written in the form :

$$f(x) = 0 \qquad (A1.5)$$

First we must find x1 and x2 that give opposite sign of f(x1) and f(x2), then calculate x3 which is closer to the root by :

x3 = x1 + f(x1)/(f(x1)-f(x2))*(x2-x1) (A1.6)

Equation (A1.6) is then applied again with x3 substituting either x1 or x2 which give f(x) that is the same sign as f(x3). Repeating until f(x3) is less enough, thus x3 is a approximate root of (A1.5).

To apply this method to (A1.1), we use the slip at maximum torque s_m and slip = 0, which will give opposite sign of (A1.1).

The slip at maximum torque can be written as :

$$s_m = r_r G$$

$$G = \left[\frac{(\omega_e/\omega_b)^{-2} r_s^2 + X_{ss}^2}{(X_M^2 - X_{ss}X_{rr})^2\left(\frac{\omega_e}{\omega_b}\right)^2 + r_s^2 X_{rr}^2}\right]^{1/2}$$

Once a slip at given voltage and frequency is derived, we can calculate the input impedance of the equivalent circuit shown in Figure A1.1 by the following equation :

$$Z = \frac{\frac{r_s r_r}{s} + \left(\frac{\omega_e}{\omega_b}\right)^2 (X_M^2 - X_{ss}X_{rr}) + j\frac{\omega_e}{\omega_b}\left(\frac{r_r}{s}X_{ss} + r_s X_{rr}\right)}{\frac{r_r}{s} + j\frac{\omega_e}{\omega_b}X_{rr}}$$

Finally, the active and reactive power can be calculated as :

P = Re [(V**2/Z*)]

Q = Im [(V**2/Z*)]

APPENDIX 2

DERIVATION OF INDUCTION MOTOR DYNAMIC CHARACTERISTIC

Neglecting stator transients the per unit voltage equations in d, q-axis are :

$$v_{qs} = Rs*Xrr/D*F_{qs} + w_e/w_b*F_{ds} - Rs*Xm/D*F_{qr} \qquad (A2.1)$$

$$v_{ds} = Rs*Xrr/D*F_{ds} - w_e/w_b*F_{qs} - Rs*Xm/D*F_{dr} \qquad (A2.2)$$

$$v_{qr} = Rr*Xss/D*F_{qr} + pF_{qr}/w_b - Rr*Xm/D*F_{qs} + (w_e - w_r)/w_b*F_{dr} \qquad (A2.3)$$

$$v_{dr} = Rr*Xss/D*F_{dr} + pF_{dr}/w_b - Rr*Xm/D*F_{ds} - (w_e - w_r)/w_b*F_{qr} \qquad (A2.4)$$

where

$$Xss = Xs + Xm$$

$$Xrr = Xr + Xm$$

$$D = Xss*Xrr - Xm**2$$

The equation of motion is :

$$2*H*pw_r/w_b = Te - Tm \qquad (A2.5)$$

where

$$Te = Xm/D*(F_{qs}*F_{dr} - F_{qr}*F_{ds})$$

$$Tm = a + b*w_r + c*w_r**2$$

The corresponding equations are :

$$F_{qs} = Xs*i_{qs} + Xm*(i_{qs} + i_{qr}) \quad (A2.6)$$

$$F_{ds} = Xs*i_{ds} + Xm*(i_{ds} + i_{dr}) \quad (A2.7)$$

$$F_{qr} = Xr*i_{qr} + Xm*(i_{qs} + i_{qr}) \quad (A2.8)$$

$$F_{dr} = Xr*i_{dr} + Xm*(i_{ds} + i_{dr}) \quad (A2.9)$$

and

$$v_{qs} = Rs*i_{qs} + w_e/w_b*F_{ds} \quad (A2.10)$$

$$v_{ds} = Rs*i_{ds} - w_e/w_b*F_{qs} \quad (A2.11)$$

$$v_{qr} = Rr*i_{qr} + (w_e-w_r)/w_b*F_{dr} + pF_{qr}/w_b \quad (A2.12)$$

$$v_{dr} = Rr*i_{dr} - (w_e-w_r)/w_b*F_{qr} + pF_{dr}/w_b \quad (A2.13)$$

To develop induction motor model we assume that
- stator transients are negligible
- rotor is short circuit, thus $v_{dr} = v_{qr} = 0$
- resistances and reactances are constant.

The differential equations of the rotor circuits and the differential equation of motion are solved in the present work by numerical method based on the trapezoidal rule. At each time interval these equations together with the stator voltage equations can be solved iteratively beginning with known initial condition in the steady state. Note that the zero position of the reference frame is selected so that $v_{ds} = 0$.

Initial condition can be derived from active and reactive power which can be calculated by the method presented in Appendix 1. Beginning with the active and reactive power in the steady state Po, Qo the following initial values can be derive :

$$i_{qso} = (Po - v_{dso}*i_{dso})/v_{qso} \quad \text{(A2.14)}$$

$$i_{dso} = (Qo + v_{dso}*iqso)/v_{qso} \quad \text{(A2.15)}$$

From (A2.14) - (A2.15) and (A2.1) - (A2.9) with neglecting the differential terms due to steady state condition one can find the initial values of F_{qso}, F_{dso}, F_{qro}, F_{dro}, and w_{ro}.

At each time step i_{ds} and i_{qs} are calculated by (A2.10) and (A2.11) and then the active and reactive power can be calculated as :

$$P = v_{qs}*i_{qs} + v_{ds}*i_{ds} \quad \text{(A2.16)}$$

$$Q = v_{qs}*i_{ds} - v_{ds}*i_{qs} \quad \text{(A2.17)}$$

APPENDIX 3

MOTOR PARAMETERS APPROXIMATION

The method used here is similar to that used in ref. [15]. However, it is different in finding leakage reactances. The purpose is to make the method simple as possible.

The input and output power of an induction motor in per unit is :

$$P_{in} = V_s * I_s * \cos\phi \qquad (A3.1)$$

$$P_o = T(1-s) \qquad (A3.2)$$

$$T = (I_r ** 2) * Rr/s \qquad (A3.3)$$

According to ref.[15], we make the approximation that :

$$I_r = I_s * \cos\phi \qquad (A3.4)$$

Input and output power power are related by the following equation :

$$(I_s ** 2) * (\cos^2\phi) * (Rr/s) * (1-s)/n = V_s * I_s * \cos\phi \qquad (A3.5)$$

In steady state, we assume that V_s = 1.0 pu. and I_s = 1.0 pu.

From these equations we can obtain :

$$Rr = \eta * s/[(1-s)*\cos\phi]$$

$$Xm = \eta/[(1-s)*\sin\phi]$$

$$Rs = (\cos\phi)*[1-\eta/(1-s)]$$

To find Xs and Xr we assume that the two values are equal. The starting current I_{st} is assumed by :

$$I_{st} = V_s/(Xs+Xr)$$

where I_{st} is obtained from manufacturer data. Thus

$$Xs = Xr = V_s/(2*I_{st})$$

The inertia constant is :

$$H = (0.5*J*w_s**2)/P_B$$

where

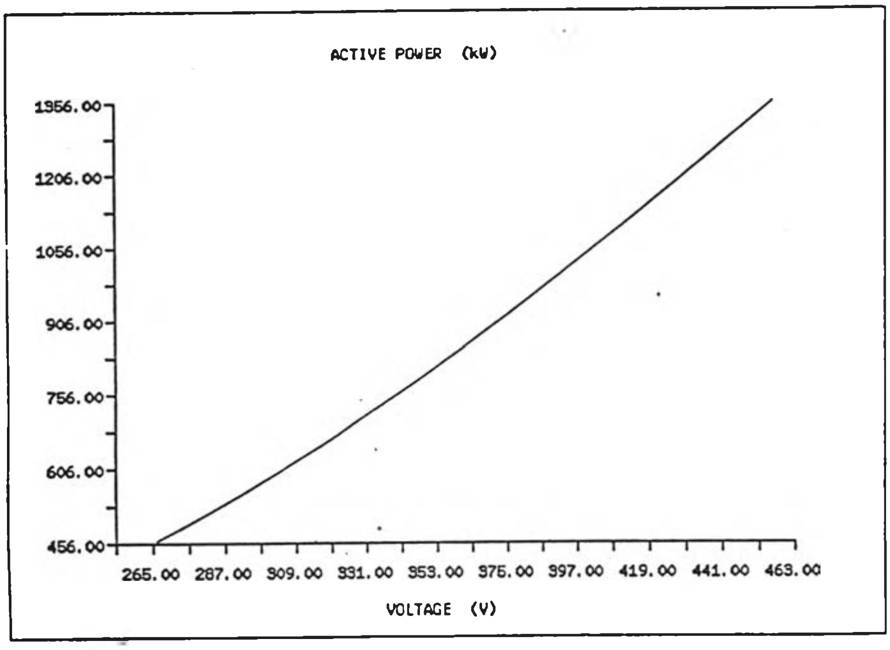
J is moment of inertia

w_s is synchronous speed

P_B is base power

APPENDIX 4

COMPUTER SIMULATION RESULTS



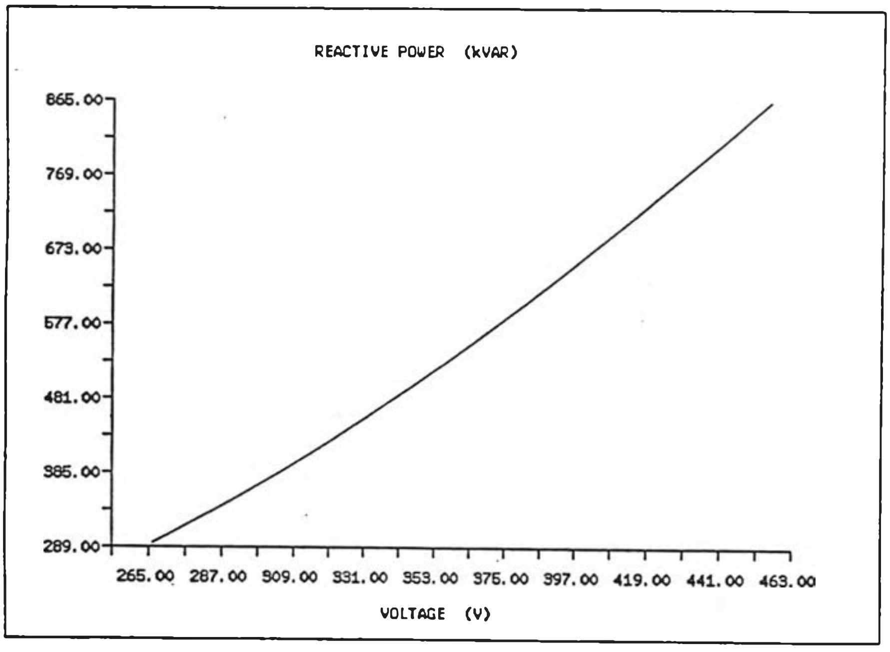
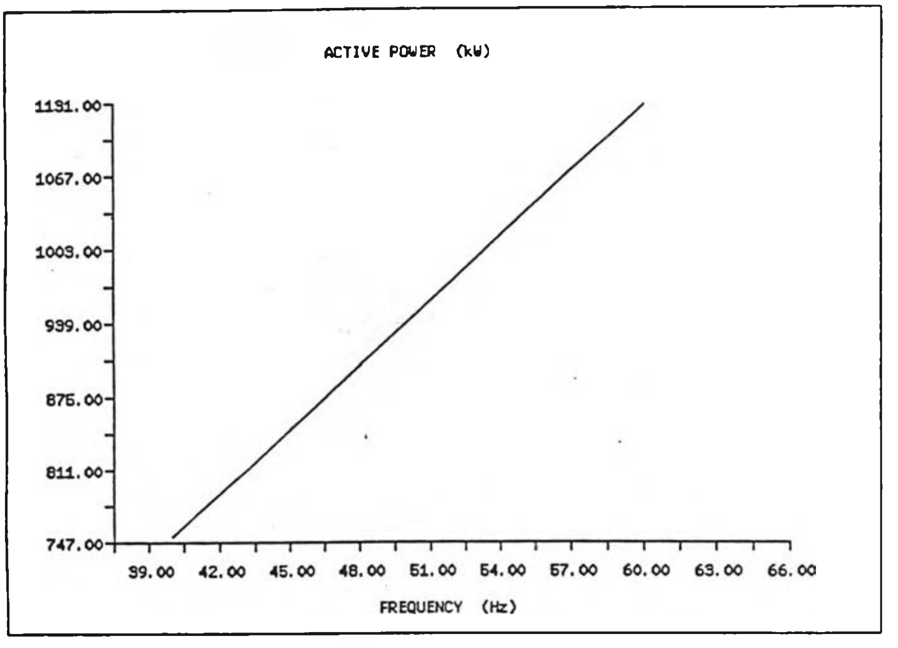


Fig. A4.1 Steady state voltage characteristic of load case 1



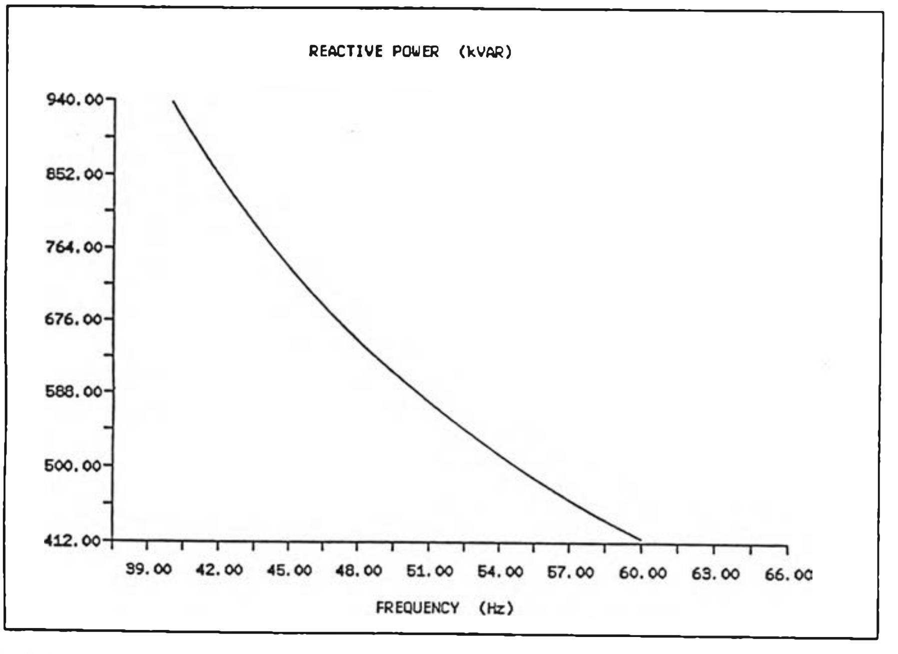
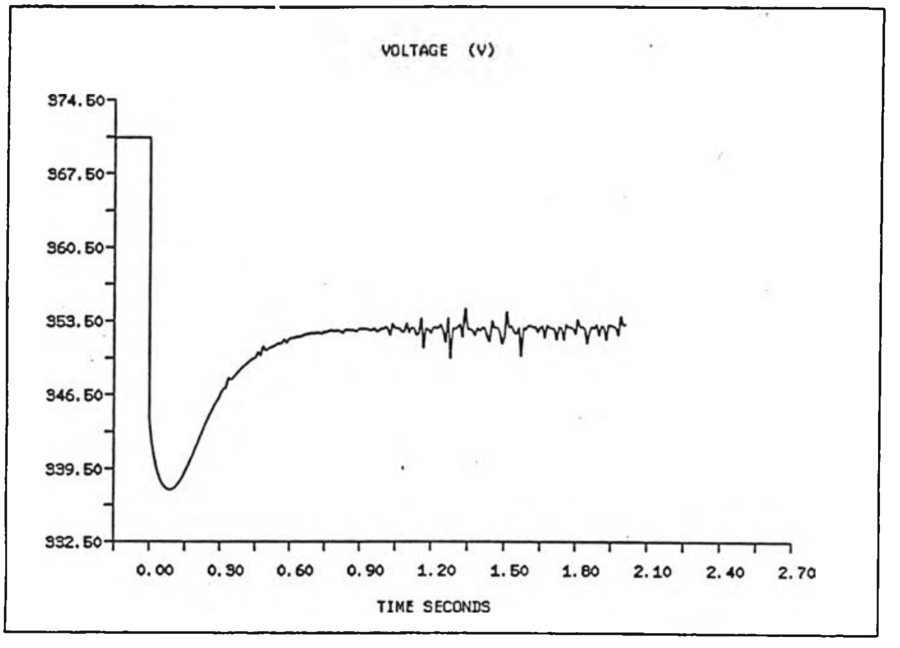


Fig. A4.2 Steady state frequency characteristic of load case 1



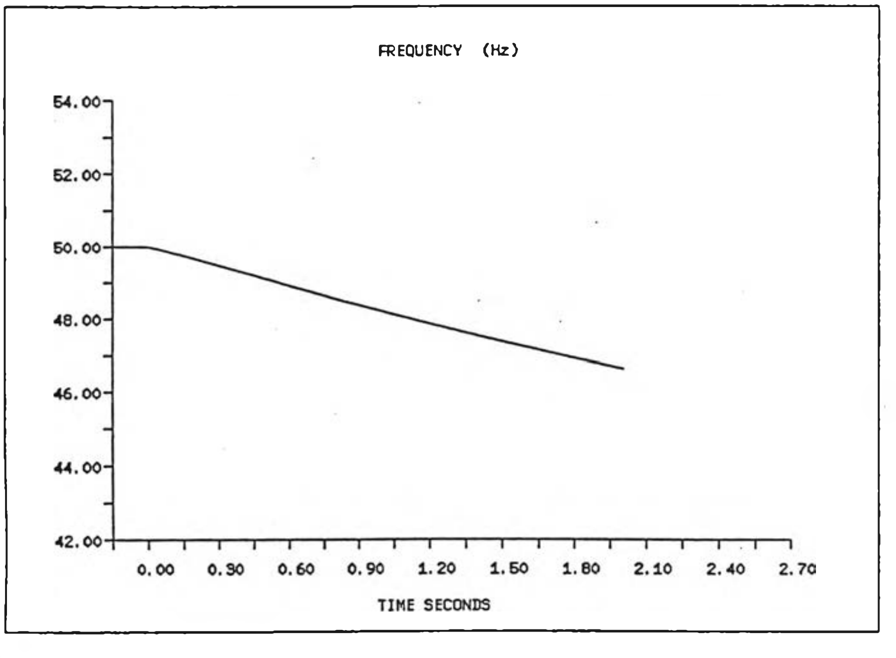
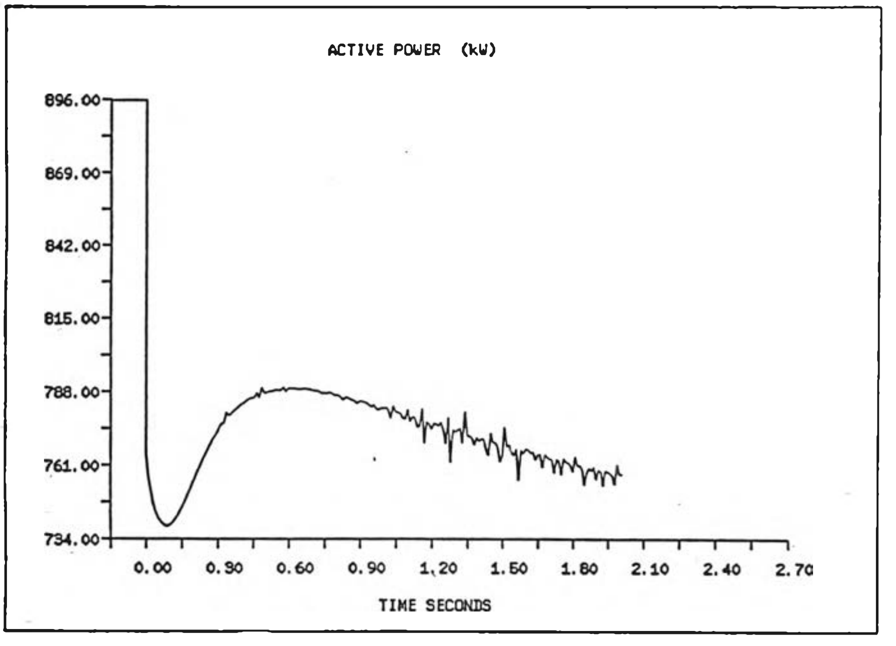


Fig. A4.3 Voltage and frequency at bus 3 during gen. 2 disconnected

a



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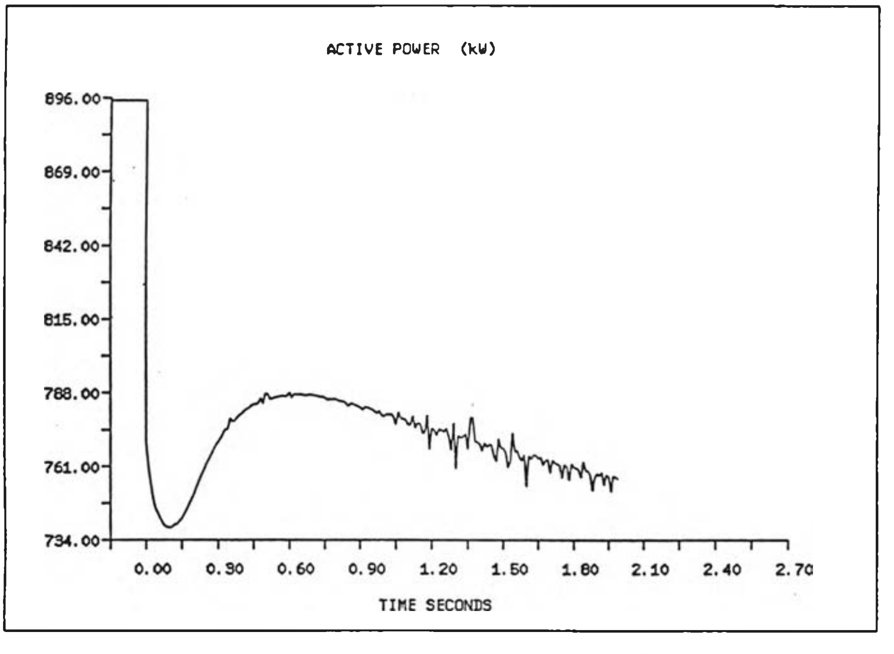
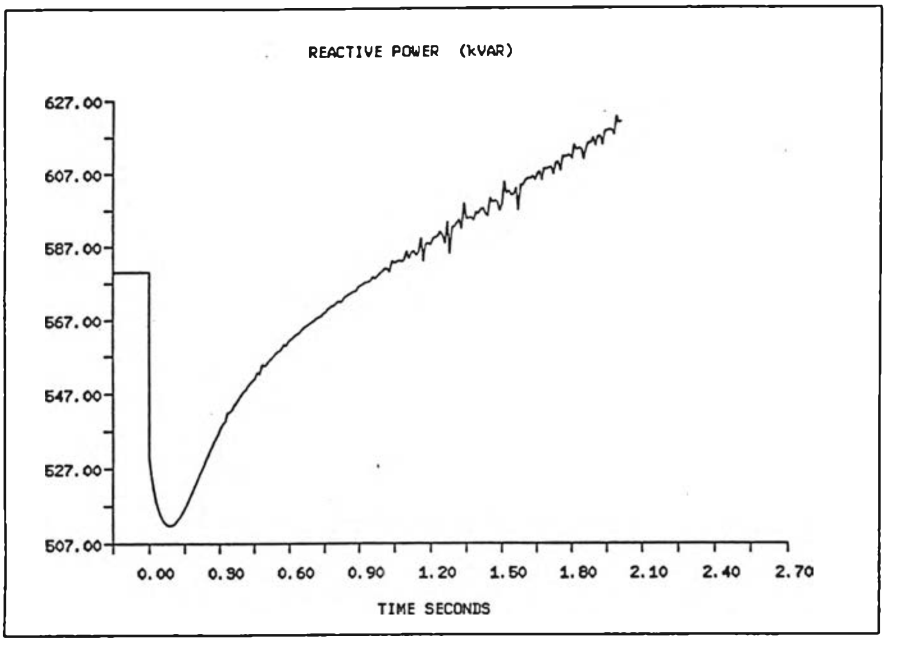


Fig. A4.4 Active power of load case 1 during gen. 2 disconnected

a. from SIMPOW

b. from developed programme

a



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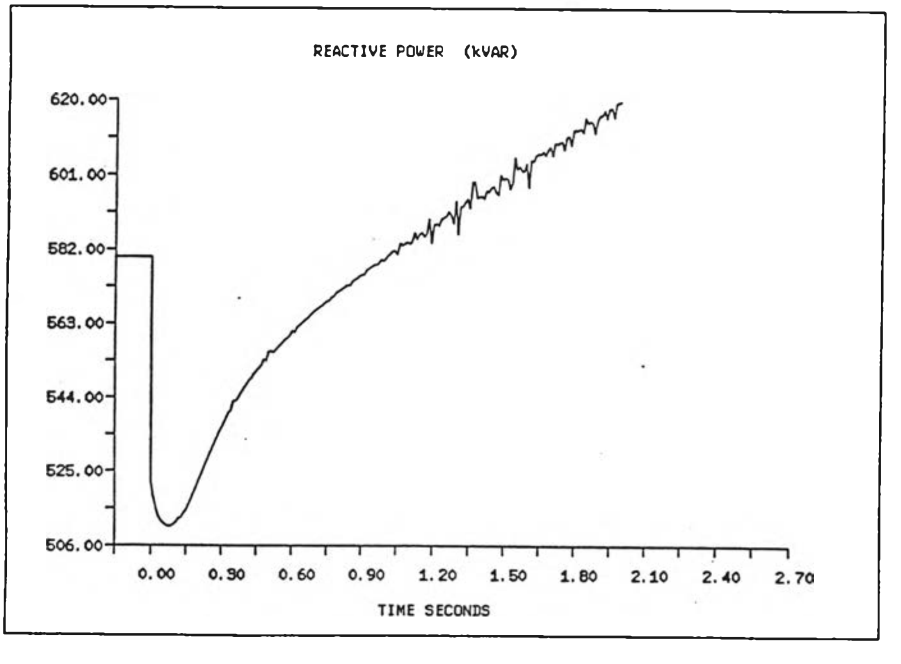
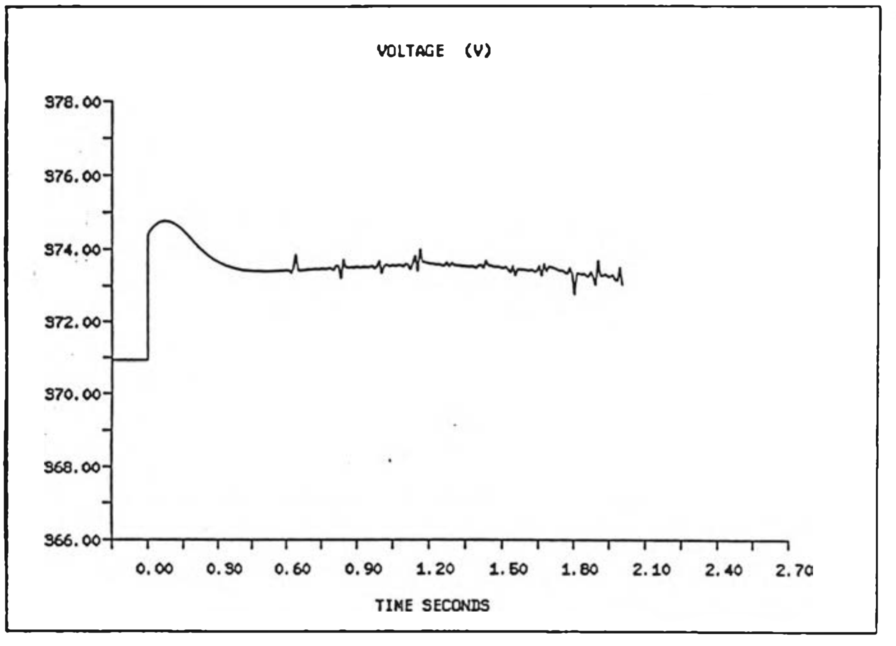


Fig. A4.5 Reactive power of load case 1 during gen. 2 disconnected

a. from SIMPOW

b. from developed programme



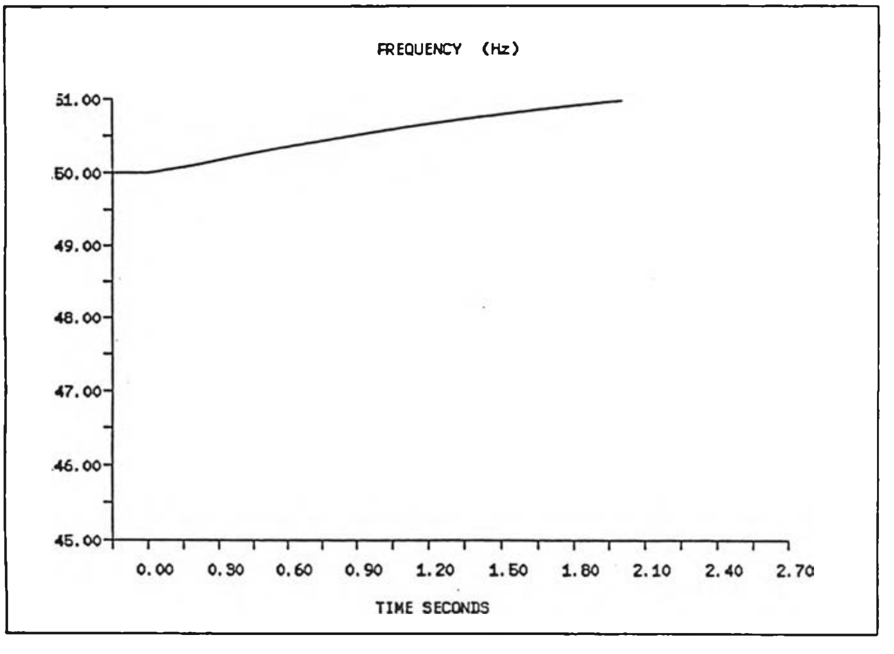
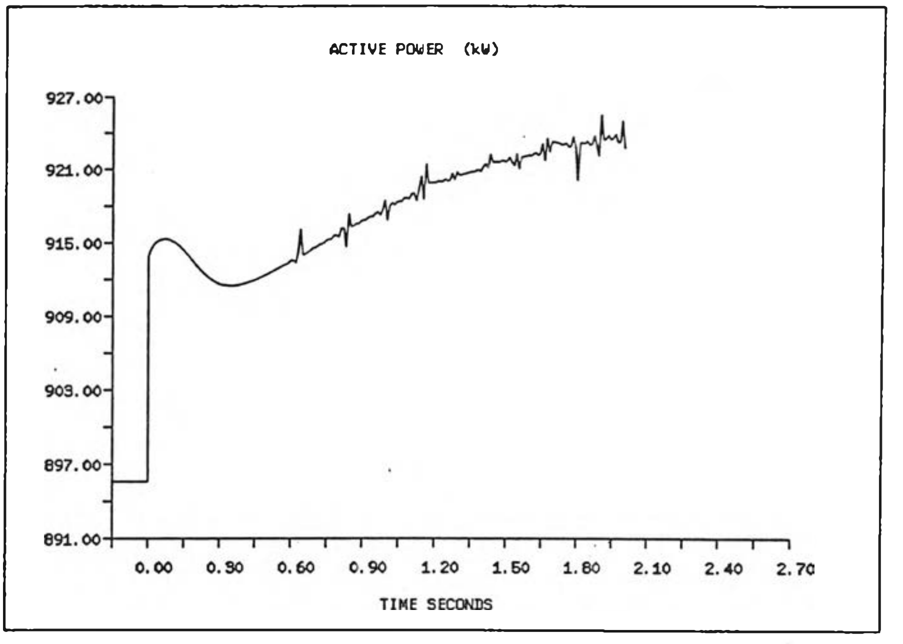


Fig. A4.6 Voltage and frequency at bus 3 during load at bus 2 disconnected

a



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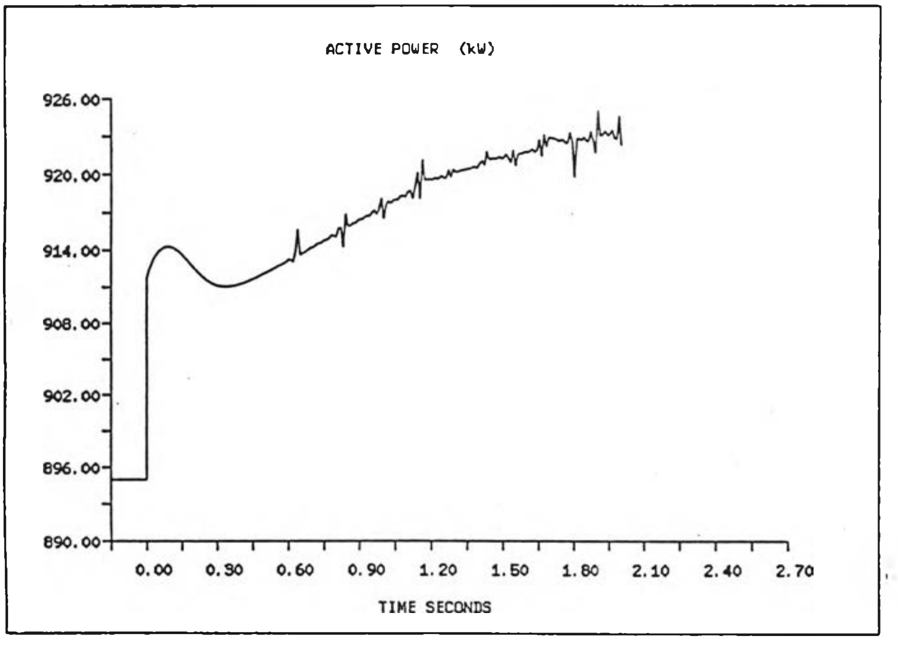
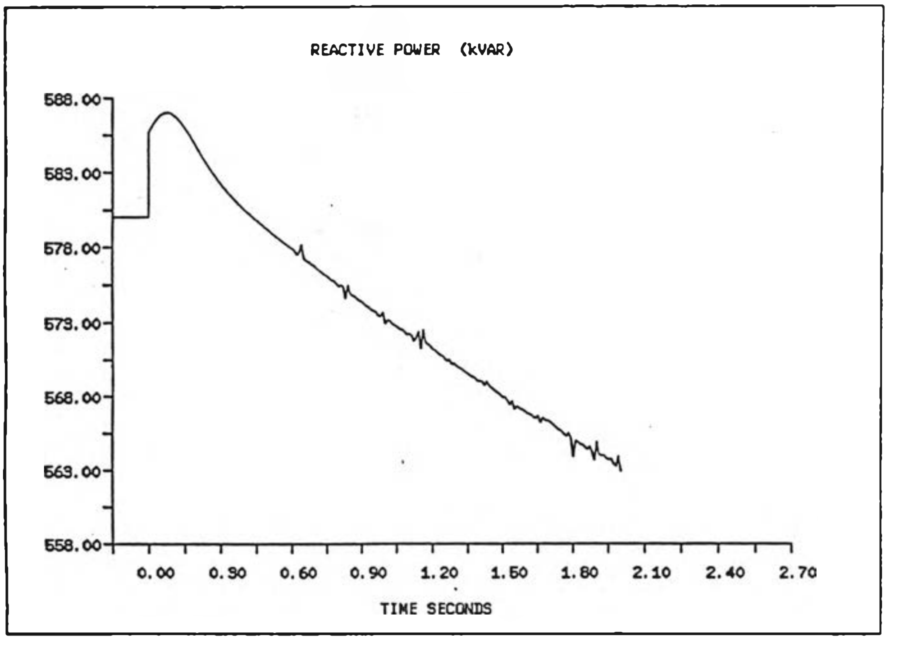


Fig. A4.7 Active power at bus 3 during load at bus 2 disconnected

a. from SIMPOW

b. from developed programme

a



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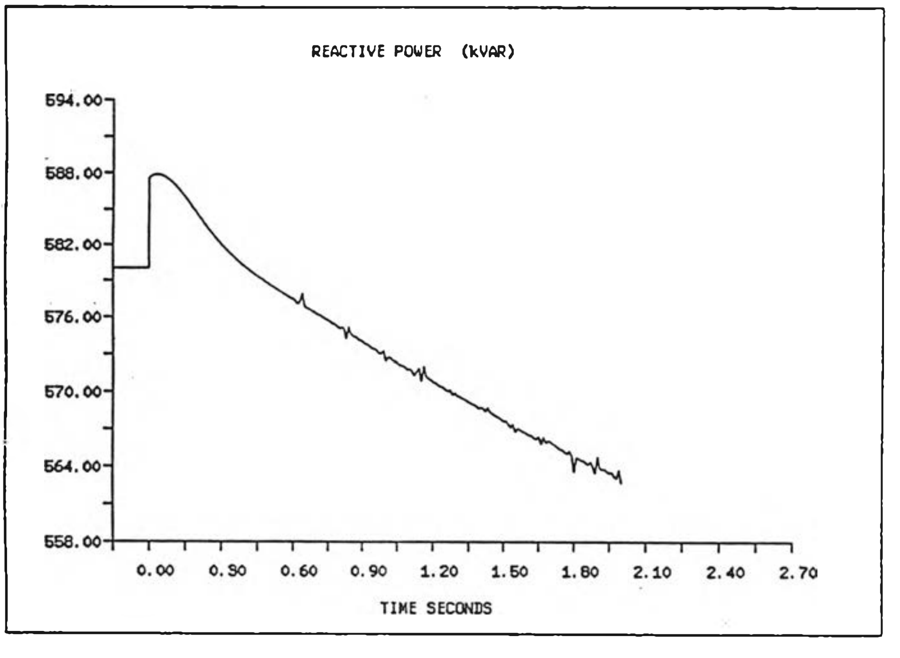
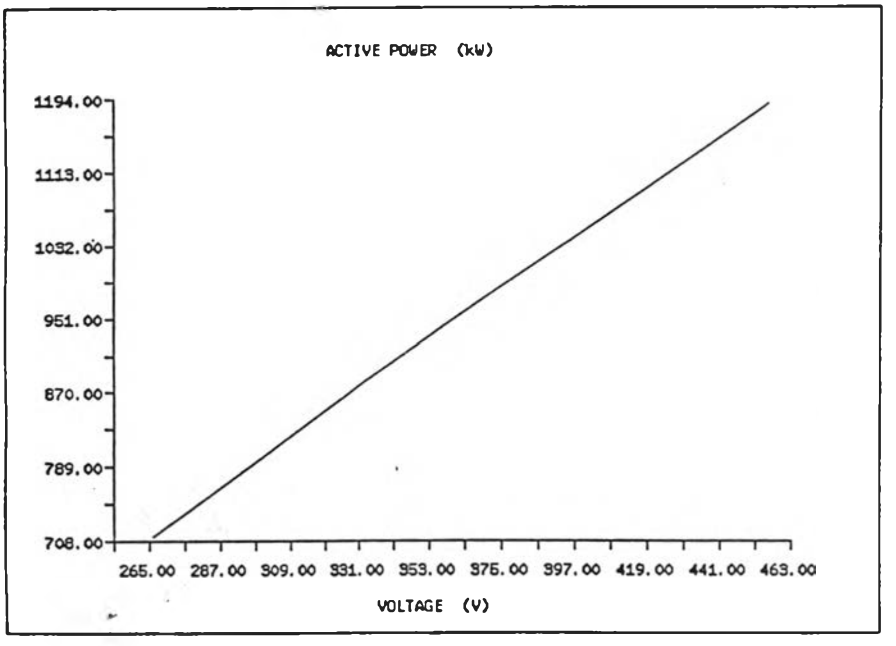


Fig. A4.8 Reactive power at bus 3 during load at bus 2 disconnected

a. from SIMPOW

b. from developed programme



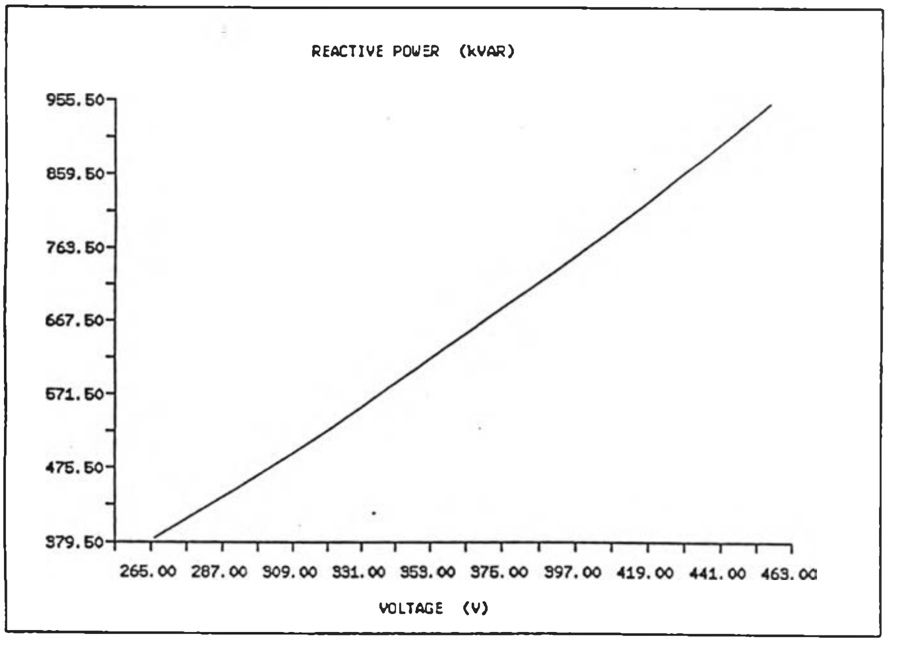
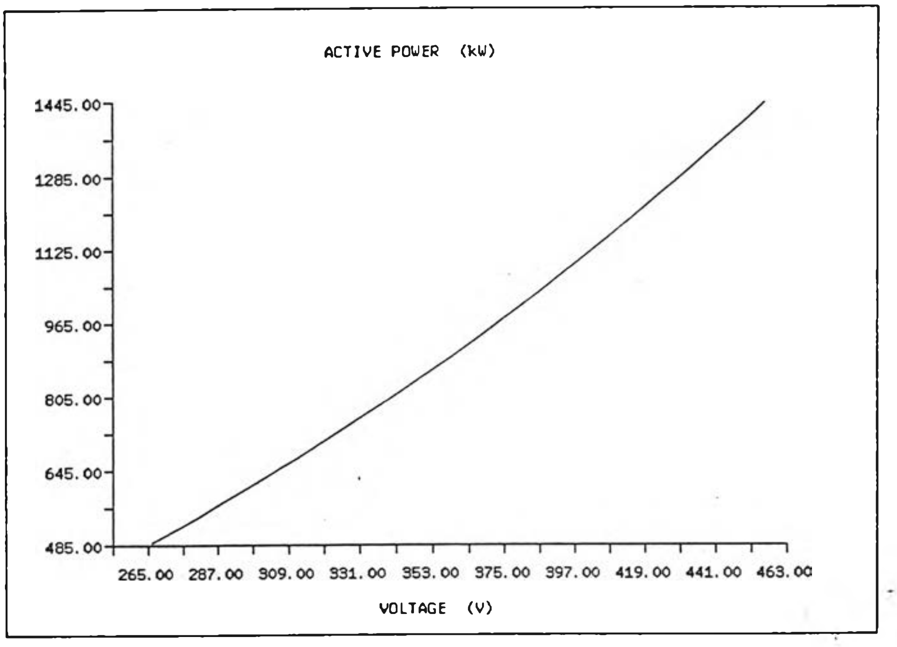


Fig. A4.9 Steady state voltage characteristic of load case 2 used aggregate model



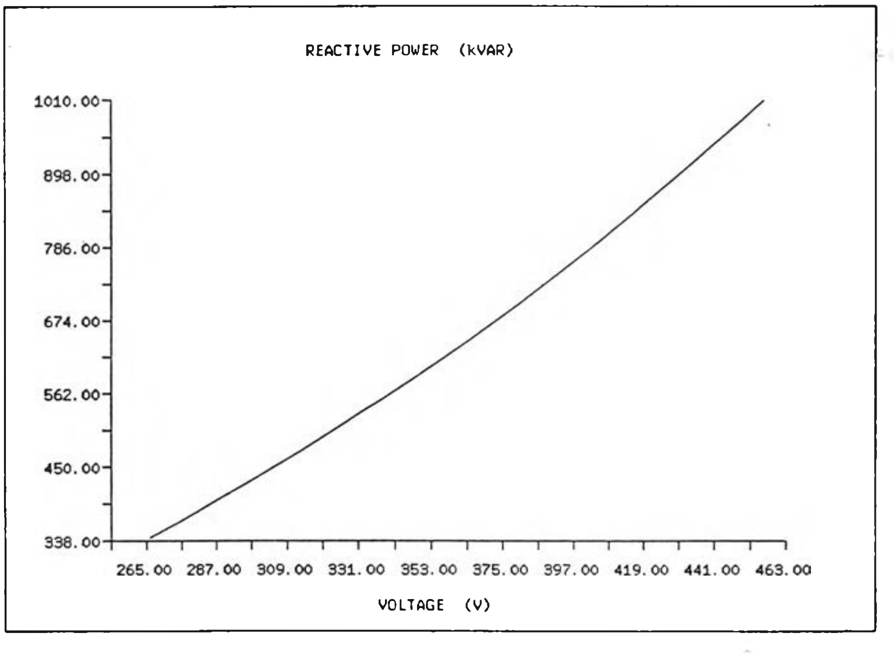


Fig.A4. 10 Steady state voltage characteristic of load case 2 used constant impedance model

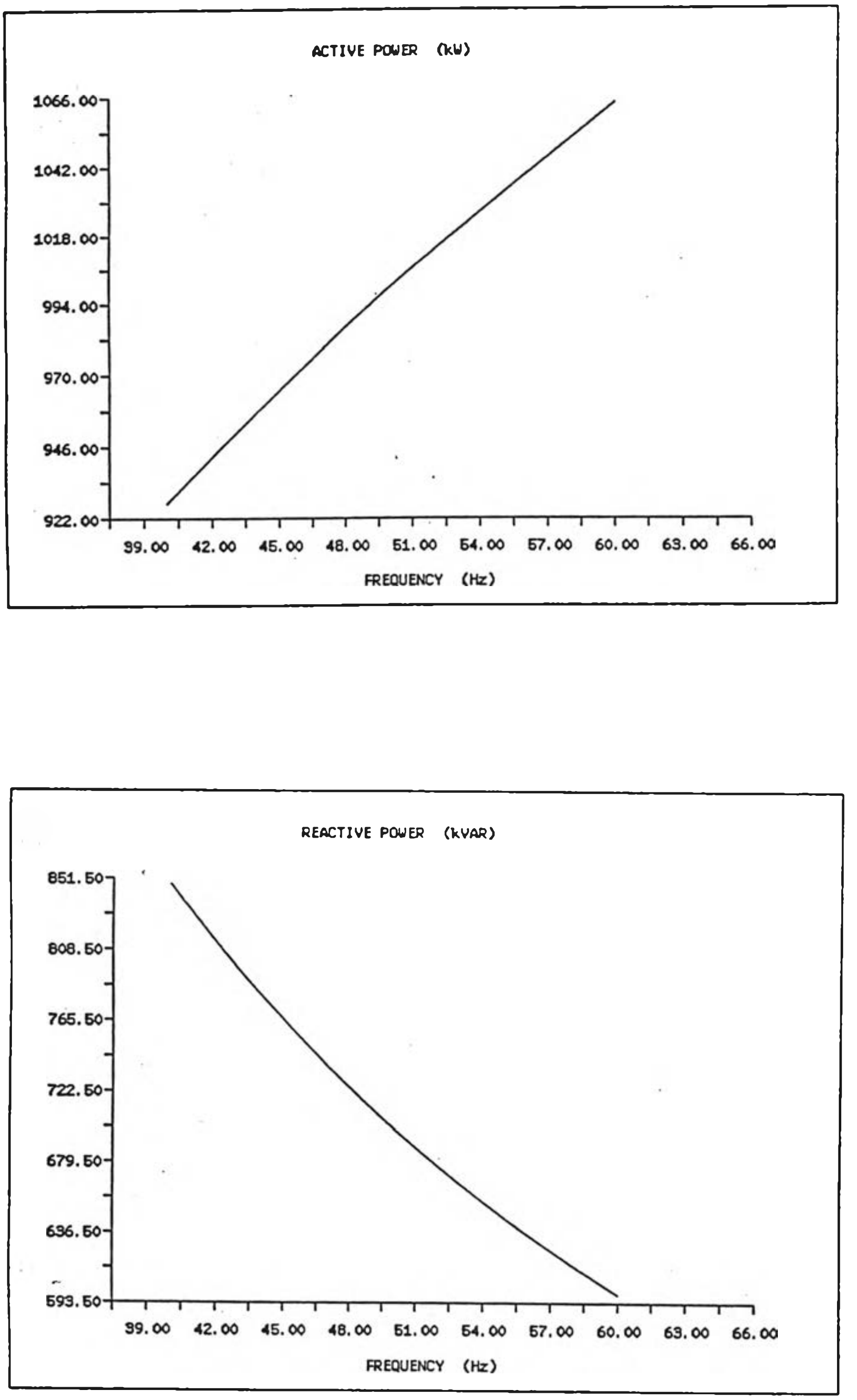
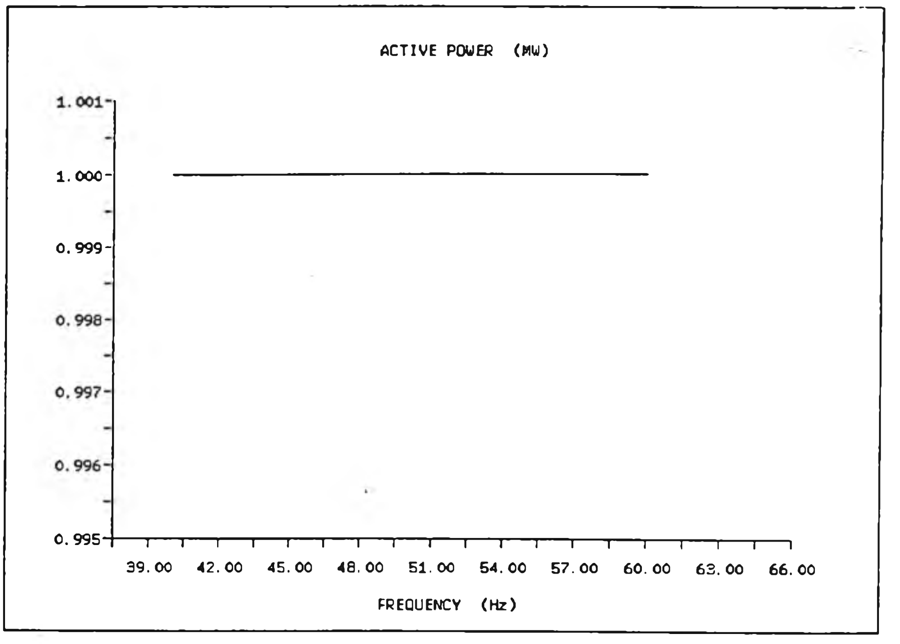


Fig. A4.11 Steady state frequency characteristic of load case 2 used aggregate model



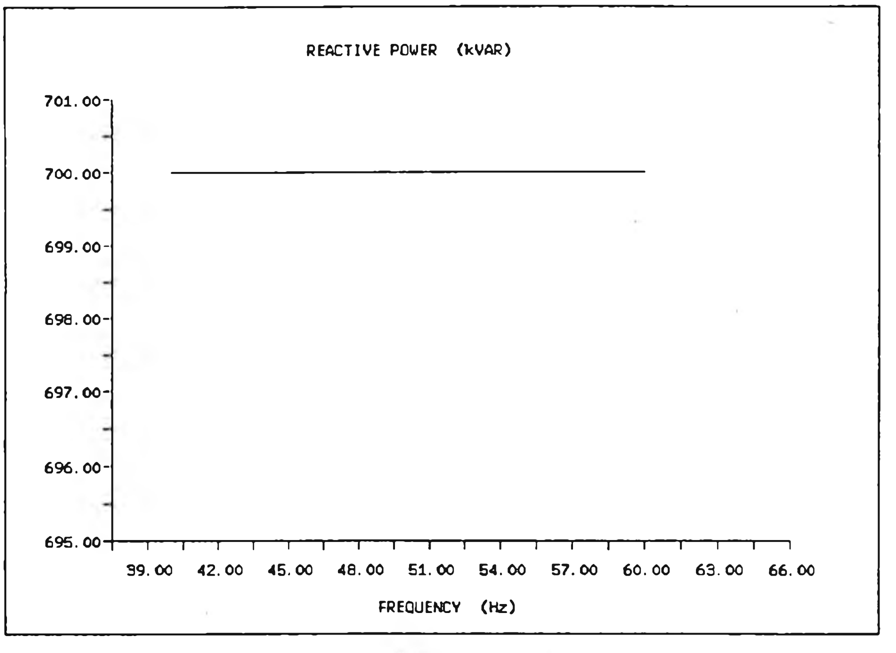
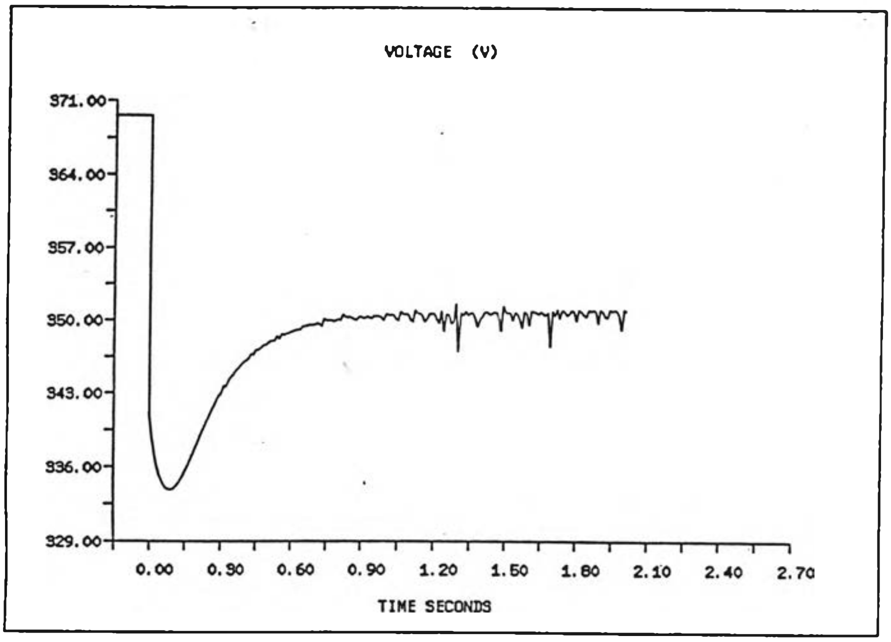


Fig. A4.12 Steady state frequency characteristic of load case 2 used constant impedance model



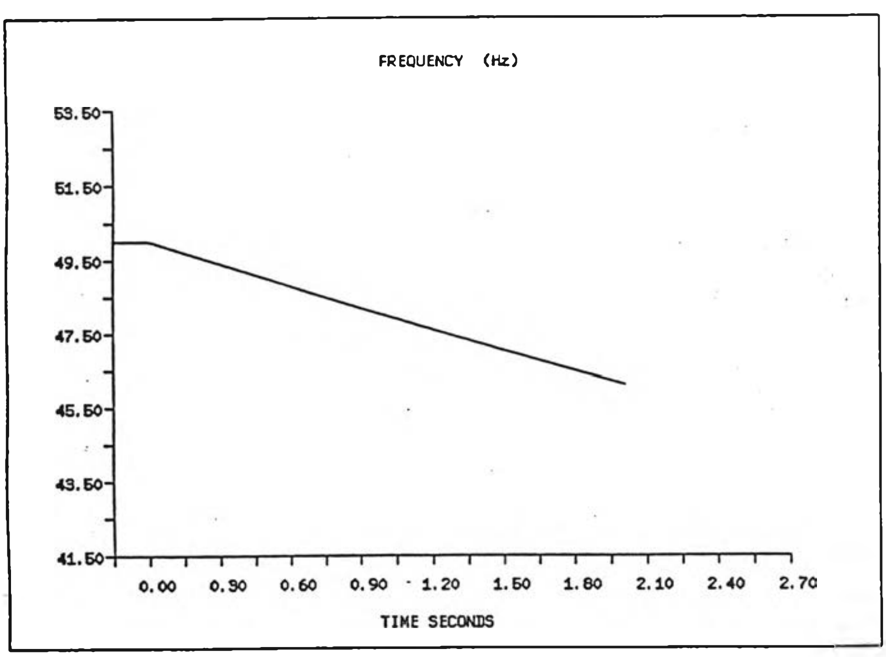
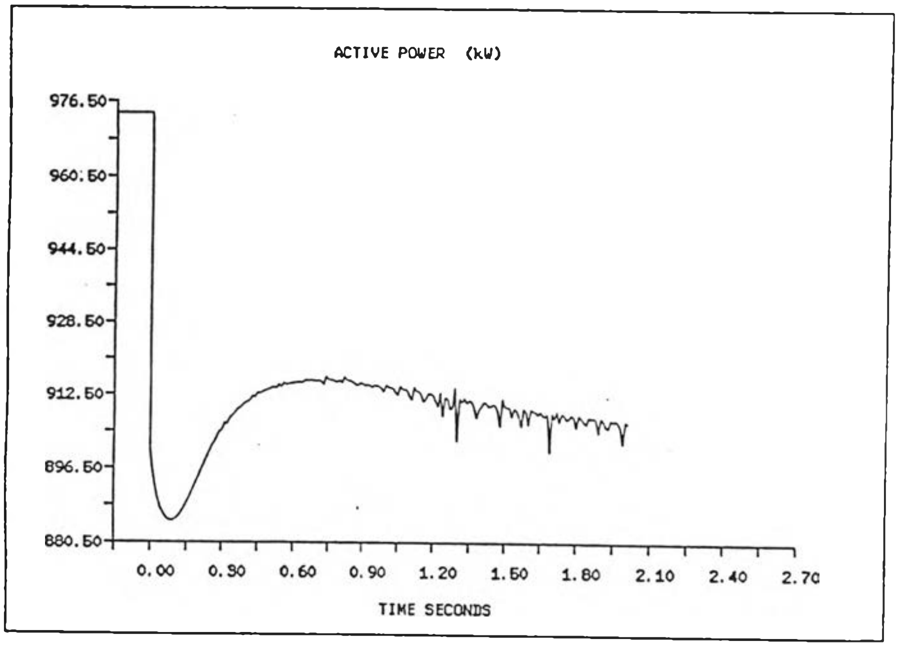


Fig. A4.13 Voltage and frequency at bus 3 during gen. 2 disconnected

a



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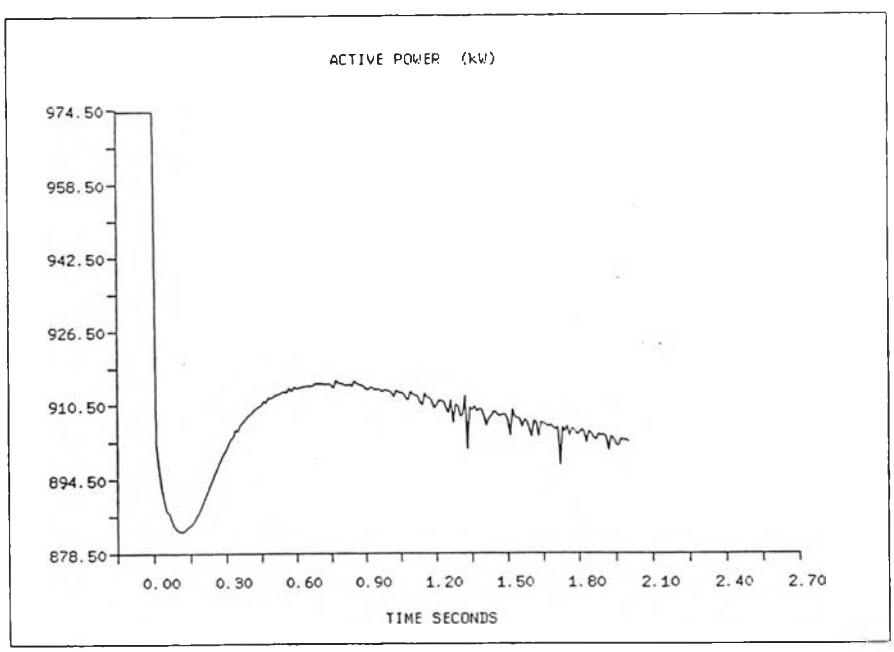
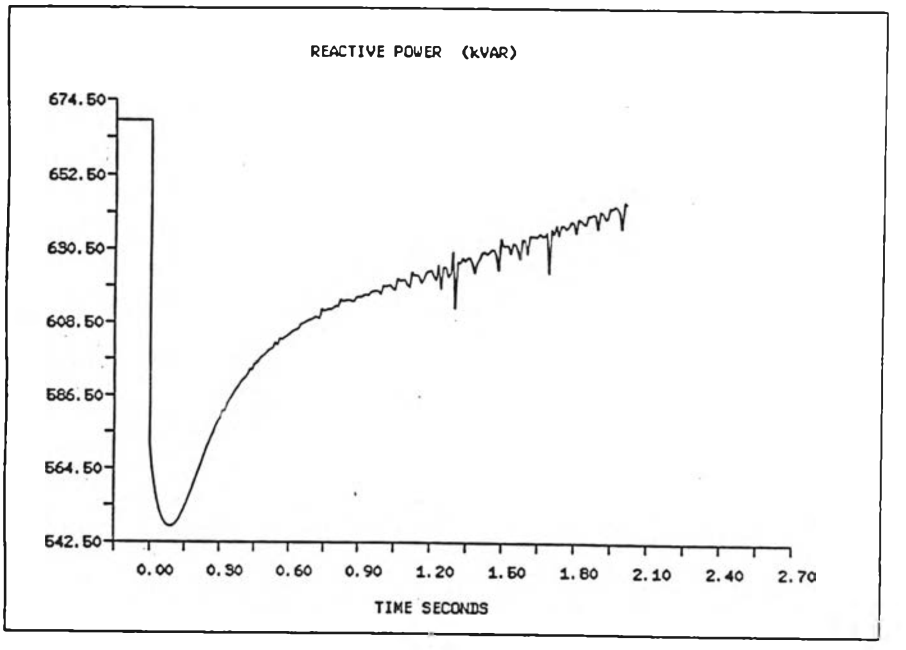


Fig. A4.14 Active power at bus 3 during gen. 2 disconnected

a. from SIMPOW based on individual representation

b. from developed programme based on aggregate model

a



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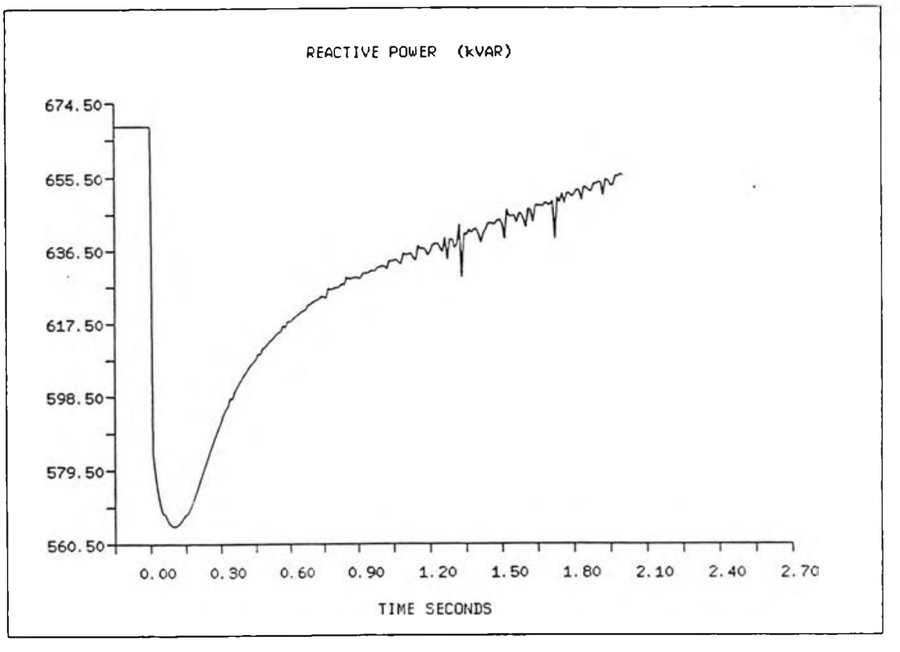
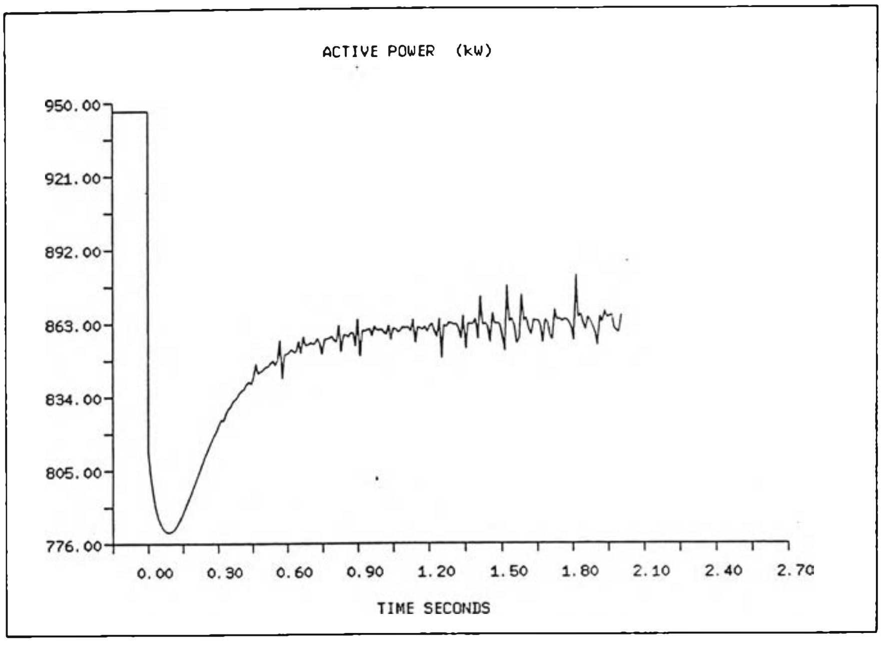


Fig. A4.15 Reactive power at bus 3 during gen. 2 disconnected

a. from SIMPOW based on individual representation

b. from developed programme based on aggregate model



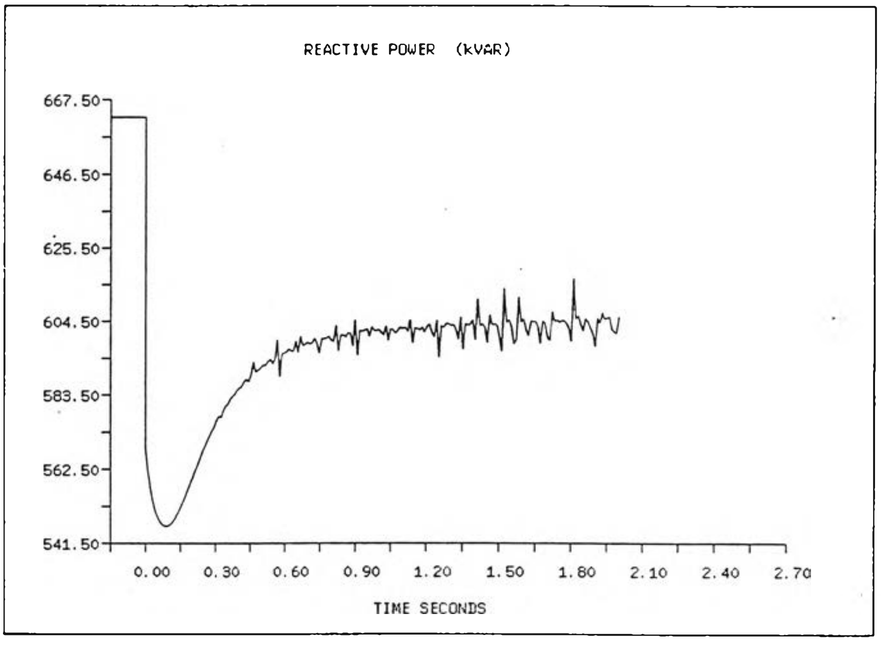
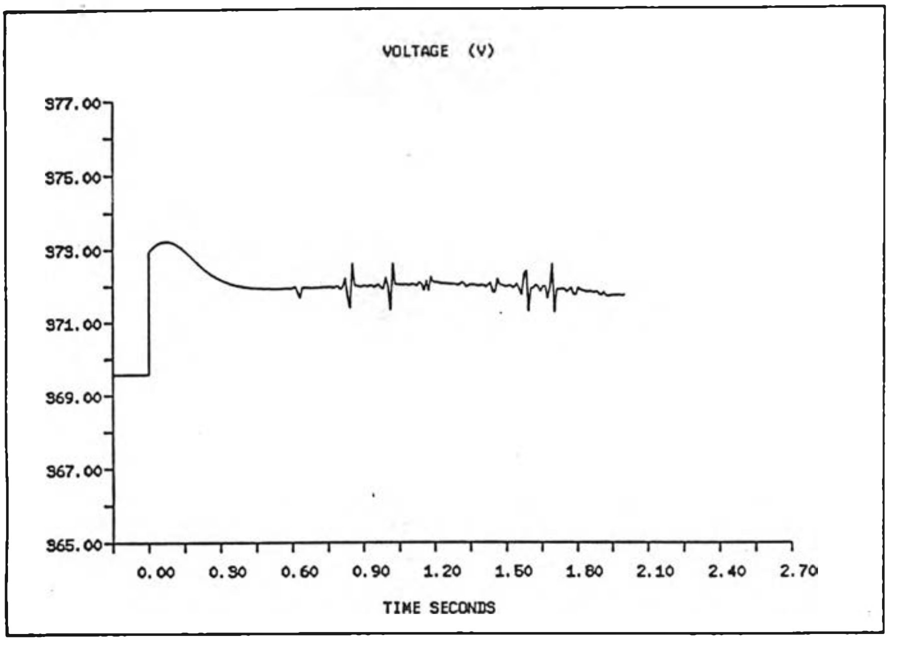


Fig. A4.16 Active and reactive power during gen. 2 disconnected used constant impedance model



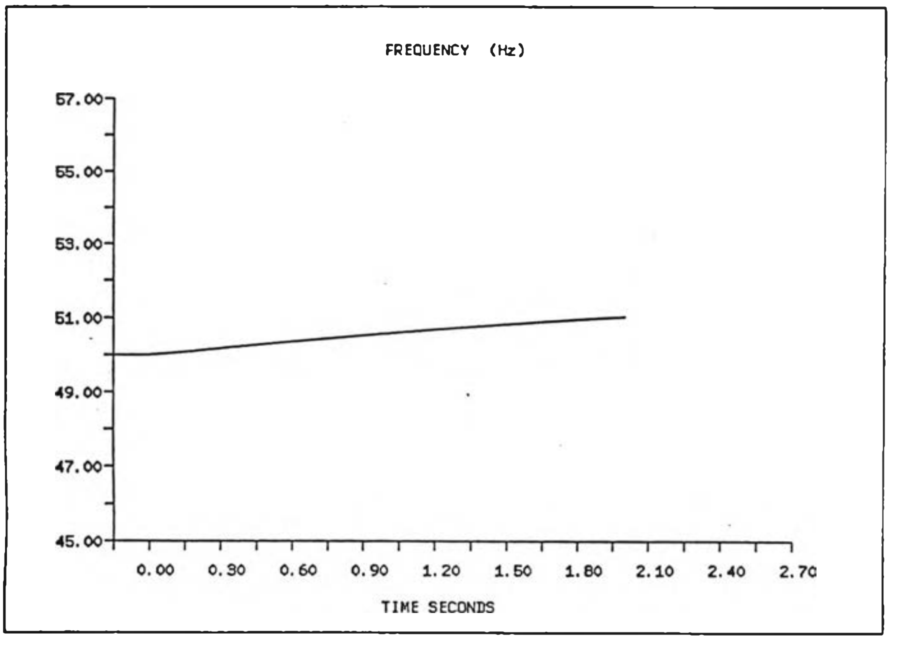
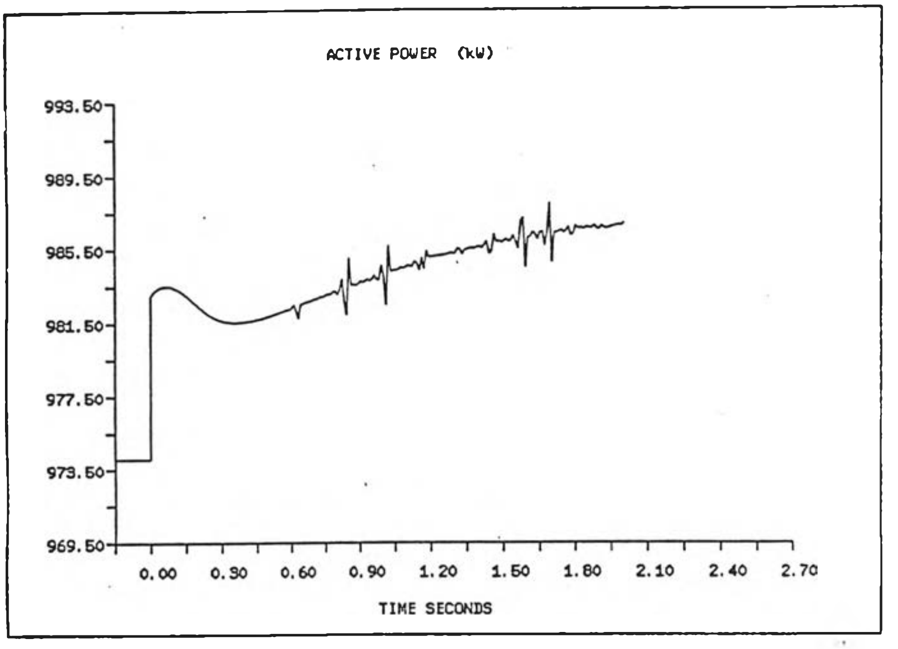


Fig. A4.17 Voltage and frequency at bus 3 during load bus 2 disconnected

a



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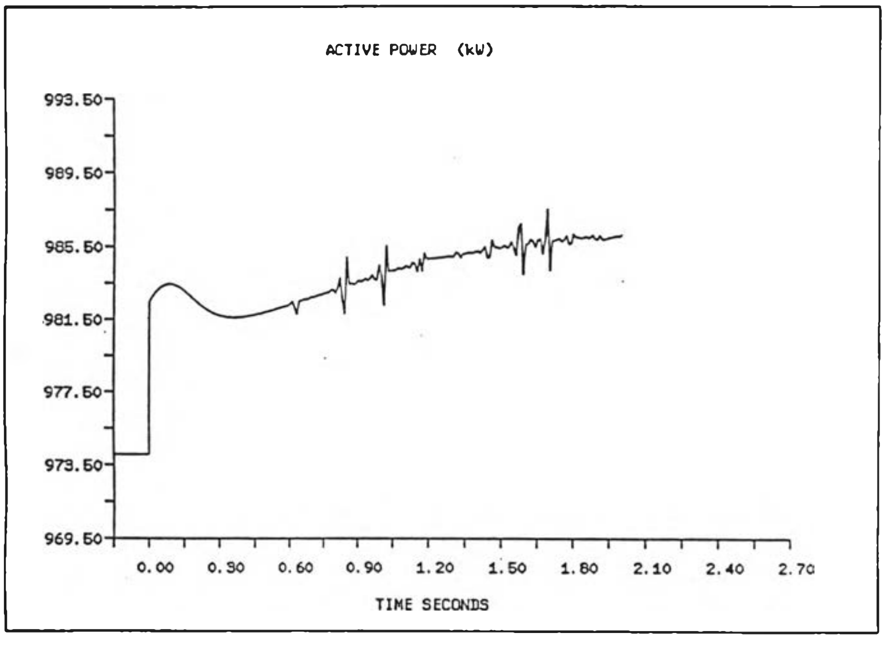
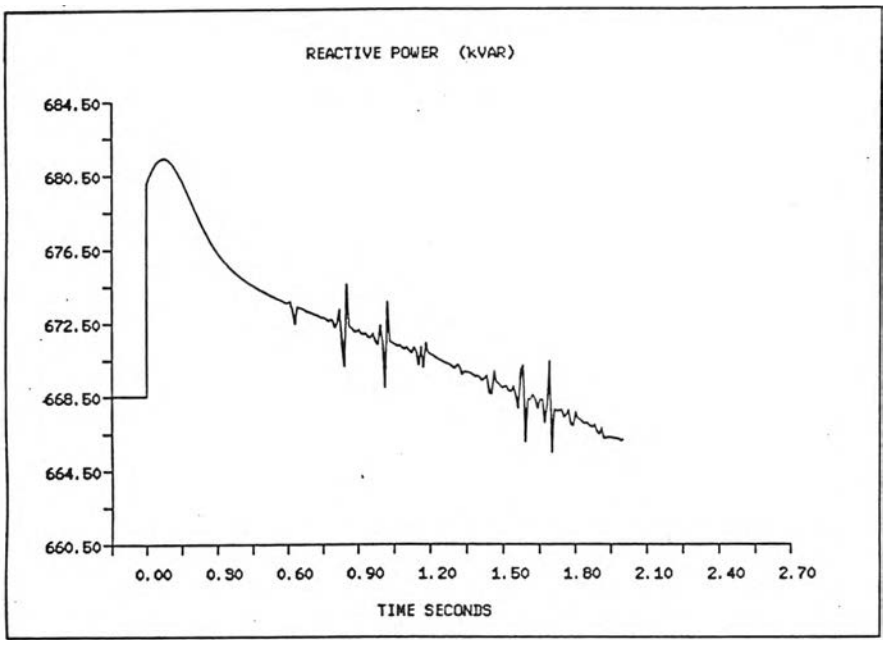


Fig. A4.18 Active power at bus 3 during load bus 2 disconnected

a. from SIMPOW based on individual representation

b. from developed programme based on aggregate model

a



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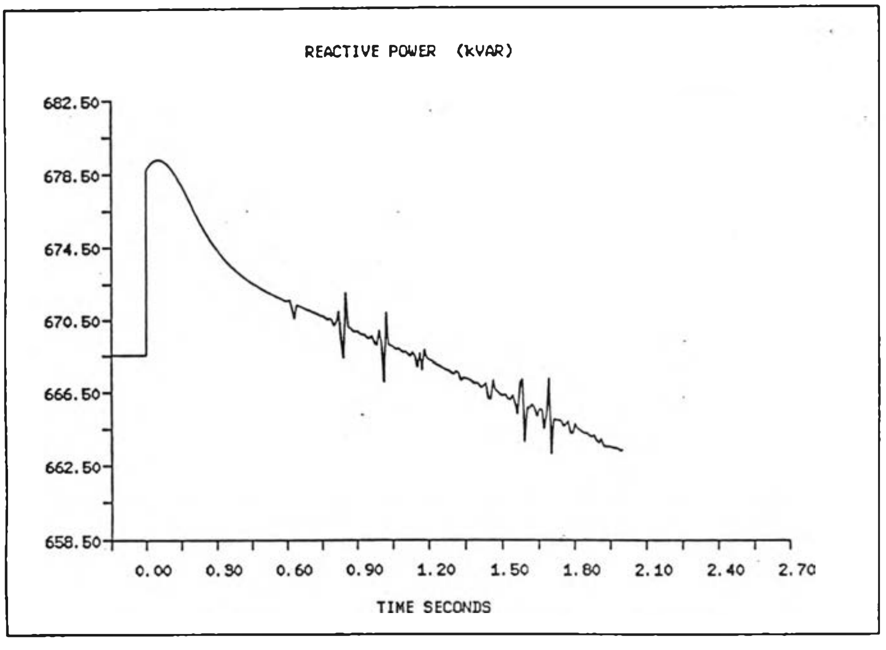
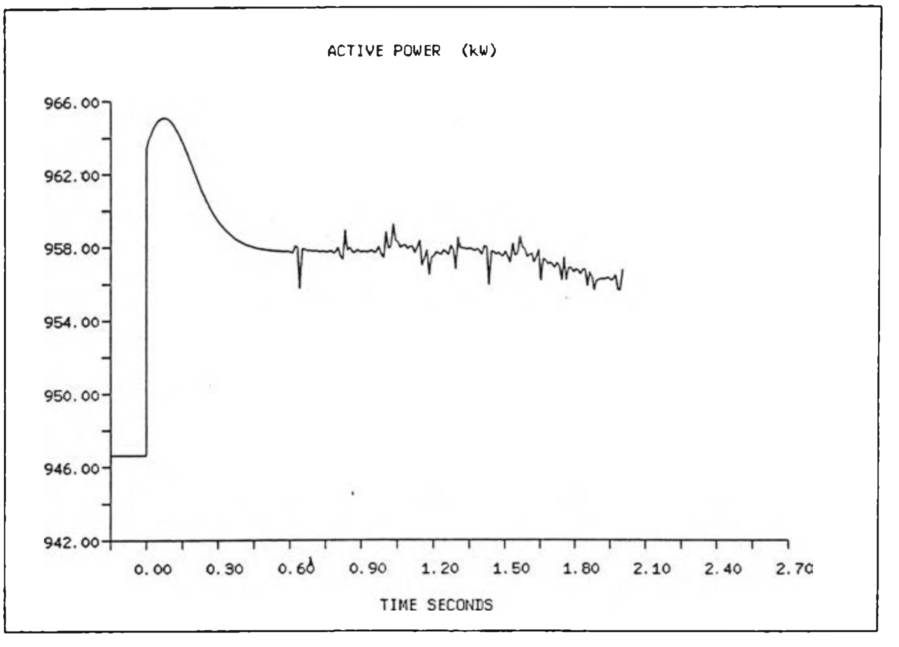


Fig. A4.19 Reactive power at bus 3 during load bus 2 disconnected

a. from SIMPOW based on individual representation

b. from developed programme based on aggregate model



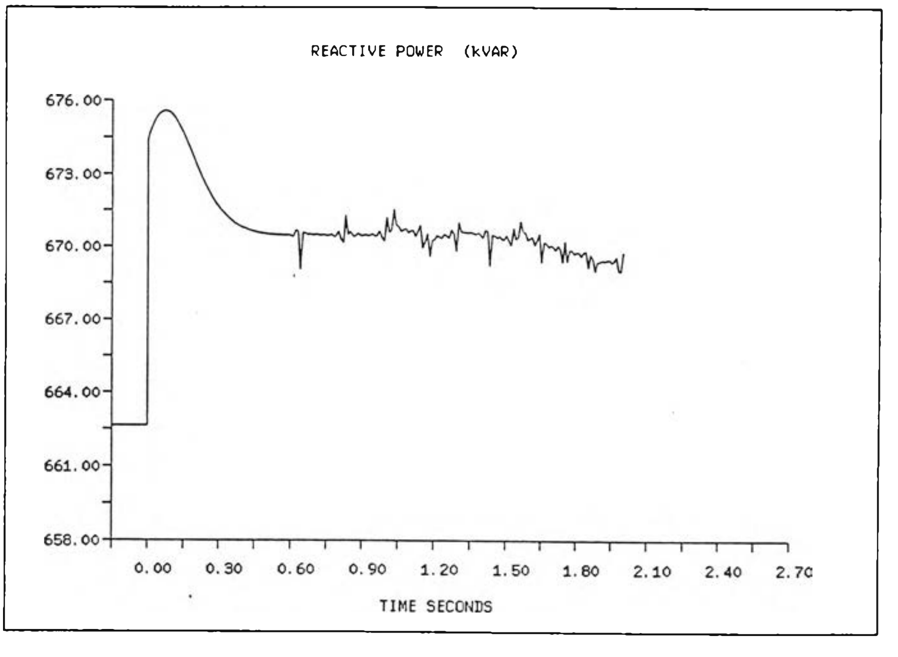
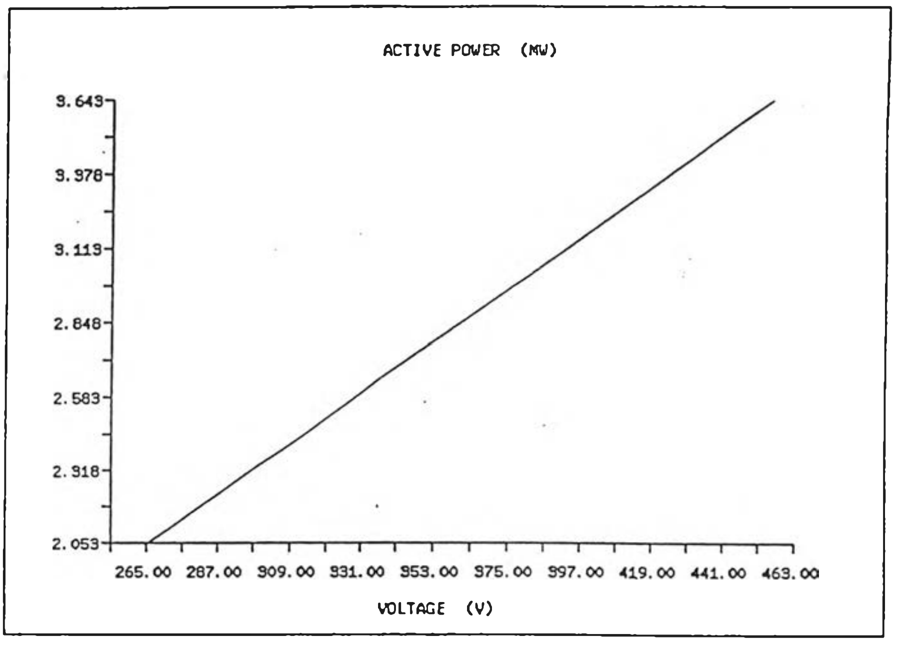


Fig. A4.20 Active and reactive power during load bus 2 disconnected used constant impedance model



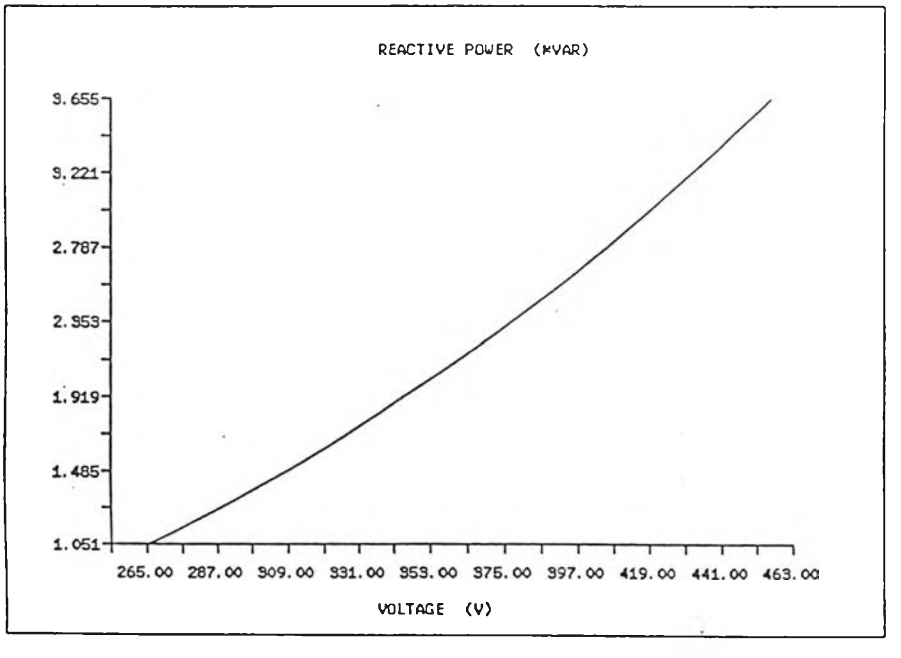
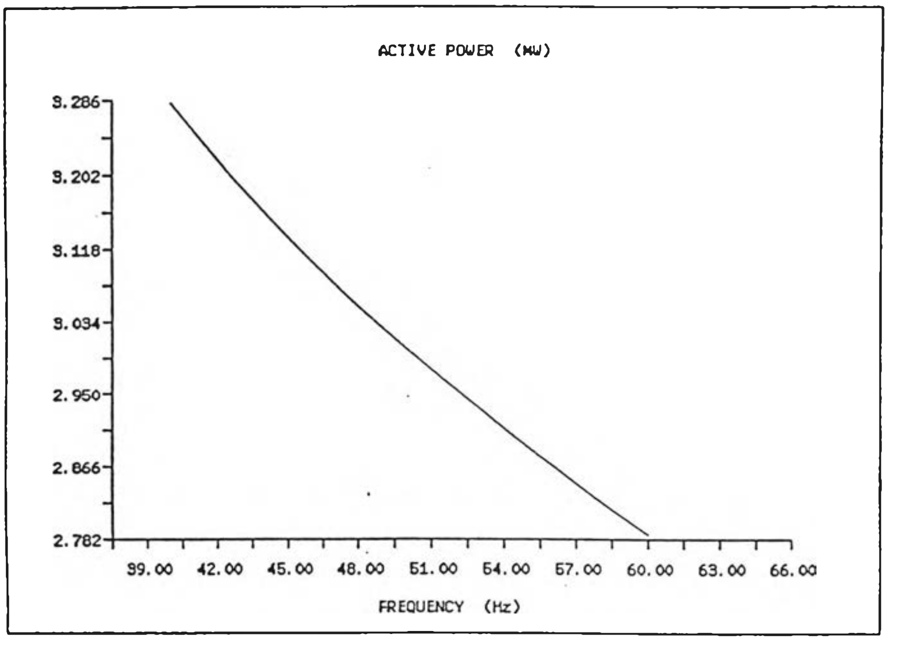


Fig. A4.21 Steady state voltage characteristic of load case 3 used aggregate model



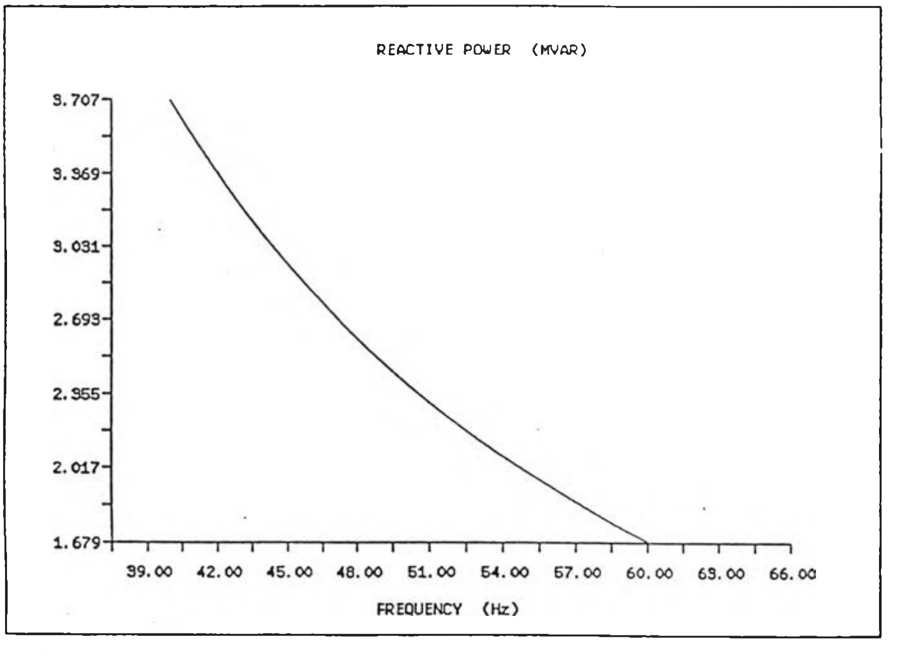
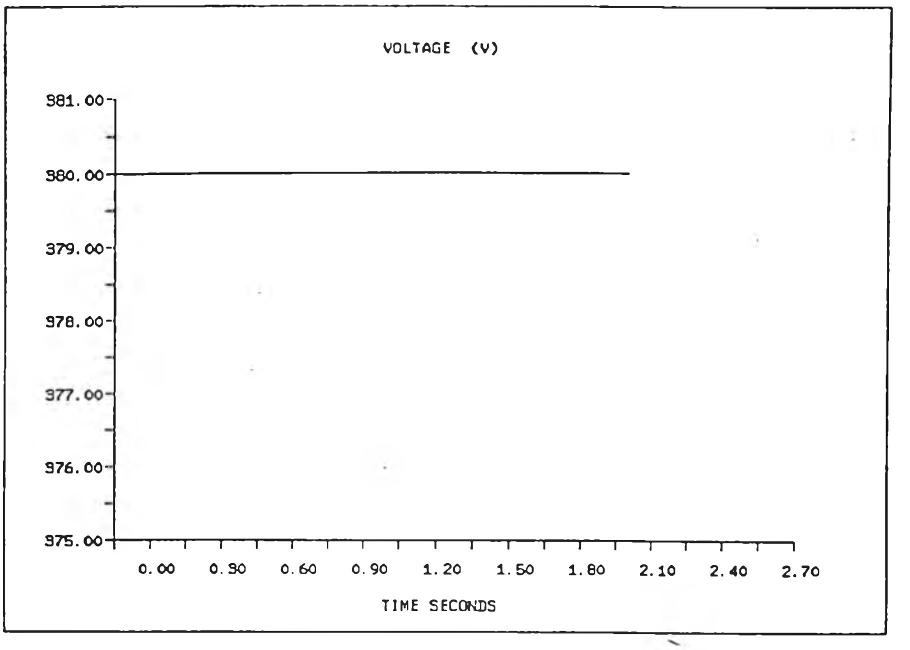


Fig. A4.22 Steady state frequency characteristic of load case 3 used aggregate model



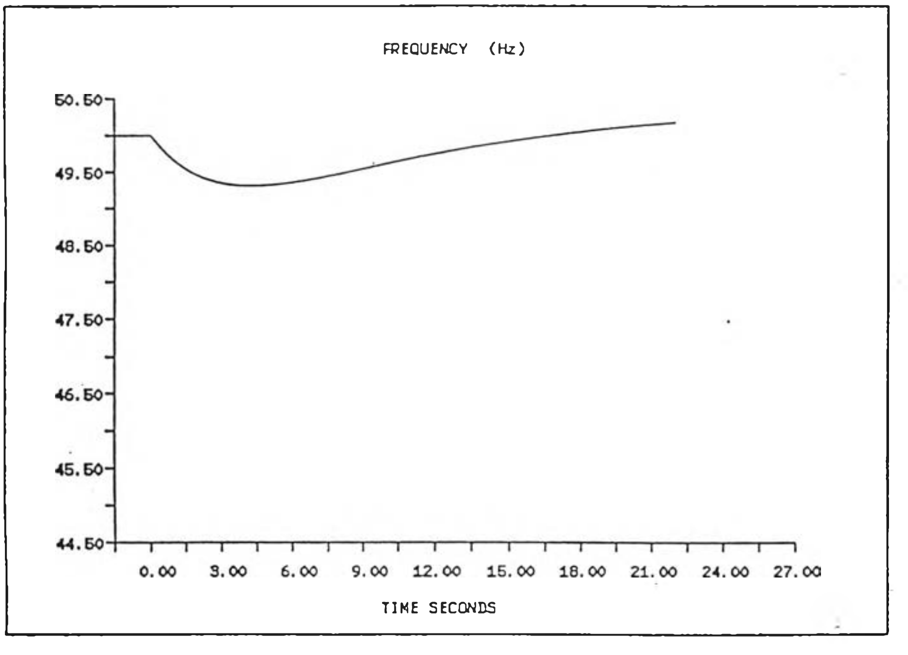
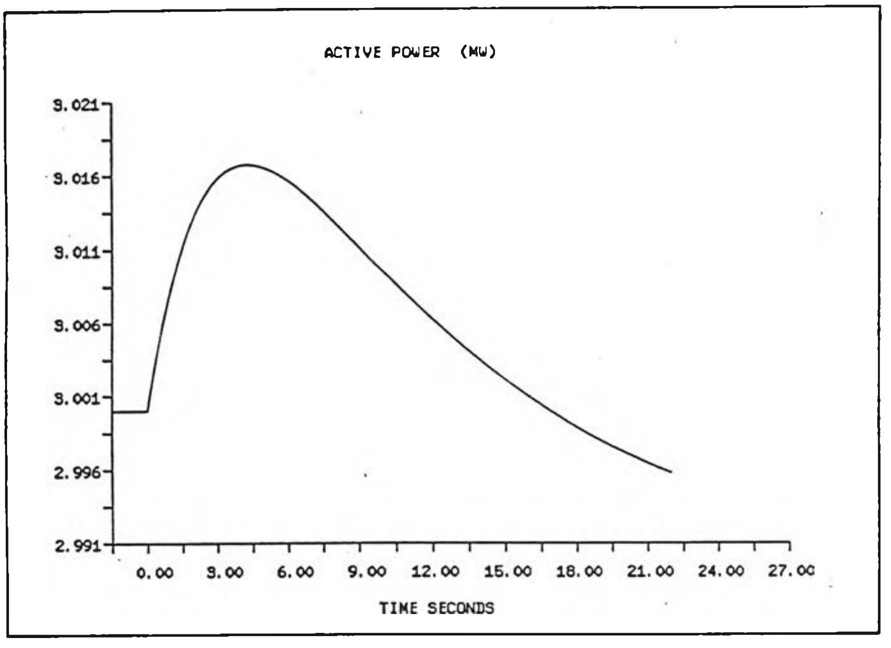


Fig. A4.23 Voltage and frequency at bus 3 during frequency dip

a



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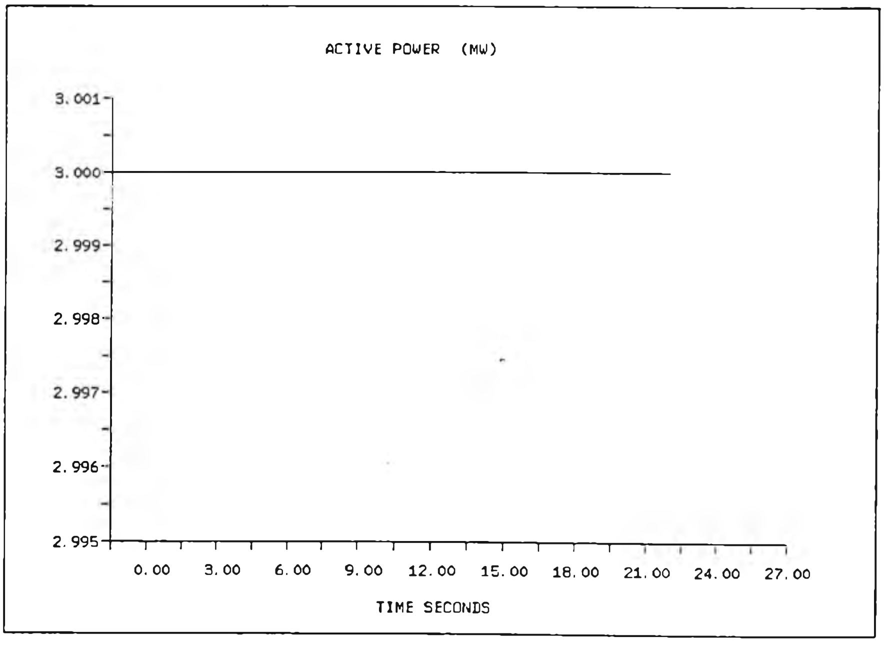
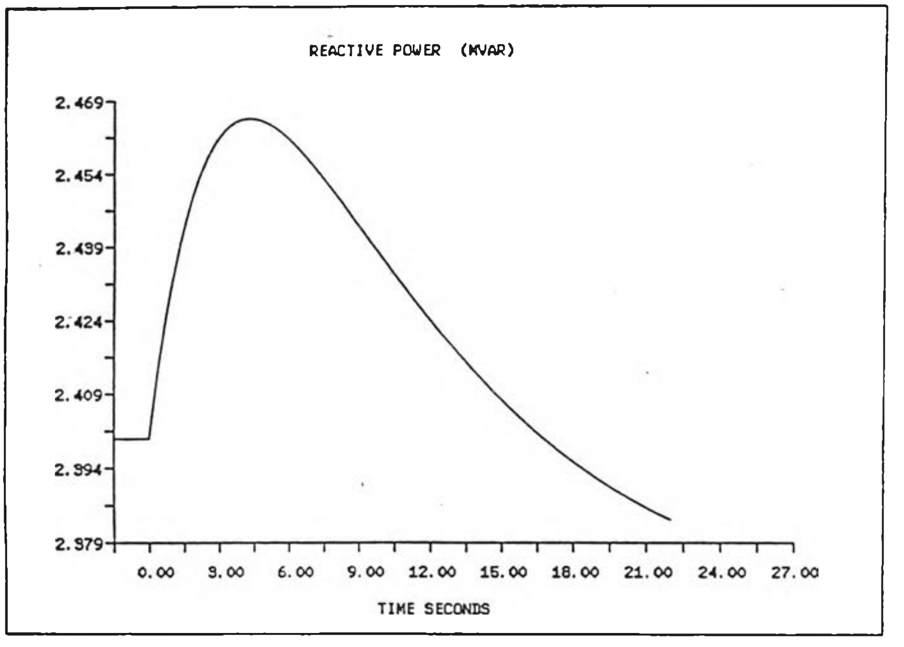


Fig. A4.24 Active power at bus 3 during frequency dip

a. used aggregate model

b. used constant MVA model

a



b

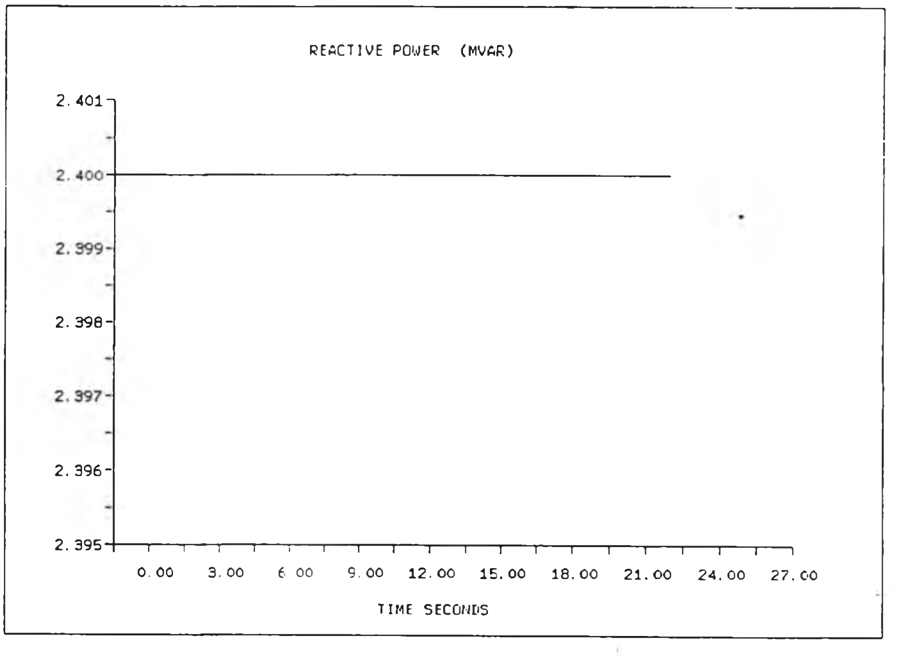
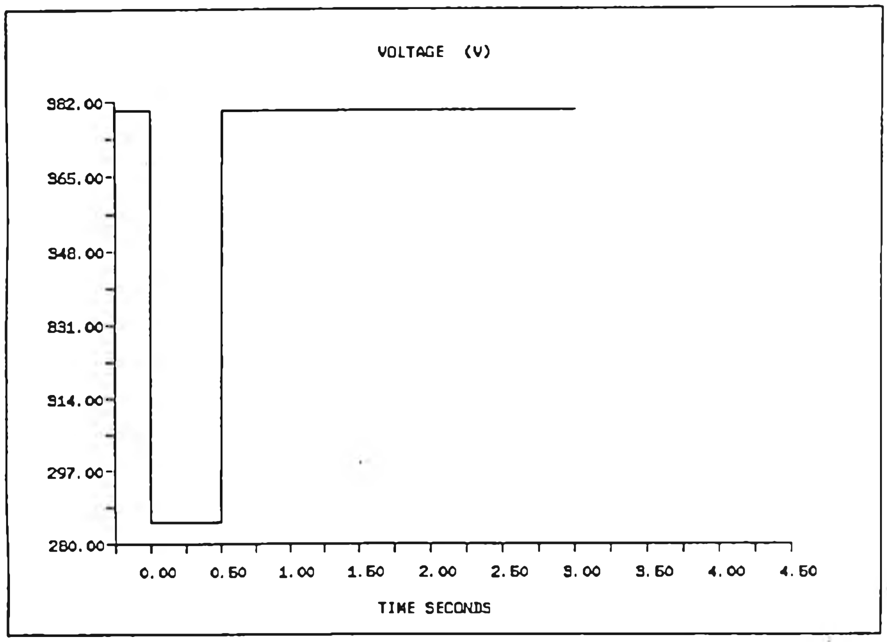


Fig. A4. 25 Reactive power at bus 3 during frequency dip

a. used aggregate model

b. used constant MVA model



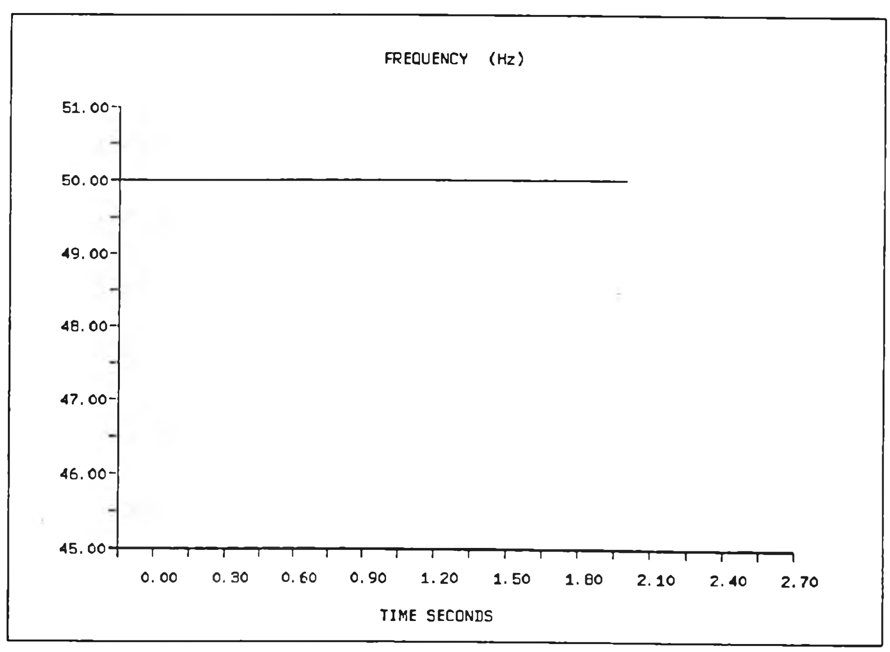
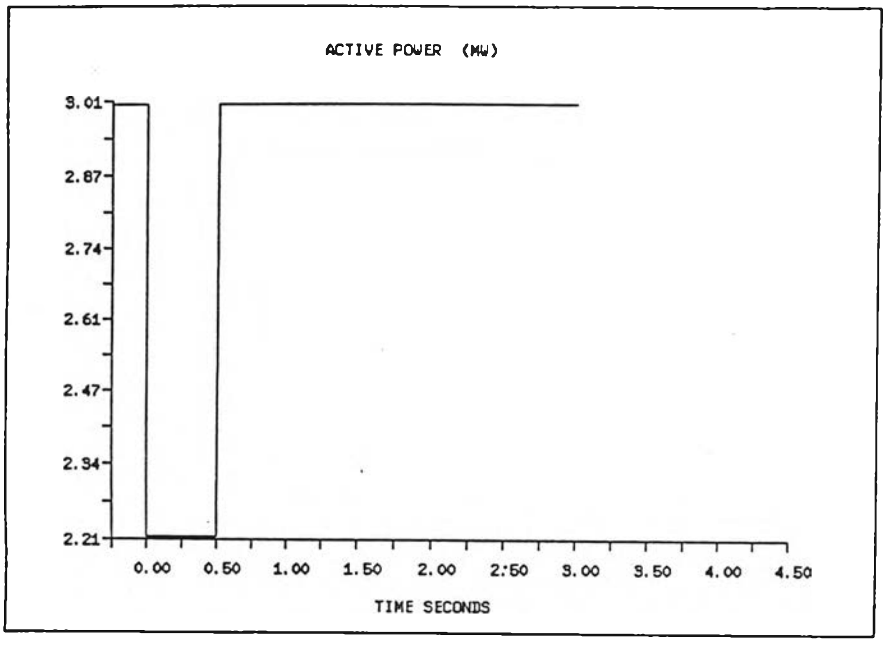


Fig. A4.26 Voltage and frequency at bus 3 during voltage dip

a



b

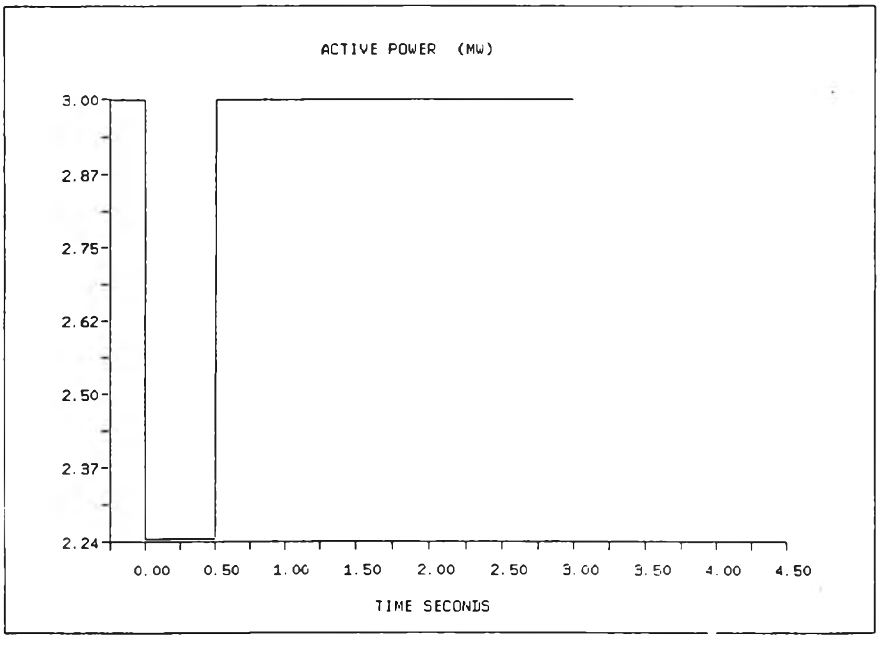
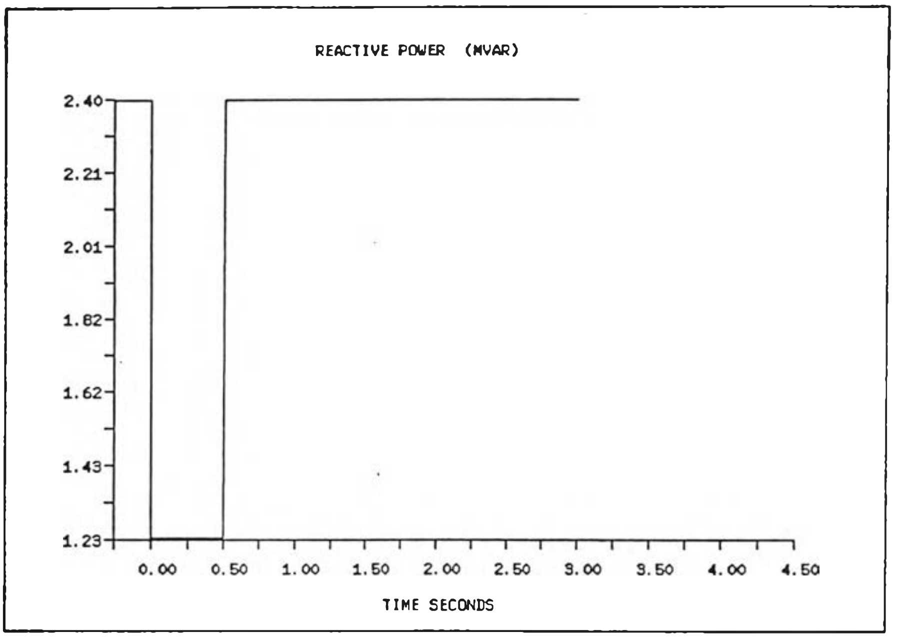


Fig. A4.27 Active power at bus 3 during voltage dip

a. used aggregate model

b. used constant current model

a



b

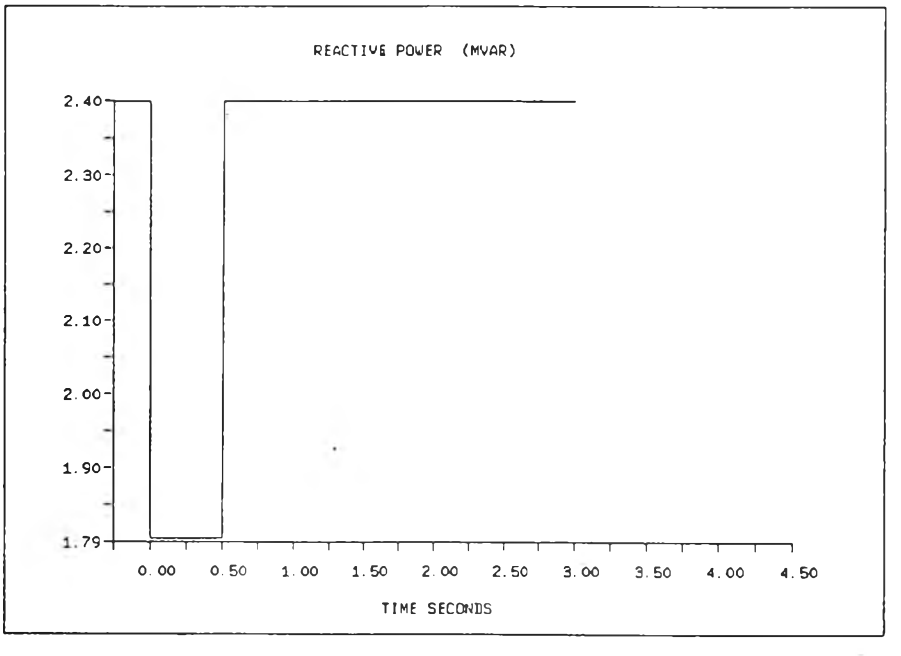
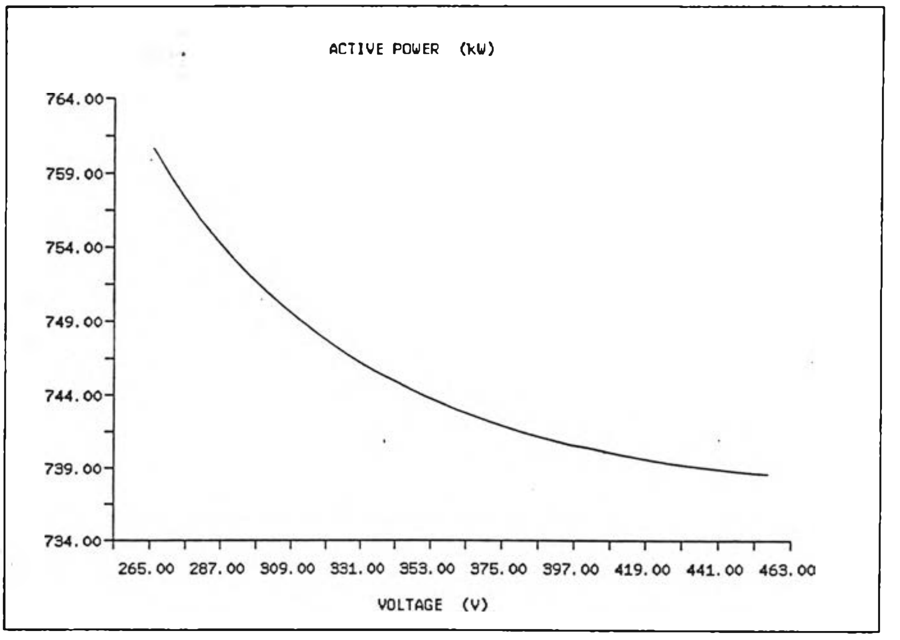


Fig. A4.28 Reactive power at bus 3 during voltage dip

a. used aggregate model

b. used constant current model

a



b

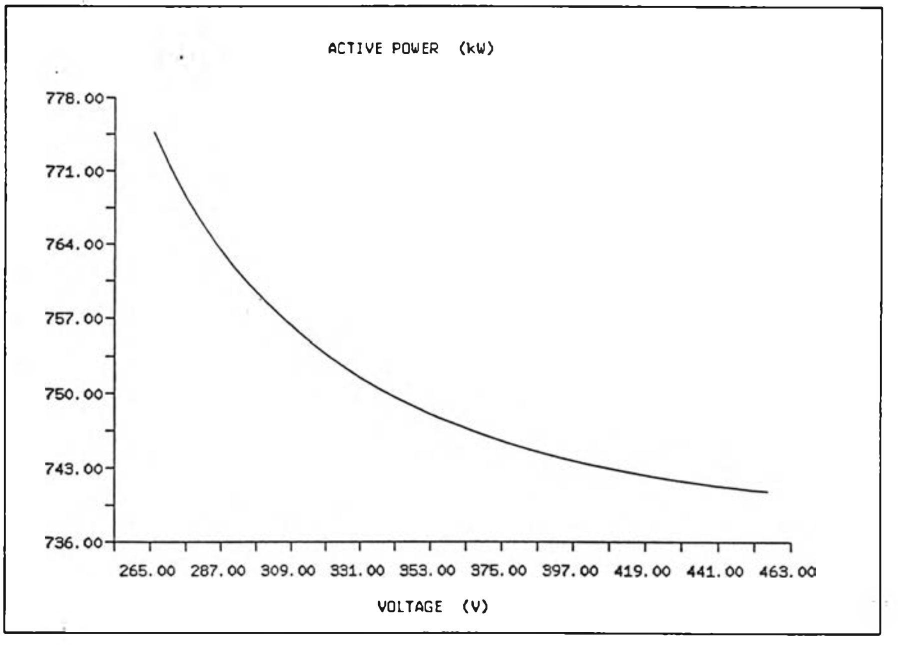
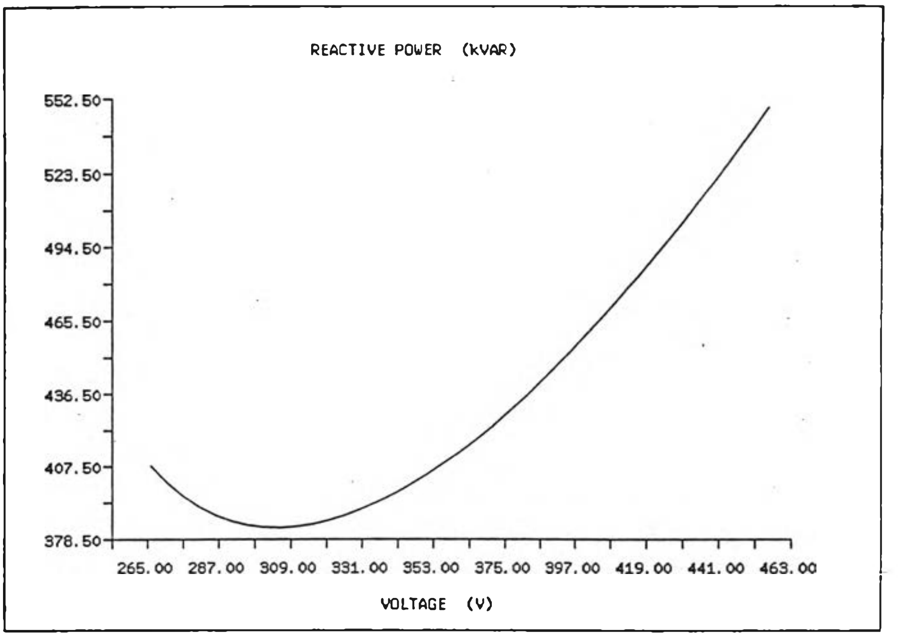


Fig. A4.29 steady state P-V characteristic of load case 1

a. used aggregate induction motor model

b. used individual motor model

a



b

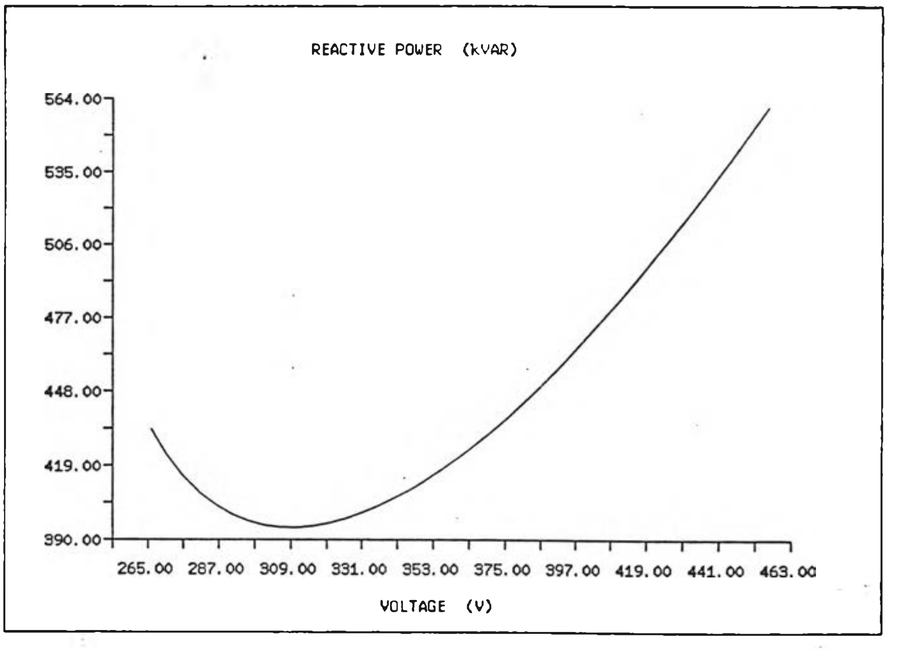
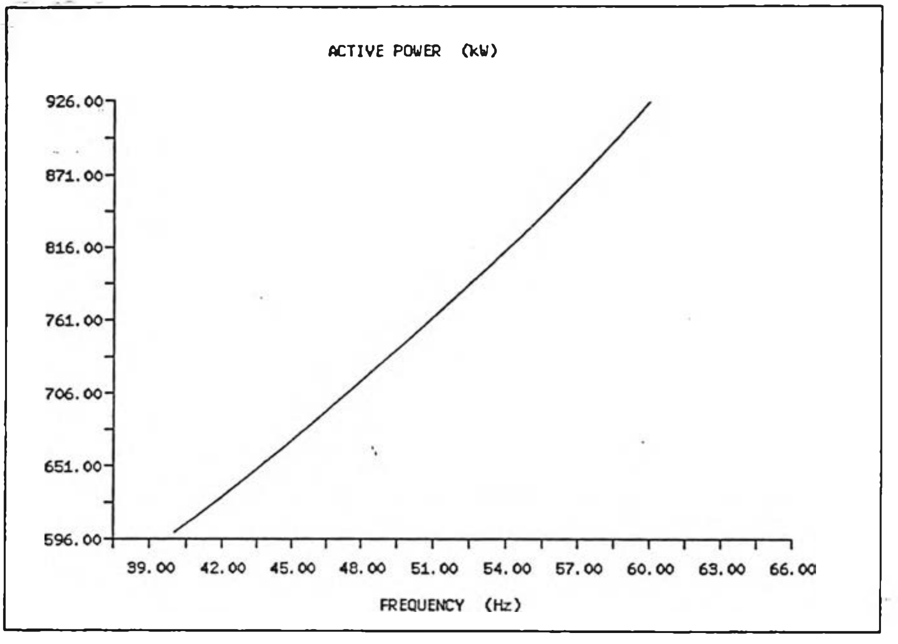


Fig. A4.30 Steady state Q-V characteristic of load case 1

a. used aggregate induction motor model

b. used individual motor model

a



b

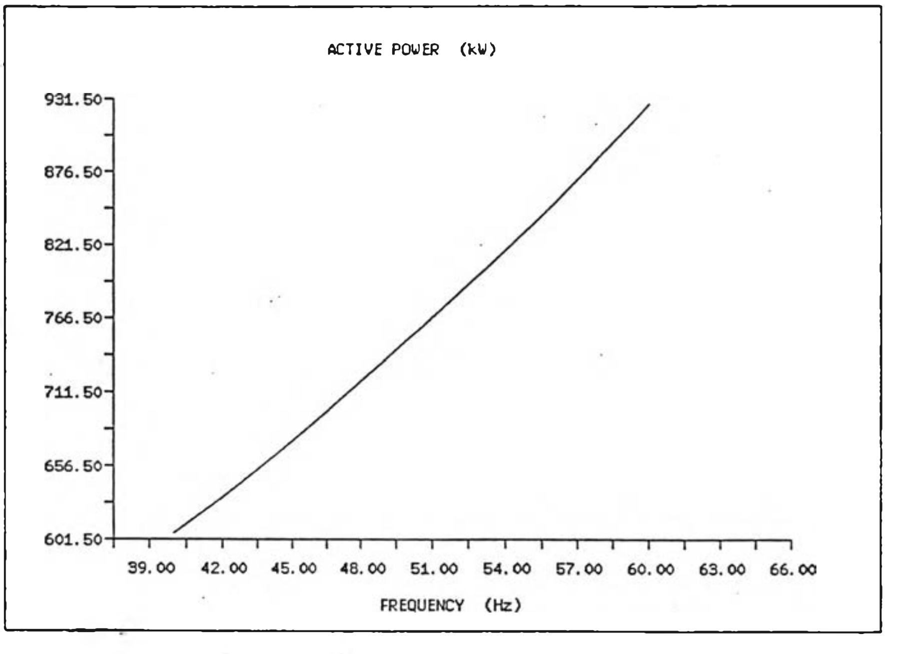
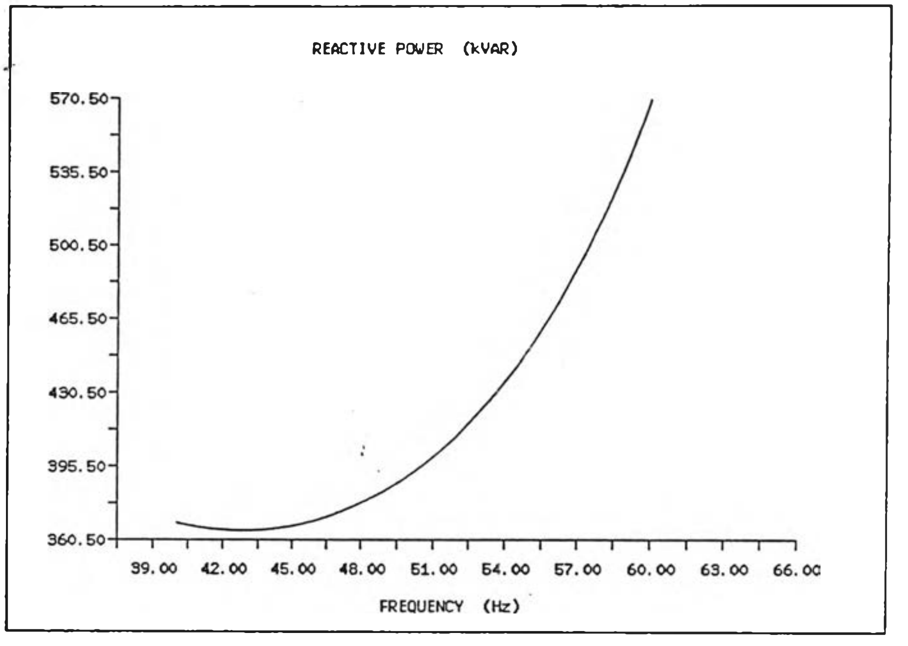


Fig.A4.31 Steady state P-f characteristic of load case 1

a. used aggregate induction motor model

b. used individual motor model

a



b

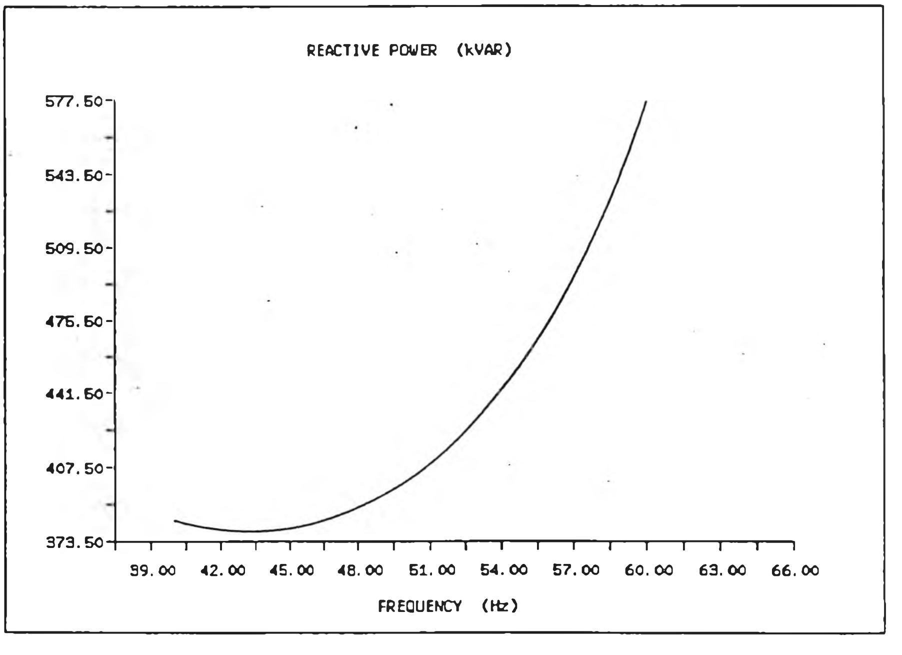
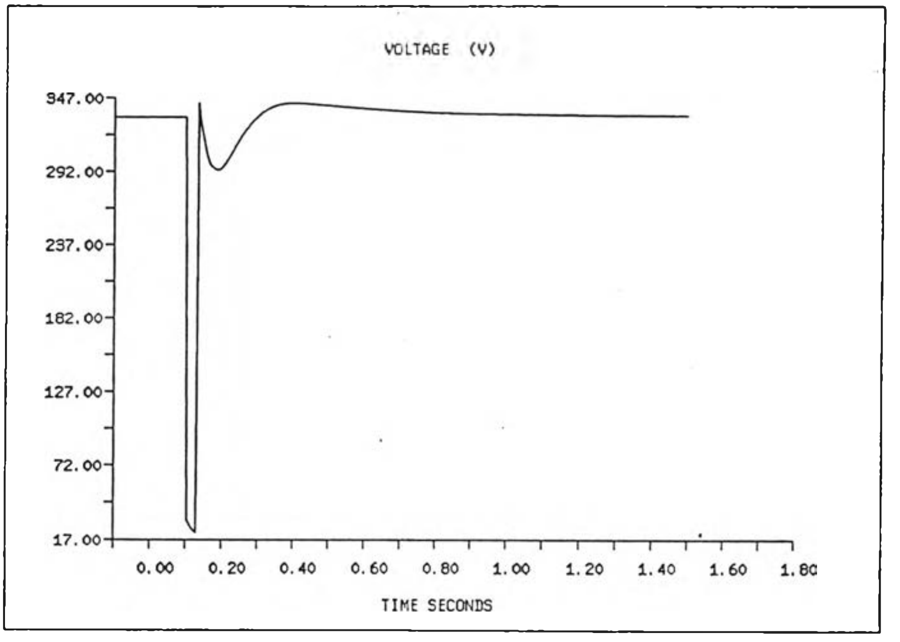


Fig. A4.32 Steady state Q-f characteristic of load case 1

a. used aggregate induction motor model

b. used individual motor model



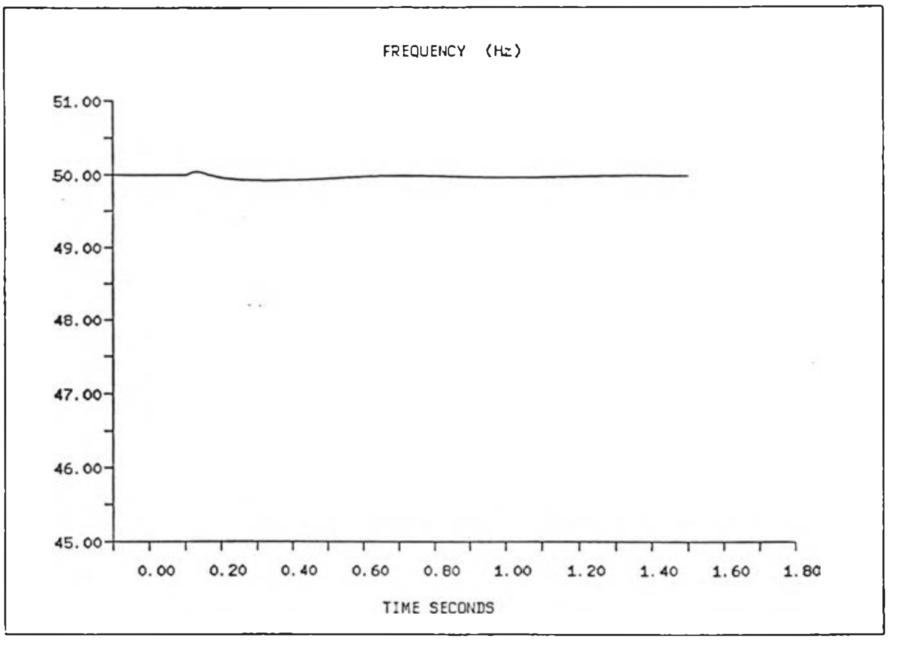
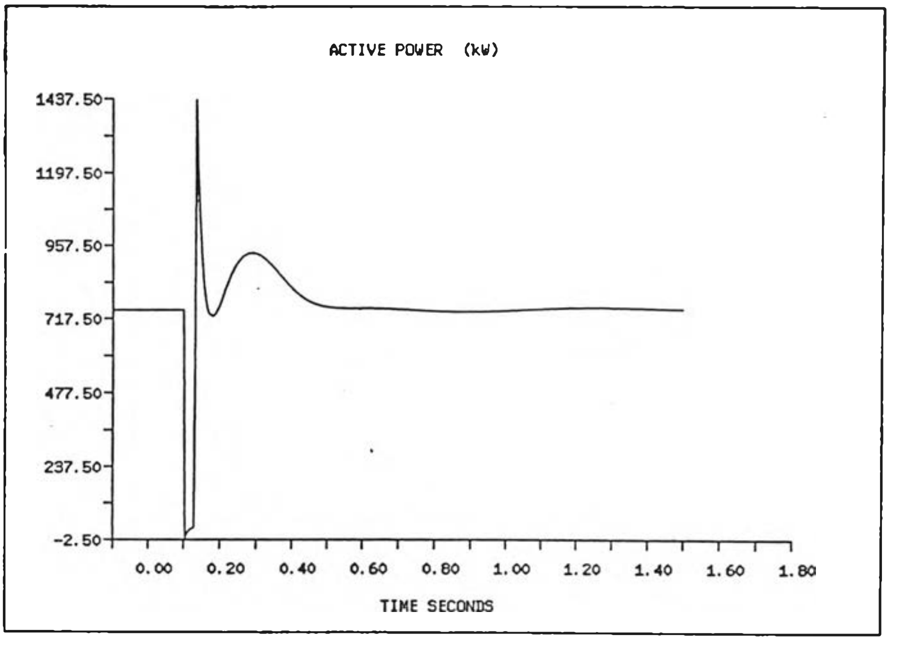


Fig. A4.33 Voltage and frequency at bus 4 during 3 phase fault at bus 3

a



b

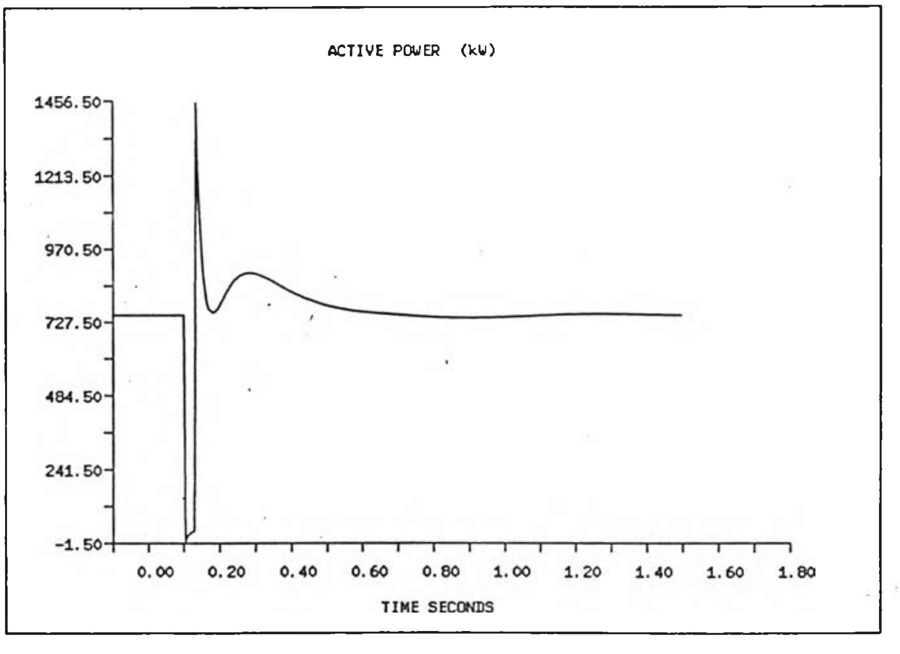
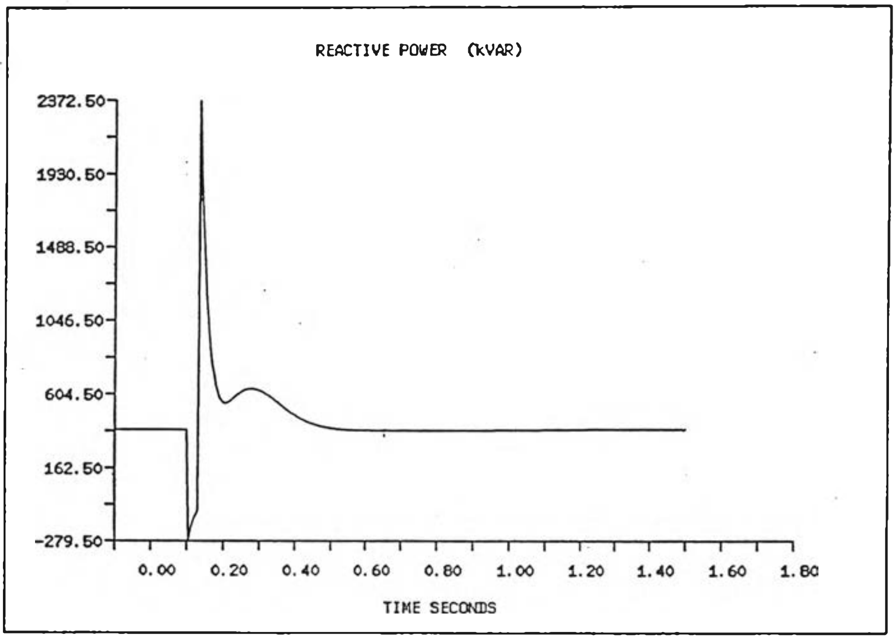


Fig. A4.34 Active power at bus 4 during 3 phase fault

a. used aggregate induction motor model

b. used individual motor model

a



b

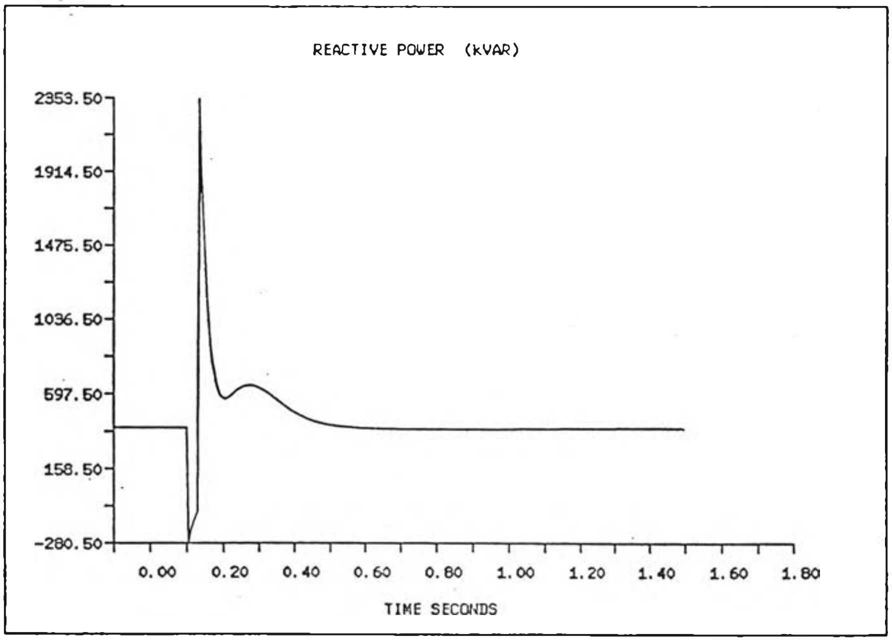
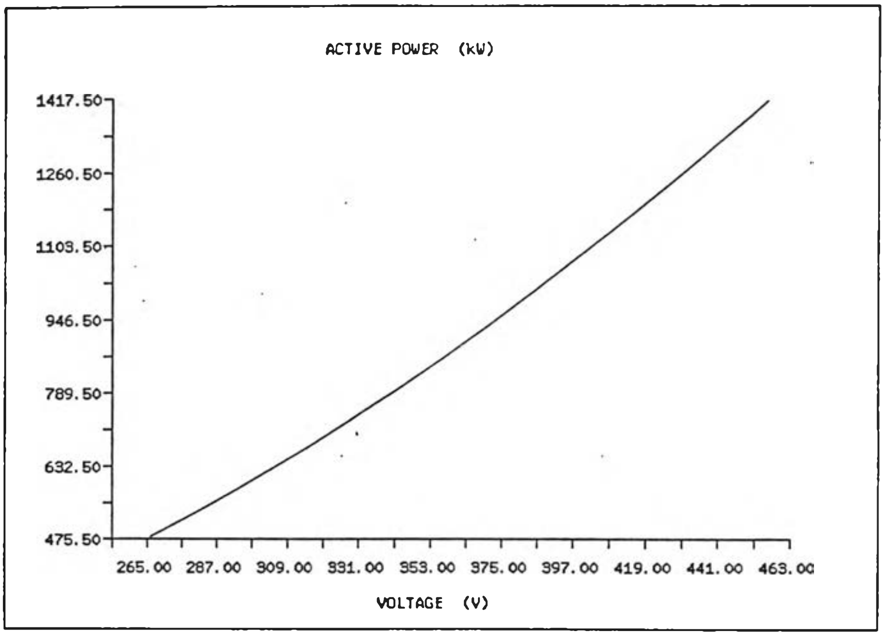


Fig. A4.35 Reactive power at bus 4 during 3 phase fault

a. used aggregate induction motor model

b. used individual motor model



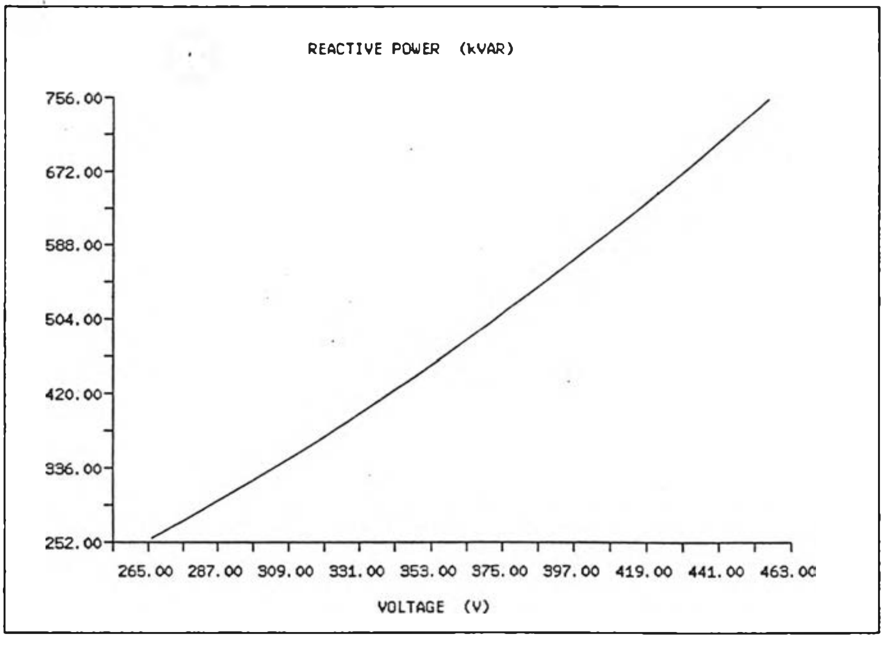
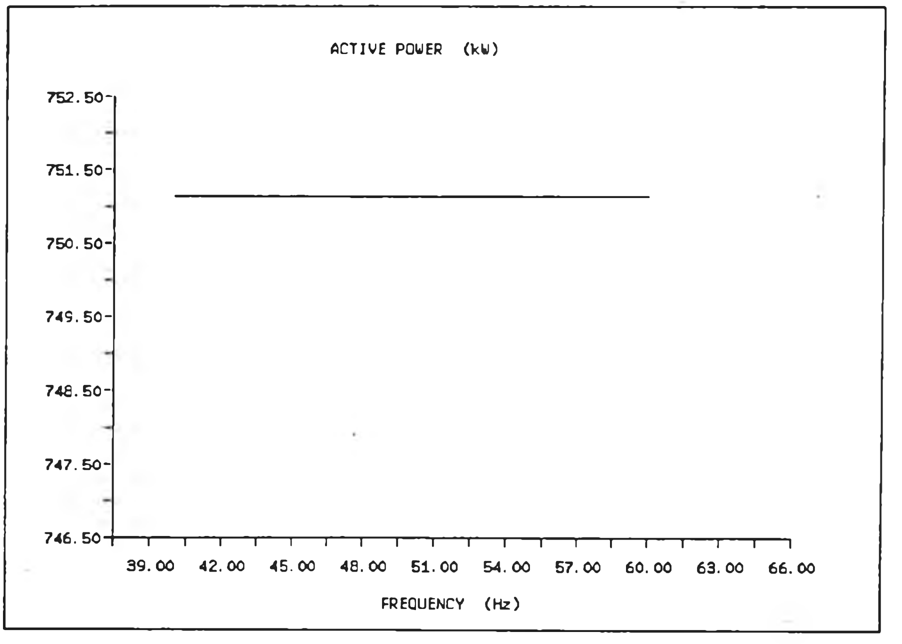


Fig. A4.36 Steady state voltage characteristic of load case 1 used constant impedance model



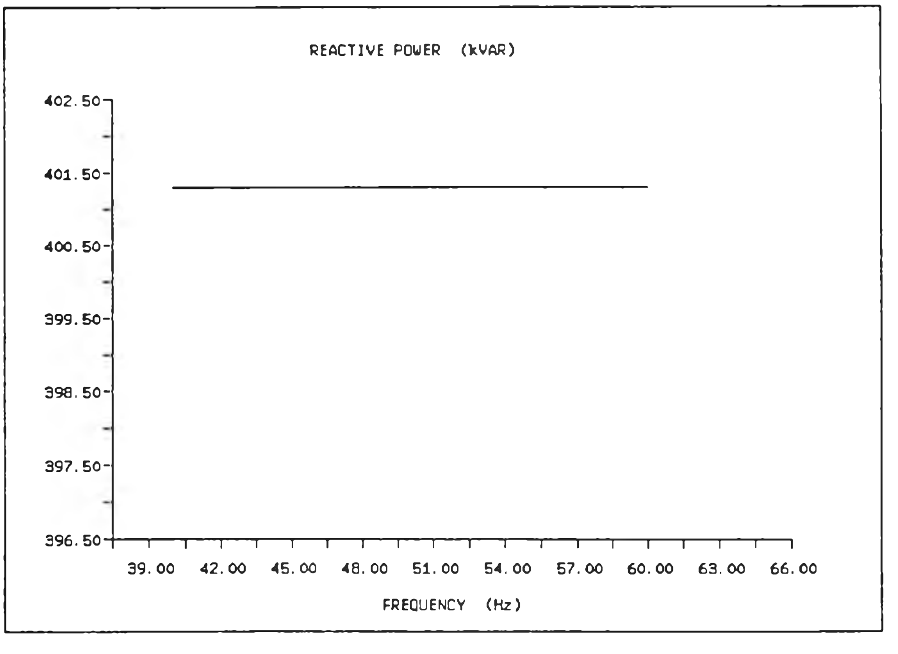
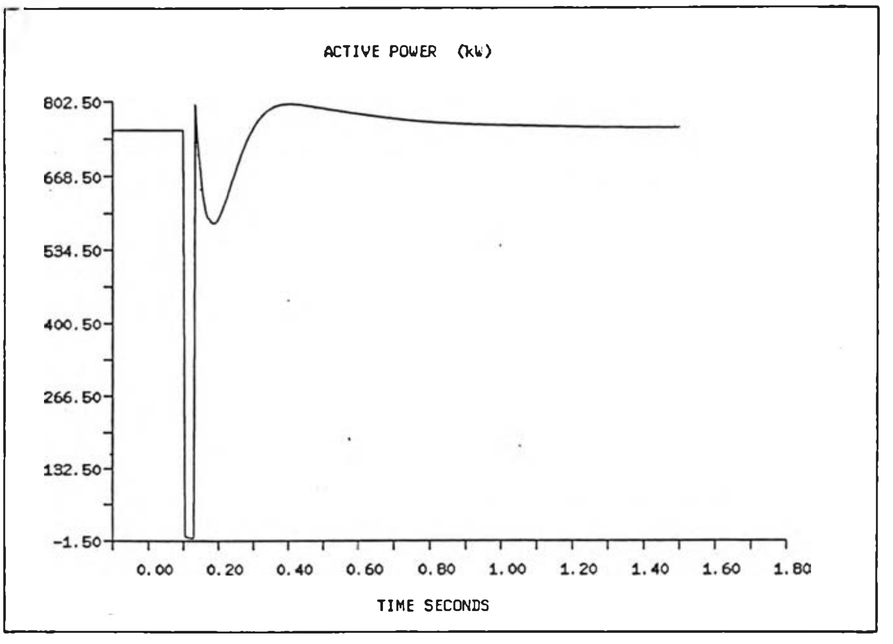


Fig. A4.37 Steady state frequency characteristic of load case 1 used constant impedance model



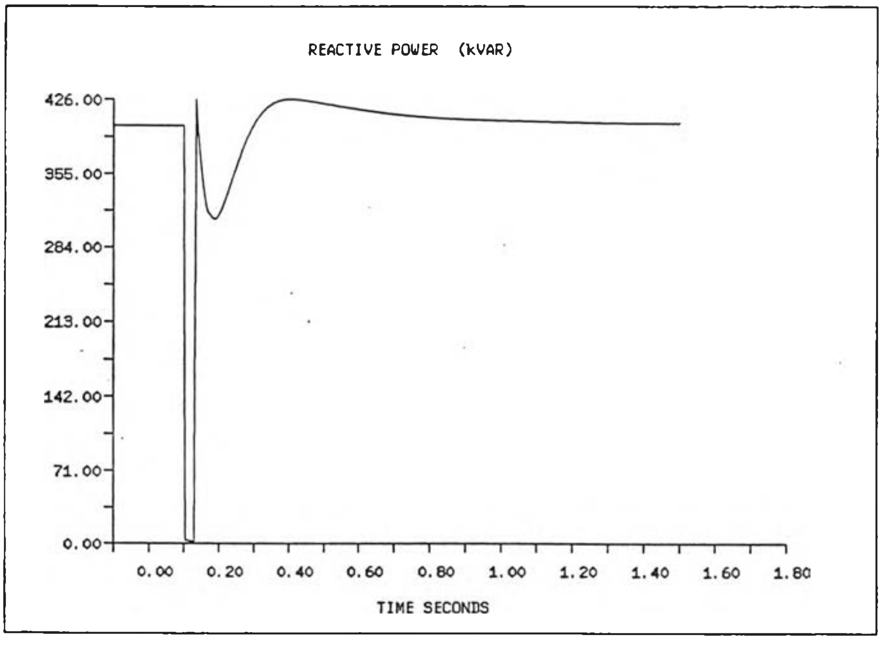


Fig. A4.38 Active and reactive power at bus 4 during 3 phase fault used constant impedance model

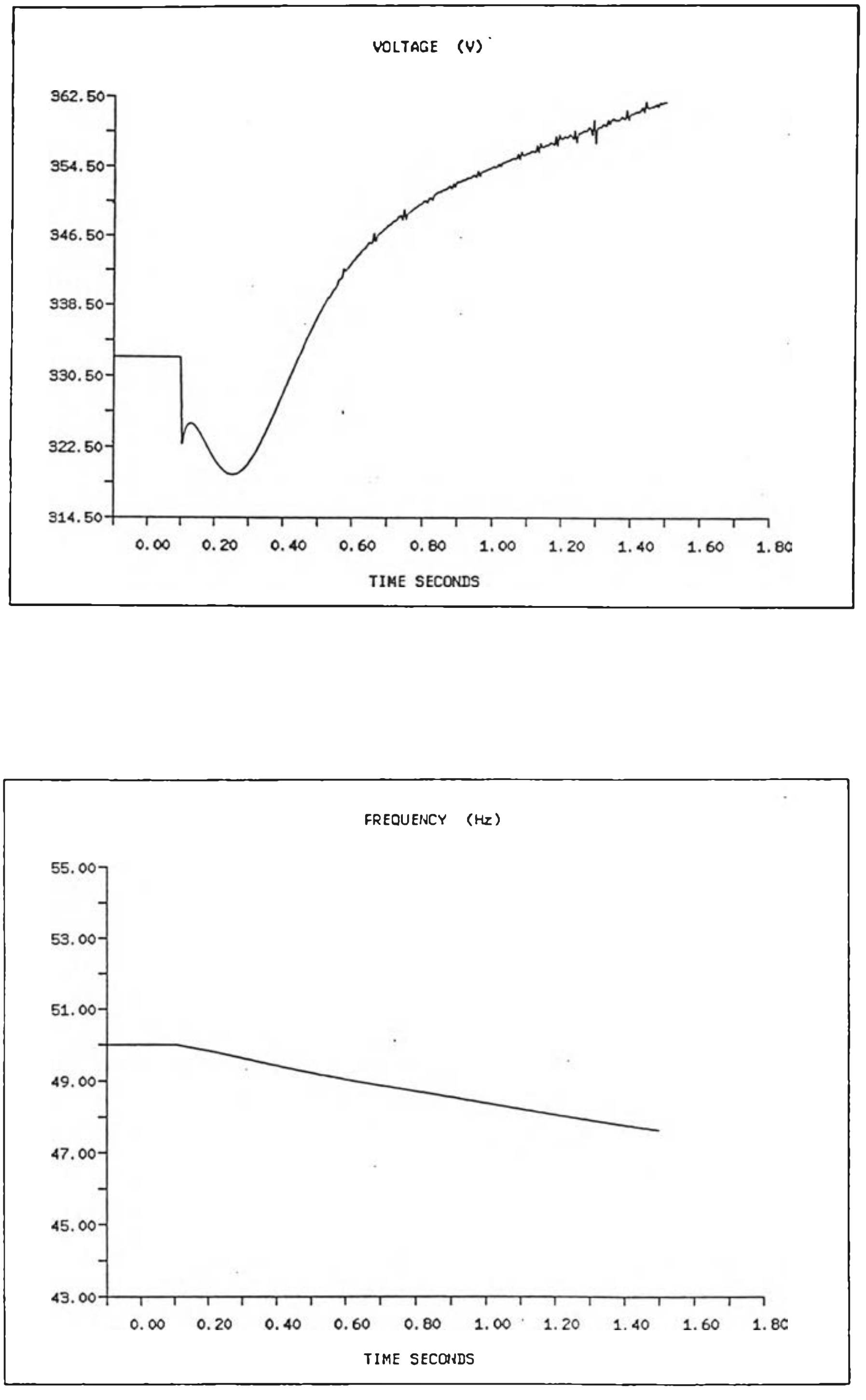
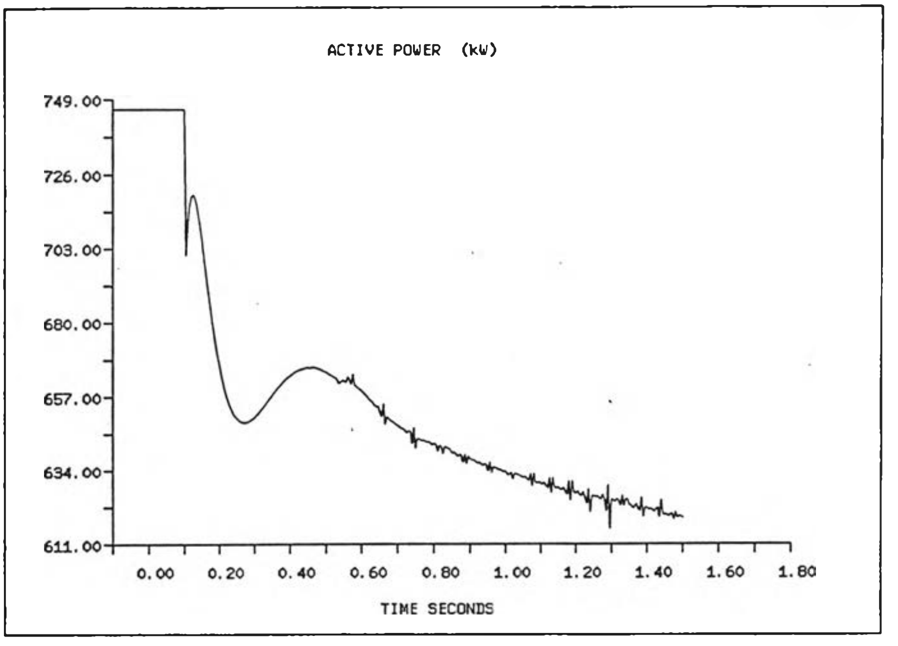


Fig. A4.39 Voltage and frequency at bus 4 during gen. 2 disconnected

a



b

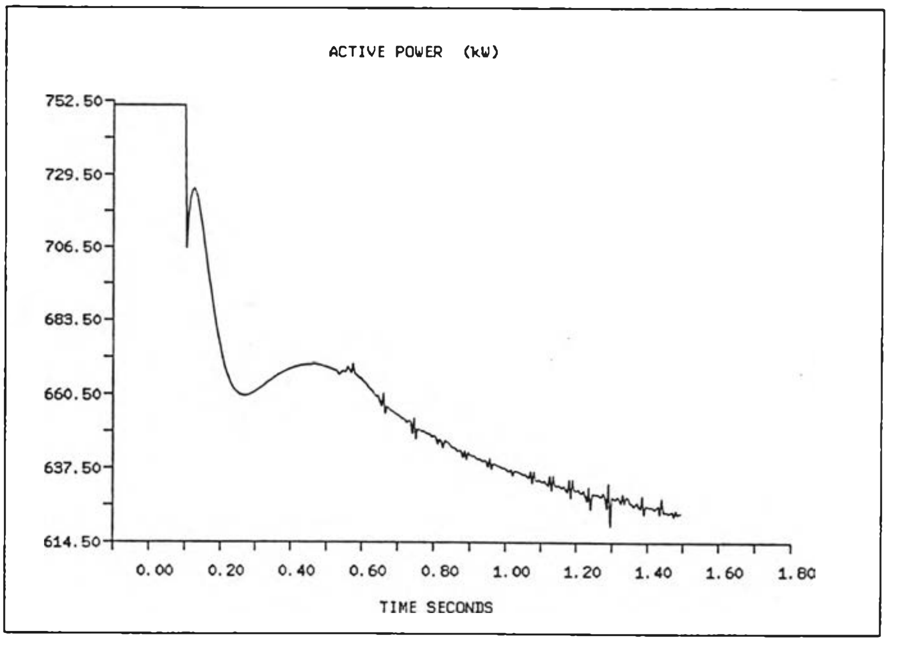
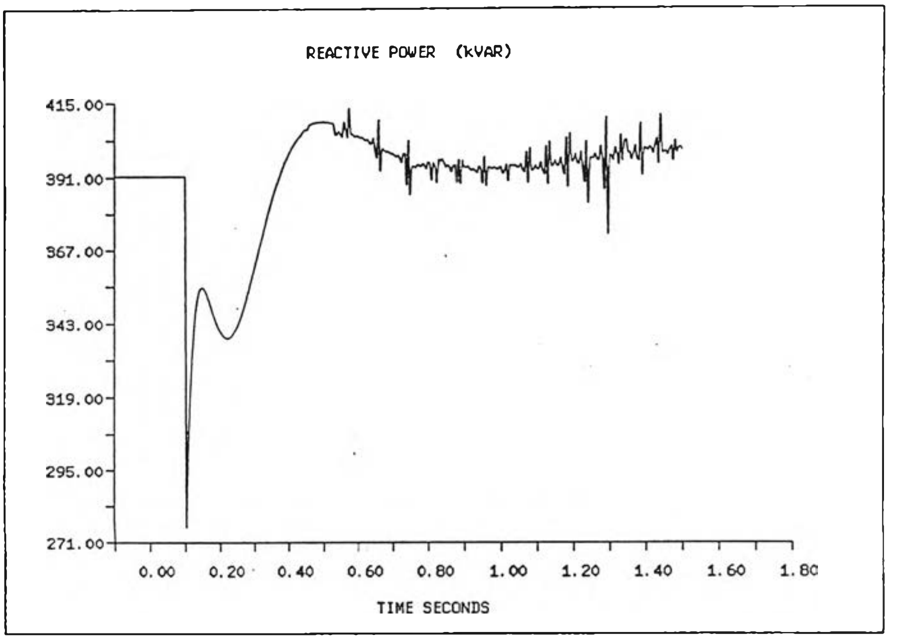


Fig. A4.40 Active power at bus 4 during gen. 2 disconnected

a. used aggregate induction motor model

b. used individual motor model

a



b

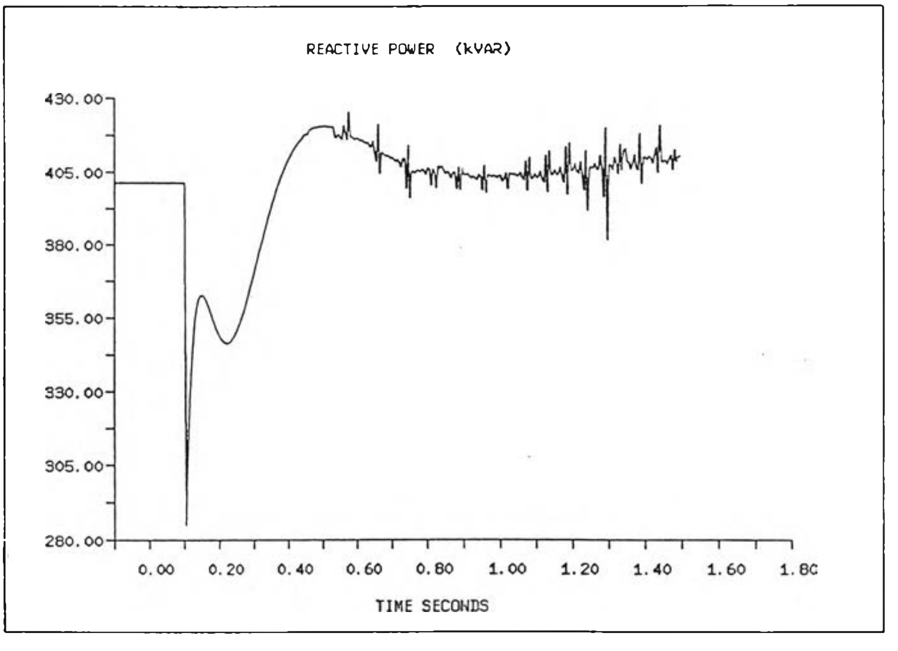
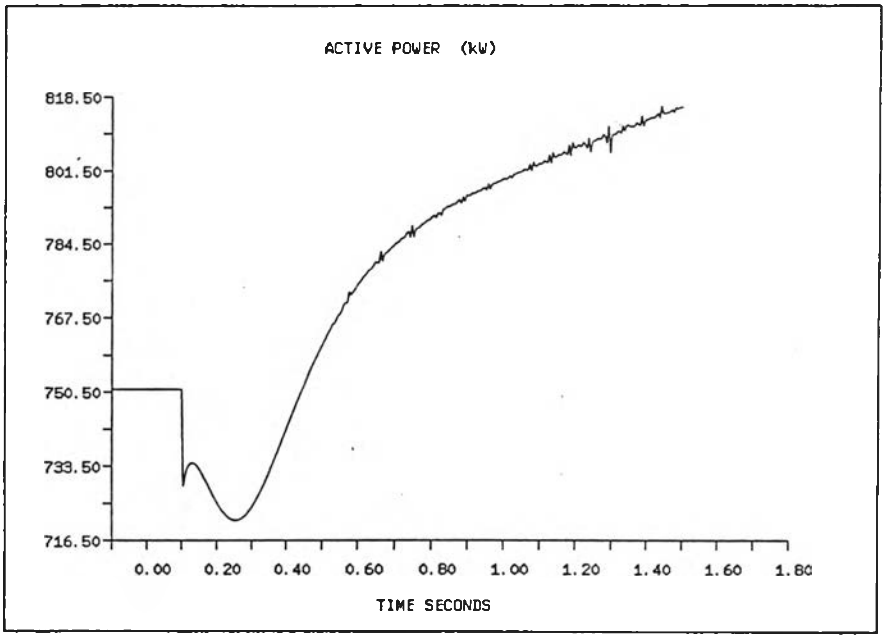


Fig. A4.41 Reactive power at bus 4 during gen. 2 disconnected

a. used aggregate induction motor model

b. used individual motor model



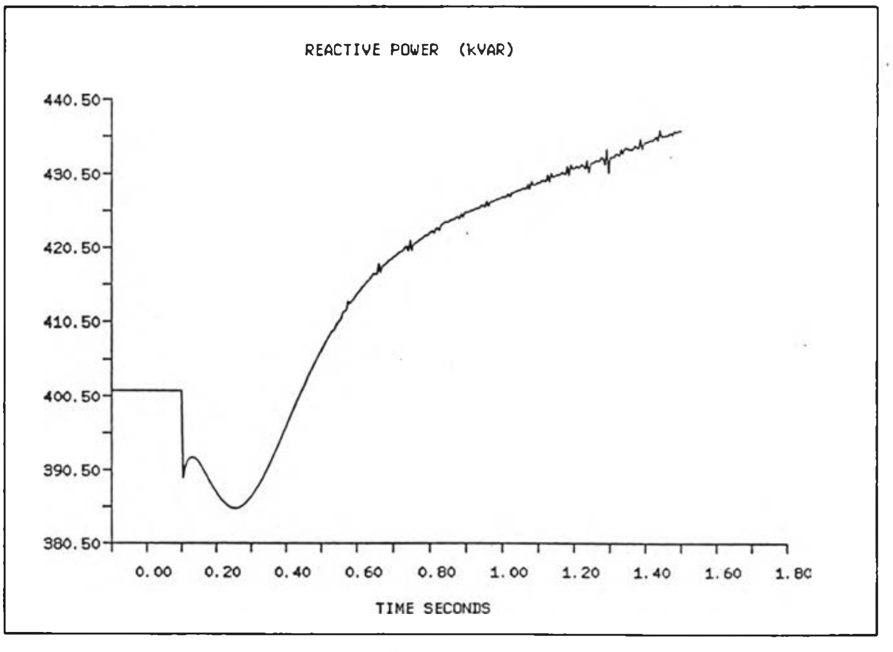
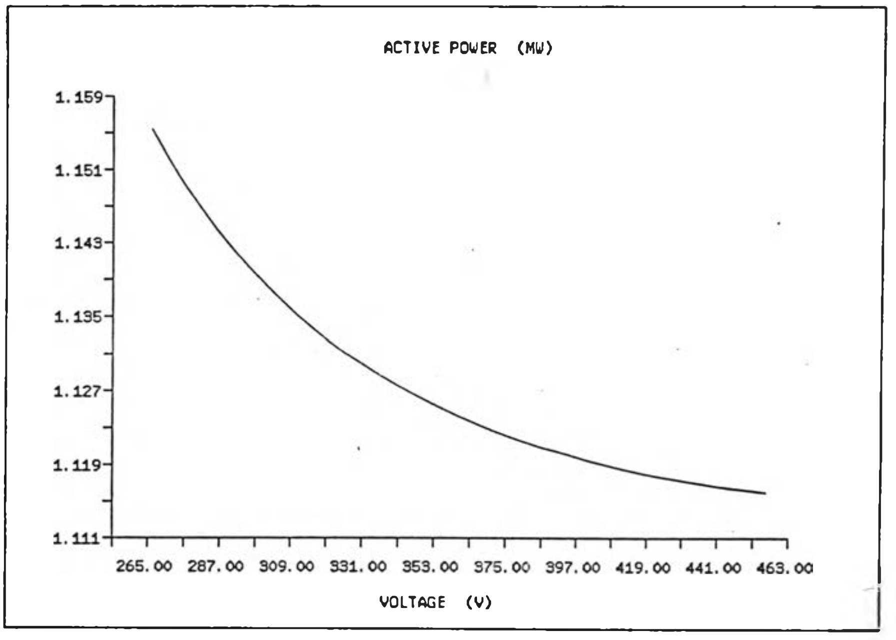


Fig. A4.42 Active and reactive power during gen. 2 disconnected used constant current model

a



b

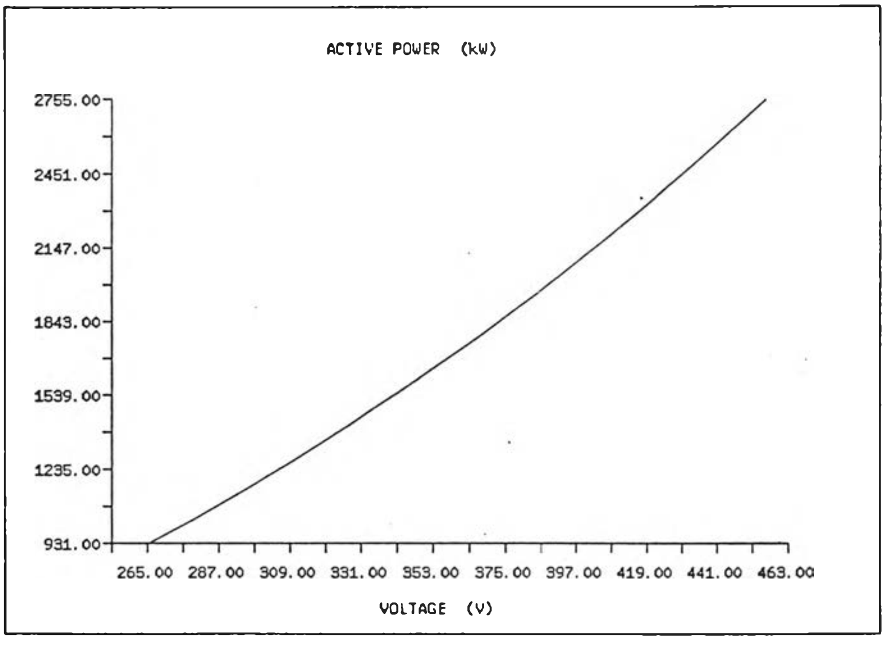
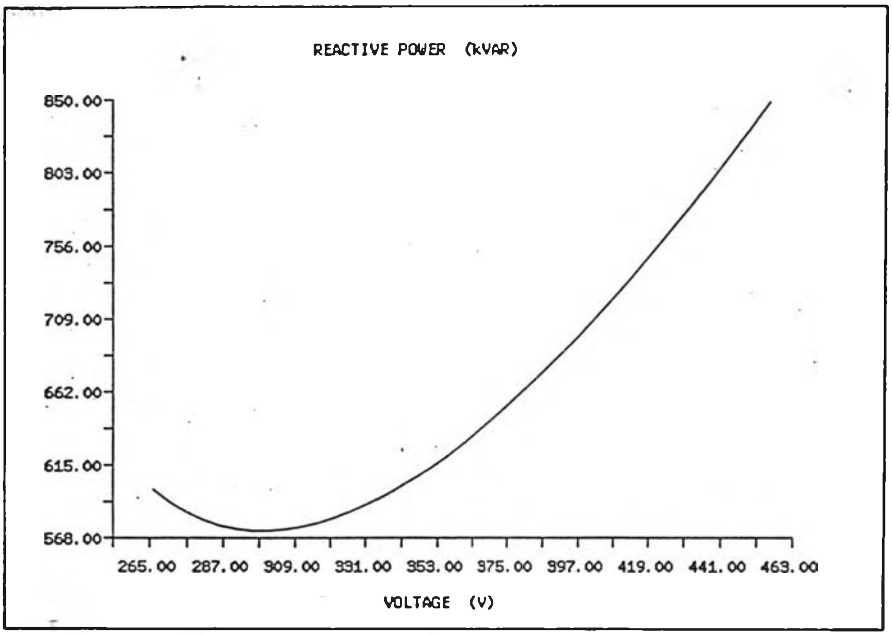


Fig. A4. 43 Steady state P-V characteristic of load case 2

a. used aggregate induction motor model

b. used constant impedance model

a



b

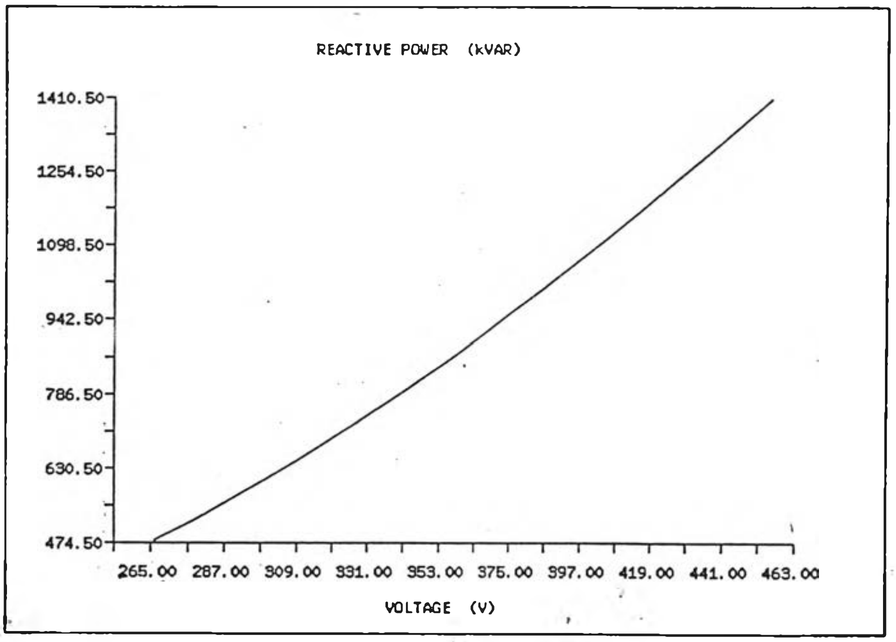
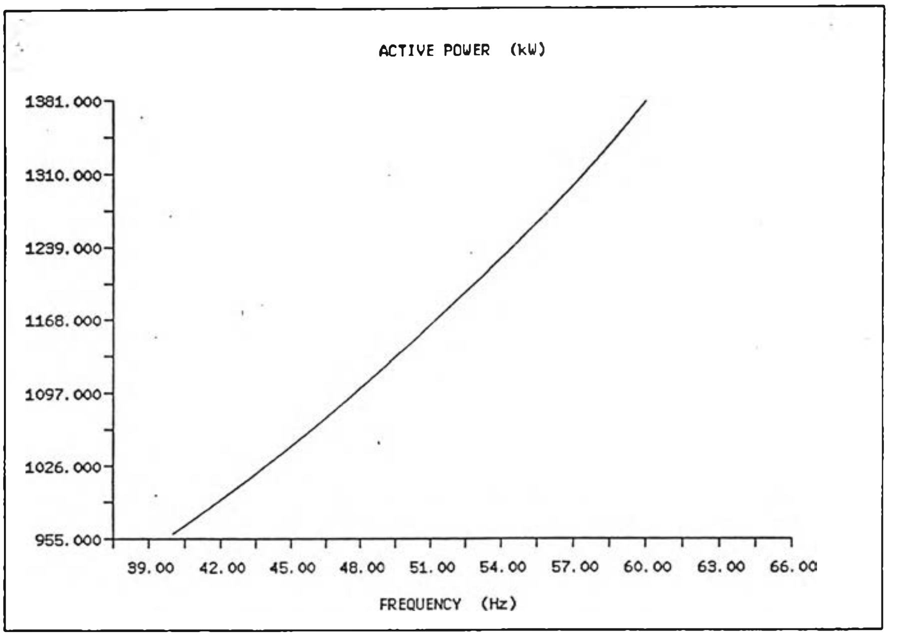


Fig. A4.44 Steady state Q-V characteristic of load case 2

a. used aggregate induction motor model

b. used constant impedance model

a



b

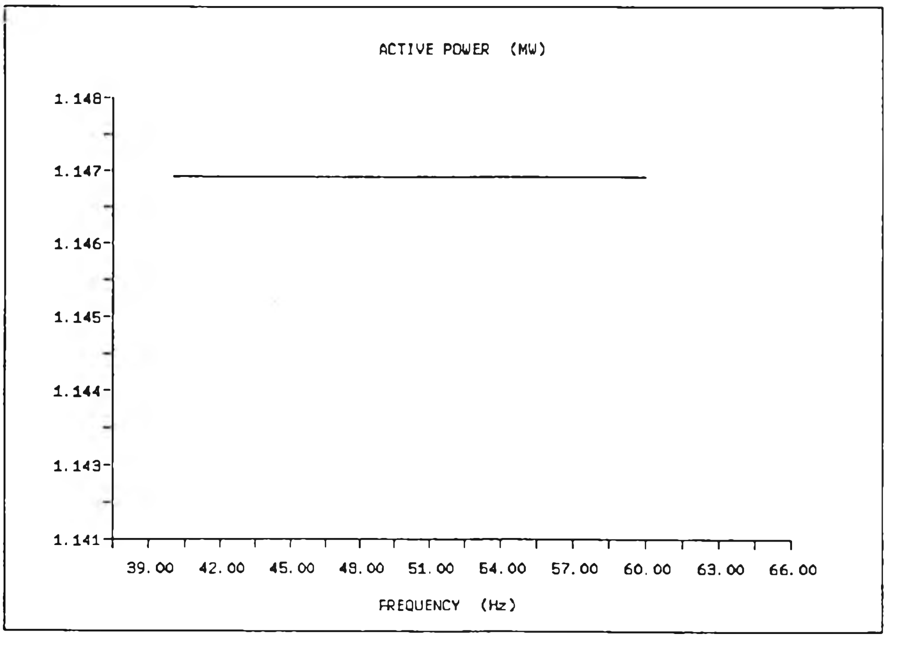
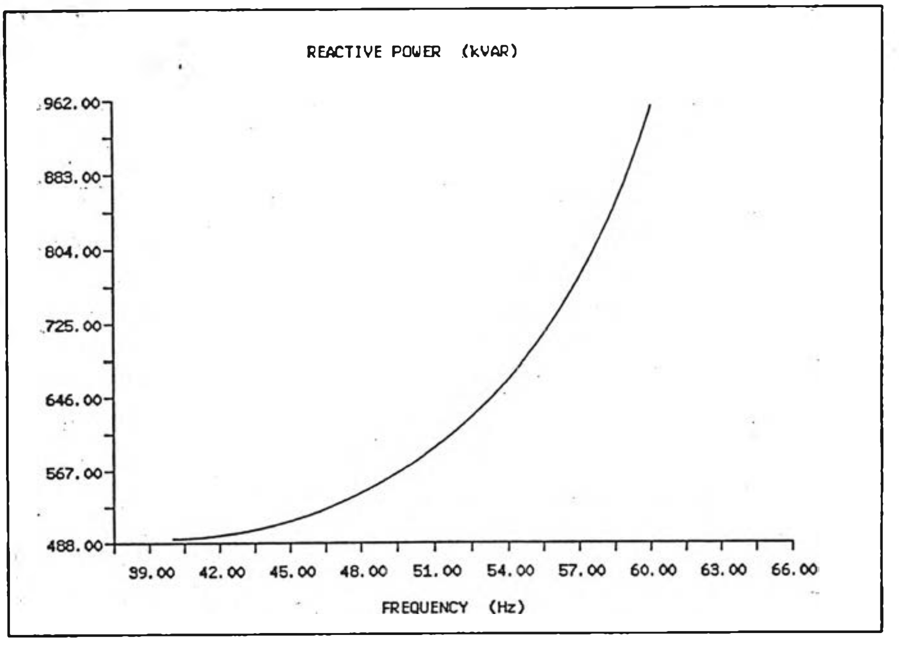


Fig. A4.45 Steady state P-f characteristic of load case 2

a. used aggregate induction motor model

b. used constant impedance model

a



b

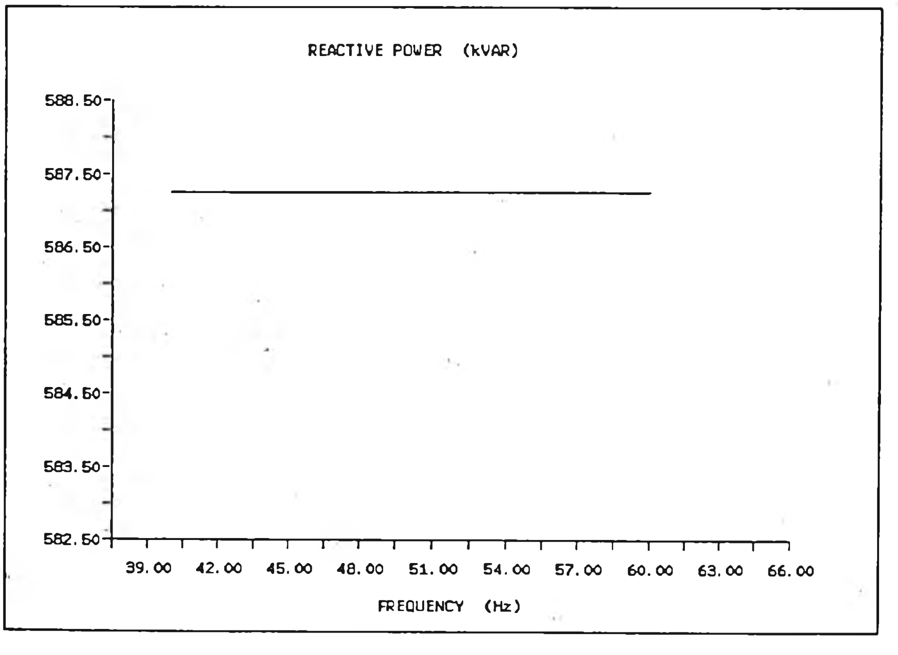
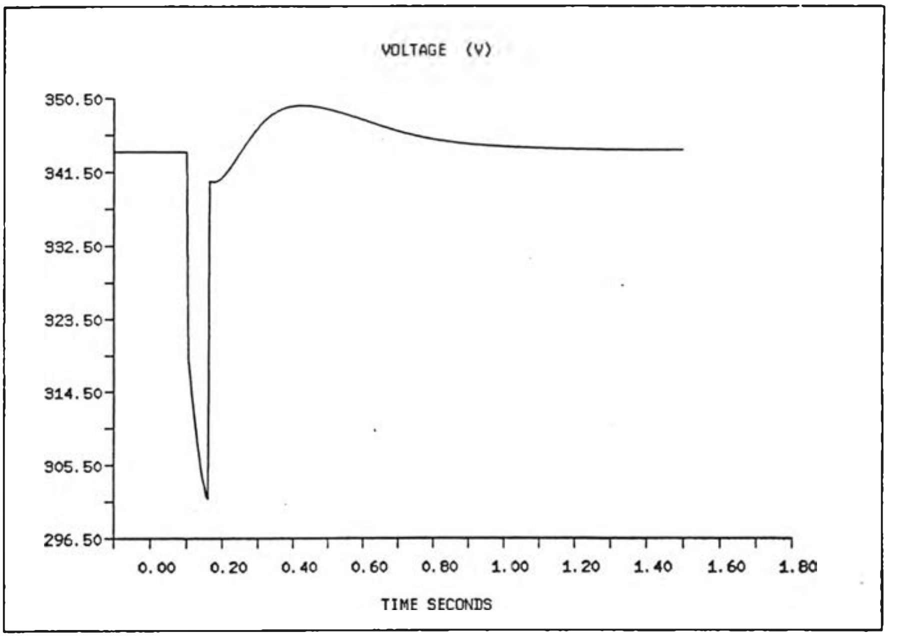


Fig. A4.46 Steady state Q-V characteristic of load case 2

a. used aggregate induction motor model

b. used constant impedance model



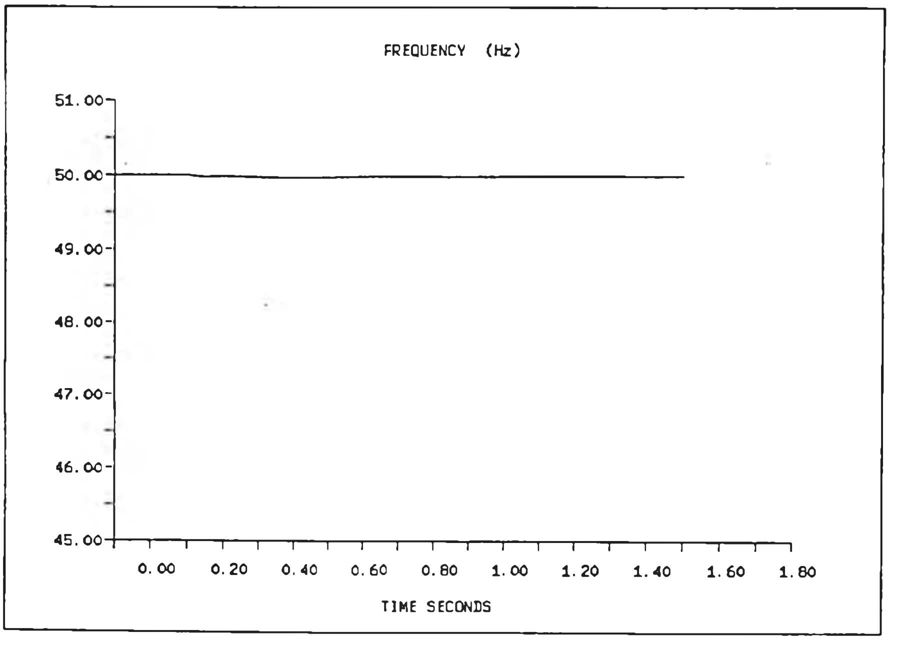
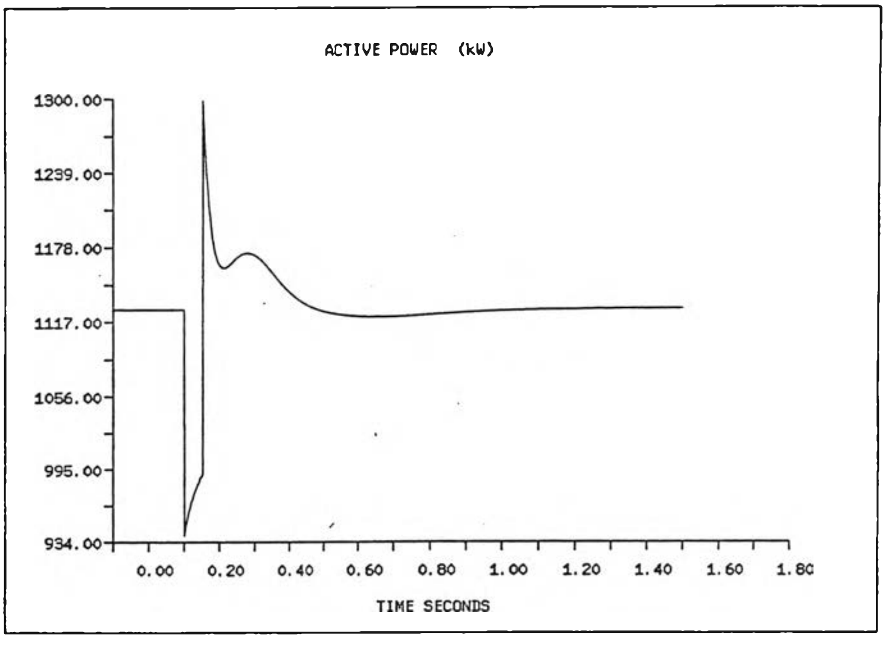


Fig. A4.47 Voltage and frequency at bus 4 when gen. 1 disconnected for 0.05 s

a



b

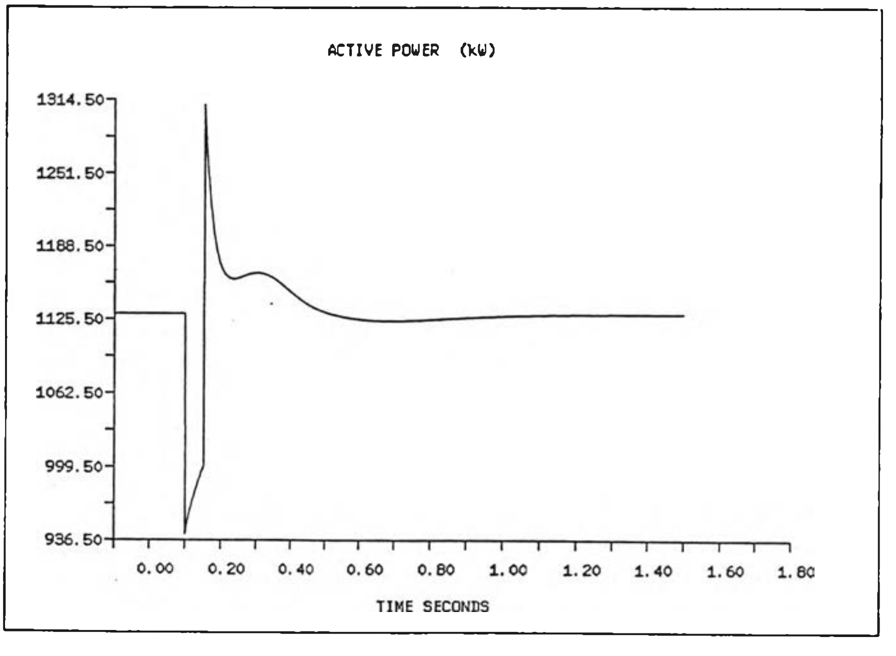
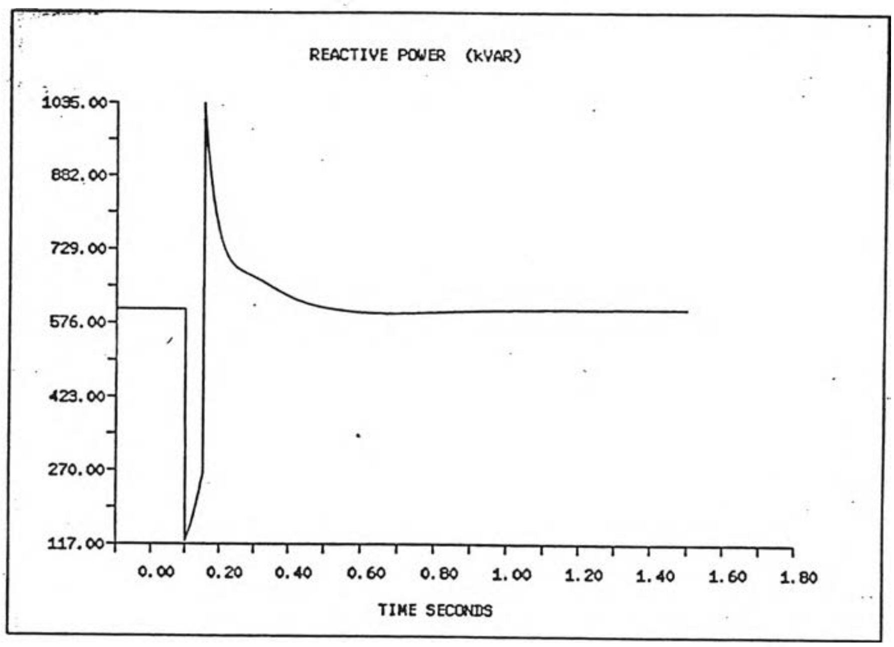


Fig. A4.48 Active power at bus 4 when gen. 1 disconnected

a. used aggregate induction motor model

b. used individual motor model

a



b

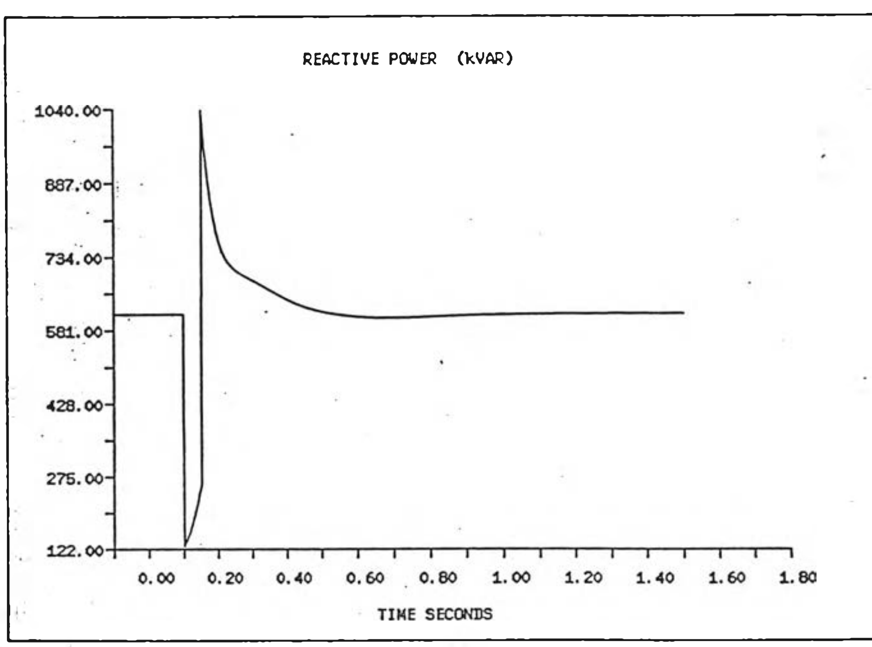
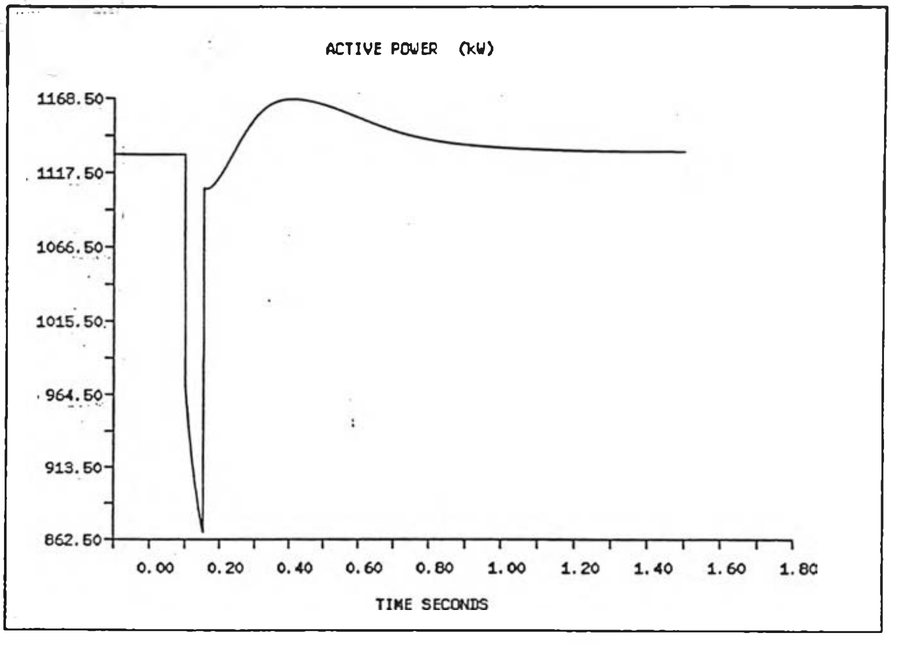


Fig. A4.49 Reactive power at bus 4 when gen. 1 disconnected

a. used aggregate induction motor model

b. used individual motor model



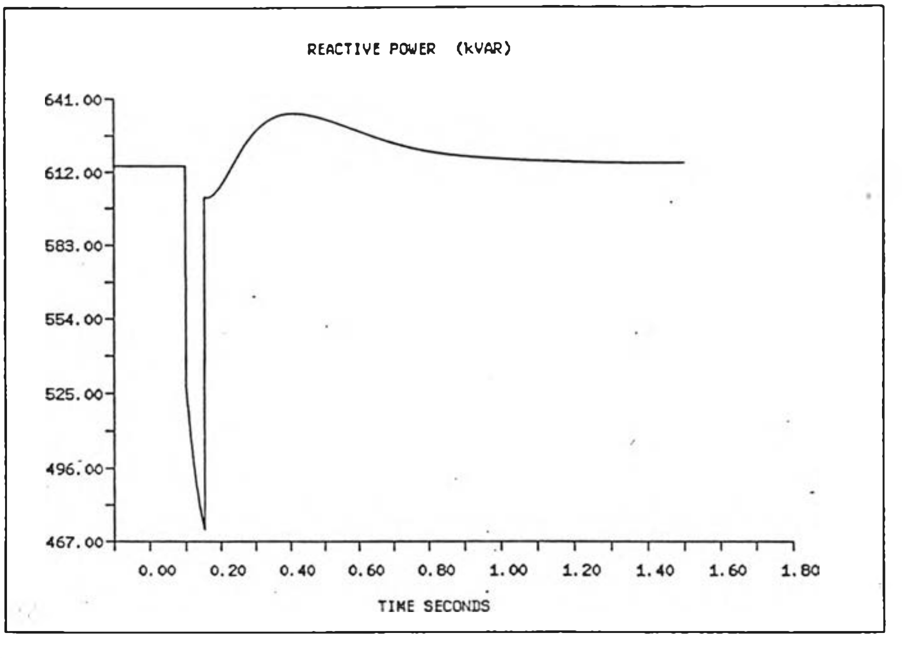
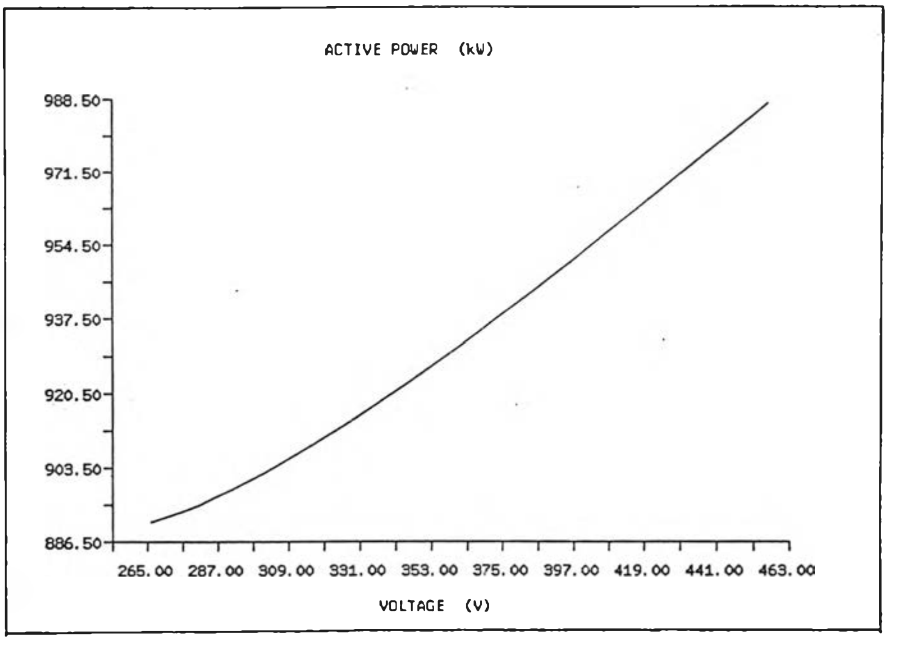


Fig. A4.50 Active and reactive power when gen. 1 disconnected used constant impedance model

a



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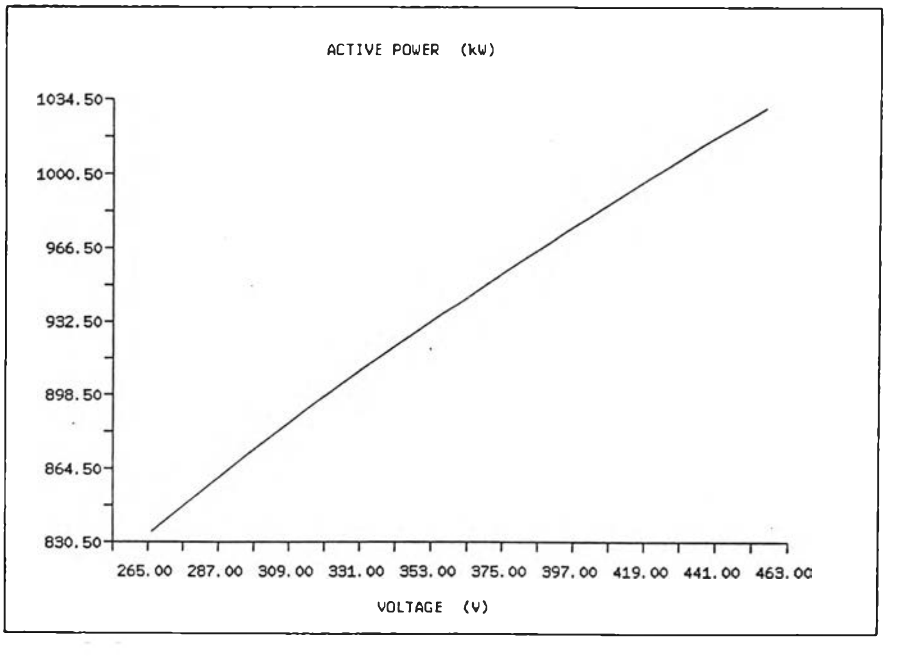
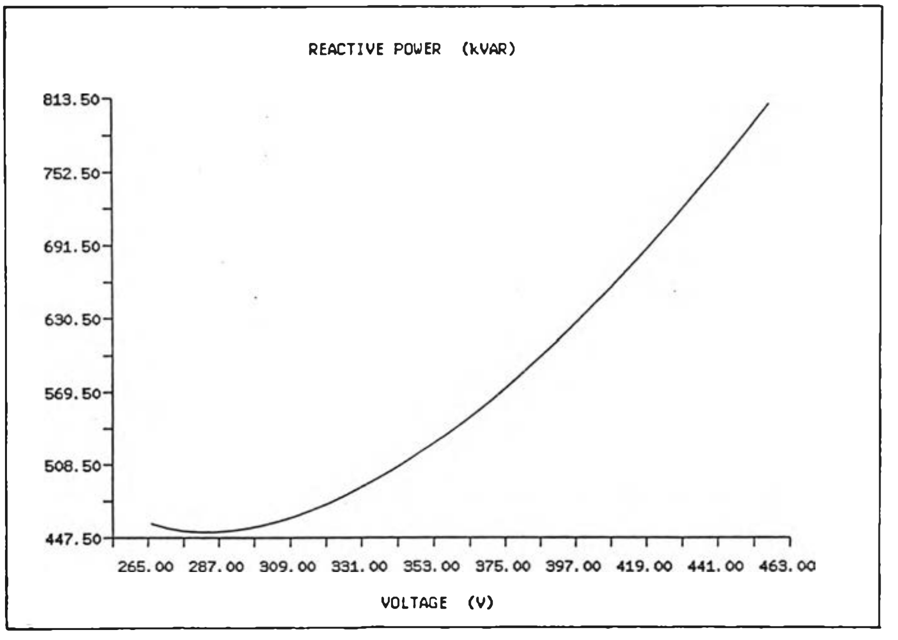


Fig. A4.51 Steady state P-V characteristic of composite load case 1

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

a



b

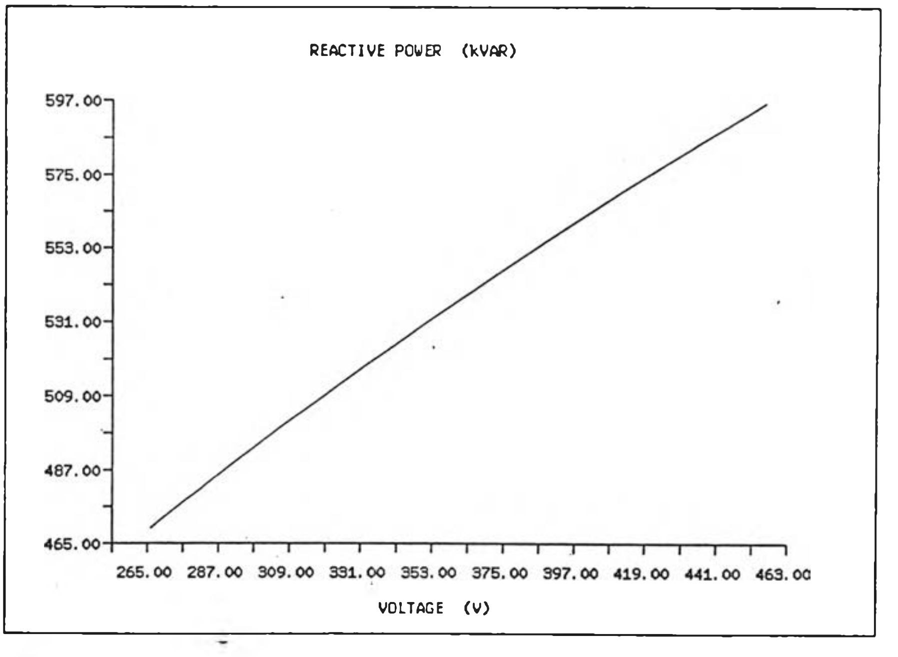
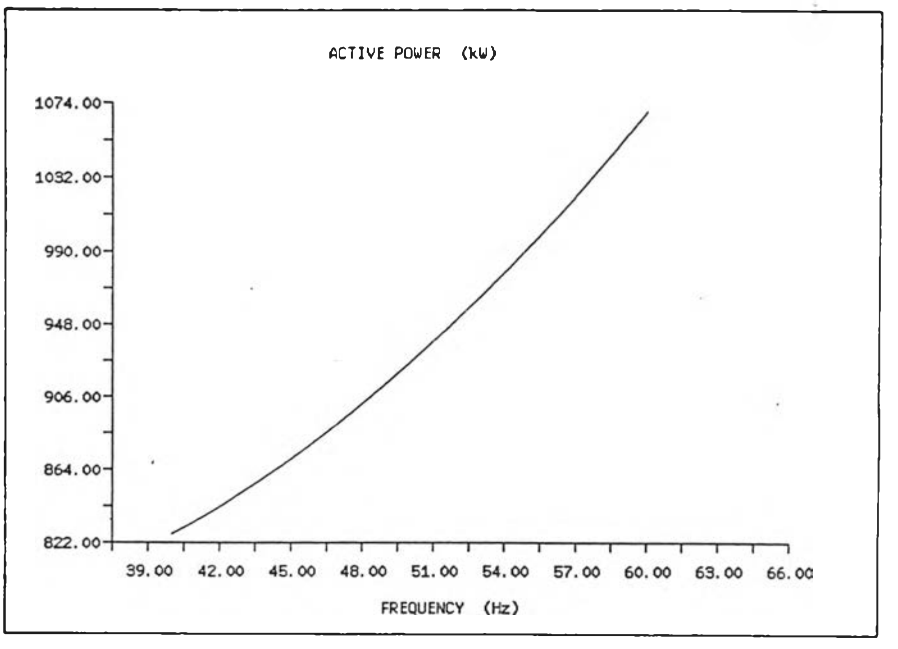


Fig. A4.52 Steady state Q-V characteristic of composite load case 1

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

a



b

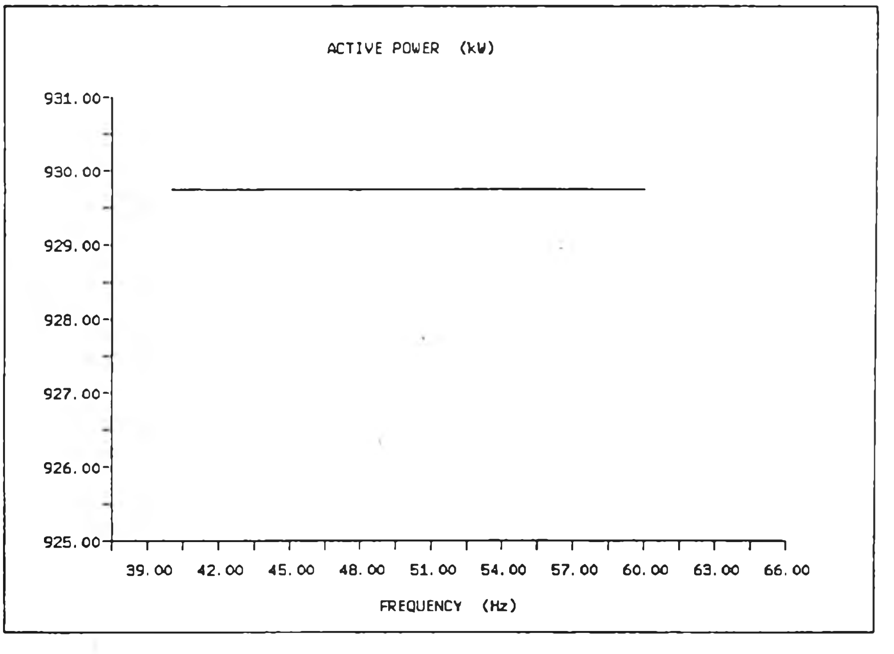
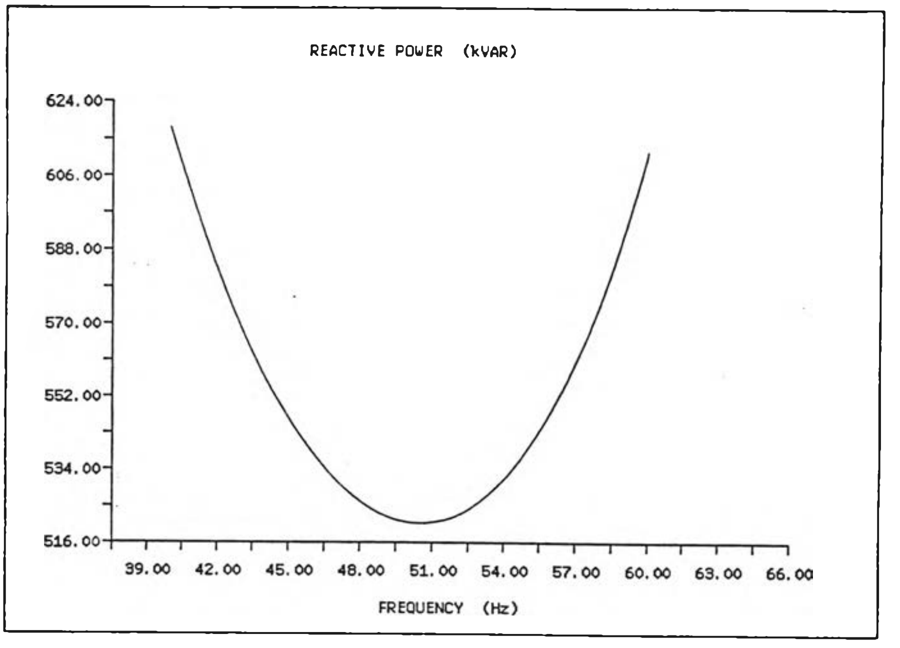


Fig. A4. 53 Steady state P-f characteristic of composite load case 1

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

a



b

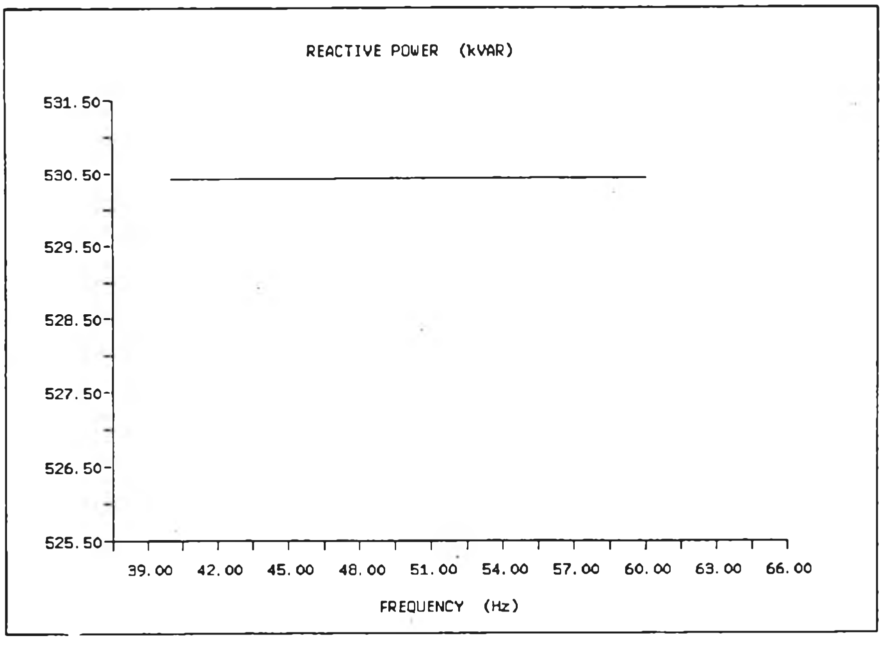
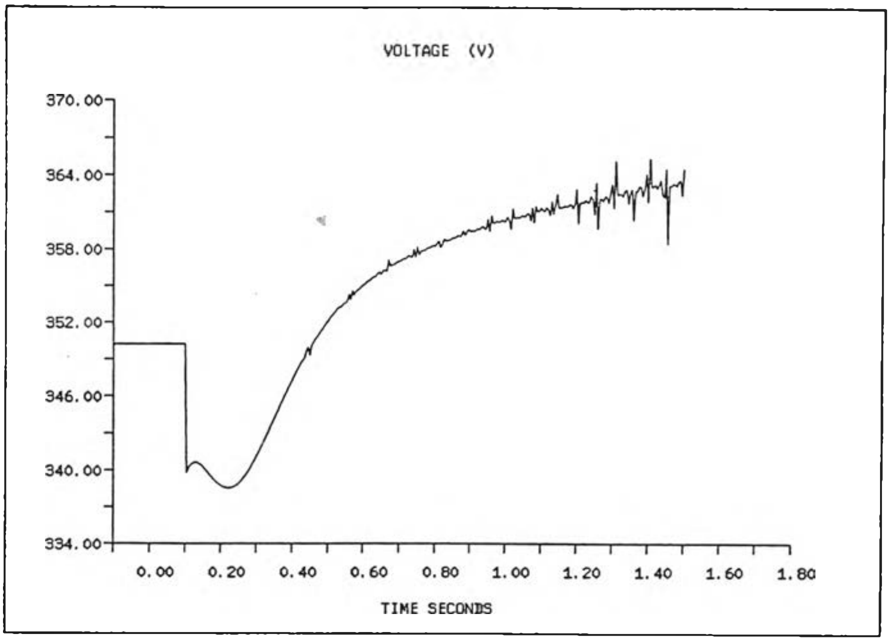


Fig. A4.54 Steady state Q-f characteristic of composite load case 1

a. used composite model

b. used constant power model for motors and constant impedance model for other loads.



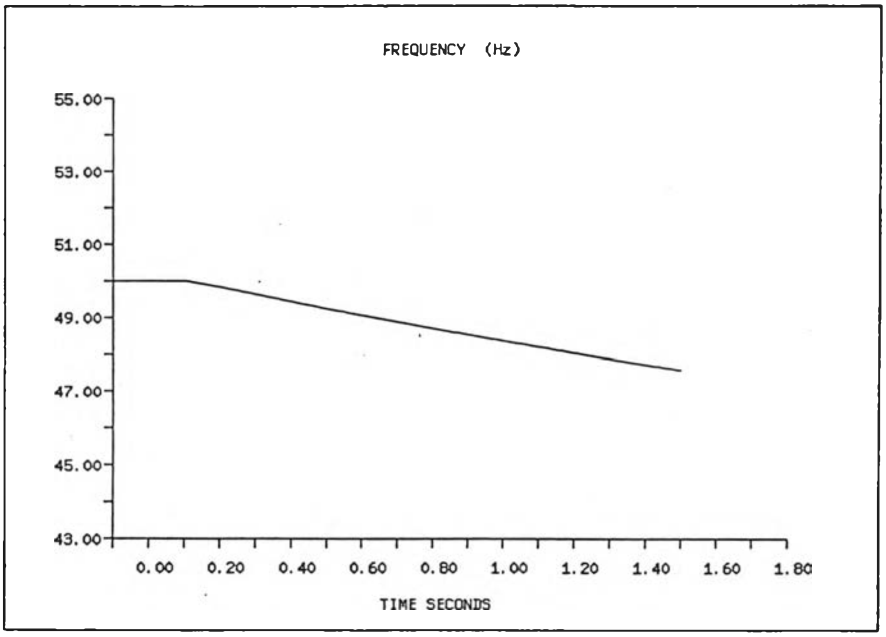
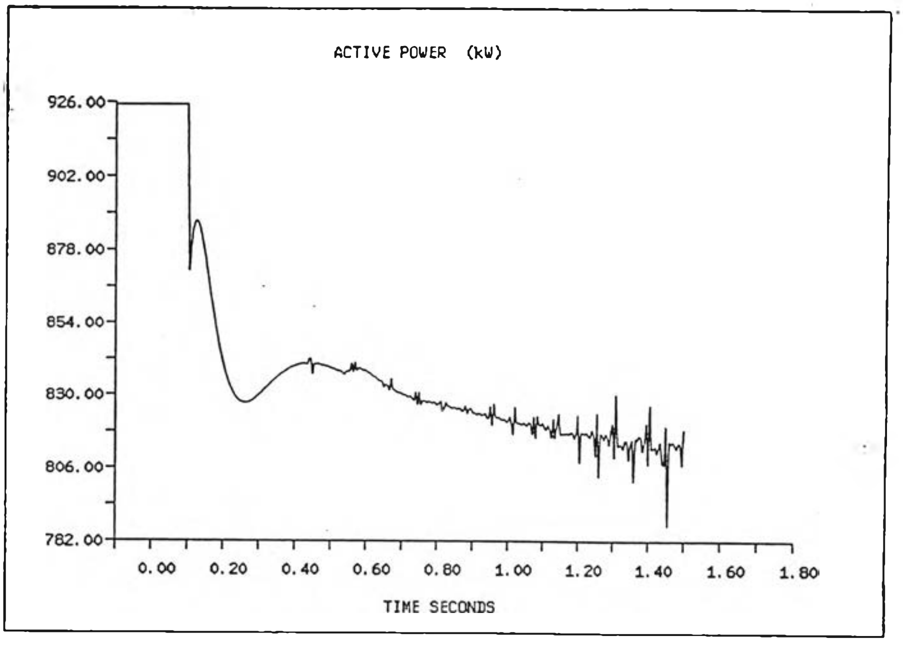


Fig. A4.55 Voltage and frequency at bus 4 during gen. 2 disconnected

a



b

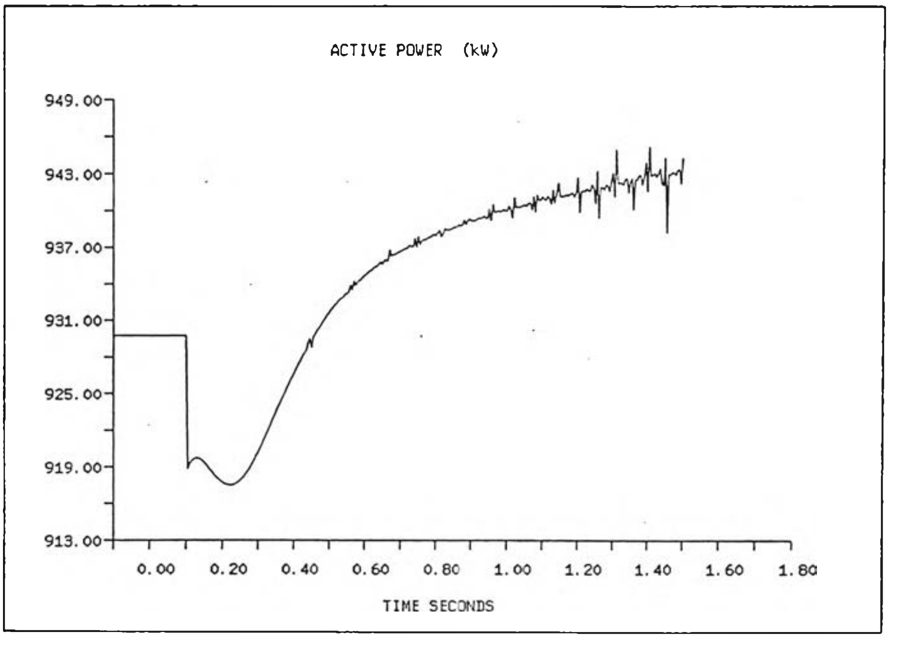
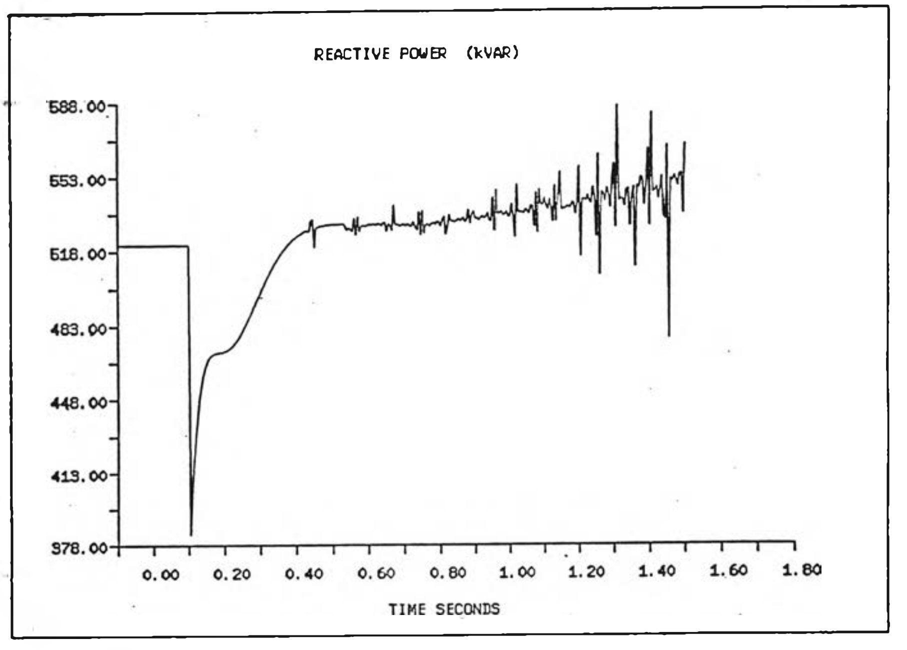


Fig. A4. 56 Active power at bus 4 during gen. 2 disconnected

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

a



b

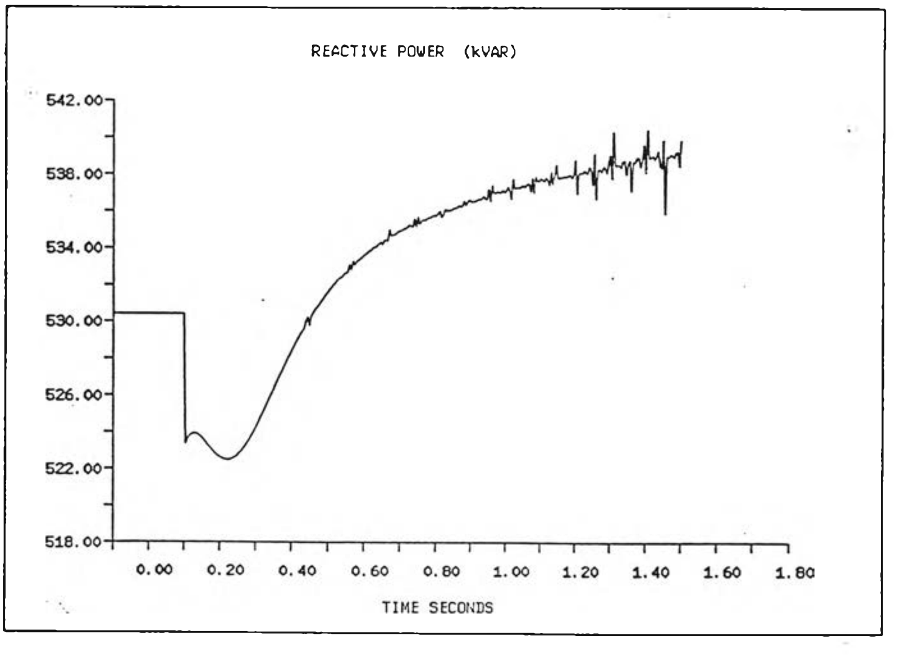
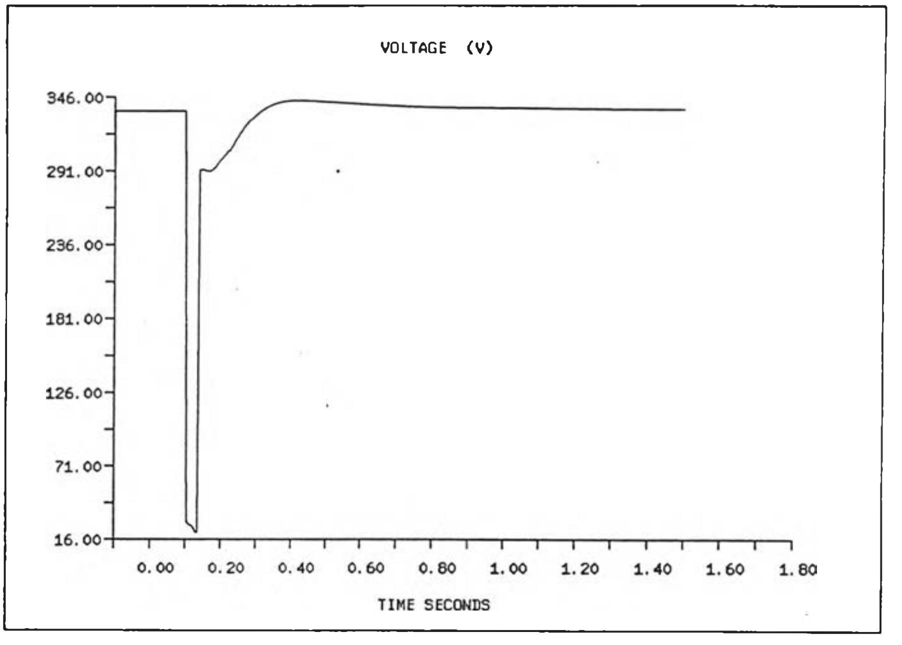


Fig. A4.57 Reactive power at bus 4 during gen. 2 disconnected

a. used composite model

b. used constant power model for motors and constant impedance model for other loads



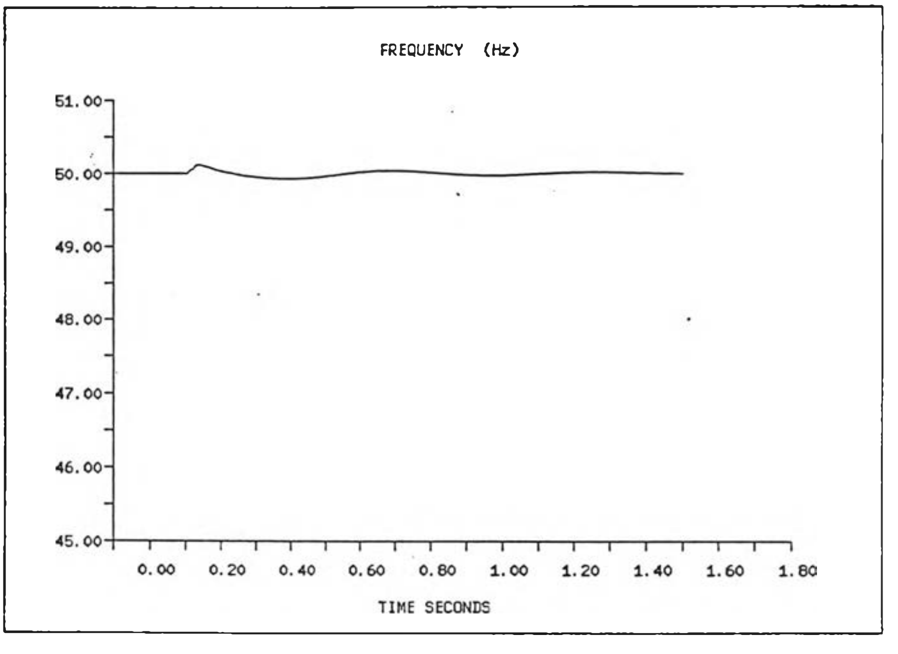
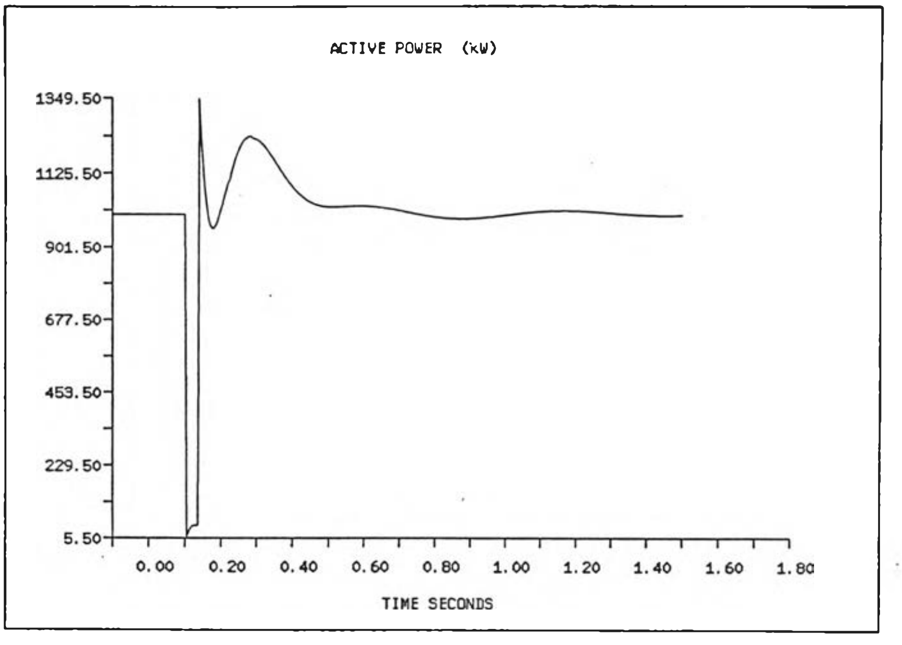


Fig.A4. 58 Voltage and frequency at bus 4 when 3 phase fault occured at bus 3 (load case 2)

a



b

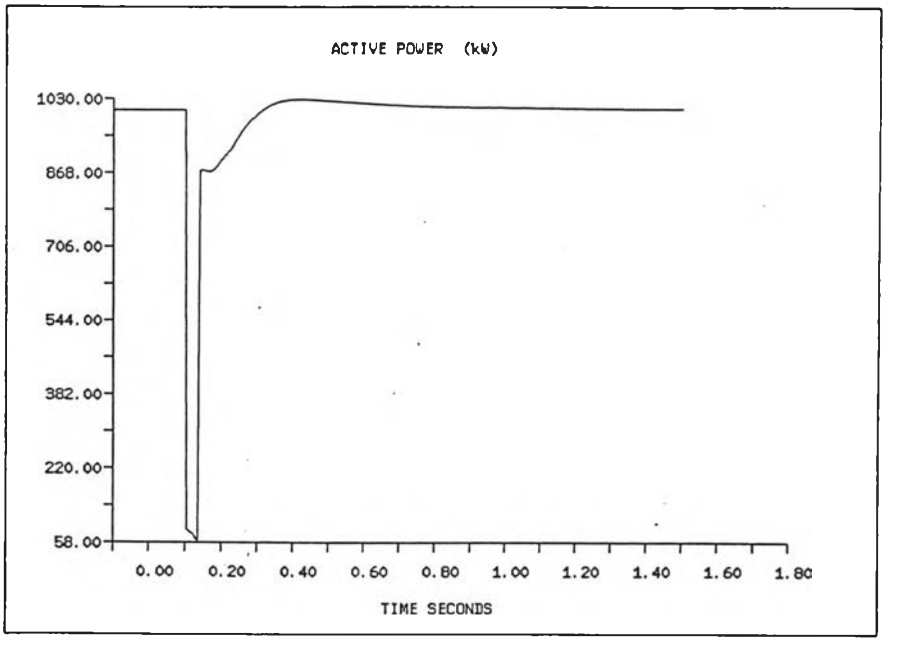
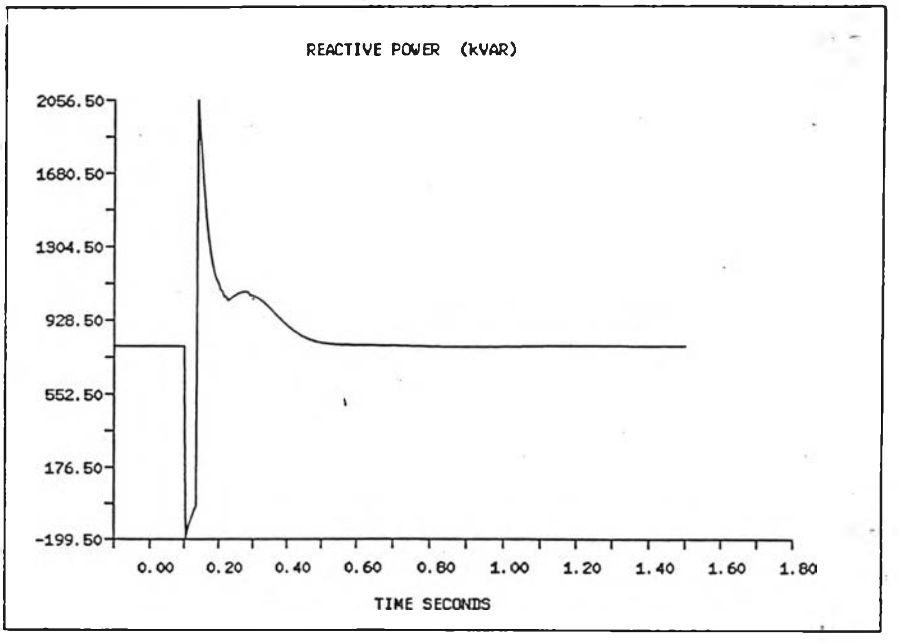


Fig.A4. 59 Active power at bus 4 when 3 phase fault occured at bus 3

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

a



b

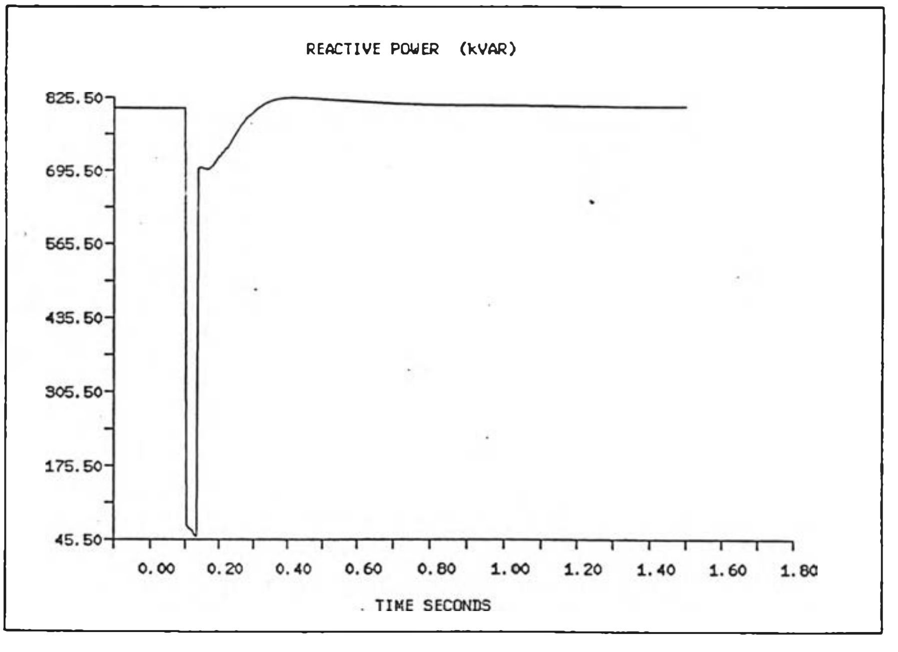


Fig.A4.60 Reactive power at bus 4 when 3 phase fault occured at bus 3

a. used composite model

b. used constant power model for motors and constant impedance model for other loads

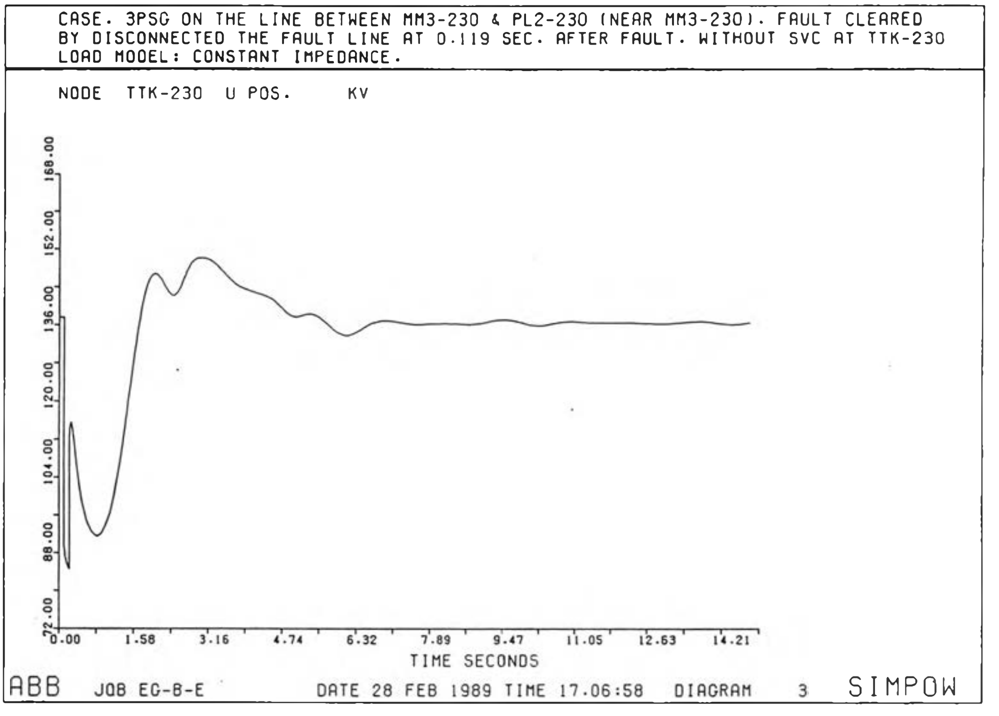
APPENDIX 5

EFFECT OF LOAD MODEL ON STABILITY STUDY

To illustrate effect of load model on stability study, the modified EGAT system was used to make stability test under two conditions of load model. The case studied is three phase fault on line. The two load models used are :

1) constant impedance
2) 20% constant current, 20% constant impedance, 60% constant power.

The results used the above two models are compared and shown in the figures on the following pages.



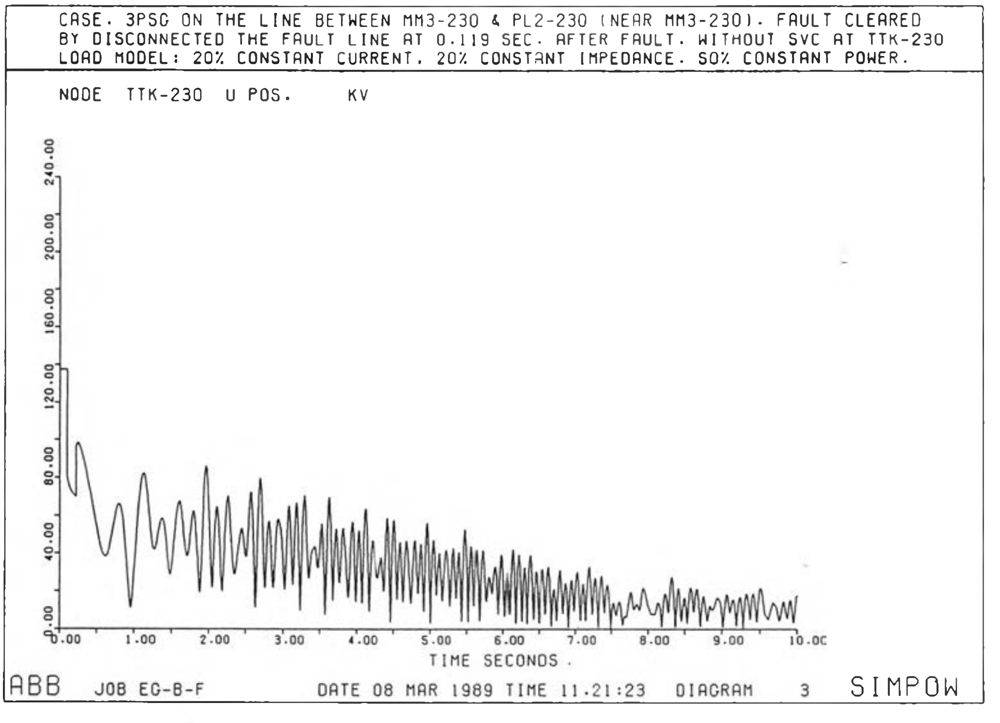
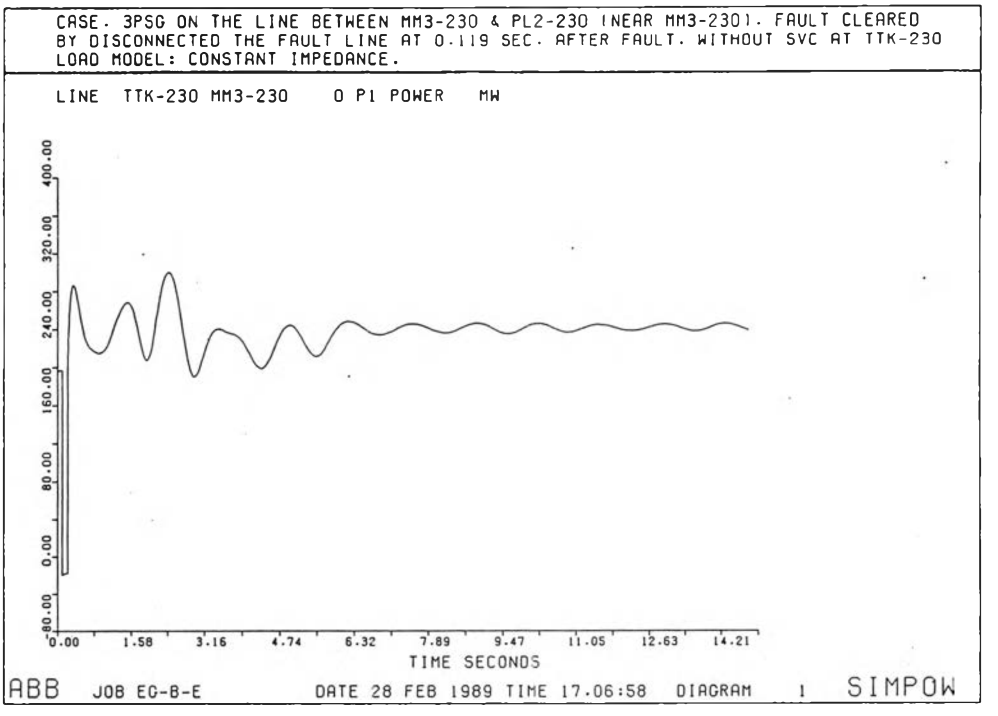


Figure A5.1 Comparison of voltage when used the two different load model



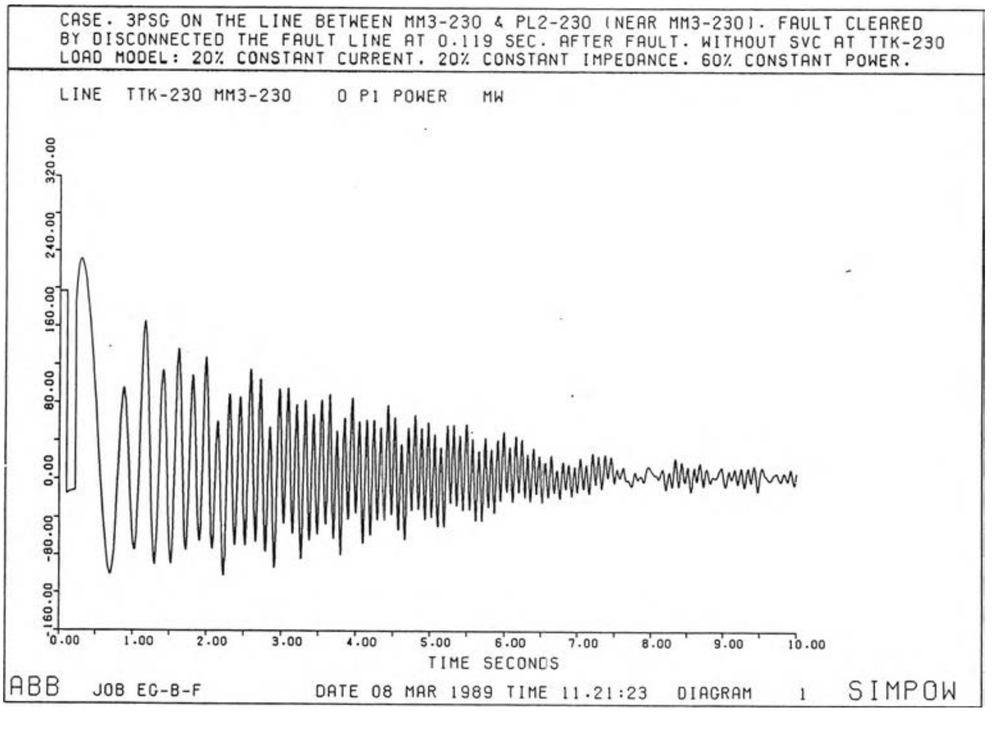
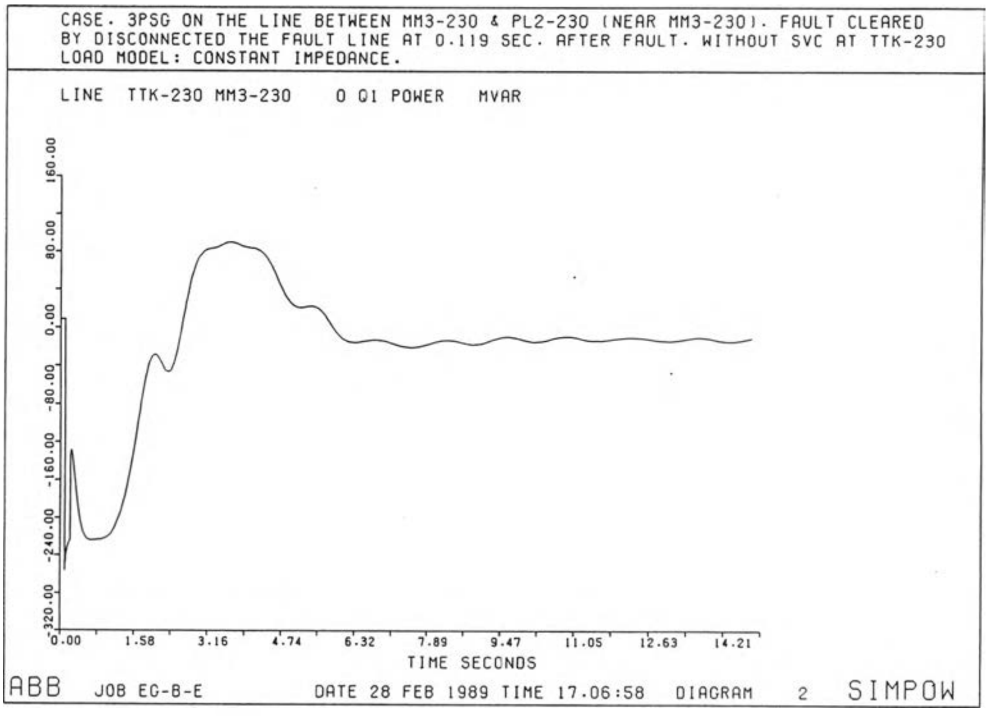


Figure A5.2 Comparison of active power



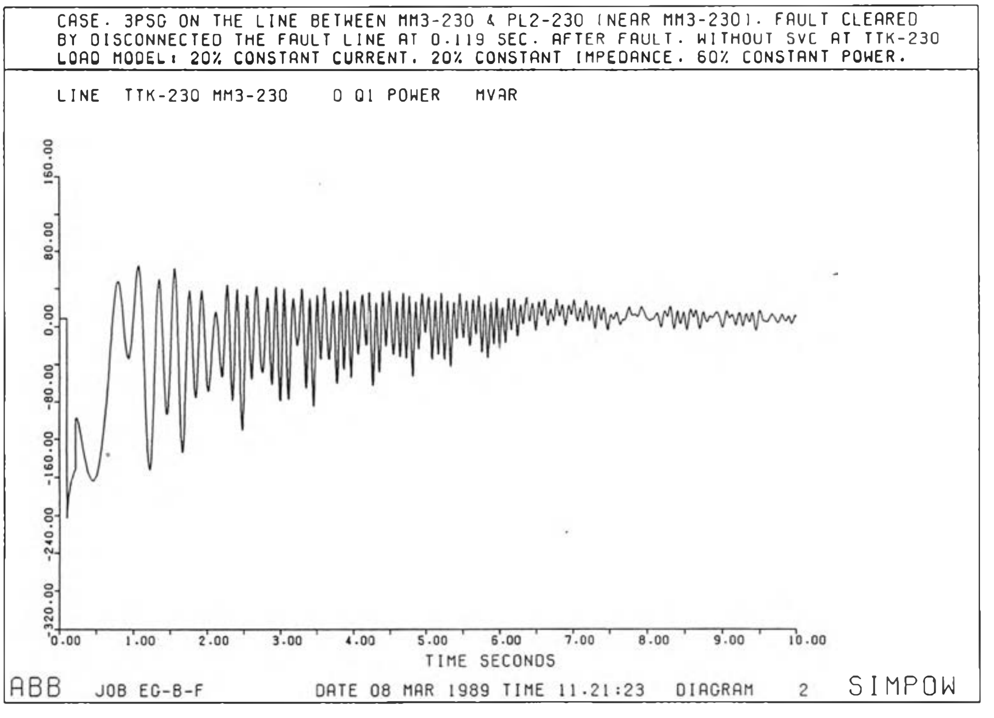
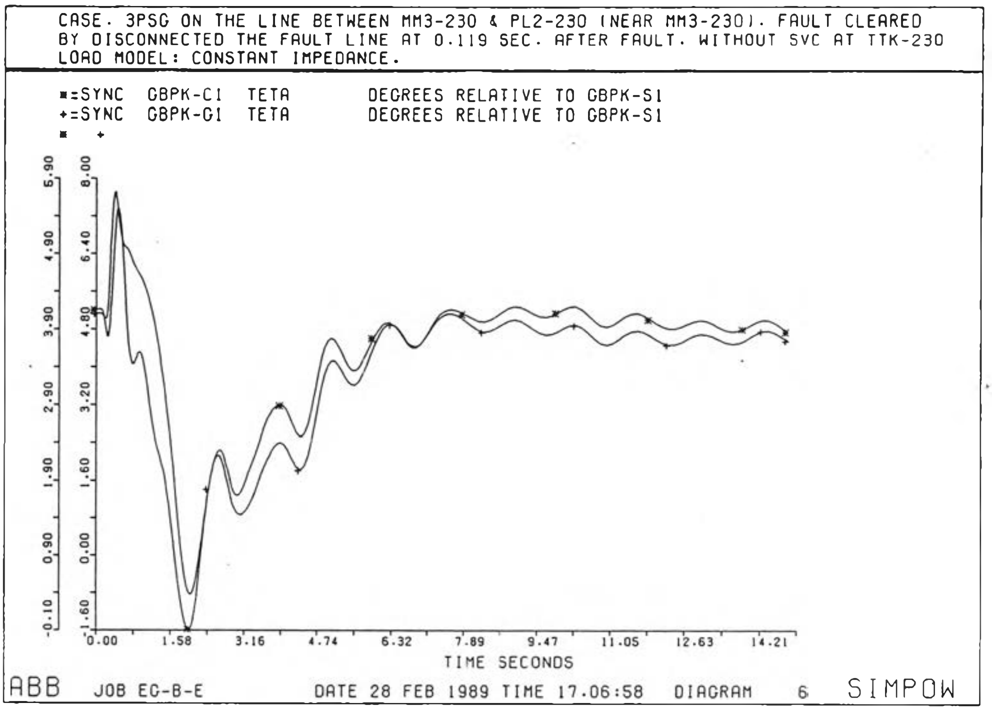


Figure A5.3 Comparison of reactive power



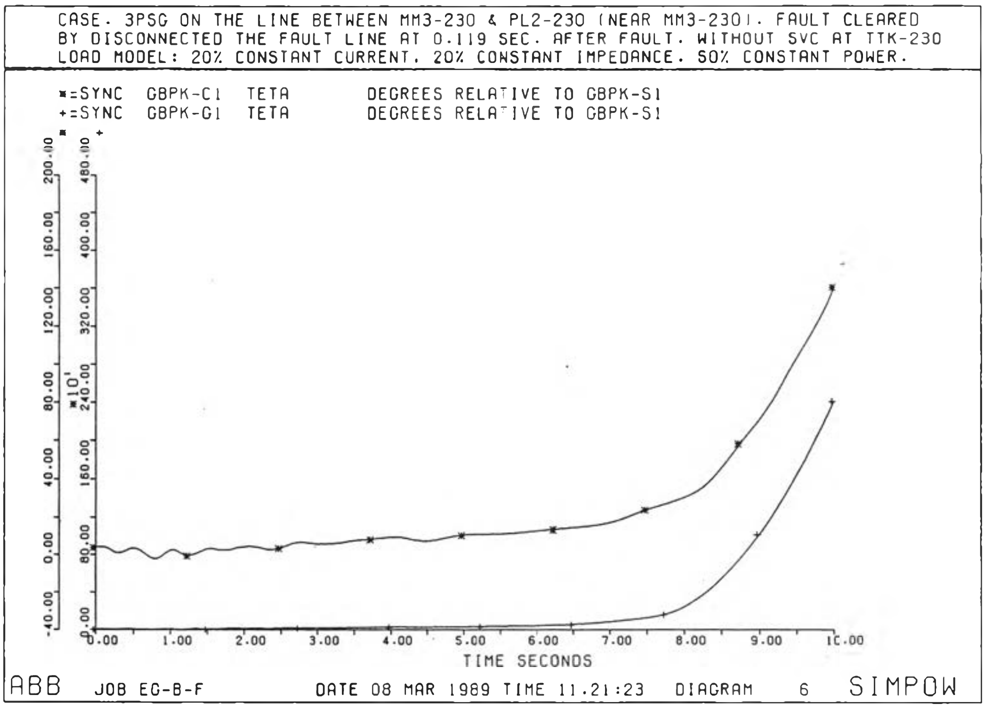
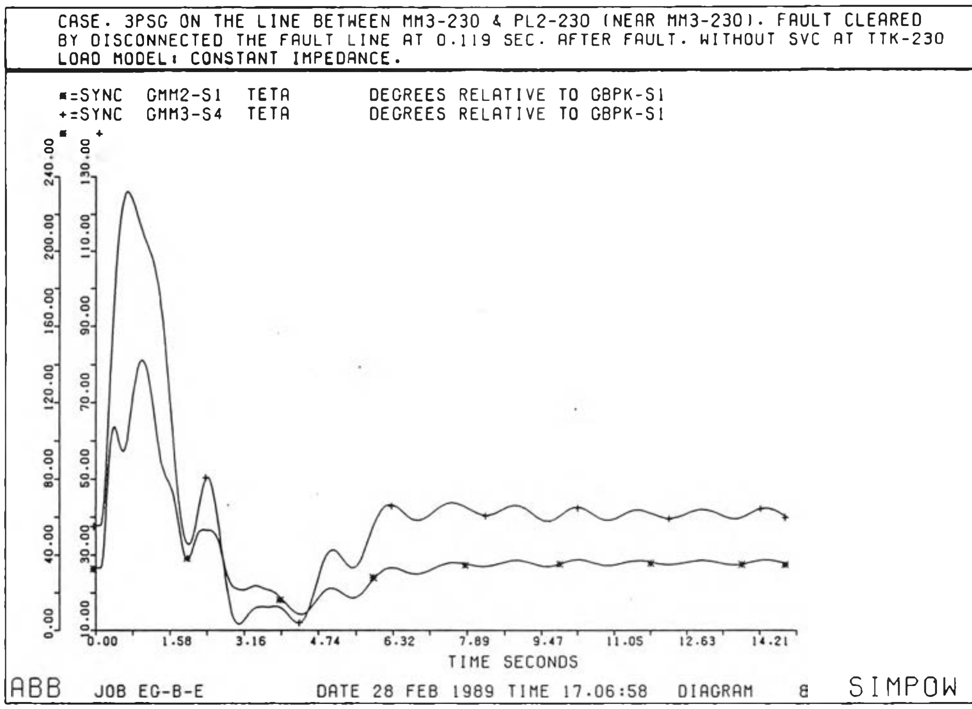


Figure A5.4 Relative angle of generators in the system



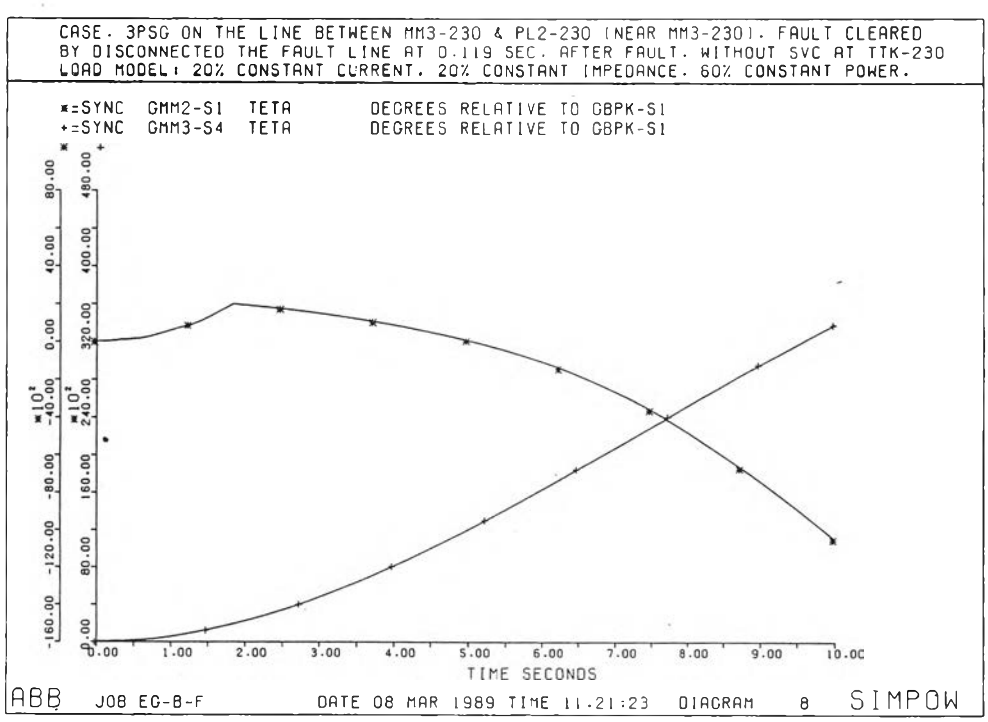
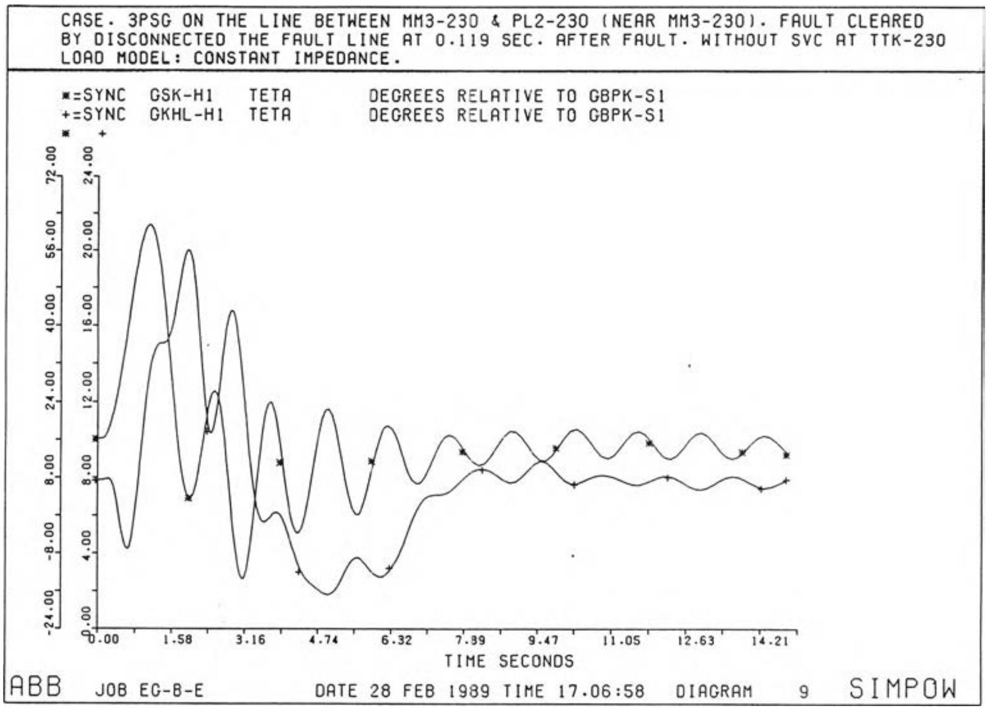


Figure A5.5 Relative angle of generators in the system



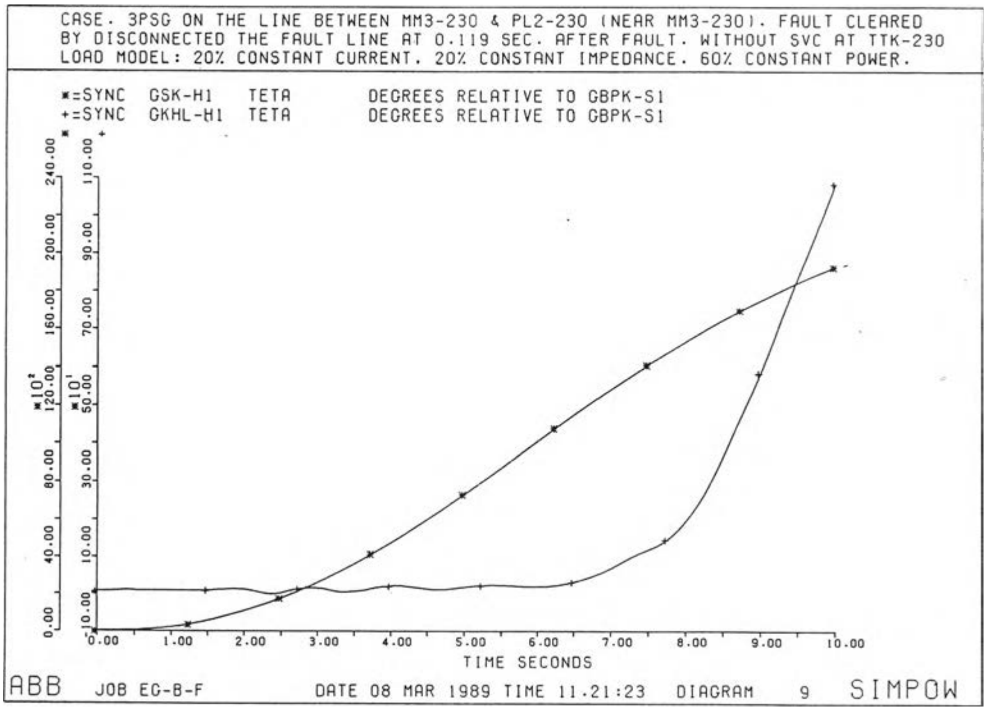
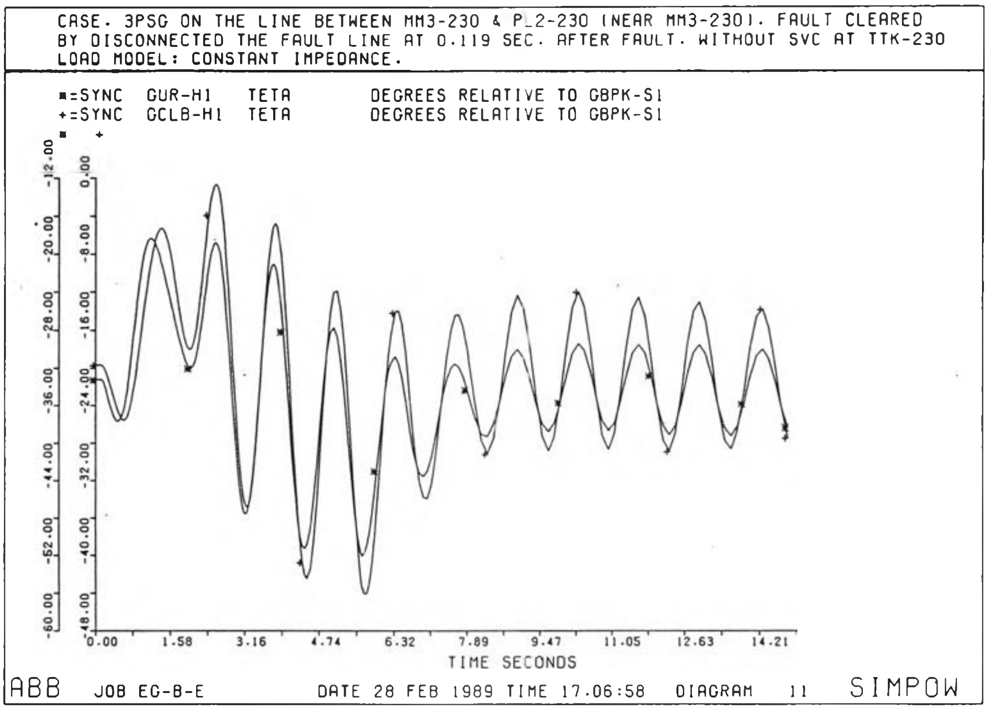


Figure A5.6 Relative angle of generators in the system



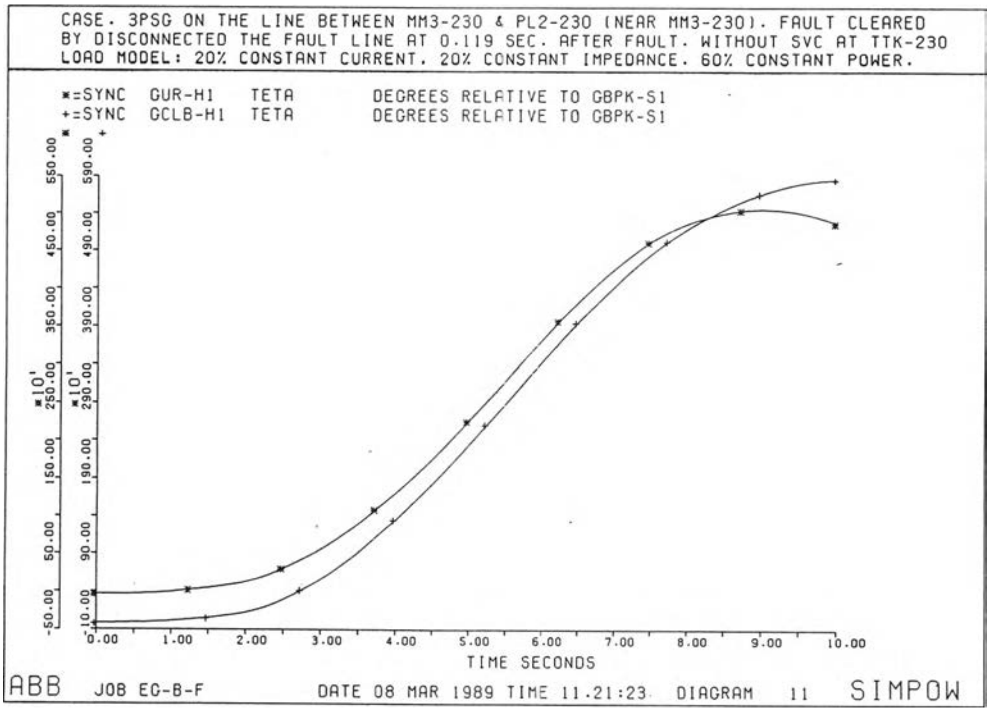
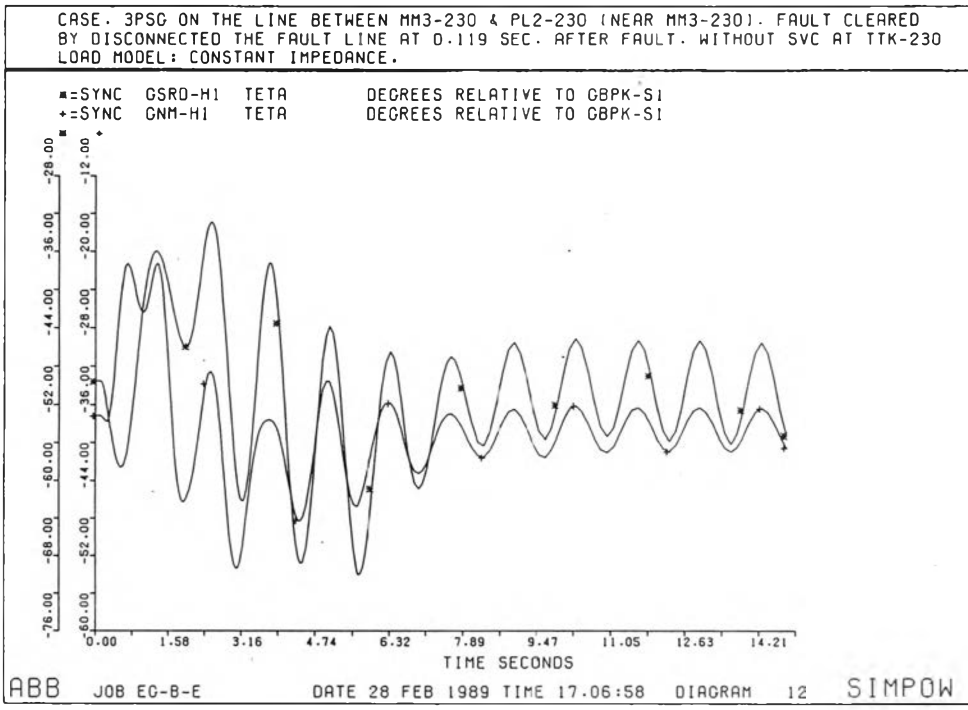


Figure A5.7 Relative angle of generators in the system



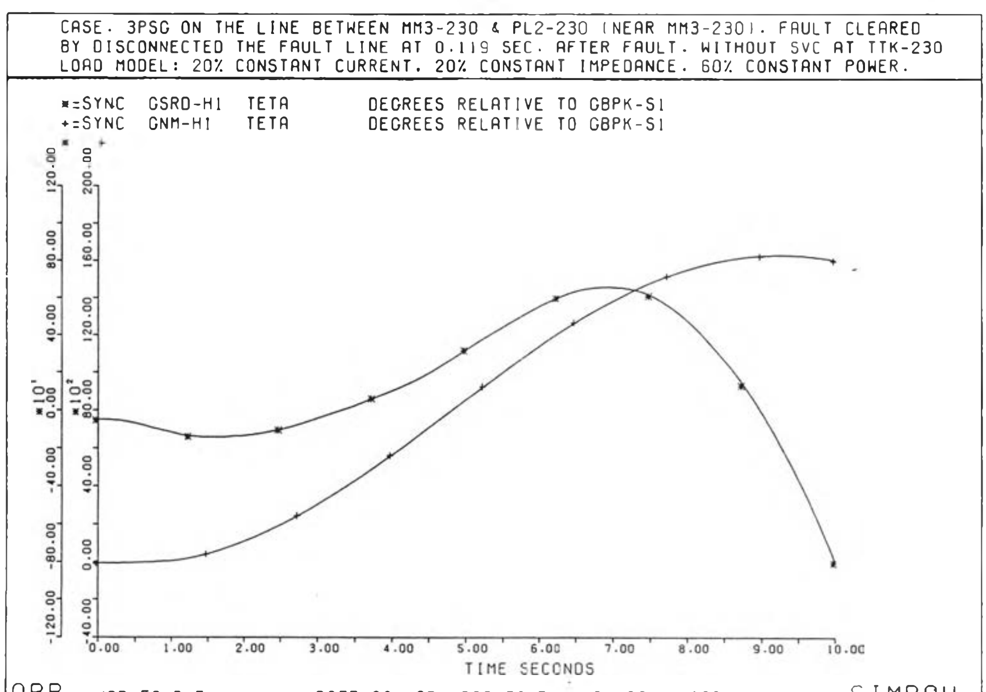


Figure A5.8 Relative angle of generators in the system

From the simulation results (e.g. Fig. A5.5, A5.8) it can be seen that when loads are modelled by constant impedance the system is stable and when loads are modelled by 20% constant current, 20% constant impedance and 60% constant power the system is unstable.

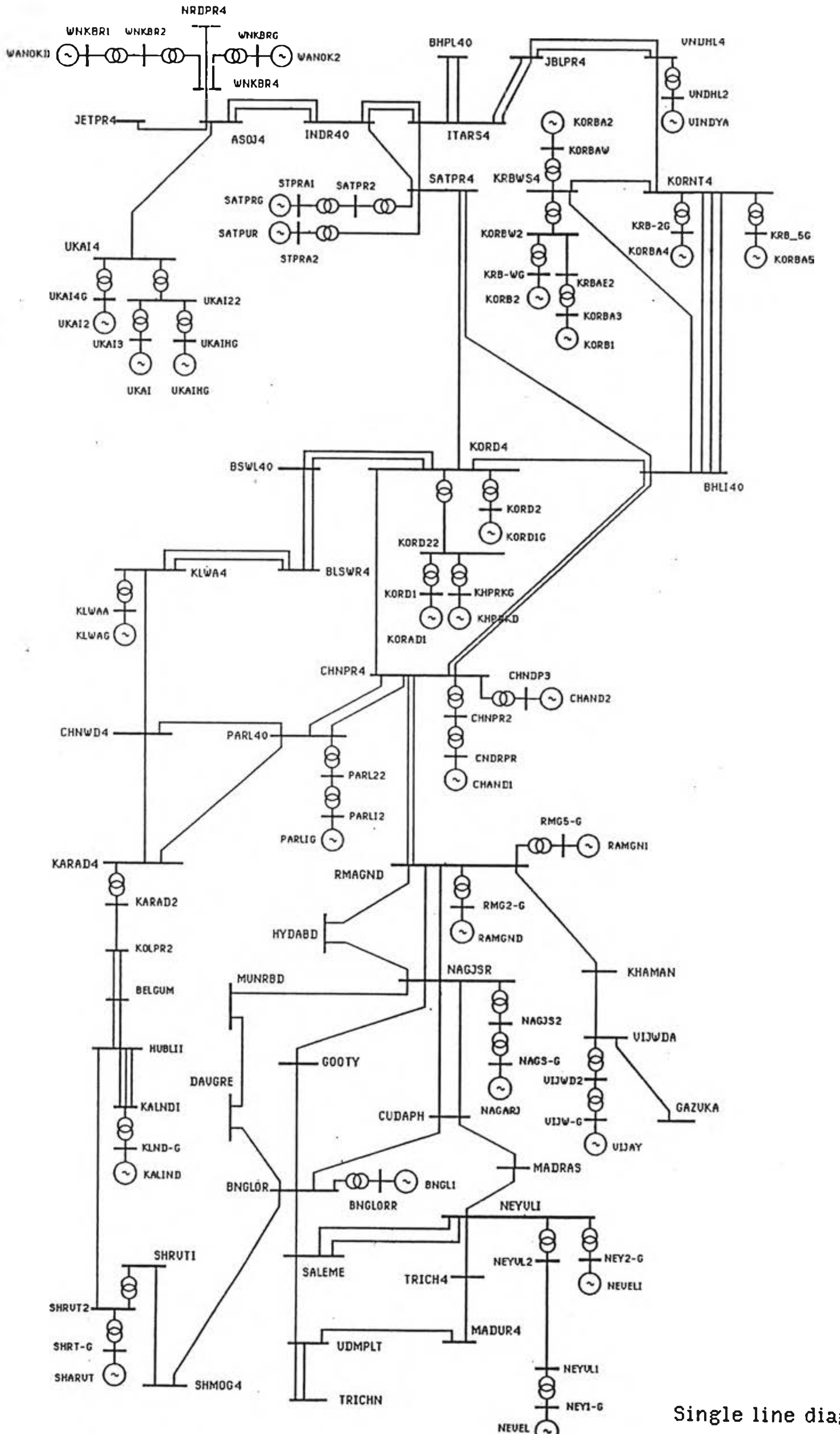
From this example it is clear that load model affects the stability results, so proper representation of loads is necessary.

APPENDIX 6

LOAD MODEL SIMULATION RESULTS OF A 91 BUSES SYSTEM

The studied system and its data are shown in figure A6.1 and table A6.1 respectively.

Bus MADRAS is selected for simulation study with 3 large motors connected to it. Dynamic responses of the motors when 3 phase fault occured at bus CHNPR4 used induction motor model and constant current model are shown in figures on the following pages.



Single line diagram of studied system

Fig. A6.1 Studied system

Table A6.1 System Data

```
STUDIED SYSTEM DATA
* *
NODES
  NAGS-G   UB 13.80    AREA 1
  KLND-G   UB  11.00   AREA 1
  KORBA3   UB= 13.80   AREA=1
  KORBAW   UB= 15.75   AREA=1
  STPRA1   UB= 15.75   AREA=1
  STPRA2   UB= 15.75   AREA=1
  KRB_2G   UB= 15.75   AREA=1
  KRB_5G   UB= 21.00   AREA=1
  VNDHL2   UB= 15.75   AREA=1
  KRB_WG   UB= 15.75   AREA=1
  KHPRKG   UB= 15.75   AREA=1
  KORD1    UB= 14.30   AREA=1
  KORD2    UB= 15.75   AREA=1
  BNGLORR  UB= 13.8    AREA=1
  KLWAA    UB= 13.8    AREA=1
  CNDRPR   UB= 15.75   AREA=1
  CHNDP3   UB= 15.75   AREA=1
  WNKBR1   UB= 15.75   AREA=1
  WNKBRG   UB= 15.75   AREA=1
  UKAIHG   UB= 11.00   AREA=1
  UKAI3    UB= 15.75   AREA=1
  UKAI4G   UB= 15.75   AREA=1
  VIJW-G   UB= 15.70   AREA=1
  SHRT-G   UB= 11.00   AREA=1
  NEY2-G   UB= 15.70   AREA=1
  NEY1-G   UB= 11.00   AREA=1
  RMG5-G   UB= 21.00   AREA=1
  RMG2-G   UB  16.50   AREA 1
  PARLI2   UB  15.75   AREA 1
  VIJWD2   UB=220.00   AREA=1
  KALNDI   UB 220.00   AREA 1
  HUBLII   UB 220.00   AREA 1
  RMNGD2   UB 220.00   AREA 1
  NEYVL1   UB 220.0    AREA 1
  NEYVL2   UB 220.0    AREA 1
  BELGUM   UB 220.00   AREA 1
  SATPR2   UB=220.00   AREA=1
  KORBW2   UB=220.00   AREA=1
  KHPRKD   UB=220.00   AREA=1
  KORD22   UB=220.00   AREA=1
  CHNPR2   UB=220.00   AREA=1
  KARAD2   UB=220.00   AREA=1
  KOLPR2   UB=220.00   AREA=1
  WNKBR2   UB=220.00   AREA=1
  UKAI22   UB=220.00   AREA=1
  SHRVT2   UB  220.0   AREA 1
  NAGJS2   UB  220.0   AREA 1
  KRBAE2   UB  220.0   AREA 1
  PARL22   UB  220.0   AREA 1
  RMAGND   UB=400.00   AREA=1
  KHAMAN   UB=400.00   AREA=1
  VIJWDA   UB=400.00   AREA=1
  GAZVKA   UB=400.00   AREA=1
  NAGJSR   UB=400.00   AREA=1
  CUDAPH   UB=400.00   AREA=1
  MADRAS   UB=400.00   AREA=1
  NEYVLI   UB=400.00   AREA=1
  SALEME   UB=400.00   AREA=1
  TRICH4   UB=400.00   AREA=1
  MADUR4   UB=400.00   AREA=1
  UDMPLT   UB=400.00   AREA=1
  BNGLOR   UB=400.00   AREA=1
  DAVGRE   UB=400.00   AREA=1
  MUNRBD   UB=400.00   AREA=1
  HYDABD   UB=400.00   AREA=1
  TRICHN   UB=400.00   AREA=1
  SHMOG4   UB=400.00   AREA=1
  SHRVTI   UB=400.00   AREA=1
  GOOTYY   UB=400.00   AREA=1
  KRBWS4   UB=400.00   AREA=1
  SATPR4   UB=400.00   AREA=1
  KORNT4   UB=400.00   AREA=1
  VNDHL4   UB=400.00   AREA=1
  BHLI40   UB=400.00   AREA=1
  JBLPR4   UB=400.00   AREA=1
  ITARS4   UB=400.00   AREA=1
  INDR40   UB=400.00   AREA=1
  BHPL40   UB=400.00   AREA=1
  KORD4    UB=400.00   AREA=1
  CHNPR4   UB=400.00   AREA=1
  PARL40   UB=400.00   AREA=1
  KARAD4   UB=400.00   AREA=1
  CHNWD4   UB=400.00   AREA=1
  KLWA4    UB=400.00   AREA=1
  BLSWR4   UB=400.00   AREA=1
  BSWL40   UB=400.00   AREA=1
  WNKBR4   UB=400.00   AREA=1
  UKAI4    UB=400.00   AREA=1
  ASOJ4    UB=400.00   AREA=1
  NRDPR4   UB=400.00   AREA=1
  JETPR4   UB=400.00   AREA=1
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LINES
  SHRVT2   HUBLII   NO   1  R  0.01180  X  0.063    B 0.4354    TYPE 12
  HUBLII   KALNDI   NO   1  R  0.00500  X  0.02670  B 0.18500   TYPE 12
  HUBLII   KALNDI   NO   2  R  0.0050   X  0.0267   B 0.185     TYPE 12
  HUBLII   KALNDI   NO   3  R  0.01     X  0.0536   B 0.0925    TYPE 12
  HUBLII   BELGUM   NO   1  R  0.0072   X  0.0380   B 0.26460   TYPE 12
  HUBLII   BELGUM   NO   2  R  0.0144   X  0.076    B 0.1323    TYPE 12
  NEYVL1   NEYVL2   NO   1  R  0.0008   X  0.0041   B 0.0285    TYPE 12
  KARAD2   KOLPR2   NO   1  R  0.0039   X  0.0157   B 0.01570   TYPE 12
  KRBAE2   KORBW2   NO   1  R  0.0012   X  0.0056   B 0.0398    TYPE 12
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  DAVGRE   BNGLOR   NO=  1  R= 0.00450  X= 0.04800  B=1.50780   TYPE=12
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  KRBWS4   KORNT4   NO=  1  R= 0.00020  X= 0.00280  B=0.07400   TYPE=12
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  KORNT4   BHLI40   NO=  1  R= 0.00330  X= 0.04050  B=1.05770   TYPE=12
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  ITARS4   INDR40   NO=  2  R= 0.00380  X= 0.04730  B=1.23400   TYPE=12
  INDR40   ASOJ4    NO=  2  R= 0.00470  X= 0.05900  B=1.54000   TYPE=12
  INDR40   ASOJ4    NO=  1  R= 0.00470  X= 0.05900  B=1.54000   TYPE=12
  KHPRKD   KORD22   NO=  1  R= 0.00450  X= 0.02100  B=0.03220   TYPE=12
  KHPRKD   KORD22   NO=  2  R= 0.00450  X= 0.02100  B=0.03220   TYPE=12
  KORD4    CHNPR4   NO=  1  R= 0.00243  X= 0.02860  B=0.79460   TYPE=12
  KORD4    BSWL40   NO=  1  R= 0.00569  X= 0.07100  B=1.85230   TYPE=12
  KORD4    BSWL40   NO=  2  R= 0.00569  X= 0.07100  B=1.85230   TYPE=12
  CHNPR4   PARL40   NO=  2  R= 0.00510  X= 0.06260  B=1.64800   TYPE=12
  CHNPR4   PARL40   NO=  1  R= 0.00510  X= 0.06260  B=1.64800   TYPE=12
  PARL40   KARAD4   NO=  1  R= 0.00502  X= 0.06250  B=1.63200   TYPE=12
  PARL40   CHNWD4   NO=  1  R= 0.00495  X= 0.06170  B=1.61070   TYPE=12
  KARAD4   CHNWD4   NO=  1  R= 0.00264  X= 0.03290  B=0.85900   TYPE=12
  CHNWD4   KLWA4    NO=  1  R= 0.00210  X= 0.02720  B=0.70870   TYPE=12
  KLWA4    BLSWR4   NO=  1  R= 0.00320  X= 0.03820  B=0.99330   TYPE=12
  KLWA4    BLSWR4   NO=  2  R= 0.00320  X= 0.03820  B=0.99330   TYPE=12
  BLSWR4   BSWL40   NO=  1  R= 0.00380  X= 0.04770  B=1.24560   TYPE=12
  BLSWR4   BSWL40   NO=  2  R= 0.00380  X= 0.04770  B=1.24560   TYPE=12
  WNKBR4   ASOJ4    NO=  1  R= 0.00120  X= 0.01500  B=0.39200   TYPE=12
  WNKBR4   NRDPR4   NO=  1  R= 0.00100  X= 0.01140  B=1.22100   TYPE=12
  UKAI4    ASOJ4    NO=  1  R= 0.00240  X= 0.03080  B=0.80400   TYPE=12
  ASOJ4    JETPR4   NO=  1  R= 0.00490  X= 0.06170  B=1.61000   TYPE=12
END
```

```
TRANSFORMERS
  NAGS-G  NAGJS2  SN 100  UN1  13.8    UN2 220.     EX12 0.0227
  KLND-G  KALNDI  SN 100  UN1  11.0    UN2 220.     EX12 0.0188
  NEY1-G  NEYVL1  SN 100  UN1  11.0   UN2 220.     EX12 0.0450
  NEYVL2  NEYVLI  SN 100  UN1 220.     UN2 400.     EX12 0.0381
  SHRT-G  SHRVT2  SN 100  UN1  11.00   UN2 220.00   EX12 0.0143
  VIJW-G  VIJWD2  SN 100  UN1  15.75   UN2 220.00   EX12 0.0189
  RMNGD2  RMAGND  SN 100  UN1 220.00   UN2 400.00   EX12 0.0381
  WNKBR1  WNKBR2  SN 100  UN1  15.75   UN2 220.00   EX12 0.0280
  UKAIHG  UKAI22  SN 100  UN1  11.00   UN2 220.00   EX12 0.0463
  NEY2-G  NEYVLI  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0189
  RMG2-G  RMAGND  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0199
  RMG5-G  RMAGND  SN=100  UN1= 21.00   UN2=400.00   EX12=0.0119
  SHRVT2  SHRVTI  SN=100  UN1=220.00   UN2=400.00   EX12=0.0381
  VIJWD2  VIJWDA  SN=100  UN1=220.00   UN2=400.00   EX12=0.0381
  NAGJS2  NAGJSR  SN=100  UN1=220.00   UN2=400.00   EX12=0.0381
  KORBA3  KRBAE2  SN=100  UN1= 13.80   UN2=220.00   EX12=0.0481
  KORBAW  KRBWS4  SN=100  UN1= 15.80   UN2=400.00   EX12=0.0580
  STPRA1  SATPR2  SN=100  UN1= 15.80   UN2=220.00   EX12=0.0560
  STPRA2  SATPR4  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0580
  KRB_2G  KORNT4  SN=100  UN1= 15.80   UN2=400.00   EX12=0.0187
  KRB_5G  KORNT4  SN=100  UN1= 21.00   UN2=400.00   EX12=0.0125
  VNDHL2  VNDHL4  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0112
  KRB_WG  KORBW2  SN=100  UN1= 15.80   UN2=220.00   EX12=0.0580
  SATPR2  SATPR4  SN=100  UN1=220.00   UN2=400.00   EX12=0.0300
  KORBW2  KRBWS4  SN=100  UN1=220.00   UN2=400.00   EX12=0.0300
  KHPRKG  KHPRKD  SN=100  UN1= 15.75   UN2=220.00   EX12=0.0290
  KORD1   KORD22  SN=100  UN1= 14.30   UN2=220.00   EX12=0.0278
  CNDRPR  CHNPR2  SN=100  UN1= 15.75   UN2=220.00   EX12=0.0600
  PARLI2  PARL22  SN=100  UN1= 15.75   UN2=220.00   EX12=0.0300
  CHNDP3  CHNPR4  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0250
  KORD22  KORD4   SN=100  UN1=220.00   UN2=400.00   EX12=0.0417
  CHNPR2  CHNPR4  SN=100  UN1=220.00   UN2=400.00   EX12=0.0500
  PARL22  PARL40  SN=100  UN1=220.00   UN2=400.00   EX12=0.0500
  KARAD2  KARAD4  SN=100  UN1=220.00   UN2=400.00   EX12=0.0397
  WNKBRG  WNKBR4  SN=100  UN1= 15.75   UN2=400.00   EX12=0.0187
  UKAI3   UKAI22  SN=100  UN1= 15.75   UN2=220.00   EX12=0.0280
  UKAI4G  UKAI4   SN=100  UN1= 15.75   UN2=400.00   EX12=0.0560
  WNKBR2  WNKBR4  SN=100  UN1=220.00   UN2=400.00   EX12=0.0300
  UKAI22  UKAI4   SN=100  UN1=220.00   UN2=400.00   EX12=0.0500
  KORD2   KORD4   SN 100  UN1=15.75    UN2=400.00   EX12=0.025
  KLWAA   KLWA4   SN 100  UN1=13.8     UN2=400.00   EX12=0.025
  BNGLORR BNGLOR  SN 100  UN1=13.8     UN2=400.00   EX12=0.025
END
SHUNT IMPEDANCES
  KOLPR2  Q   -80.0   UN  220.
  BELGUM  Q   -40.0   UN  220.0
  KARAD2  Q   -50.   UN  220.
  KHAMAN  Q    90.    UN  400.00
  RMAGND  Q    90.    UN  400.00
  VIJWDA  Q   114.    UN  400.00
  GAZVKA  Q    57.    UN  400.00 NCON 1
  NAGJSR  Q   282.    UN  400.00
  CUDAPH  Q   180.    UN  400.00
  MADRAS  Q    90.    UN  400.00
  NEYVLI  Q    90.00  UN  400.00
  SALEME  Q   135.00  UN  400.00
  TRICH4  Q    45.00  UN  400.00
  MADUR4  Q    90.00  UN  400.00
  UDMPLT  Q=   90.00  UN= 400.00
  BNGLOR  Q=  236.00  UN= 400.00
  DAVGRE  Q=  135.00  UN= 400.00
  MUNRBD  Q=  102.00  UN= 400.00
  HYDABD  Q=   45.00  UN= 400.00
  TRICHN  Q=   45.00  UN= 400.00
  SHMOG4  Q=  090.00  UN= 400.00
  SHRVTI  Q=   45.00  UN= 400.00
  GOOTYY  Q=   90.00  UN= 400.00
  SATPR4  Q=   90.60  UN= 400.00
  KORNT4  Q=   45.30  UN= 400.00
  VNDHL4  Q=  159.70  UN= 400.00
  BHLI40  Q=  415.80  UN= 400.00
  JBLPR4  Q=  205.00  UN= 400.00
  ITARS4  Q=  181.20  UN= 400.00
  INDR40  Q=  226.50  UN= 400.00
  KORD4   Q=  320.30  UN= 400.00
  CHNPR4  Q=  280.60  UN= 400.00
  PARL40  Q=  150.00  UN= 400.00
  KARAD4  Q=   50.00  UN= 400.00
  CHNWD4  Q=   90.60  UN= 400.00
  KLWA4   Q=  -50.00  UN= 400.00
  BSWL40  Q=  50.00  UN= 400.00
  UKAI4   Q=   45.30  UN= 400.00
  ASOJ4   Q=  135.90  UN= 400.00
  JETPR4  Q=   45.00  UN= 400.00
  NEY1-G  Q= 100.00   UN= 11.00
END
```

```
LOADS
RMNGD2  P 246.659   Q  55.1927
KALNDI  P 68.96     Q  32.93
VIJWD2  P 383.732   Q  65.6334
GAZVKA  P 110.464   Q  86.0714
NAGJS2  P 397.437   Q -41.6214
TRICH4  P 122.318   Q  40.0019
HUBLII  P 170.840   Q  98.65
CUDAPH  P 57.1499   Q  83.3083
NEYVL1  P 251.9     Q 137.86
BELGUM  P 224.586   Q 109.080
DAVGRE  P  67.9404  Q  10.7775
NEYVL2  P 172.92    Q -21.9557
SALEME  P 118.415   Q  46.1621
MADUR4  P -46.2338  Q -10.9572
UDMPLT  P -76.3952  Q 13.2961
BNGLOR  P 476.305   Q 116.046
MUNRBD  P 94.9931   Q 40.4092
HYDABD  P 219.866   Q 128.971
TRICHN  P 173.574   Q 30.2406
SHMOG4  P 75.4110   Q 14.7217
GOOTYY  P 46.5738   Q 79.7417
SATPR2  P 199.6361  Q 47.64
KORBW2  P 107.467   Q -66.2437
BHLI40  P 322.924   Q 168.279
JBLPR4  P 78.6299   Q 0.937877
ITARS4  P 54.7943   Q 6.69695
INDR40  P 357.065   Q 129.786
BHPL40  P 217.341   Q 41.6994
KHPRKD  P 311.866   Q 19.
KORD22  P 334.207   Q -3.0846
CHNPR2  P 303.617   Q 50.0
KARAD2 NO 1  P 191.85 Q 85.41
KARAD2 NO 2  P -232.402 Q -56.9
KOLPR2 NO 2  P 126. Q -6.4
KOLPR2 NO 1  P  213.52 Q 95.06
CHNWD4  P 361.155   Q 62.3821
KLWA4   P 678.513   Q 7.27344
BLSWR4  P 267.607   Q 69.6942
BSWL40  P 230.177   Q 34.7787
WNKBR2  P 271.236   Q 18.7
UKAI22  P 528.940   Q -6.0
ASOJ4   P 254.725   Q 6.73997
NRDPR4  P 421.725   Q 63.9703
JETPR4  P 247.859   Q 53.8415
SHRVT2  P 543.7     Q -33.0
PARL22  P 380.4988  Q 12.0
KRBAE2  P 515.472   Q 151.0
END
ASYNCHRONOUS MACHINES
  MOT1  MADRAS SN .375 UN 400. H 19.4689
               R1 .008 X1S .0767 X2S .0947
               XM 4.2148 LOAD 1 RTAB 1 TYPE 1A
  MOT2  MADRAS SN .95 UN 400. H 1.7453
               R1 .0052 X1S .0732 X2S .1417
               XM 7.3524 LOAD 2 RTAB 2 TYPE 1A
  MOT3  MADRAS SN .95 UN 400. H 1.7453
               R1 .0052 X1S .0732 X2S .1417
               XM 7.3524 LOAD 2 RTAB 2 TYPE 1A
END
MLOADS
  1 K 1.12 N 2 TYPE 0
  2 K 1.03 N 2 TYPE 0
END
TABLES
  1 TYPE 2  F 0.0  0.0083
              1.0  0.0083
  2 TYPE 2  F 0.0  0.0047
              1.0  0.0047
END
```

```
SYNCHRNOUS MACHINES
BNGL1  BNGLORR  TYPE 4  SN 1000. UN 13.8 RA 0. XD 0.9 XDP 0.23 XQ 0.9 H 2.95
KORD1G KORD2    TYPE 4  SN 500. UN 15.75 RA 0. XD 0.9 XDP 0.23 XQ 0.9 H 2.95
KLWAG  KLWAA    TYPE 4  SN 500. UN 13.8 RA 0. XD 0.9 XDP 0.23 XQ 0.9 H 2.95
KORB1  KORBA3   TYPE 4  SN 282. UN 13.8 RA 0. XD 0.9 XDP 0.23 XQ 0.9 H 2.95
KORAD1 KORD1    TYPE 4  SN 408. UN 14.3 RA 0. XD 0.9 XDP 0.21 XQ 0.9 H 2.95
UKAIGH UKAIHG   TYPE 4  SN 375. UN 11.  RA 0. XD 0.9 XDP 0.32 XQ 0.9 H 2.71
KORBA2 KORBAW   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
SATPRG STPRA1   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
SATPUR STPRA2   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB .078
    VREG 0  XQP 0.506
VINDYA VNDHL2   TYPE 1A SN 988. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
KORB2  KRB_WG   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
KHPRKD KHPRKG   TYPE 1A SN 494. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
CHAND1 CNDRPR   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
PARLIG PARLI2   TYPE 1A SN 494. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
CHAND2 CHNDP3   TYPE 1A SN 741. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
WANOKB WNKBR1   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
WANOK2 WNKBRG   TYPE 1A SN 741. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
UKAI   UKAI3    TYPE 1A SN 470. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
UKAI2  UKAI4G   TYPE 1A SN 247. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
VIJAY  VIJW-G   TYPE 1A SN 741. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
NEVELI NEY2-G   TYPE 1A SN 741. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
RAMGND RMG2-G   TYPE 1A SN 470. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
KORBA4 KRB_2G   TYPE 1A SN 470. UN 15.7 RA 0. XD 2.12 XDP 0.253 XQ 1.85 H 2.8
    D 0. XA 0.165 XDB 0.179 XQB 0.197 TDOP 7. TQOP 0.5 TDOB 0.04 TQOB 0.078
    VREG 0  XQP 0.506
KORBA5 KRB_5G   TYPE 1A SN 1176. UN 21. RA 0. XD 2.35 XDP 0.270 XQ 2.15 H 3.07
    D 0. XA 0.16  XDB 0.190 XQB 0.210 TDOP 8.6 TQOP 2.5 TDOB 0.04 TQOB 0.08
    VREG 0  XQP 0.67
RAMGN1 RMG5-G   TYPE 1A SN 1176. UN 21. RA 0. XD 2.35 XDP 0.270 XQ 2.15 H 3.07
    D 0. XA 0.16  XDB 0.190 XQB 0.210 TDOP 8.6 TQOP 2.5 TDOB 0.04 TQOB 0.08
    VREG 0  XQP 0.506
NEVEL  NEY1-G   TYPE 1A SN 352. UN 11.0 RA 0. XD 1.95  XDP 0.263 XQ 1.95 H 2.74
    D 0. XA 0.110  XDB 0.183 XQB 0.183 TDOP 6.50 TQOP 0.63 TDOB 0.04 TQOB 0.076

    VREG 0  XQP 0.750
NAGARJ NAGS-G   TYPE 2A SN 945. UN 11.0 RA 0. XD 0.9 XDP 0.23 XQ 0.59 H 4.0
    D 0. XA 0.089 XDB 0.185 XQB 0.185 TDOP 8.90 TDOB 0.04 TQOB 0.08 VREG 1
SHARVT SHRT-G   TYPE 2A SN 890. UN 11.0 RA 0. XD 0.9 XDP 0.27 XQ 0.59 H 3.8
    D 0. XA 0.09 XDB 0.185 XQB 0.185 TDOP 8.9 TDOB 0.03 TQOB 0.04 VREG 1
KALIND KLND-G   TYPE 2A SN 600. UN 11. RA 0. XD 0.91 XDP 0.24 XQ 0.54 H 4.4
    D 0. XA 0.09 XDB 0.145 XQB 0.145 TDOP 8.9 TDOB 0.03 TQOB 0.03 VREG 1
END
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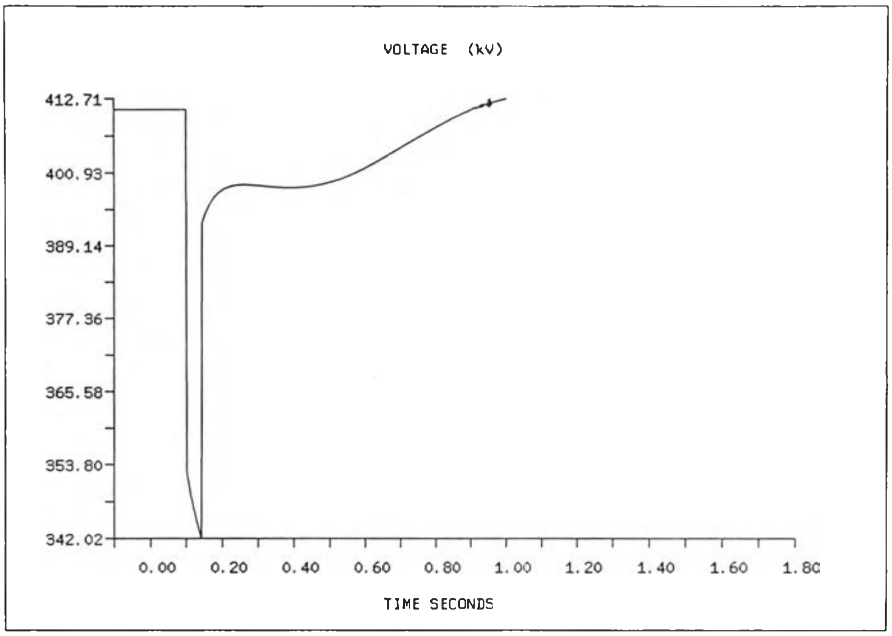


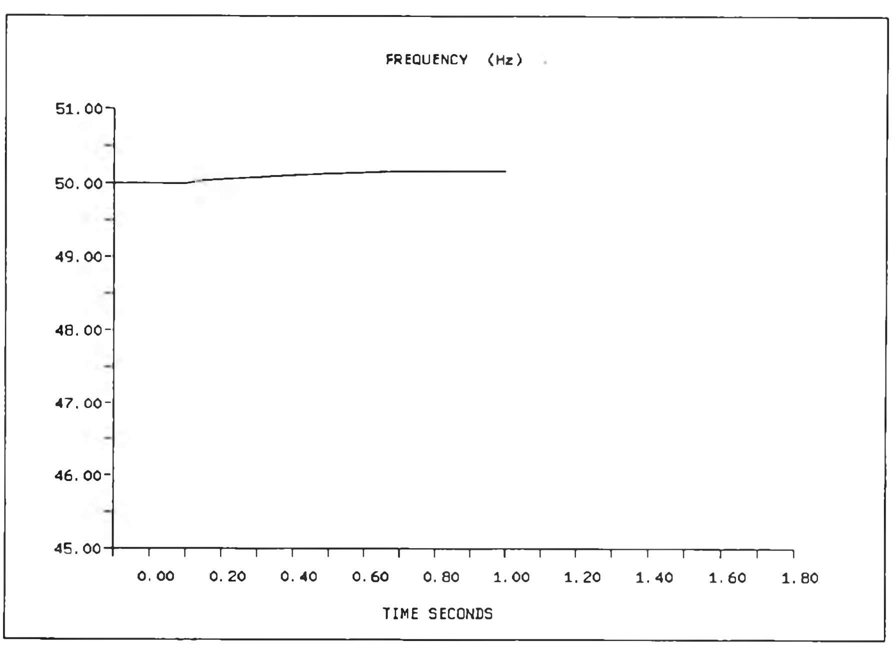
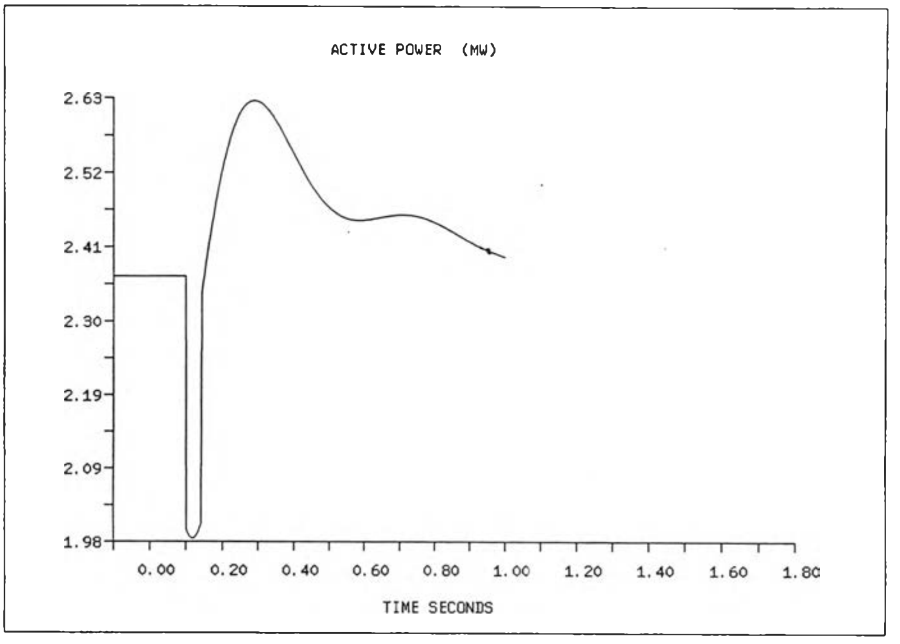


Fig. A6.2 Voltage and frequency at bus MADRAS when three phase fault occured at bus CHNPR4 a.



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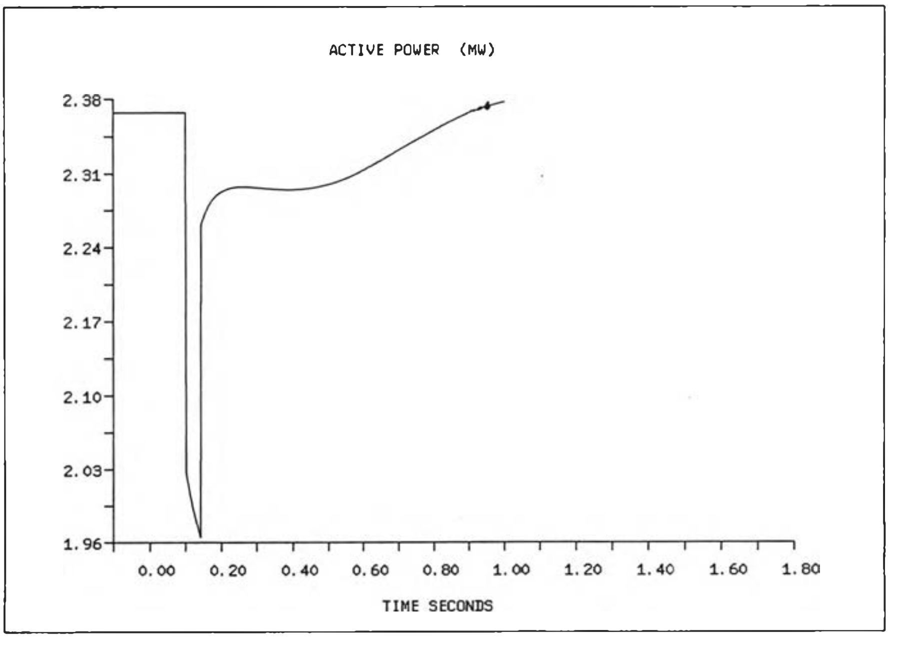
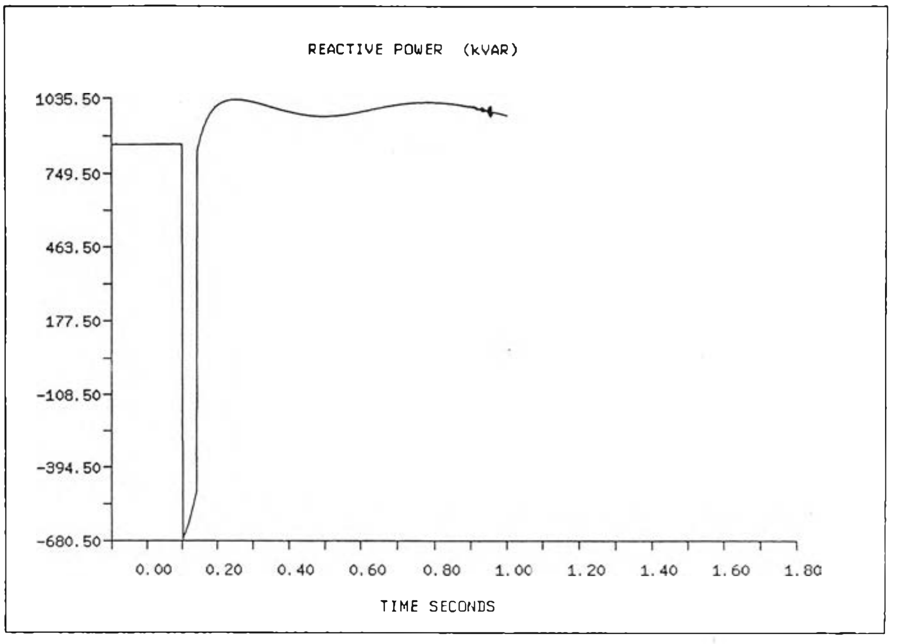


Fig. A6.3 Active power of motor loads at bus MADRAS

a. aggregate induction motor model

b. constant current model

a.



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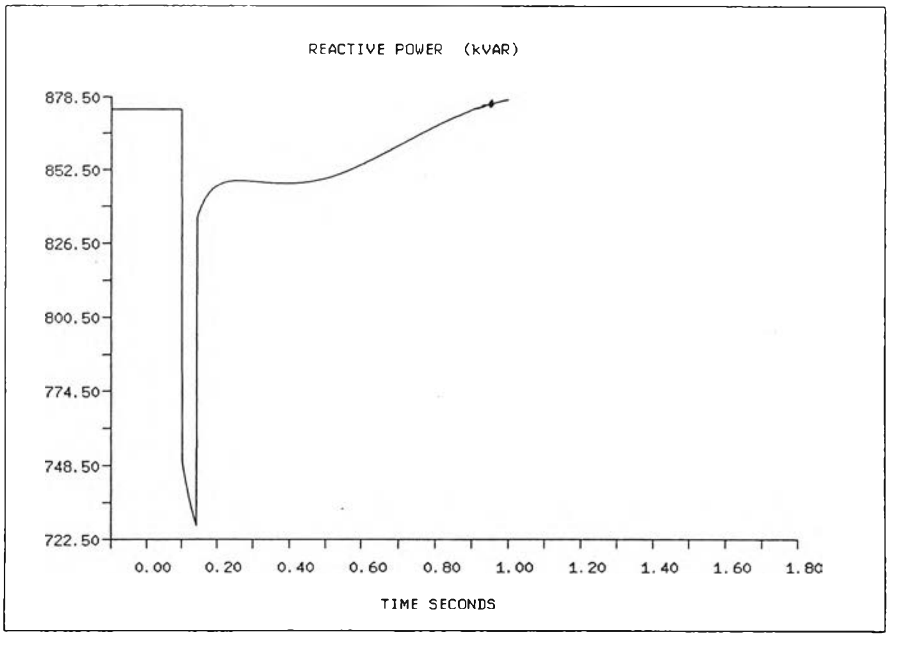

Fig. A6.4 Reactive power of motor loads at bus MADRAS

a. aggregate induction motor model

b. constant current model

Compare the simulation results obtained from the two models, large difference can be observed. This is because constant current model neglects the dynamic nature of motor loads while induction motor model includes.

VITA

The author, Mr. Somnuk Chayapornkul was born in Bangkok, Thailand on February 21, 1965. He received a Bachelor of Engineering degree in Electrical Engineering from Chulalongkorn University in 1986.