Lecture on

Simulation Cases

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Organization of the talk

Introduction

Simulation Environment

Case Studies

Relaying quantity behaviour

P R D C®
विज्ञानेन जातानि जीवन्ति

Fault occurs	SLG fault occurs in un-grounded system	Generator trips
• Voltage dips • Current increases • Reactive power feed increases • Speed increases • Rotor angle increases, • Impedance decreases.	• Healthy phase voltage increases • Capacitive current will flow at fault location.	• Frequency falls • Voltage dips

Relaying quantity behaviour

Line trips	Load trips	Motor starting
• Voltage dips, • overloading of other lines	• Frequency increases • Voltage may increase	• Voltage dips, • Current increases, • Reactive power increases

Relaying quantity behaviour

Transformer energization

- Inrush current
- 2nd harmonic predominant.

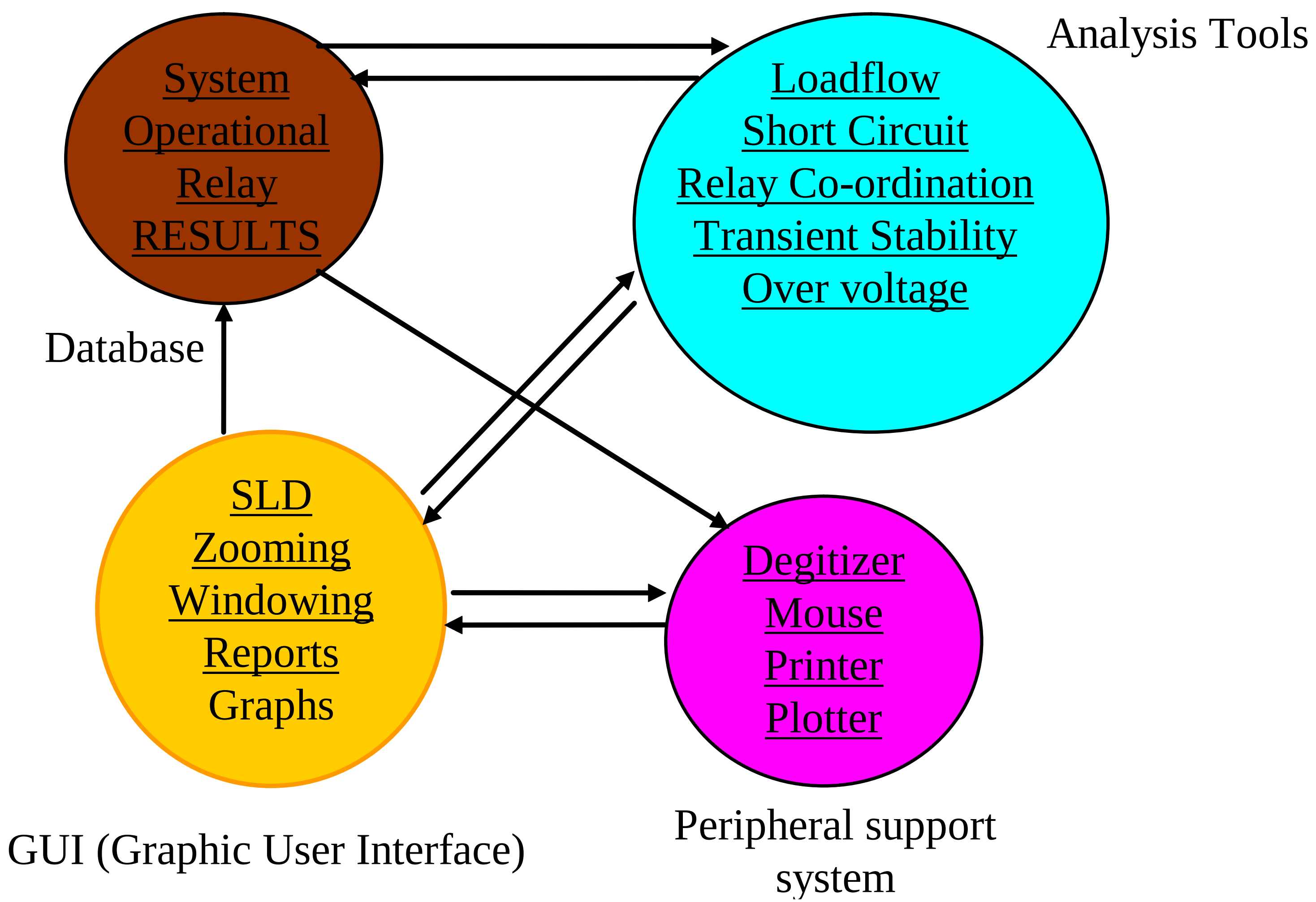
Loss of field

- Machine draws reactive power from grid
- Active power output reduces.

Capacitor energization

- Over voltage,
- Inrush current.

Computer aided protection co-ordination



Duration spectra of Main effects

Electrical Switching Transients **Over Voltages** **Fault Transients**	**Electrical machine & System Dynamics**	**System Governing & load Controls**	**Prime mover energy supply system dynamics**	**Energy resource dynamics**
μs/ms	Few seconds	Seconds to minutes	Several minutes	Days to weeks

Transient Phenomena

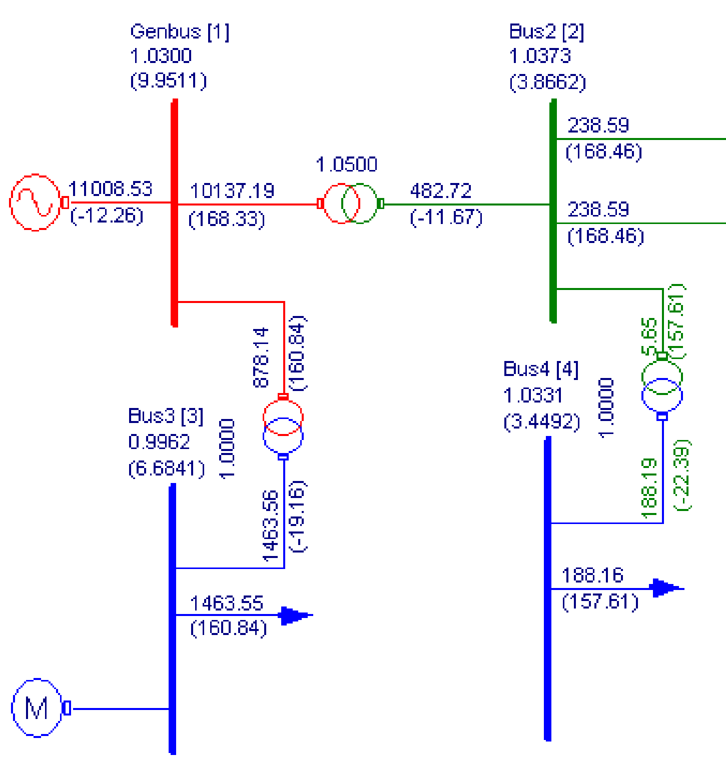
- **Scale** ⇒
  - **μs** → **Initial transient, Recovery Voltage**
  - **ms** → **Switching surges, Fault transients**
  - **Several cycles** → **Ferro - resonance**

- **Surge period**
- **Dynamic period**
- **Steady State period**

Simulation Cases

Why Load flow study for protection engineer?

MiGUI - A Power System Network Editor - [psti_12]



Power flow to know

1. **Normal load current**
2. **Worst contingency load current**

Plug setting based on this information

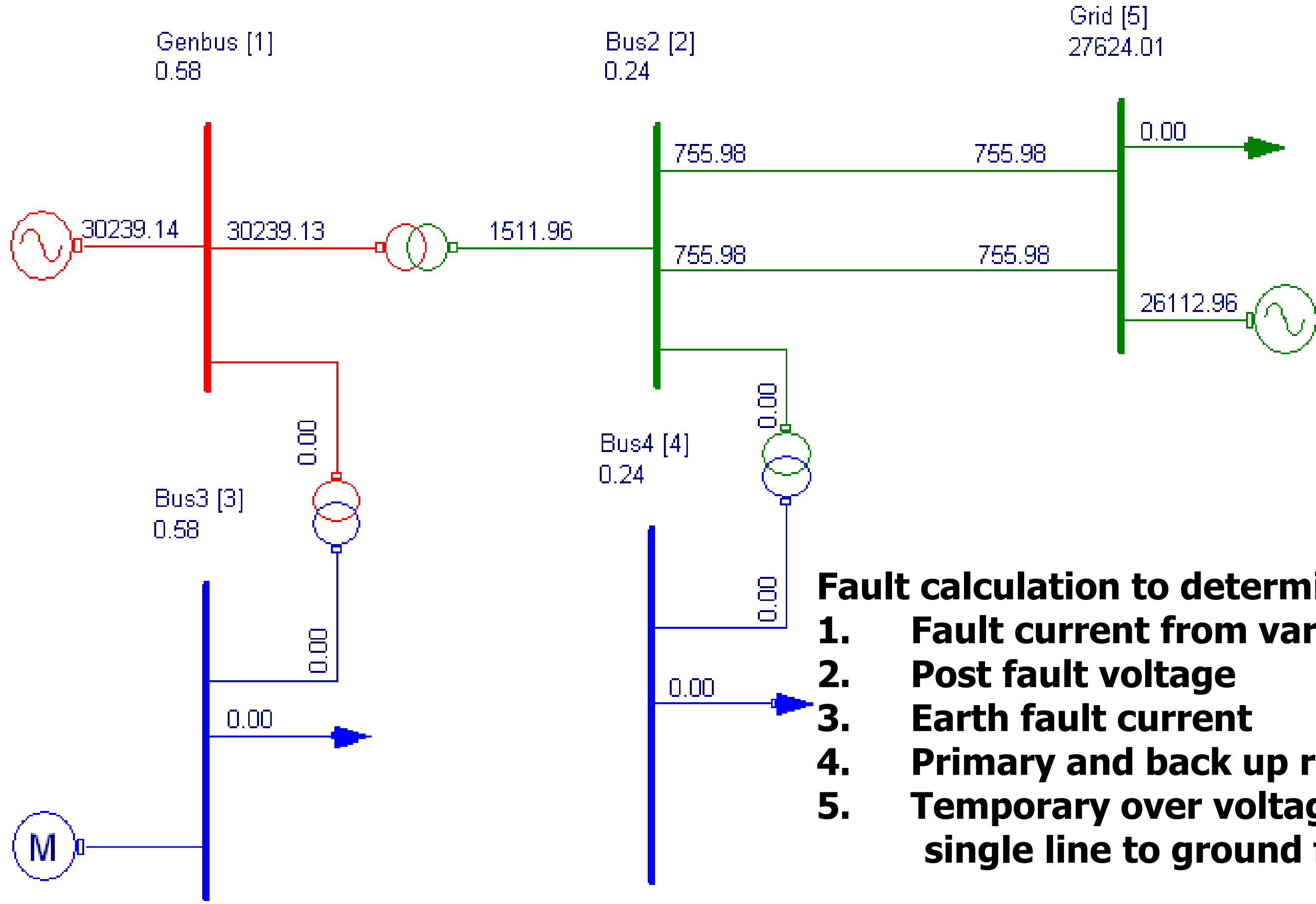
1. **Steady state maximum voltage**
2. **Steady state minimum voltage**

Voltage relay setting based on this info.

Contingency : 0 | Schedule : 0 | Reference X <0>,Y <0> Dist: 796.414 Km

Ready

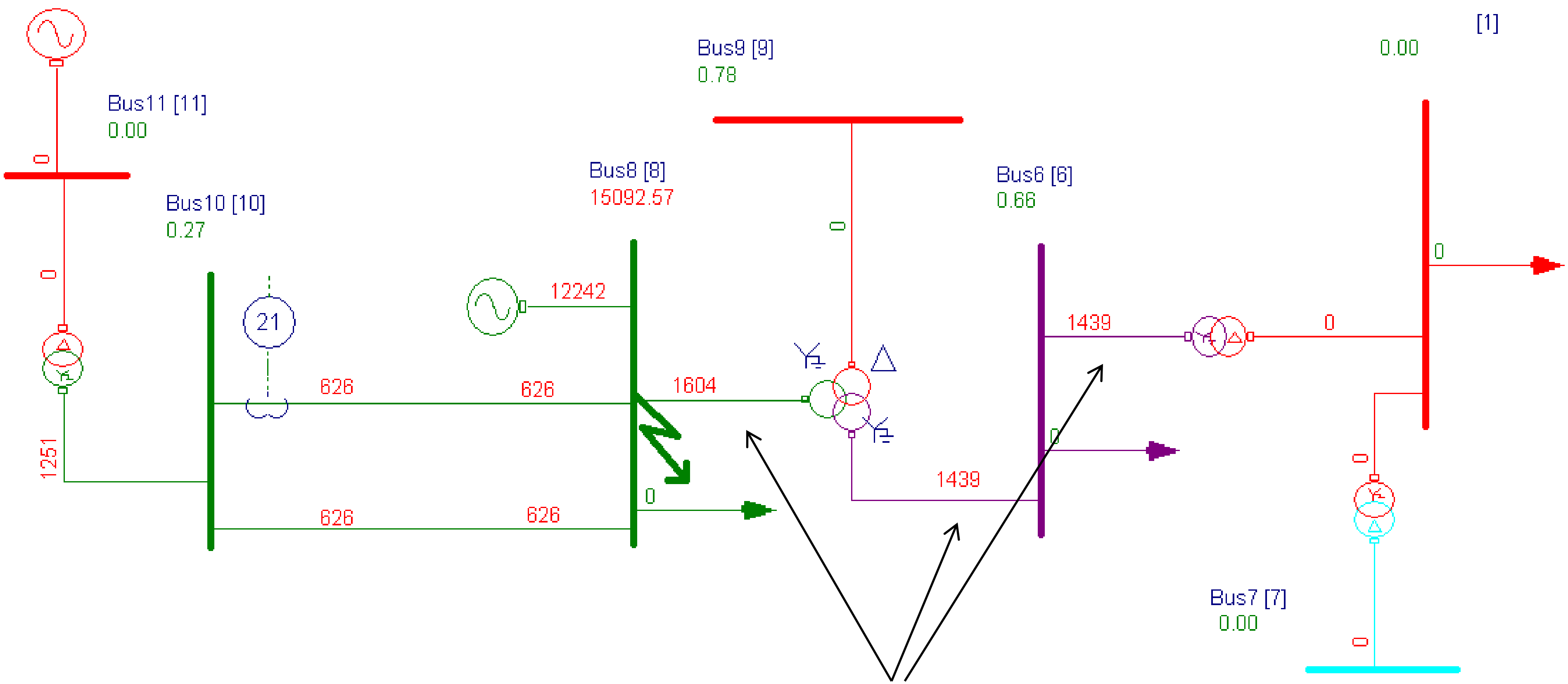
Fault simulation to aid protection engineer



Fault calculation to determine

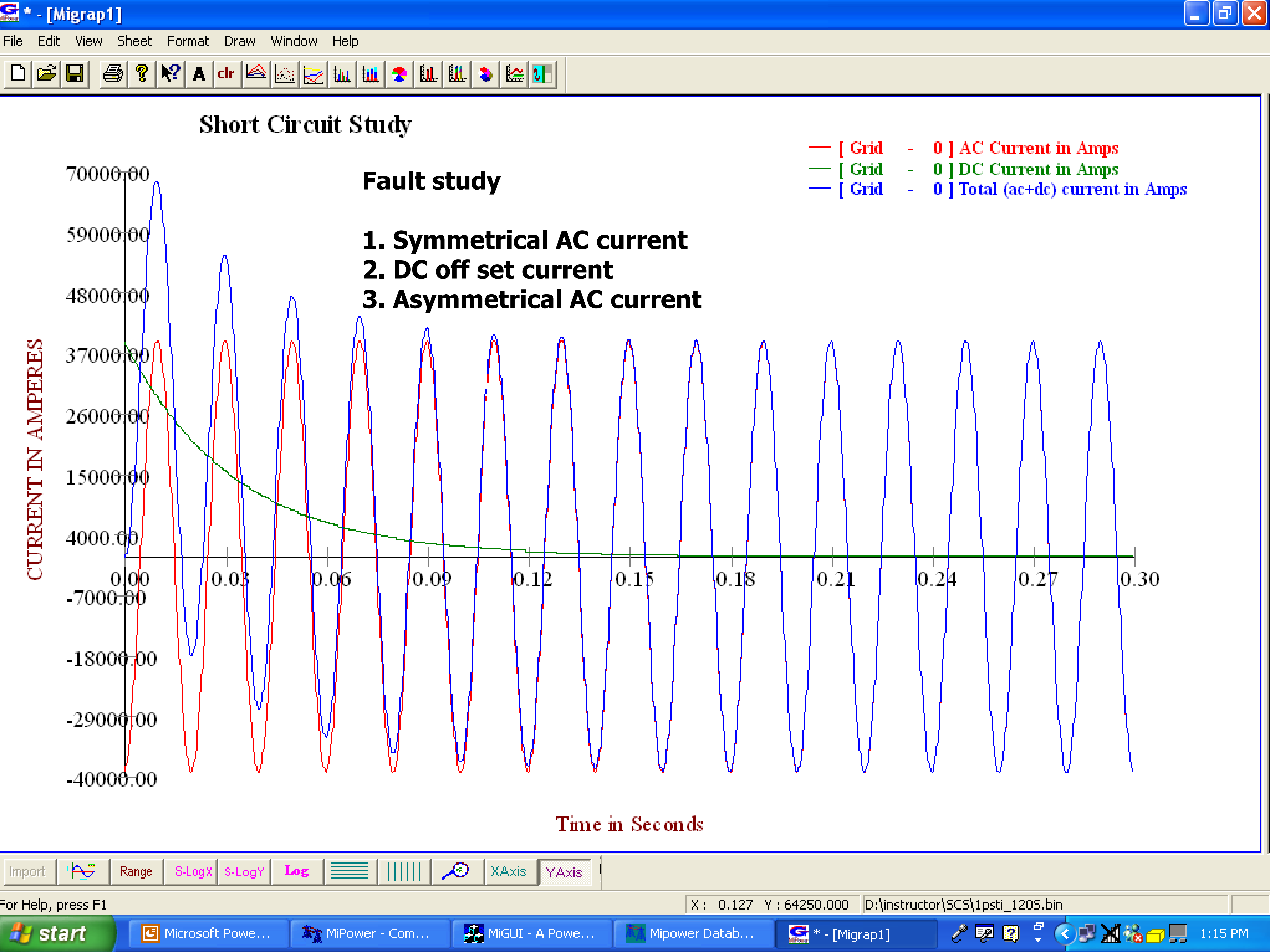
1. **Fault current from various sources**
2. **Post fault voltage**
3. **Earth fault current**
4. **Primary and back up relay current**
5. **Temporary over voltage (during single line to ground fault)**

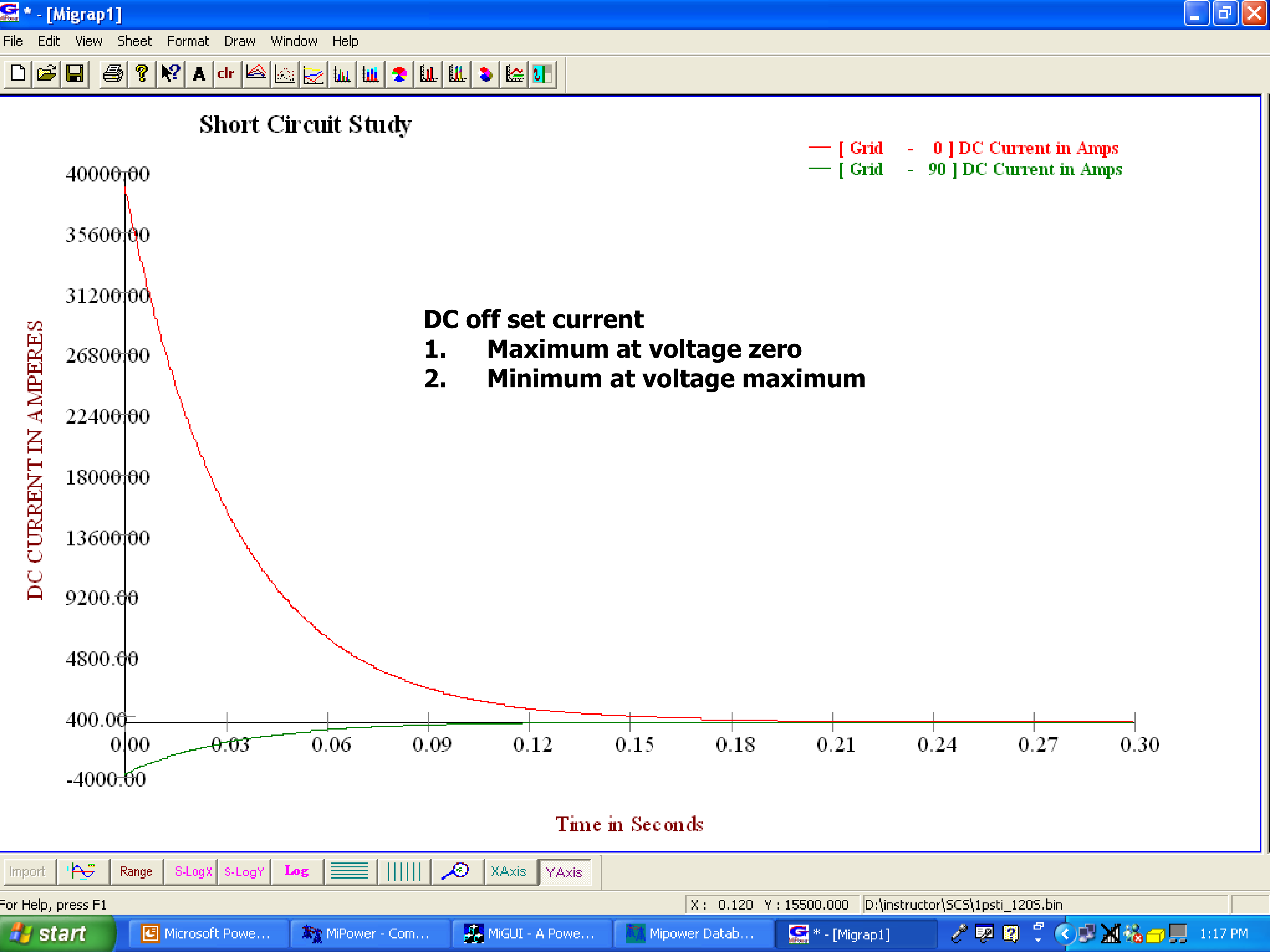
Earth fault relay operation - Explained



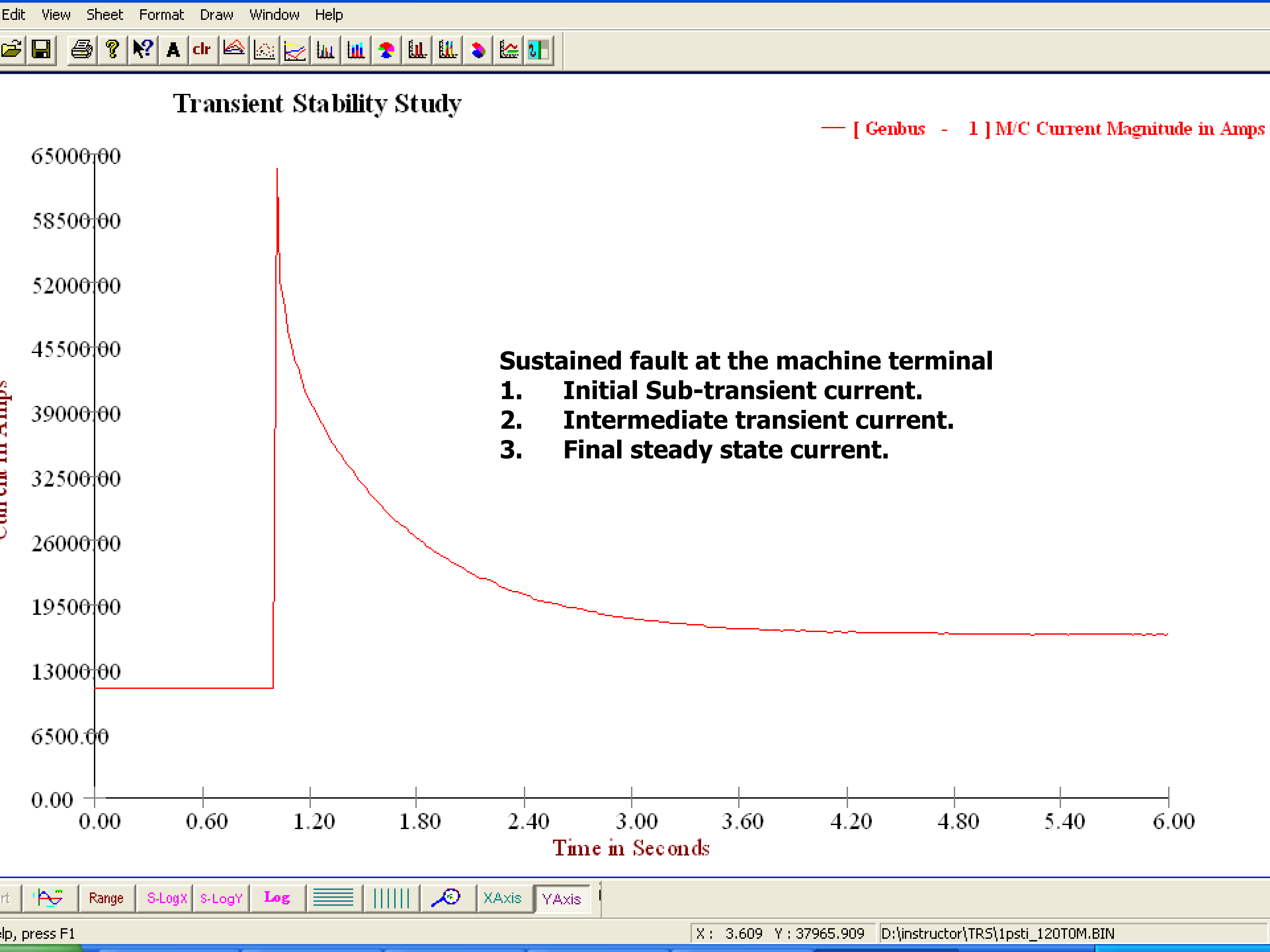
No source in this part of the network

Earth fault relay picks up, because of transformer Vector group


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Short Circuit Study
Fault study
1. Symmetrical AC current
2. DC off set current
3. Asymmetrical AC current
[Grid - 0] AC Current in Amps
[Grid - 0] DC Current in Amps
[Grid - 0] Total (ac+dc) current in Amps
70000.00
59000.00
48000.00
37000.00
26000.00
15000.00
4000.00
-7000.00
-18000.00
-29000.00
-40000.00
CURRENT IN AMPERES
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.30
Time in Seconds
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 0.127 Y : 64250.000
D:\instructor\SCS\1psti_120S.bin
start
Microsoft Powe...
MiPower - Com...
MiGUI - A Powe...
Mipower Datab...
* - [Migrap1]
1:15 PM

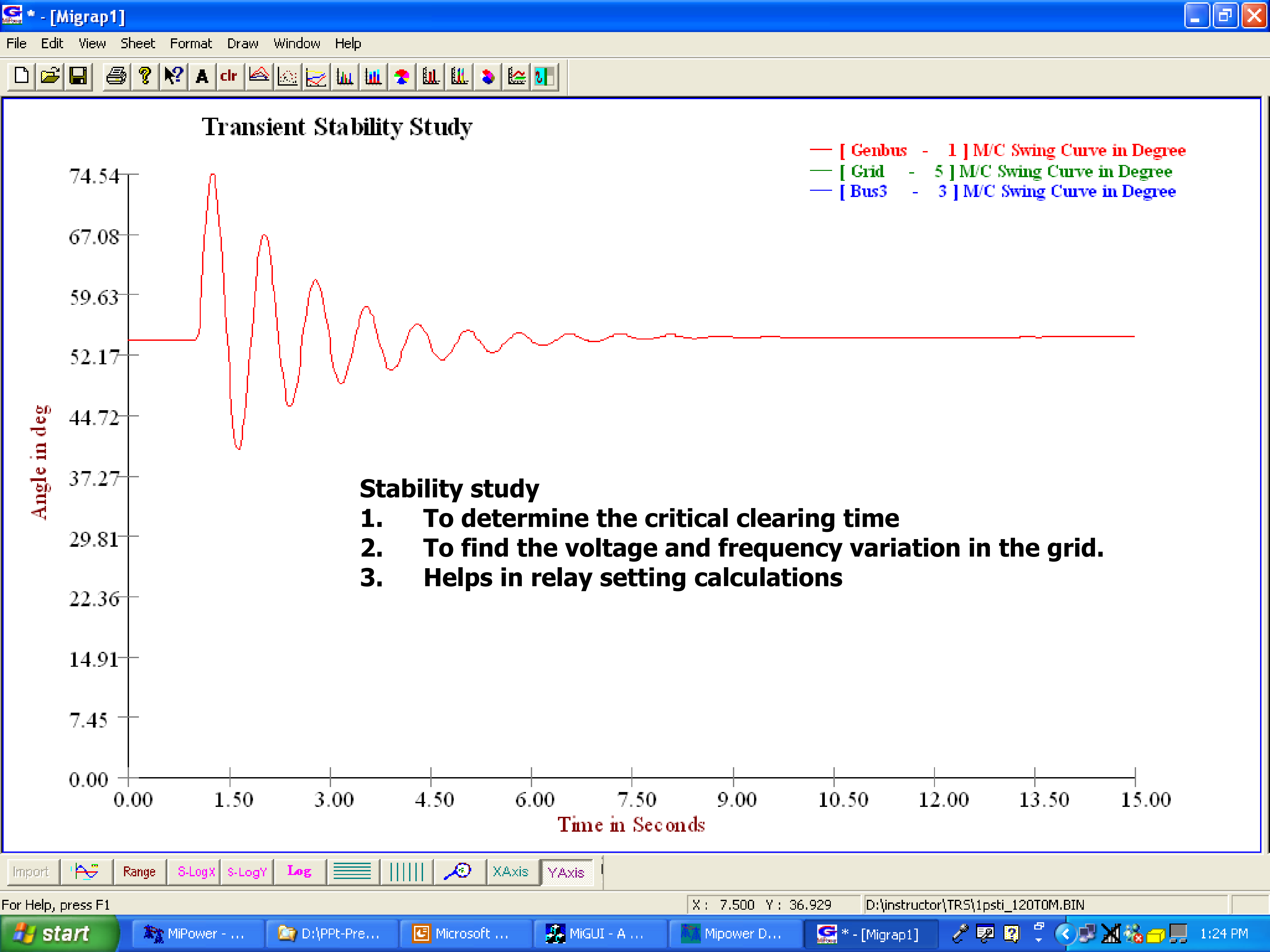

* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Short Circuit Study
— [Grid - 0] DC Current in Amps
— [Grid - 90] DC Current in Amps
DC off set current
1. Maximum at voltage zero
2. Minimum at voltage maximum
DC CURRENT IN AMPERES
40000.00
35600.00
31200.00
26800.00
22400.00
18000.00
13600.00
9200.00
4800.00
400.00
-4000.00
0.00
0.03
0.06
0.09
0.12
0.15
0.18
0.21
0.24
0.27
0.30
Time in Seconds
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 0.120 Y : 15500.000
D:\instructor\SCS\1psti_120S.bin
start
Microsoft Powe...
MiPower - Com...
MiGUI - A Powe...
Mipower Datab...
* - [Migrap1]
1:17 PM

What machine impedance to consider for fault study and relay-coordination?



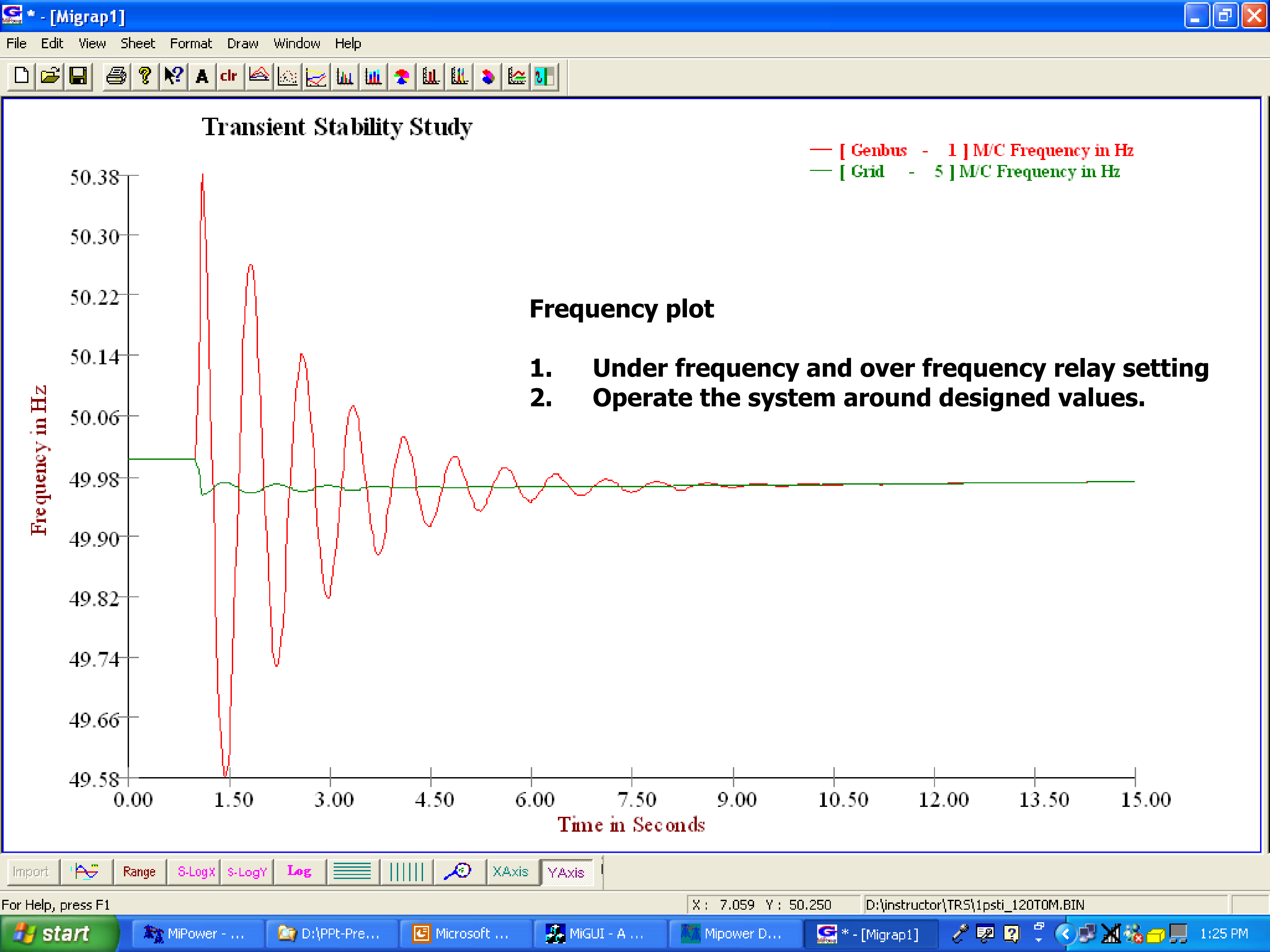
Edit View Sheet Format Draw Window Help
Transient Stability Study
[Genbus - 1] M/C Current Magnitude in Amps
65000.00
58500.00
52000.00
45500.00
39000.00
32500.00
26000.00
19500.00
13000.00
6500.00
0.00
0.00 0.60 1.20 1.80 2.40 3.00 3.60 4.20 4.80 5.40 6.00
Time in Seconds
Sustained fault at the machine terminal
1. Initial Sub-transient current.
2. Intermediate transient current.
3. Final steady state current.
Range S-LogX S-LogY Log XAxis YAxis
lp, press F1
X : 3.609 Y : 37965.909
D:\instructor\TRS\1psti_120T0M.BIN

Stability study simulation and its importance



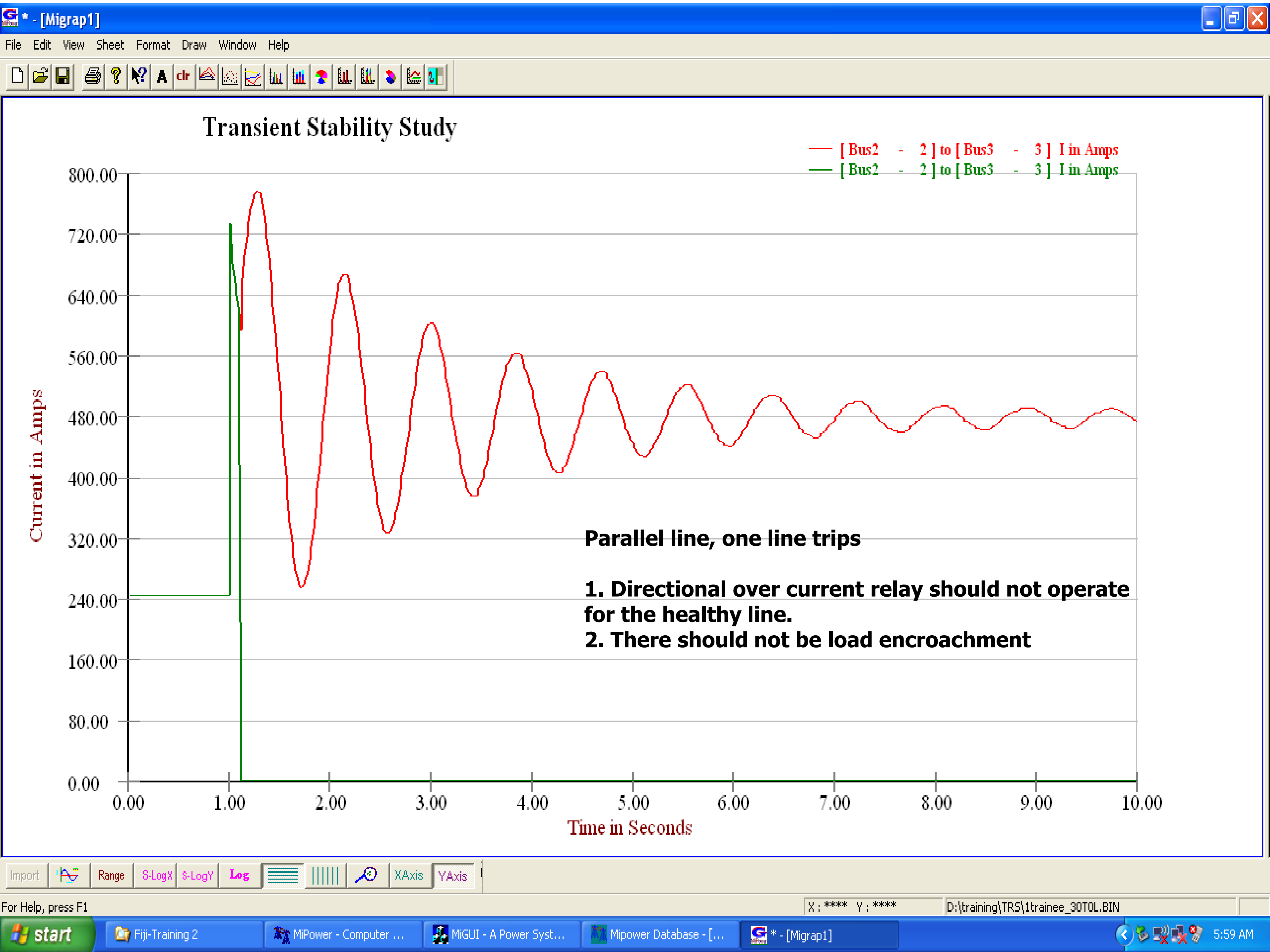
Stability study

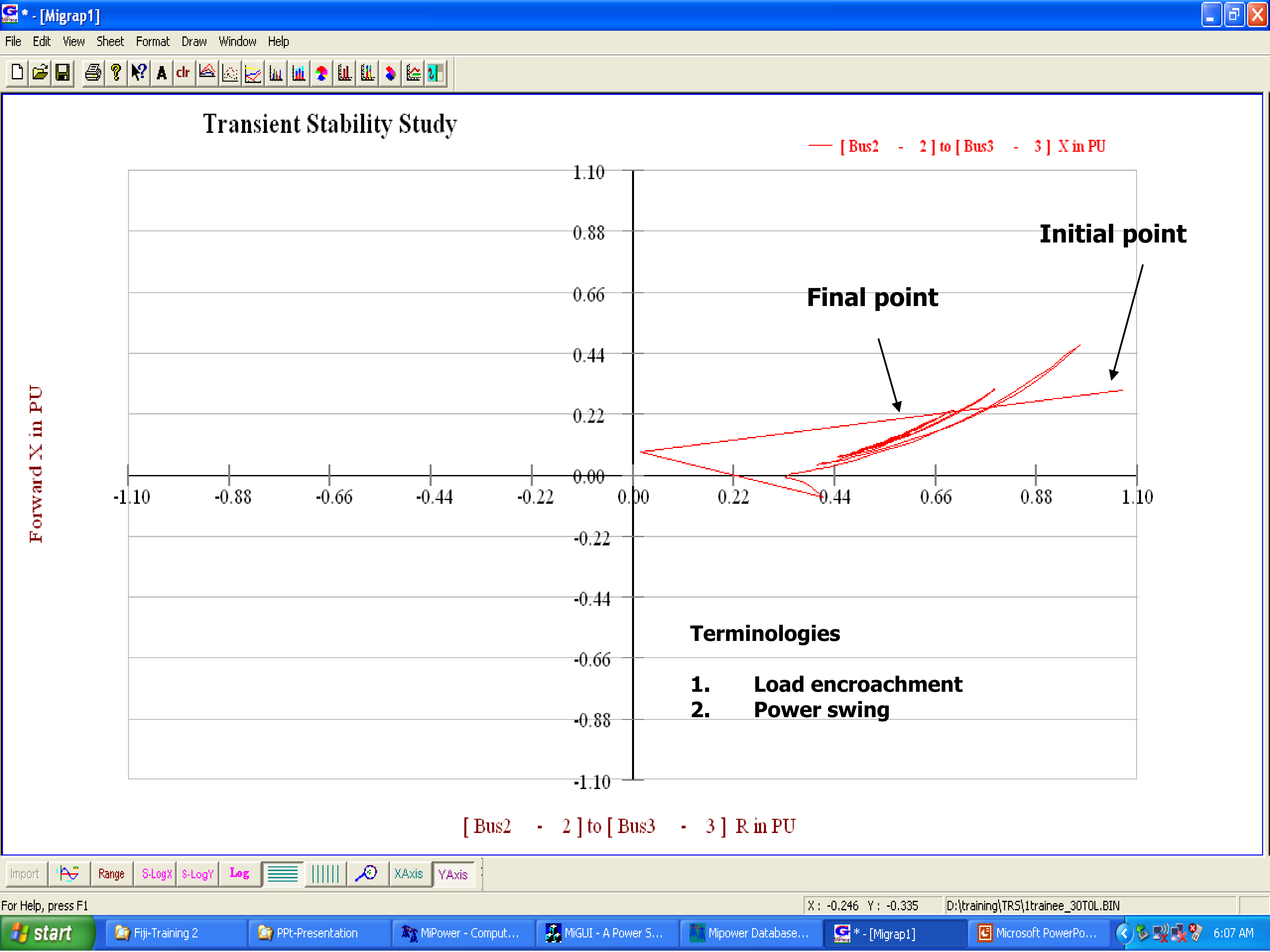
1. **To determine the critical clearing time**
2. **To find the voltage and frequency variation in the grid.**
3. **Helps in relay setting calculations**



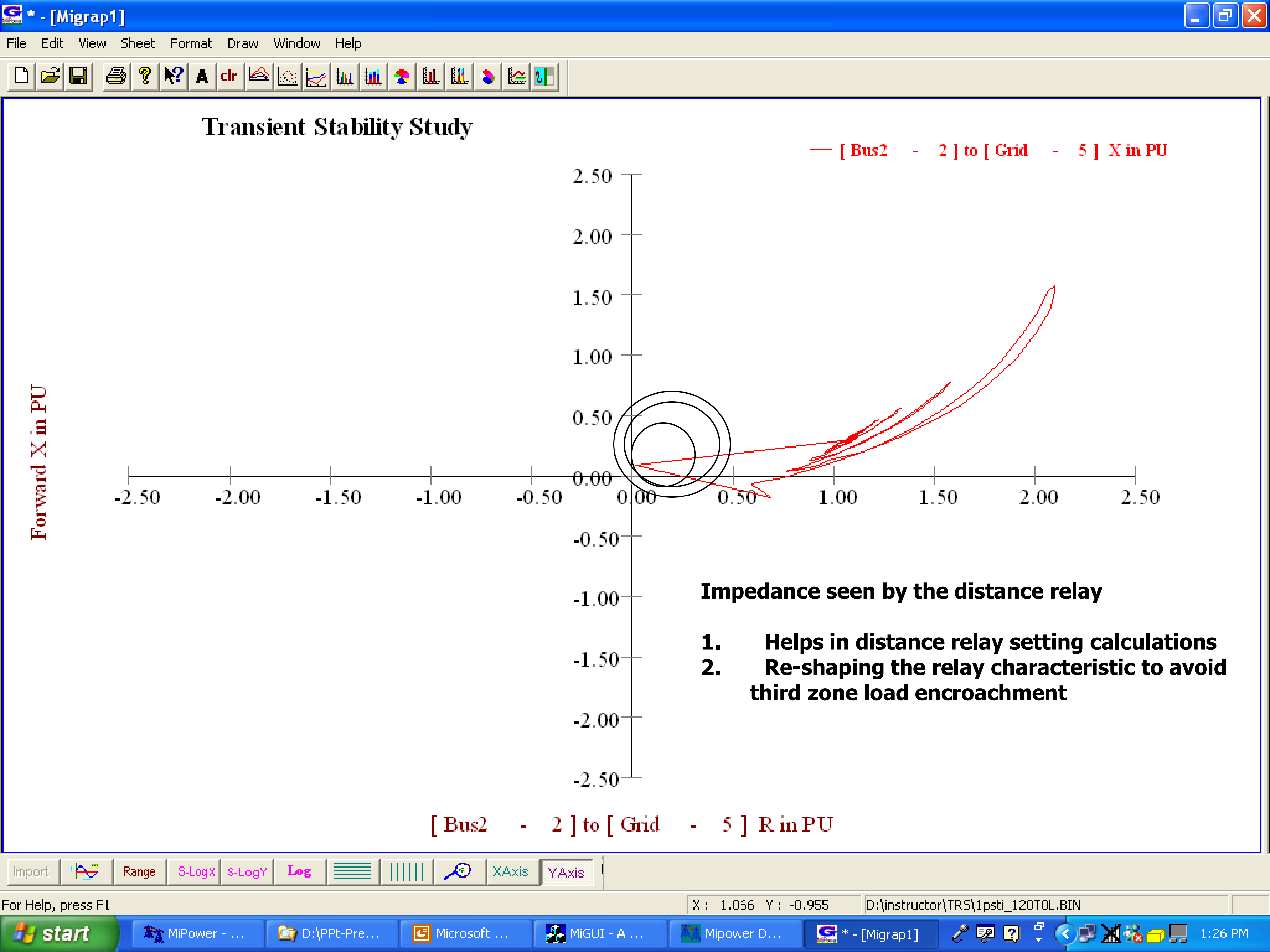
Frequency plot

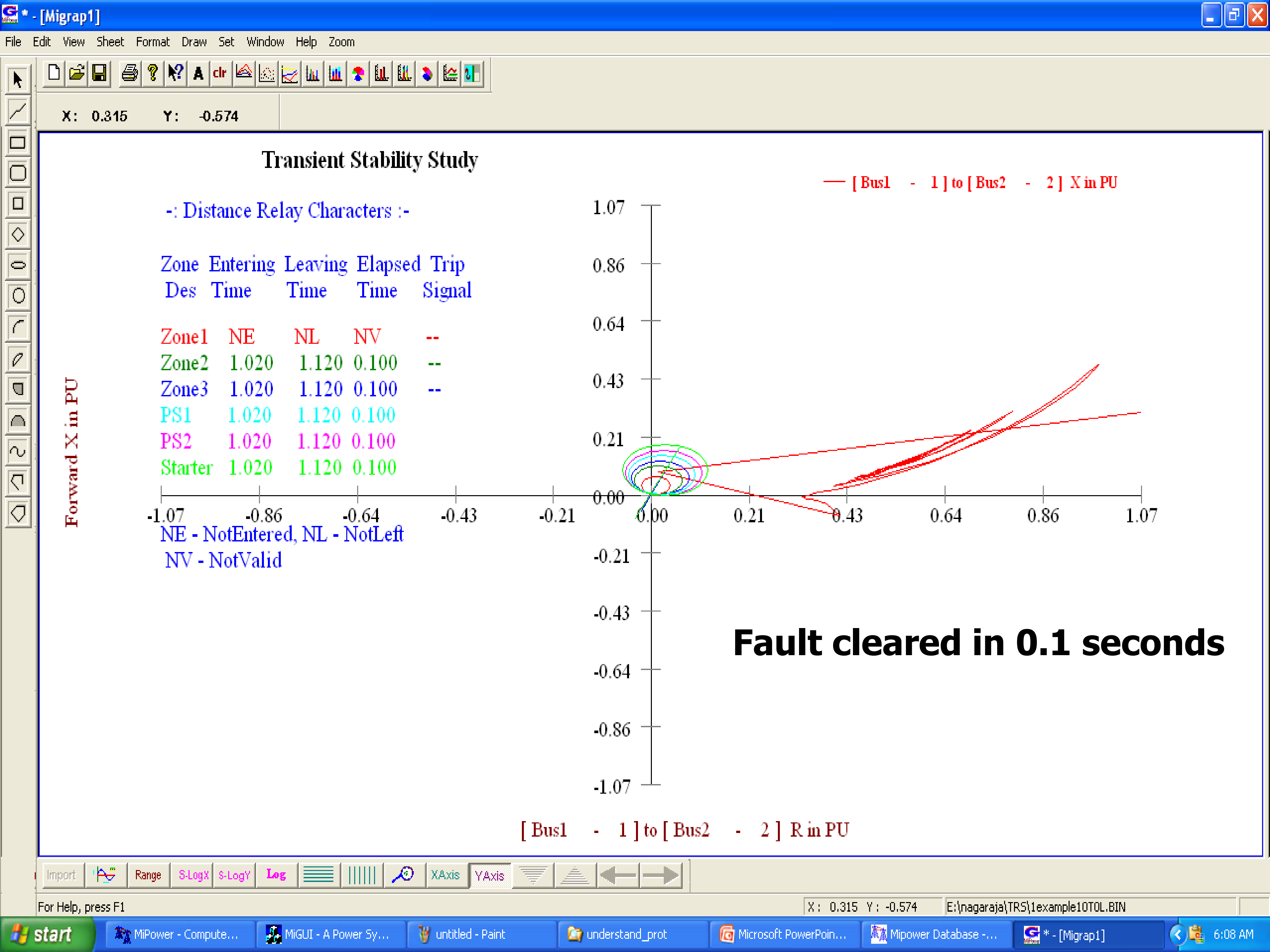
1. Under frequency and over frequency relay setting
2. Operate the system around designed values.


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Transient Stability Study
[Bus2 - 2] to [Bus3 - 3] I in Amps
[Bus2 - 2] to [Bus3 - 3] I in Amps
Current in Amps
800.00
720.00
640.00
560.00
480.00
400.00
320.00
240.00
160.00
80.00
0.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Time in Seconds
Parallel line, one line trips
1. Directional over current relay should not operate for the healthy line.
2. There should not be load encroachment
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : **** Y : ****
D:\training\TRS\1trainee_30TOL.BIN
start
Fiji-Training 2
MiPower - Computer ...
MiGUI - A Power Syst...
Mipower Database - [...
* - [Migrap1]
5:59 AM

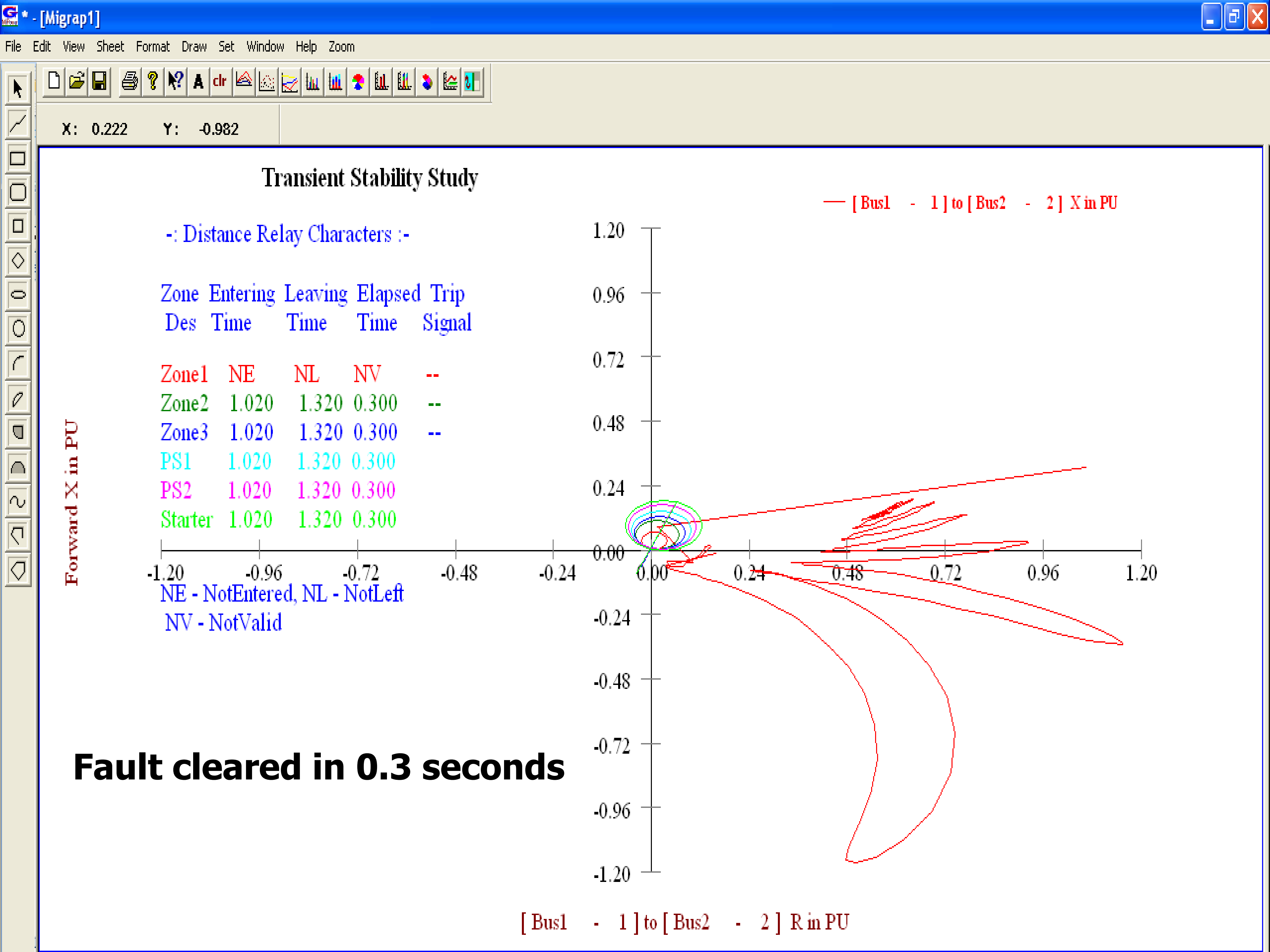


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Transient Stability Study
[Bus2 - 2] to [Bus3 - 3] X in PU
Initial point
Final point
Forward X in PU
1.10
0.88
0.66
0.44
0.22
0.00
-0.22
-0.44
-0.66
-0.88
-1.10
-1.10 -0.88 -0.66 -0.44 -0.22 0.00 0.22 0.44 0.66 0.88 1.10
Terminologies
1. Load encroachment
2. Power swing
[Bus2 - 2] to [Bus3 - 3] R in PU
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X : -0.246 Y : -0.335
D:\training\TRS\1trainee_30TOL.BIN
start Fiji-Training 2 PPt-Presentation MiPower - Comput... MiGUI - A Power S... Mipower Database... * - [Migrap1] Microsoft PowerPo... 6:07 AM

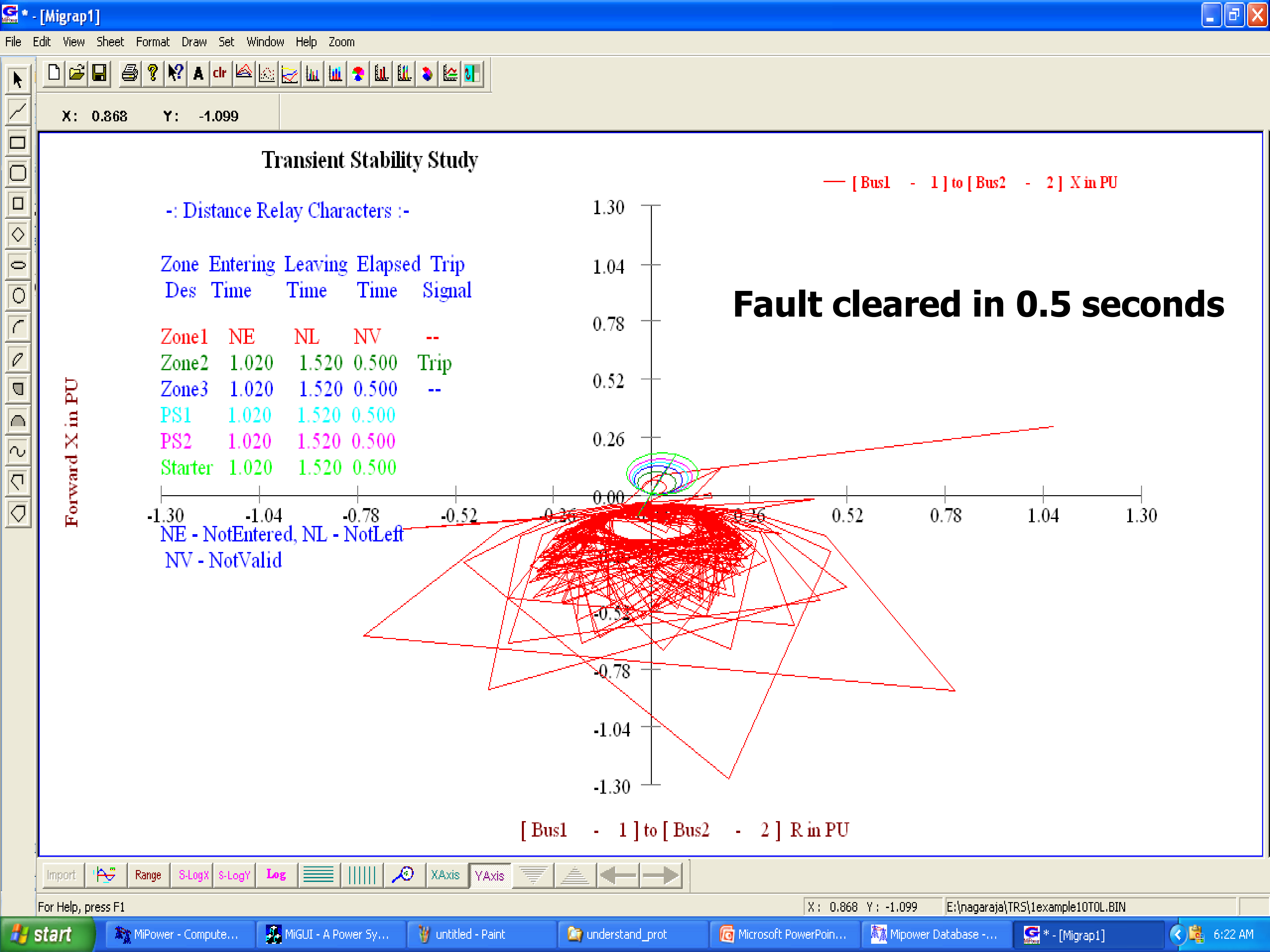

* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Transient Stability Study
[Bus2 - 2] to [Grid - 5] X in PU
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-2.50 -2.00 -1.50 -1.00 -0.50 0.00 0.50 1.00 1.50 2.00 2.50
Forward X in PU
[Bus2 - 2] to [Grid - 5] R in PU
Impedance seen by the distance relay
1. Helps in distance relay setting calculations
2. Re-shaping the relay characteristic to avoid third zone load encroachment
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 1.066 Y : -0.955
D:\instructor\TRS\1psti_120TOL.BIN
start
MiPower - ...
D:\PPt-Pre...
Microsoft ...
MiGUI - A ...
Mipower D...
* - [Migrap1]
1:26 PM



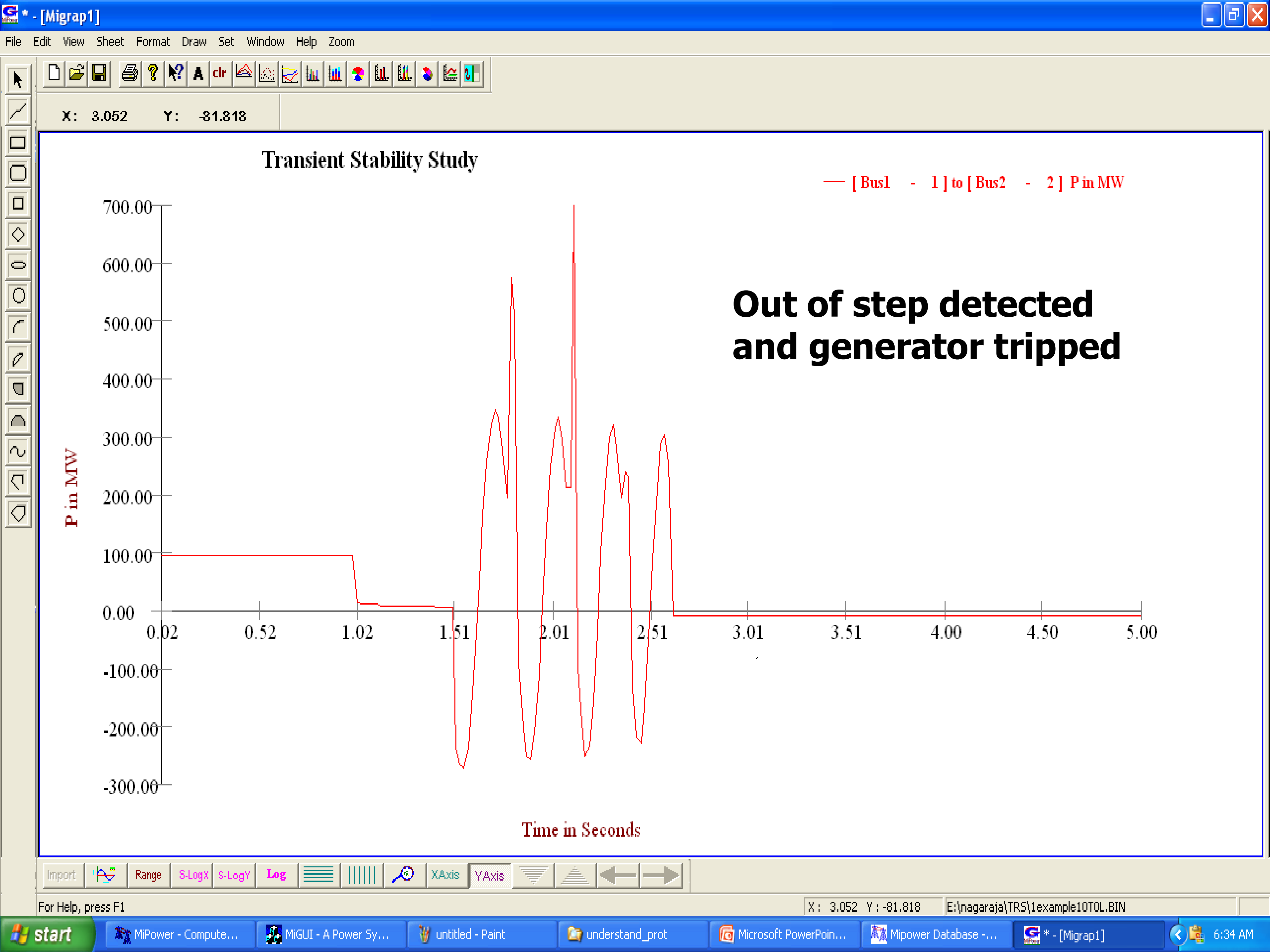
* - [Migrap1]
File Edit View Sheet Format Draw Set Window Help Zoom
X: 0.315 Y: -0.574
Transient Stability Study
-: Distance Relay Characters :-
Zone Des | Entering Time | Leaving Time | Elapsed Time | Trip Signal
Zone1 NE NL NV --
Zone2 1.020 1.120 0.100 --
Zone3 1.020 1.120 0.100 --
PS1 1.020 1.120 0.100
PS2 1.020 1.120 0.100
Starter 1.020 1.120 0.100
NE - NotEntered, NL - NotLeft
NV - NotValid
[Bus1 - 1] to [Bus2 - 2] X in PU
Forward X in PU
[Bus1 - 1] to [Bus2 - 2] R in PU
Fault cleared in 0.1 seconds
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X: 0.315 Y: -0.574
E:\nagaraja\TRS\1example10TOL.BIN
start
MiPower - Compute...
MiGUI - A Power Sy...
untitled - Paint
understand_prot
Microsoft PowerPoin...
Mipower Database -...
* - [Migrap1]
6:08 AM



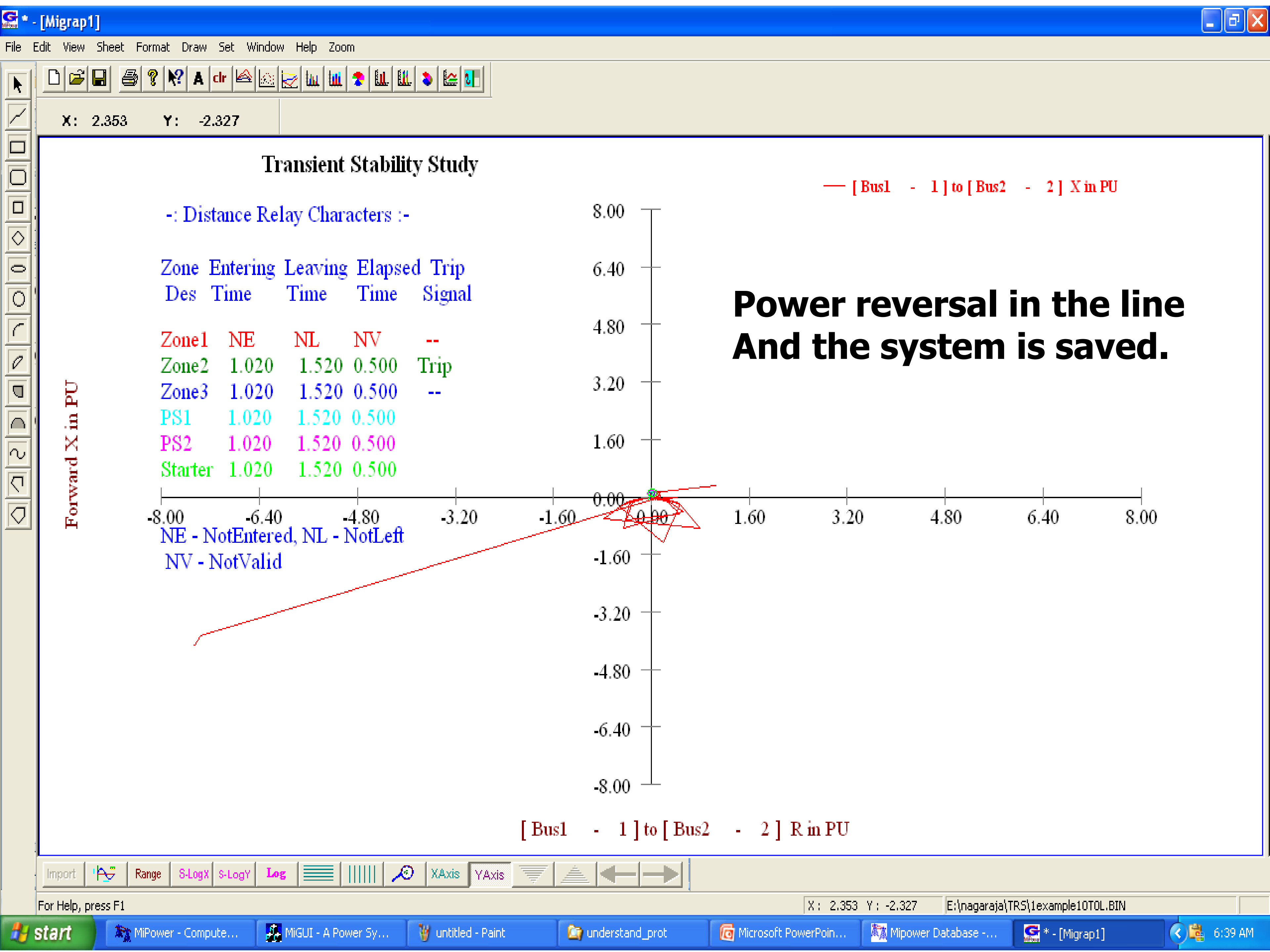
Fault cleared in 0.3 seconds



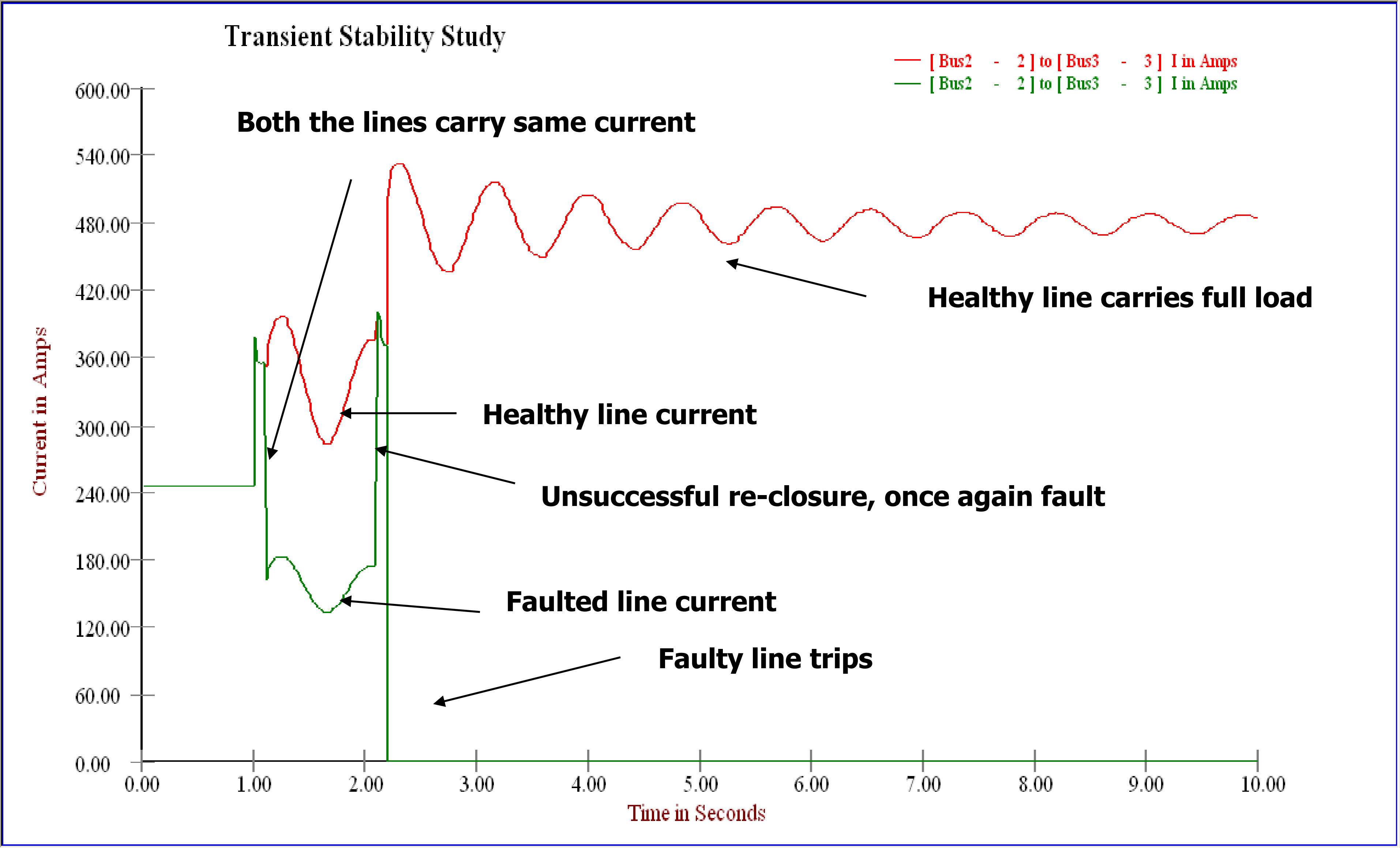
* - [Migrap1]
File Edit View Sheet Format Draw Set Window Help Zoom
X: 0.868 Y: -1.099
Transient Stability Study
-: Distance Relay Characters :-
Zone Des | Entering Time | Leaving Time | Elapsed Time | Trip Signal
Zone1 NE NL NV --
Zone2 1.020 1.520 0.500 Trip
Zone3 1.020 1.520 0.500 --
PS1 1.020 1.520 0.500
PS2 1.020 1.520 0.500
Starter 1.020 1.520 0.500
NE - NotEntered, NL - NotLeft
NV - NotValid
[Bus1 - 1] to [Bus2 - 2] X in PU
Fault cleared in 0.5 seconds
Forward X in PU
[Bus1 - 1] to [Bus2 - 2] R in PU
1.30
1.04
0.78
0.52
0.26
0.00
-0.78
-1.04
-1.30
-1.30 -1.04 -0.78 -0.52 0.52 0.78 1.04 1.30
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X: 0.868 Y: -1.099
E:\nagaraja\TRS\1example10TOL.BIN
start
MiPower - Compute...
MiGUI - A Power Sy...
untitled - Paint
understand_prot
Microsoft PowerPoin...
Mipower Database -...
* - [Migrap1]
6:22 AM

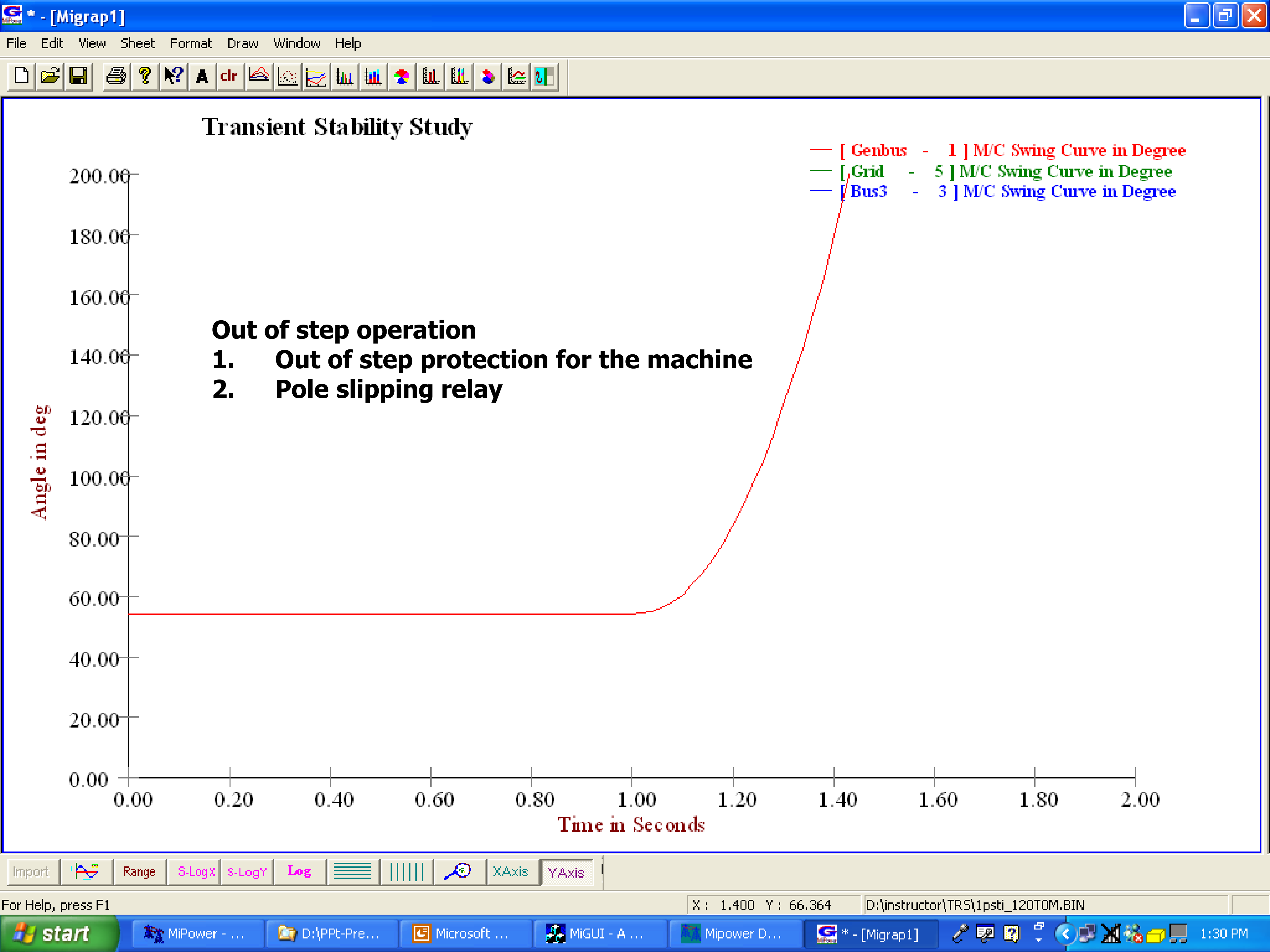


* - [Migrap1]
File Edit View Sheet Format Draw Set Window Help Zoom
X: 3.052 Y: -81.818
Transient Stability Study
[Bus1 - 1] to [Bus2 - 2] P in MW
Out of step detected and generator tripped
P in MW
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
-100.00
-200.00
-300.00
0.02
0.52
1.02
1.51
2.01
2.51
3.01
3.51
4.00
4.50
5.00
Time in Seconds
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X: 3.052 Y: -81.818
E:\nagaraja\TRS\1example10TOL.BIN
start
MiPower - Compute...
MiGUI - A Power Sy...
untitled - Paint
understand_prot
Microsoft PowerPoin...
Mipower Database -...
* - [Migrap1]
6:34 AM

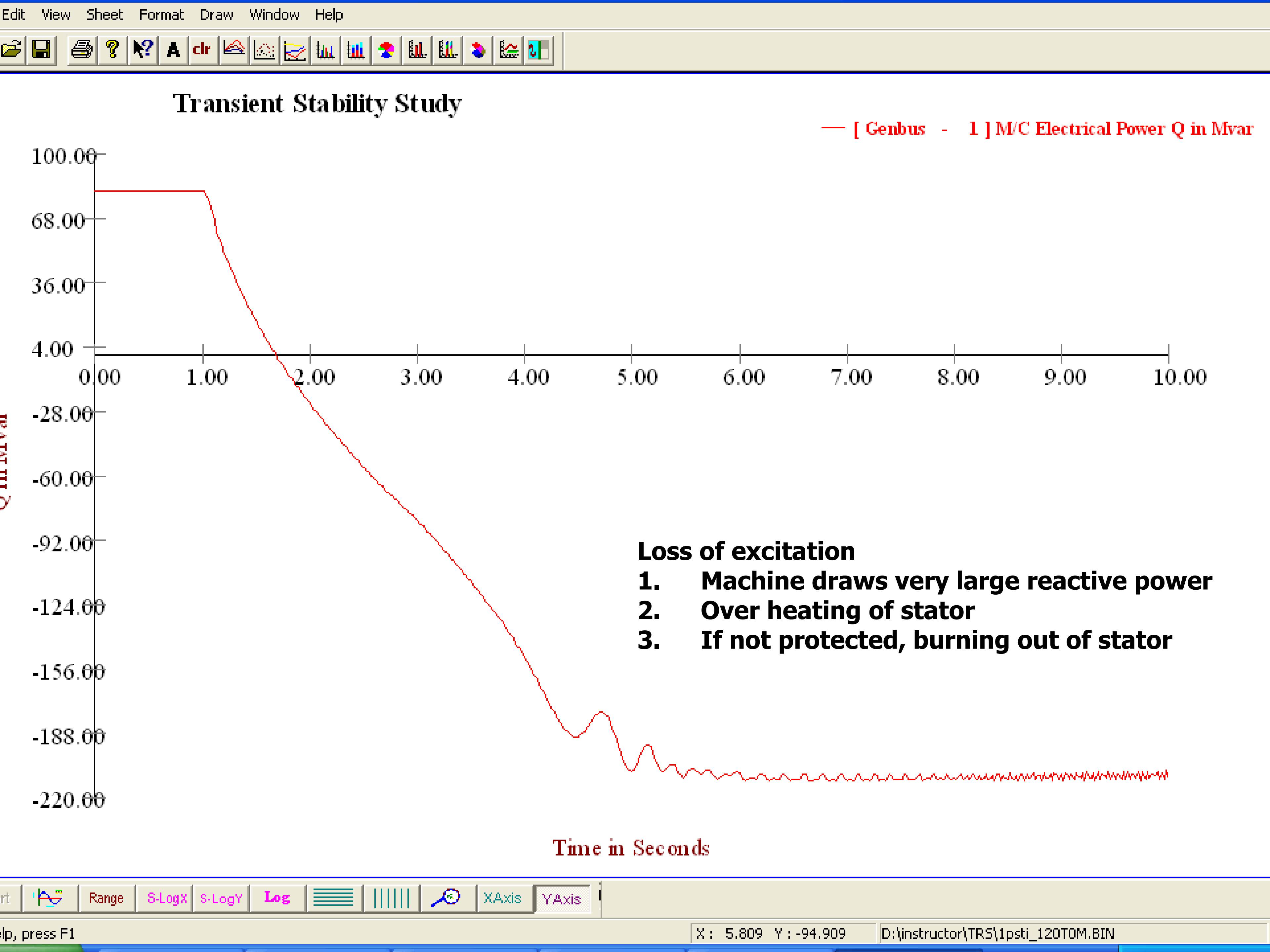

* - [Migrap1]
File Edit View Sheet Format Draw Set Window Help Zoom
X: 2.353 Y: -2.327
Transient Stability Study
[Bus1 - 1] to [Bus2 - 2] X in PU
-: Distance Relay Characters :-
Zone Entering Leaving Elapsed Trip
Des Time Time Time Signal
Zone1 NE NL NV --
Zone2 1.020 1.520 0.500 Trip
Zone3 1.020 1.520 0.500 --
PS1 1.020 1.520 0.500
PS2 1.020 1.520 0.500
Starter 1.020 1.520 0.500
NE - NotEntered, NL - NotLeft
NV - NotValid
Power reversal in the line
And the system is saved.
Forward X in PU
8.00
6.40
4.80
3.20
1.60
0.00
-1.60
-3.20
-4.80
-6.40
-8.00
-8.00 -6.40 -4.80 -3.20 -1.60 0.00 1.60 3.20 4.80 6.40 8.00
[Bus1 - 1] to [Bus2 - 2] R in PU
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X: 2.353 Y: -2.327
E:\nagaraja\TRS\1example10TOL.BIN
start
MiPower - Compute...
MiGUI - A Power Sy...
untitled - Paint
understand_prot
Microsoft PowerPoin...
Mipower Database -...
* - [Migrap1]
6:39 AM

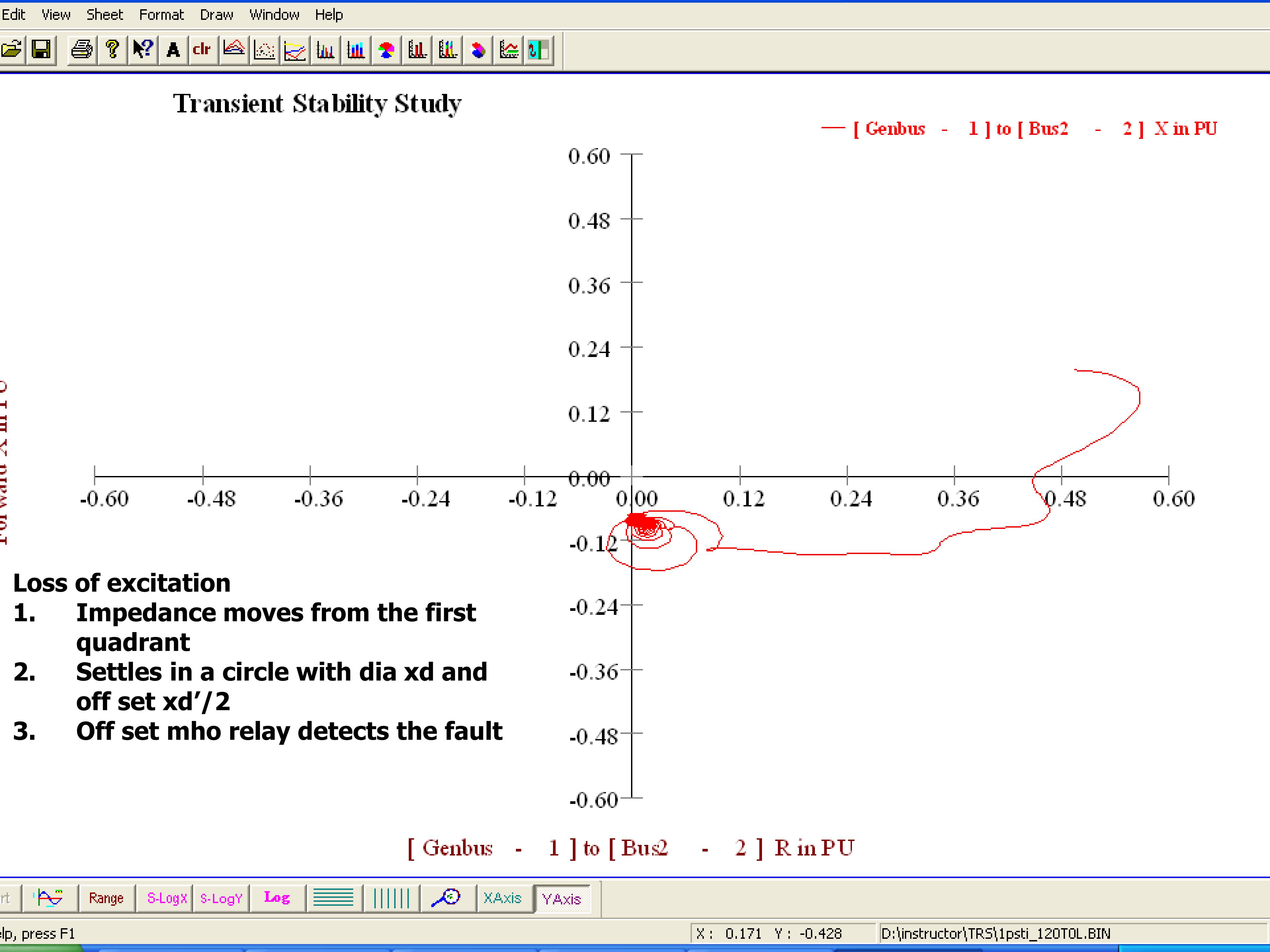
Understanding single pole auto re-closing facility




* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Transient Stability Study
[Genbus - 1] M/C Swing Curve in Degree
[Grid - 5] M/C Swing Curve in Degree
[Bus3 - 3] M/C Swing Curve in Degree
Out of step operation
1. Out of step protection for the machine
2. Pole slipping relay
Angle in deg
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40 1.60 1.80 2.00
Time in Seconds
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X : 1.400 Y : 66.364
D:\instructor\TRS\1psti_120TOM.BIN
start
MiPower - ...
D:\PPt-Pre...
Microsoft ...
MiGUI - A ...
Mipower D...
* - [Migrap1]
1:30 PM

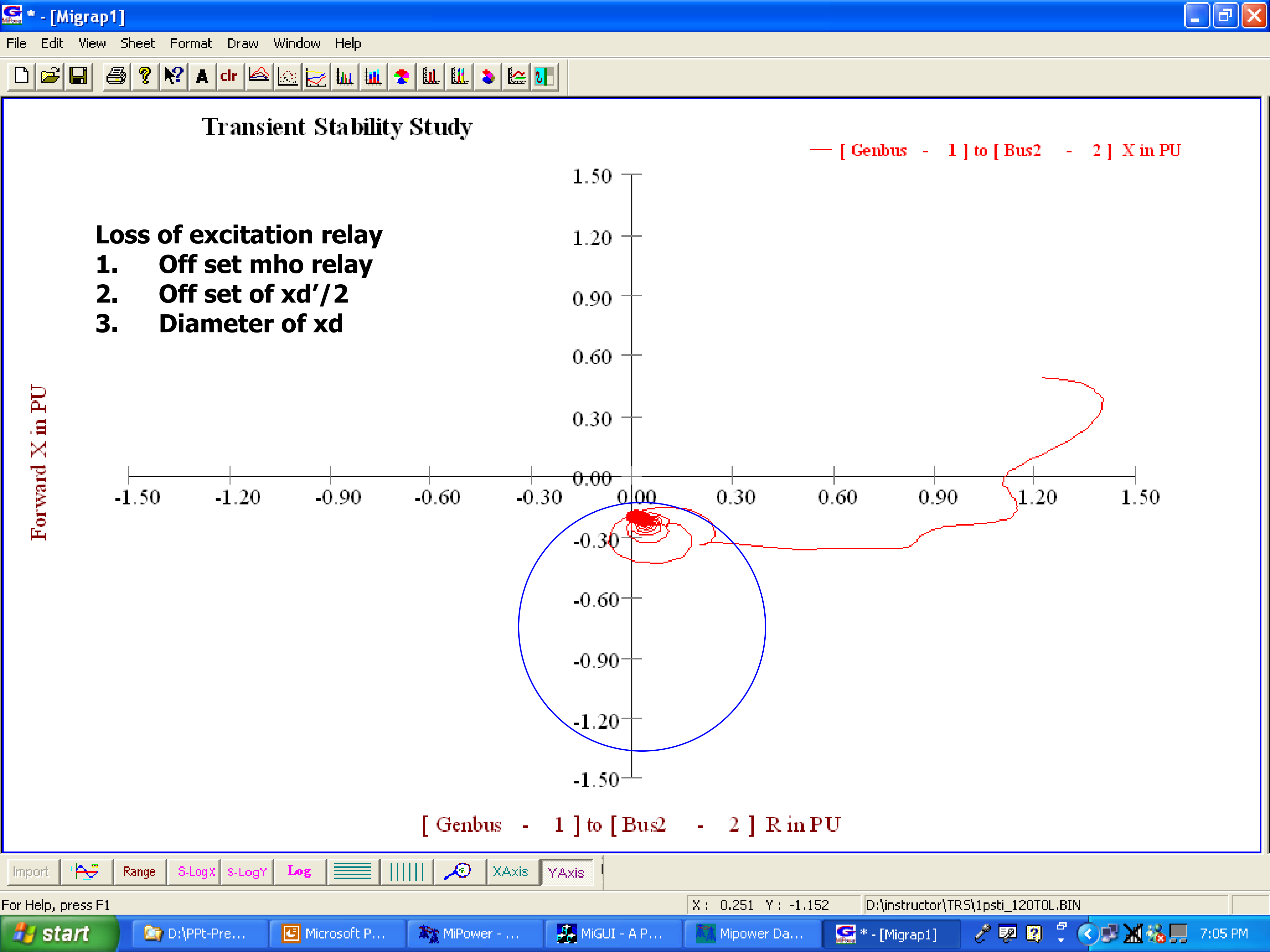
Protection Engineer designs the relay, based on system behaviour


Edit View Sheet Format Draw Window Help
Transient Stability Study
[Genbus - 1] M/C Electrical Power Q in Mvar
100.00
68.00
36.00
4.00
-28.00
-60.00
-92.00
-124.00
-156.00
-188.00
-220.00
0.00
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
9.00
10.00
Loss of excitation
1. Machine draws very large reactive power
2. Over heating of stator
3. If not protected, burning out of stator
Time in Seconds
Range
S-LogX
S-LogY
Log
XAxis
YAxis
X : 5.809 Y : -94.909
D:\instructor\TRS\1psti_120T0M.BIN

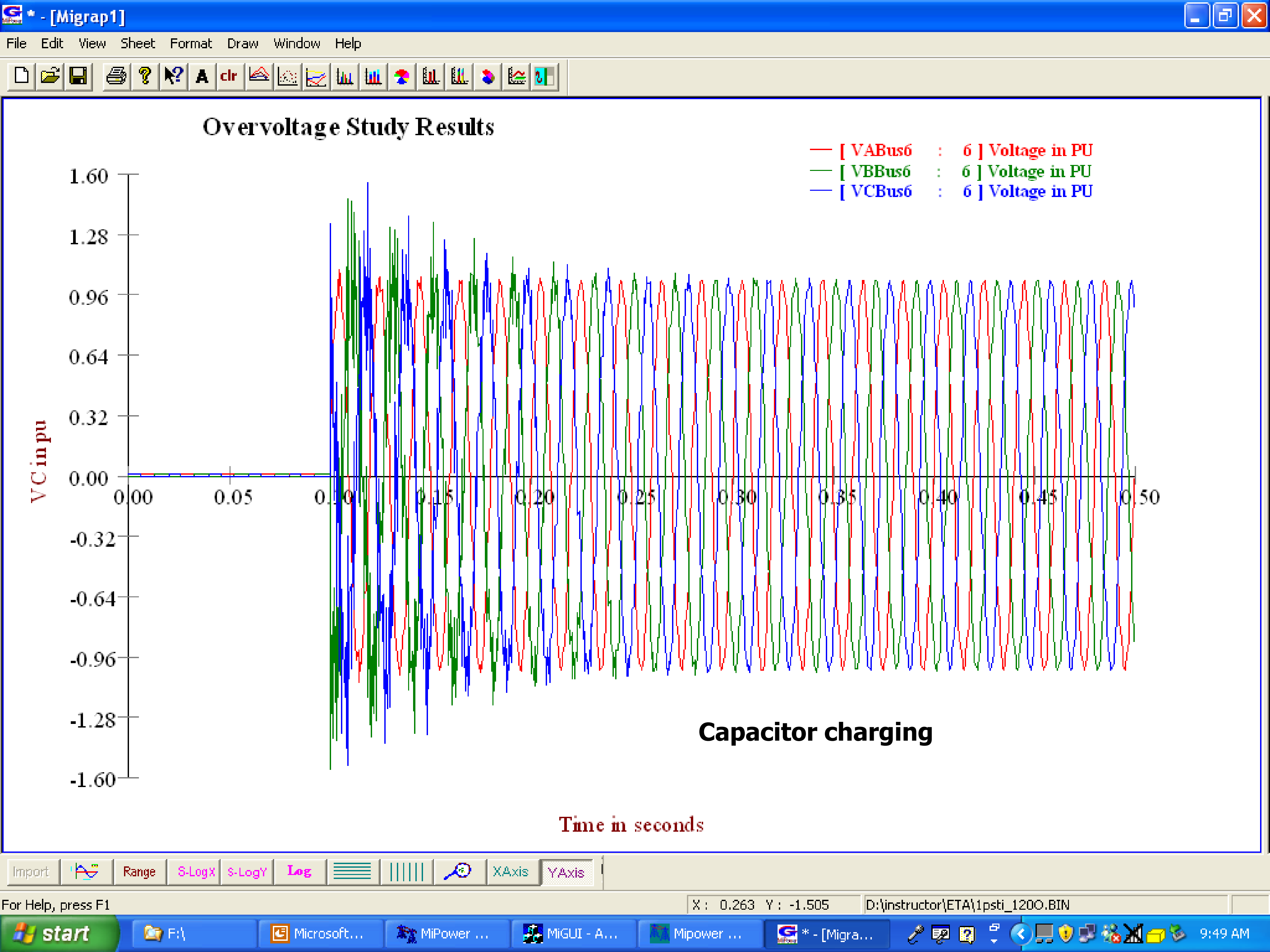


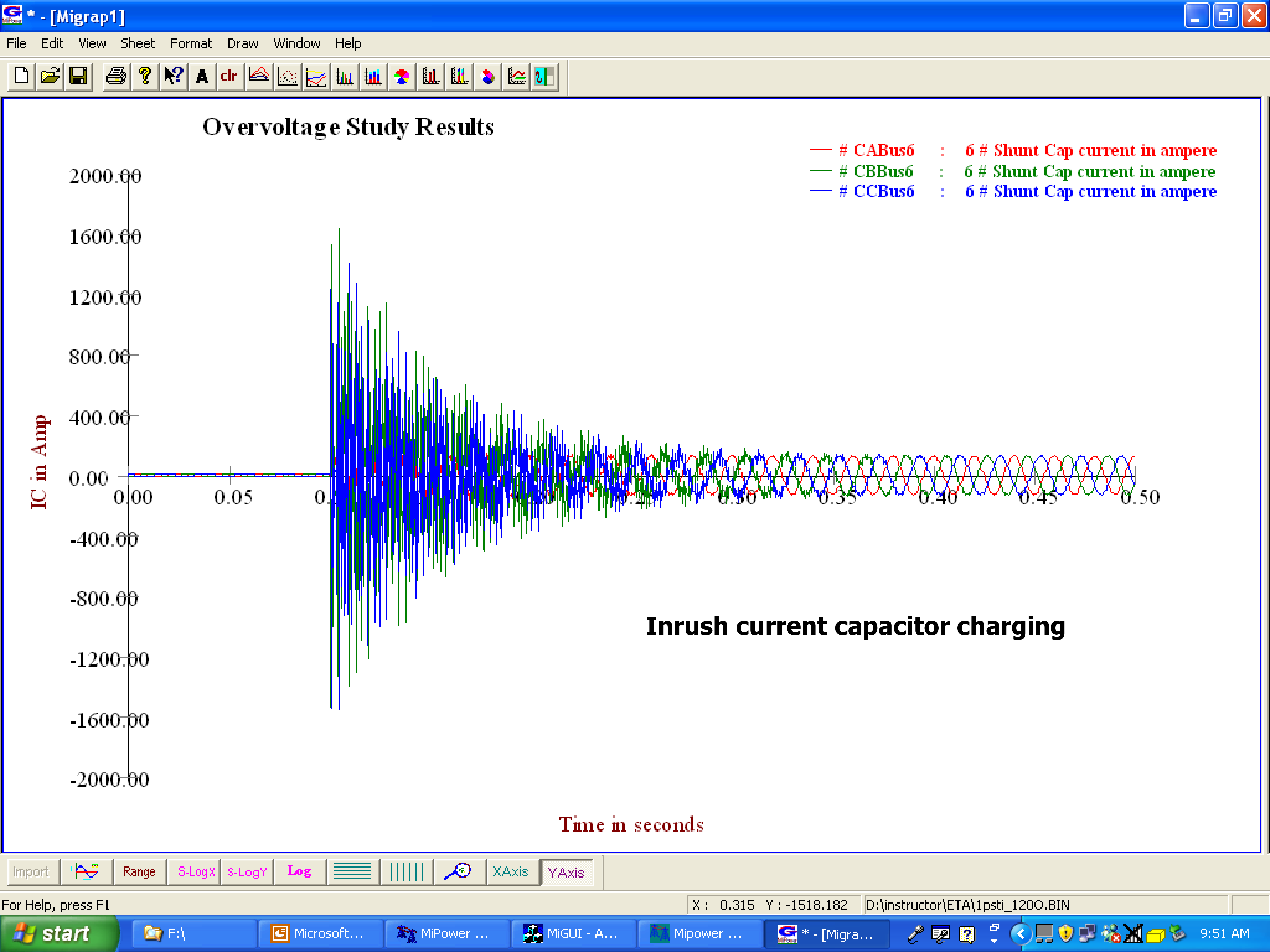
Loss of excitation

1. **Impedance moves from the first quadrant**
2. **Settles in a circle with dia xd and off set xd'/2**
3. **Off set mho relay detects the fault**

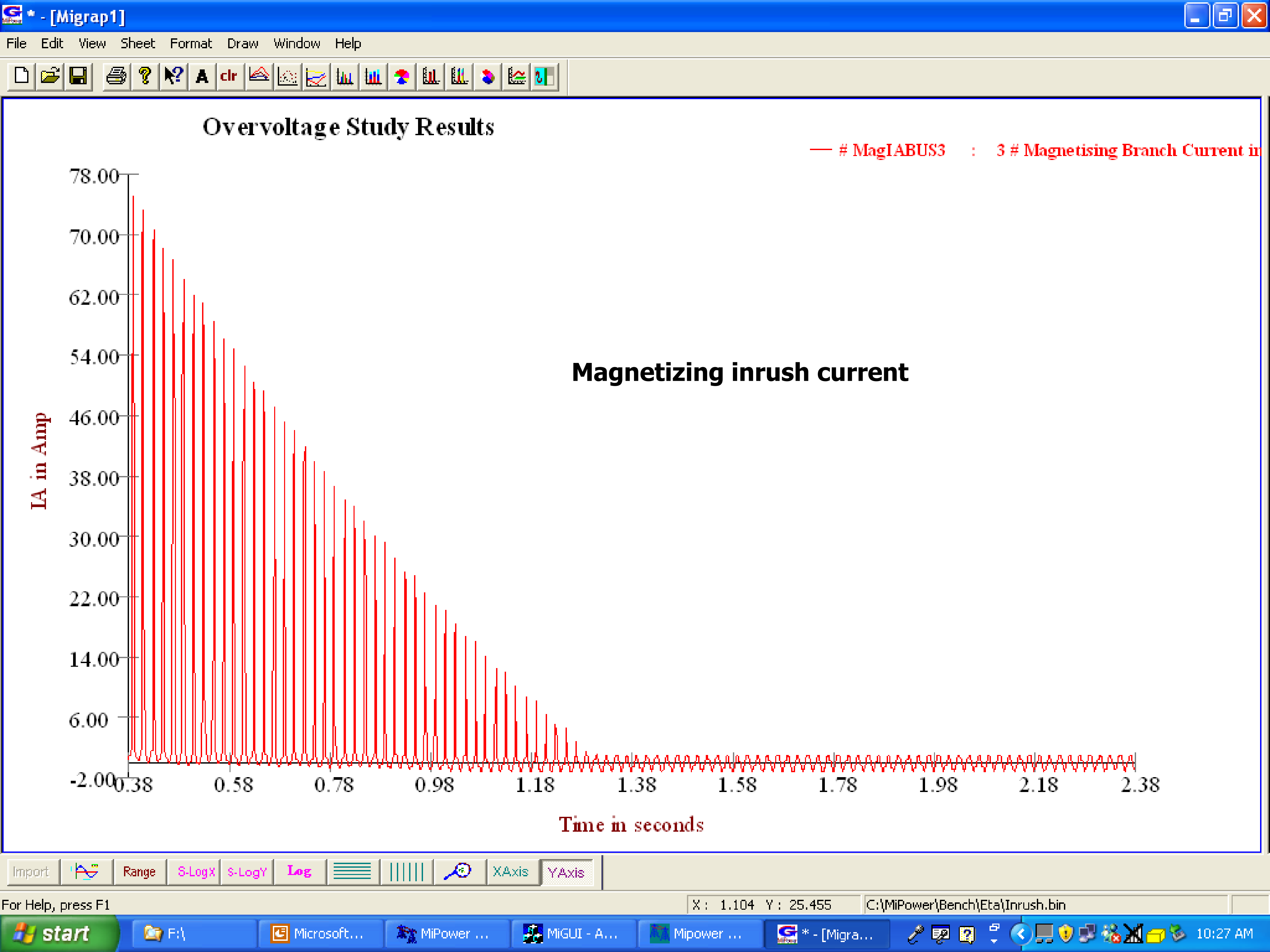

* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Transient Stability Study
[Genbus - 1] to [Bus2 - 2] X in PU
Loss of excitation relay
1. Off set mho relay
2. Off set of xd'/2
3. Diameter of xd
Forward X in PU
1.50
1.20
0.90
0.60
0.30
0.00
-0.30
-0.60
-0.90
-1.20
-1.50
-1.50
-1.20
-0.90
-0.60
-0.30
0.00
0.30
0.60
0.90
1.20
1.50
[Genbus - 1] to [Bus2 - 2] R in PU
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 0.251 Y : -1.152
D:\instructor\TRS\1psti_120TOL.BIN
start
D:\PPt-Pre...
Microsoft P...
MiPower - ...
MiGUI - A P...
Mipower Da...
* - [Migrap1]
7:05 PM

Why current limiting reactor for capacitor banks?

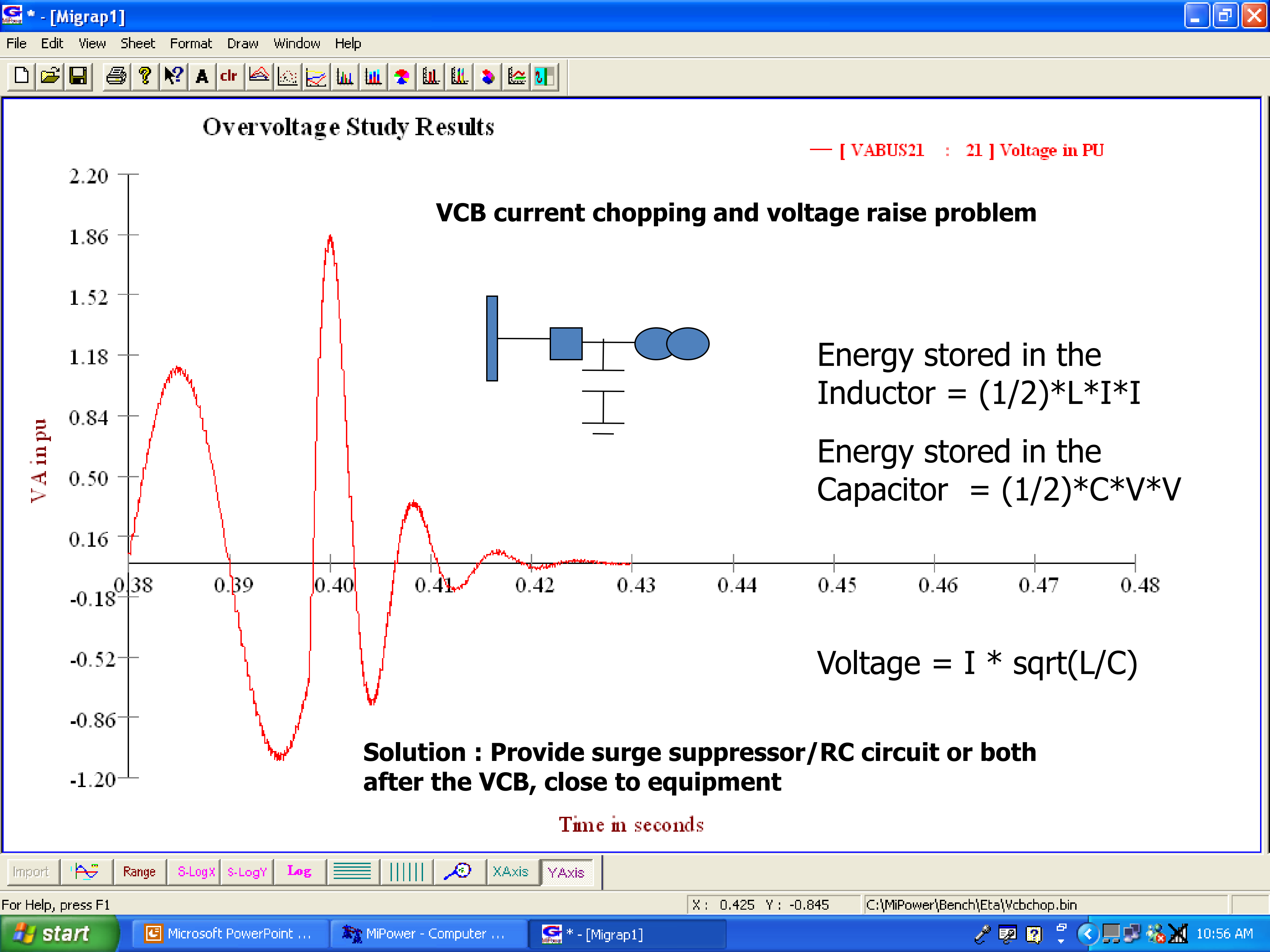

* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Overvoltage Study Results
[VABus6 : 6] Voltage in PU
[VBBus6 : 6] Voltage in PU
[VCBus6 : 6] Voltage in PU
1.60
1.28
0.96
0.64
0.32
0.00
-0.32
-0.64
-0.96
-1.28
-1.60
VC in pu
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
0.45
0.50
Capacitor charging
Time in seconds
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X : 0.263 Y : -1.505
D:\instructor\ETA\1psti_120O.BIN
start F:\ Microsoft... MiPower ... MiGUI - A... Mipower ... * - [Migra... 9:49 AM


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Overvoltage Study Results
CABus6 : 6 # Shunt Cap current in ampere
CBBus6 : 6 # Shunt Cap current in ampere
CCBus6 : 6 # Shunt Cap current in ampere
2000.00
1600.00
1200.00
800.00
400.00
0.00
-400.00
-800.00
-1200.00
-1600.00
-2000.00
IC in Amp
0.00
0.05
0.30
0.35
0.40
0.45
0.50
Inrush current capacitor charging
Time in seconds
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 0.315 Y : -1518.182
D:\instructor\ETA\1psti_120O.BIN
start
F:\
Microsoft...
MiPower ...
MiGUI - A...
Mipower ...
* - [Migra...
9:51 AM

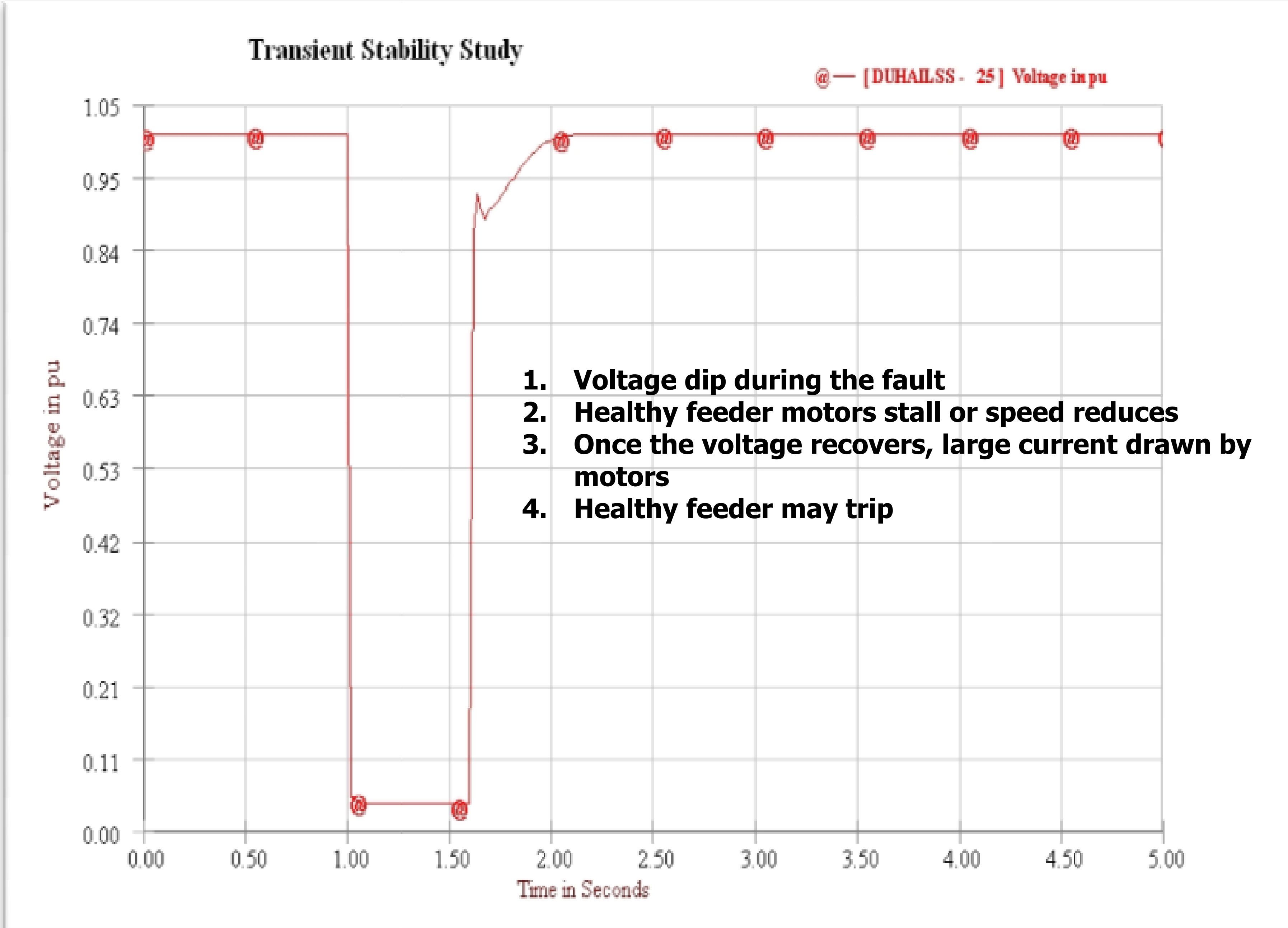
2^{nd} Harmonic and 5^{th} Harmonic restraint for transformer differential protection


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Overvoltage Study Results
MagIABUS3 : 3 # Magnetising Branch Current in
Magnetizing inrush current
IA in Amp
78.00
70.00
62.00
54.00
46.00
38.00
30.00
22.00
14.00
6.00
-2.00
0.38
0.58
0.78
0.98
1.18
1.38
1.58
1.78
1.98
2.18
2.38
Time in seconds
Import
Range
S-LogX
S-LogY
Log
XAxis
YAxis
For Help, press F1
X : 1.104 Y : 25.455
C:\MiPower\Bench\Eta\Inrush.bin
start
F:\
Microsoft...
MiPower ...
MiGUI - A...
Mipower ...
* - [Migra...
10:27 AM

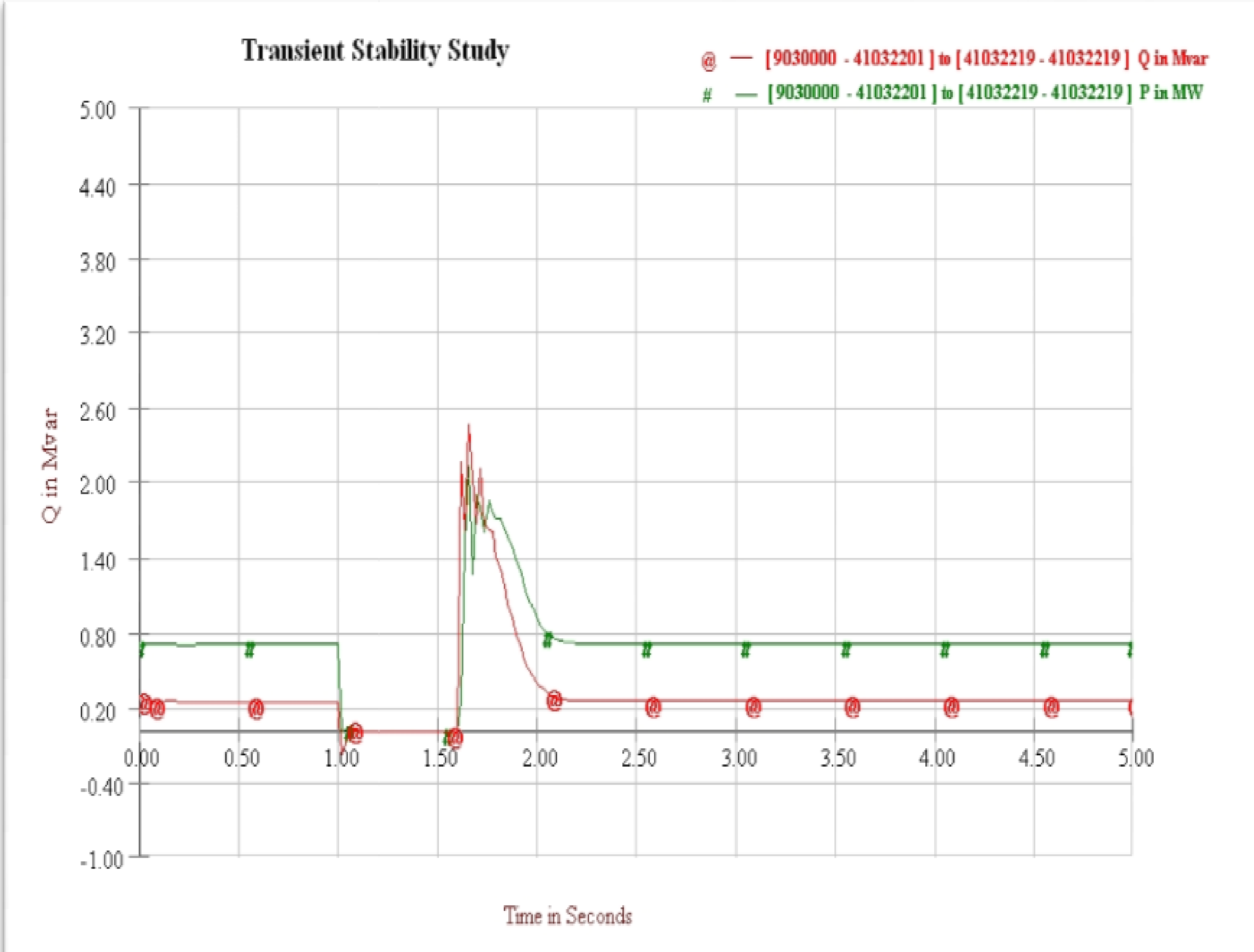
Why to provide surge arrestor and RC circuit for VCB switching


* - [Migrap1]
File Edit View Sheet Format Draw Window Help
Overvoltage Study Results
— [VABUS21 : 21] Voltage in PU
VCB current chopping and voltage raise problem
2.20
1.86
1.52
1.18
0.84
0.50
0.16
-0.18
-0.52
-0.86
-1.20
V A in pu
0.38 0.39 0.40 0.41 0.42 0.43 0.44 0.45 0.46 0.47 0.48
Energy stored in the Inductor = (1/2)*L*I*I
Energy stored in the Capacitor = (1/2)*C*V*V
Voltage = I * sqrt(L/C)
Solution : Provide surge suppressor/RC circuit or both after the VCB, close to equipment
Time in seconds
Import Range S-LogX S-LogY Log XAxis YAxis
For Help, press F1
X : 0.425 Y : -0.845
C:\MiPower\Bench\Eta\Vcbchop.bin
start
Microsoft PowerPoint ...
MiPower - Computer ...
* - [Migrap1]
10:56 AM

Simphatic Tipping, what it means?



1. Voltage dip during the fault
2. Healthy feeder motors stall or speed reduces
3. Once the voltage recovers, large current drawn by motors
4. Healthy feeder may trip

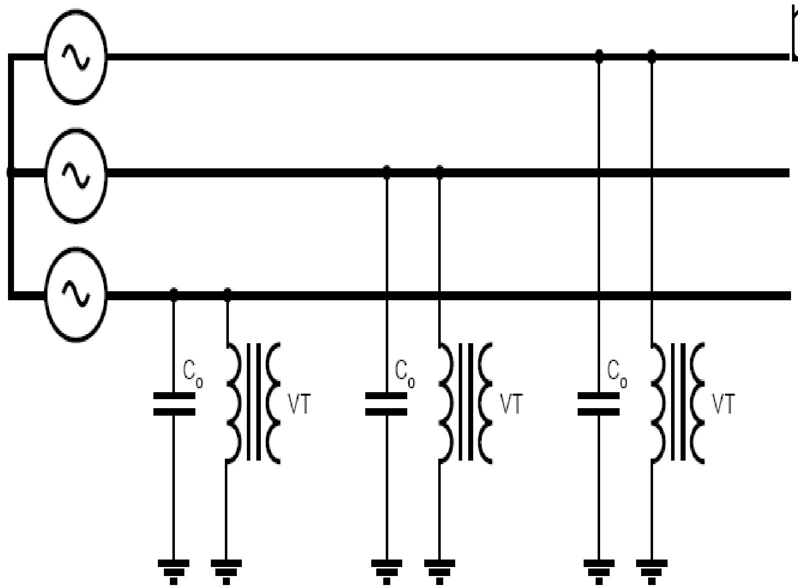

Transient Stability Study
@ — [9030000 - 41032201] to [41032219 - 41032219] Q in Mvar
# — [9030000 - 41032201] to [41032219 - 41032219] P in MW
5.00
4.40
3.80
3.20
2.60
2.00
1.40
0.80
0.20
-0.40
-1.00
Q in Mvar
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
Time in Seconds

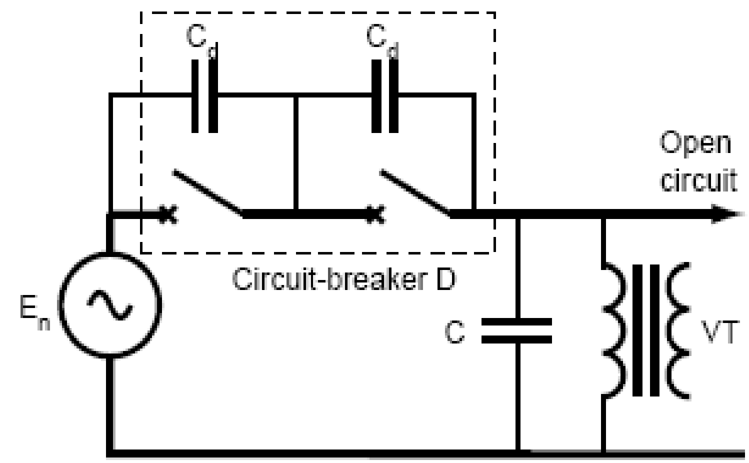
Ferroresonance when and how?

Ferro-resonance (FR) TOV

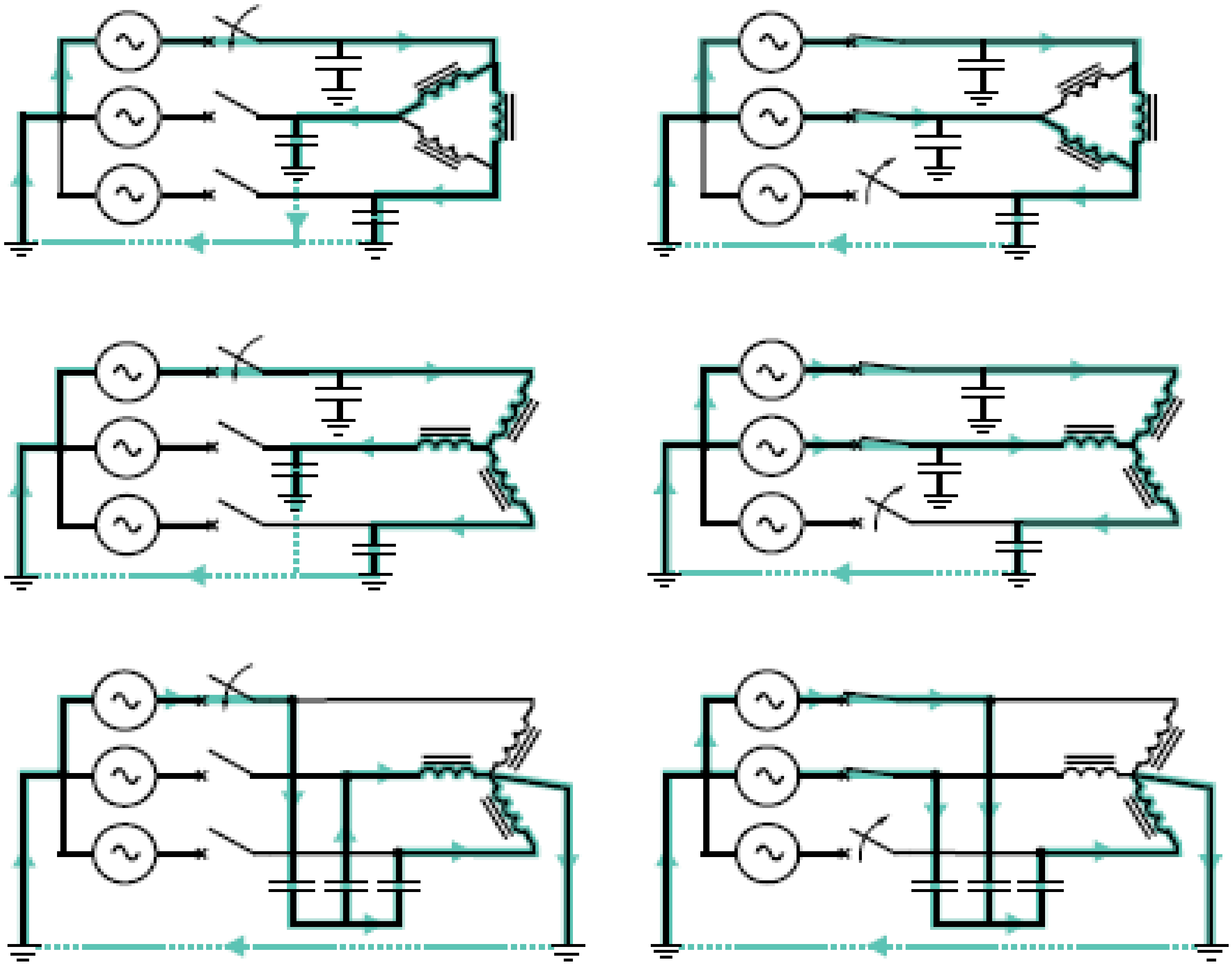
- An oscillating phenomena occurring in an electric circuit which must contain at least:
  1. a non-linear inductance
  2. a capacitor,
  3. a voltage source (generally sinusoidal),
  4. low losses.
- Transients, lightning over voltages, energizing or de-energizing transformers or loads, occurrence or removal of faults, etc…may initiate ferroresonance.
- The main feature of this phenomenon is that more than one stable steady state response is possible for the same set of the network parameters.

Examples of systems at risk

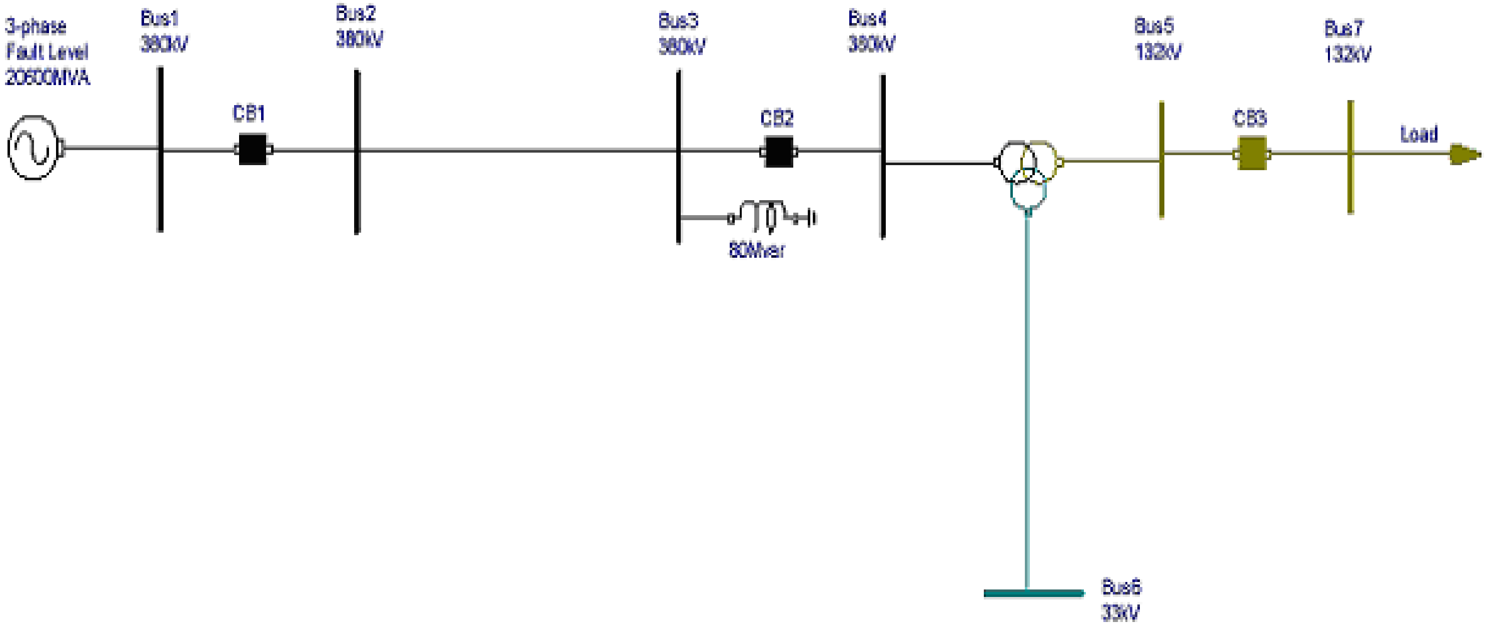


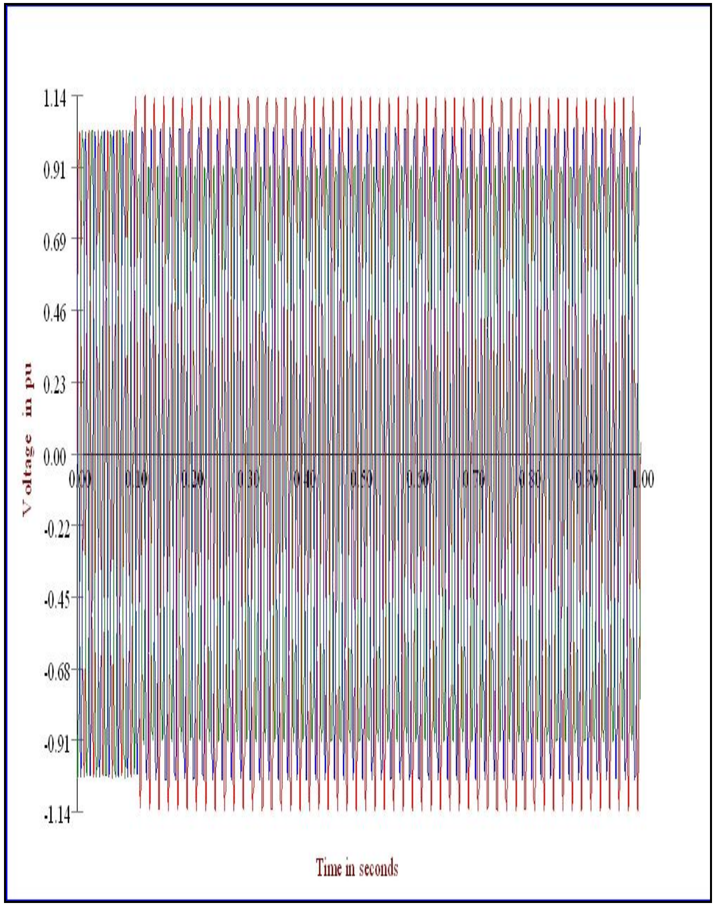


Contd.

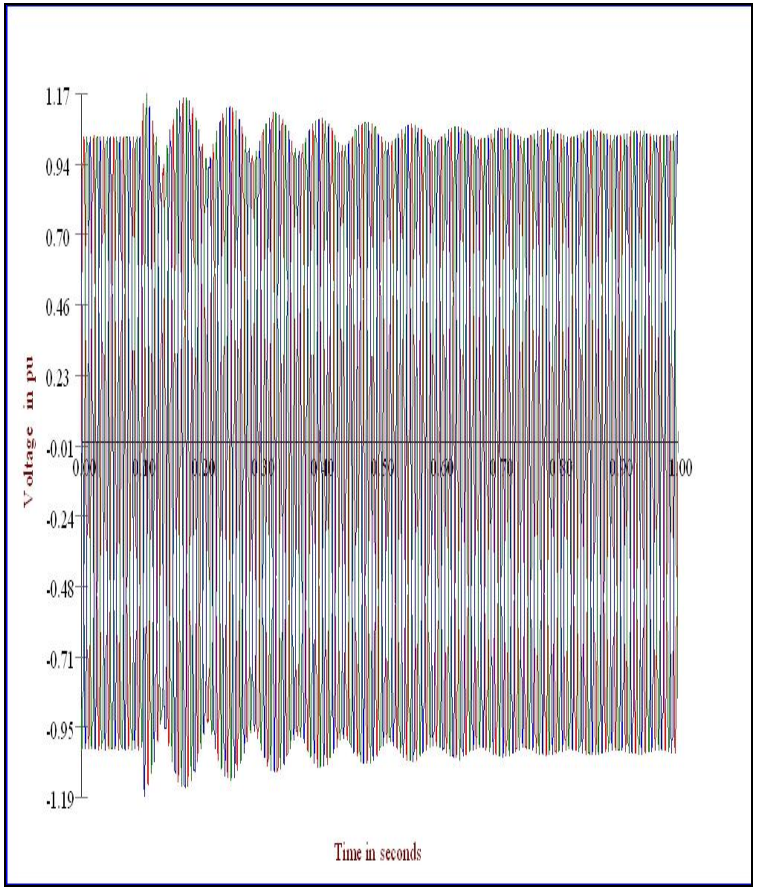


Case study for predicting and understanding of TOV and FR



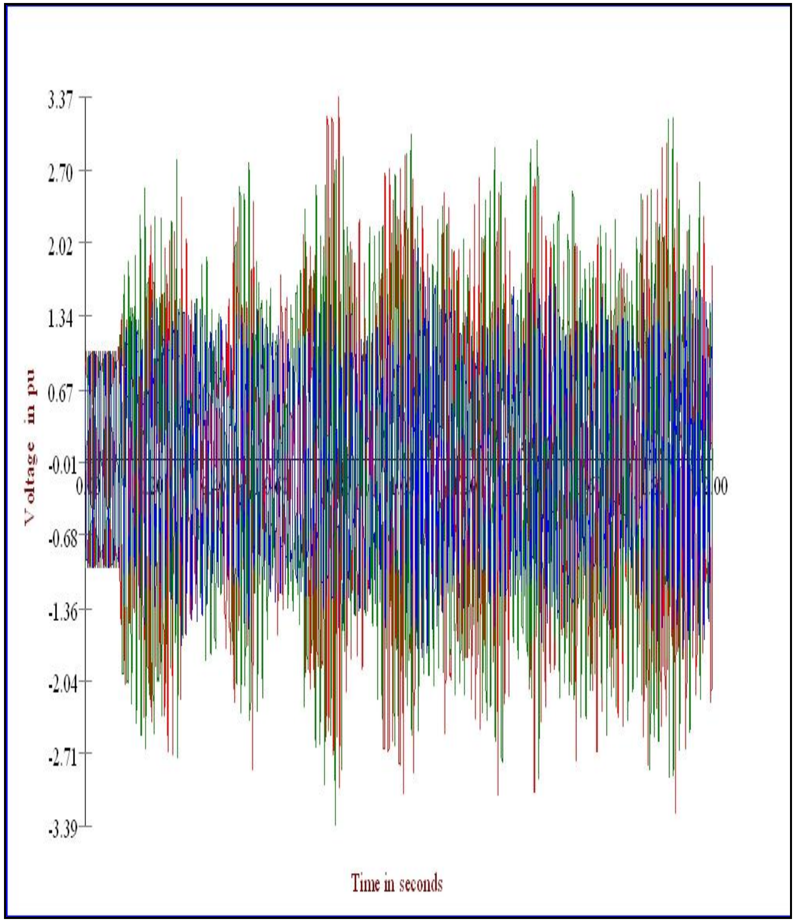


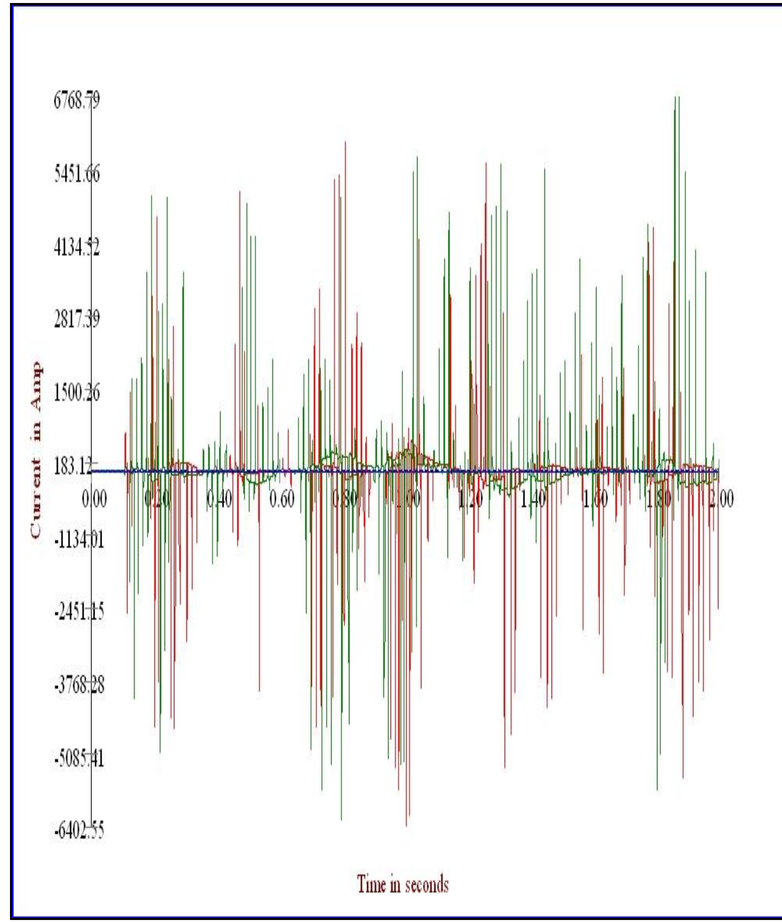
1-pole



3-pole

HT side LR by opening CB2





Voltage

Current

FR existence when 2-poles opening of CB1

Discussions

Thank You