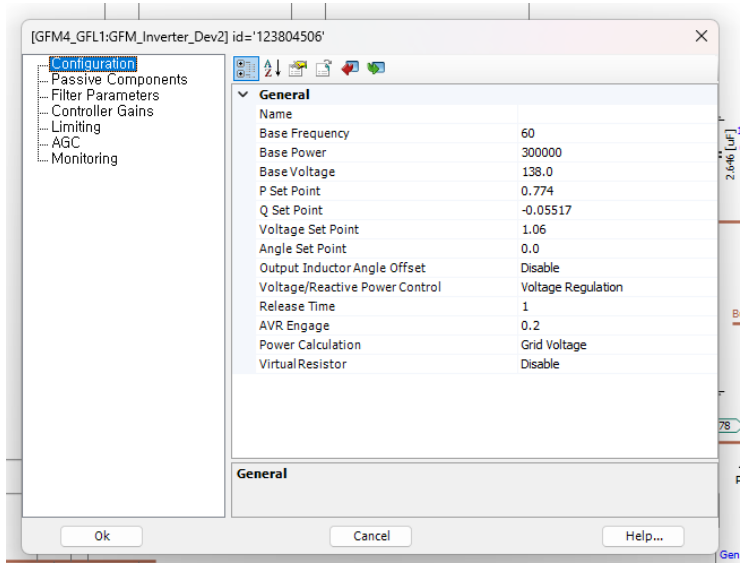
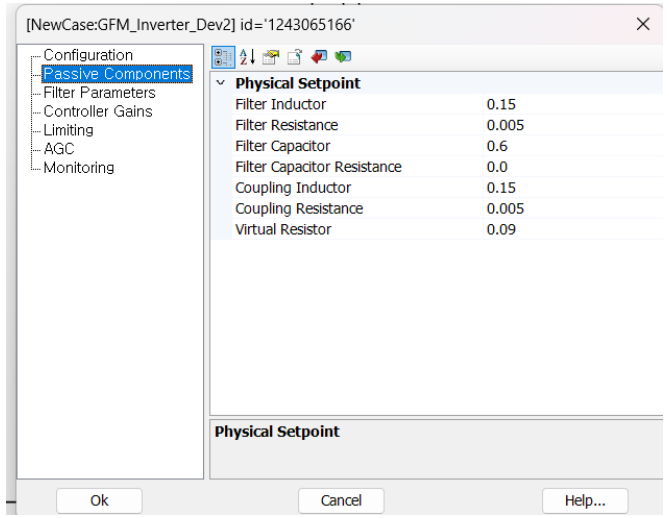
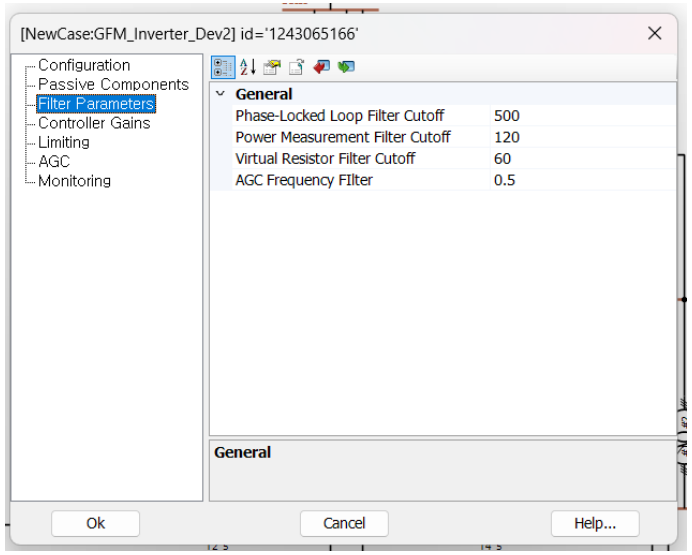
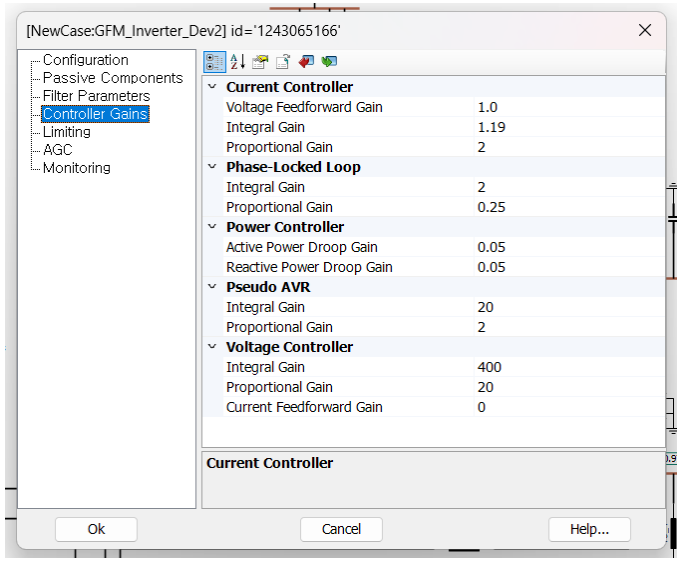
Nov. 10 Simulations:

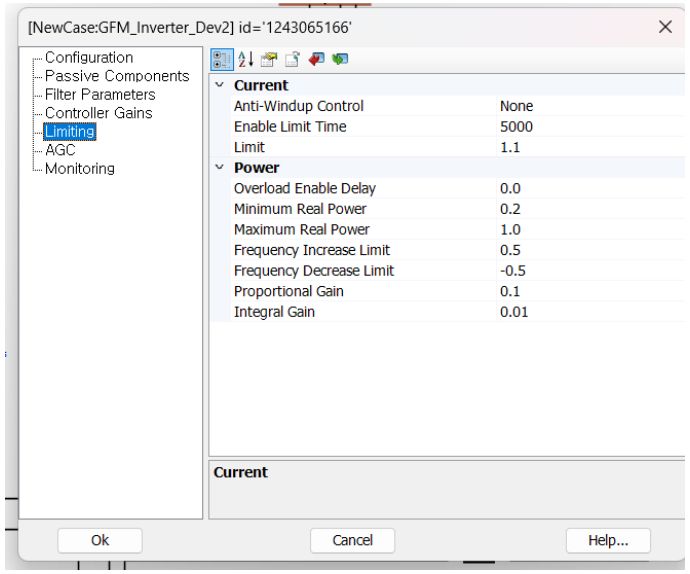
- Zero Inertia Simulations (All inverter set-up):
  - Configured the GFM A (Slack) release time.
  - Do simulations for GFM B for a slack bus.
- High Penetration Simulations:
  - Do simulations for Ideal slack bus.

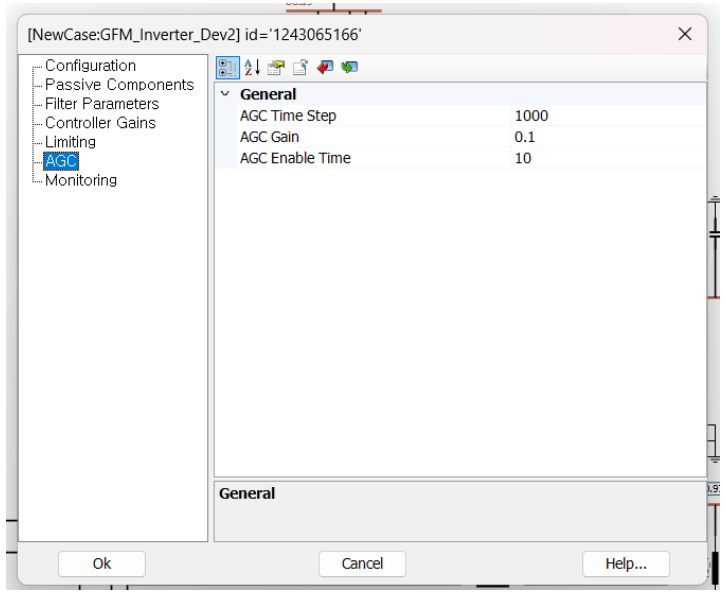






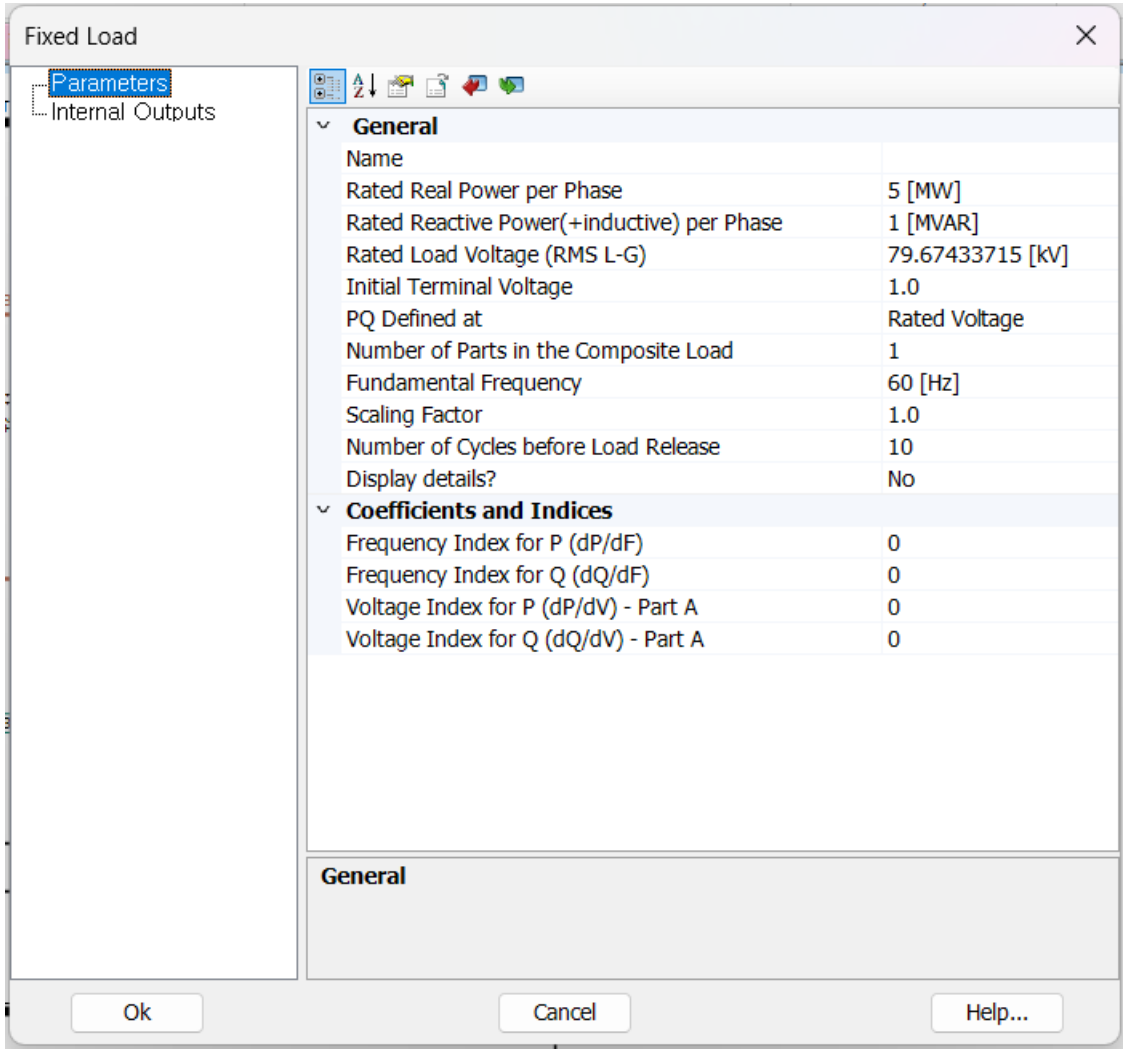




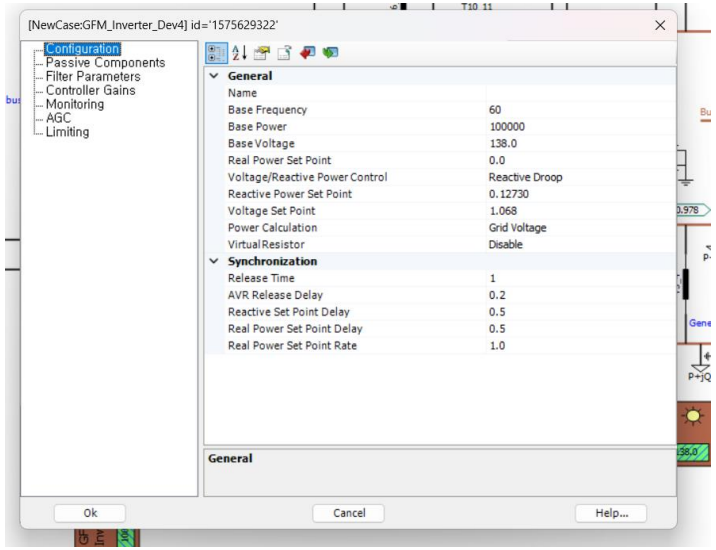


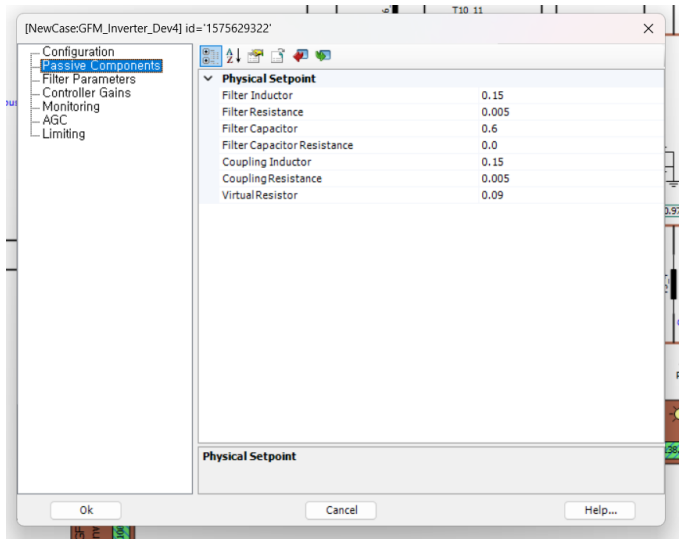
GFM A Kenyon Model Configurations

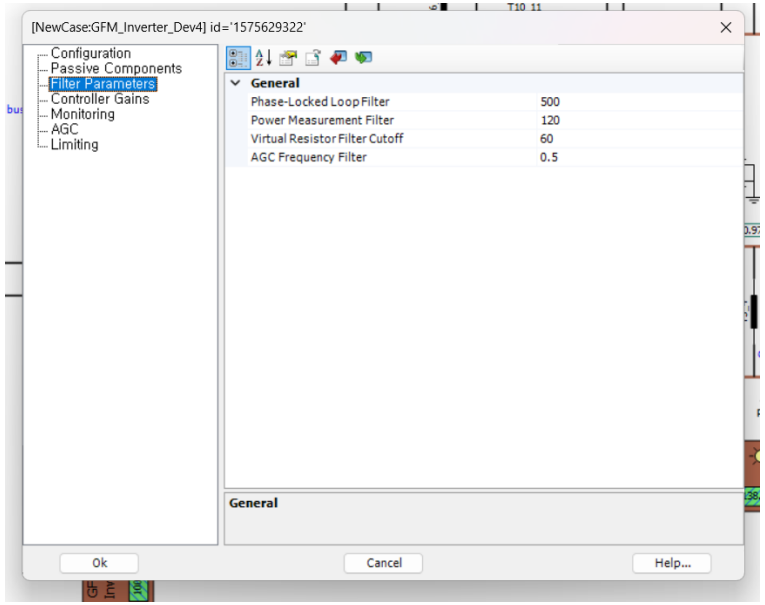
Load Increase at Bus 4

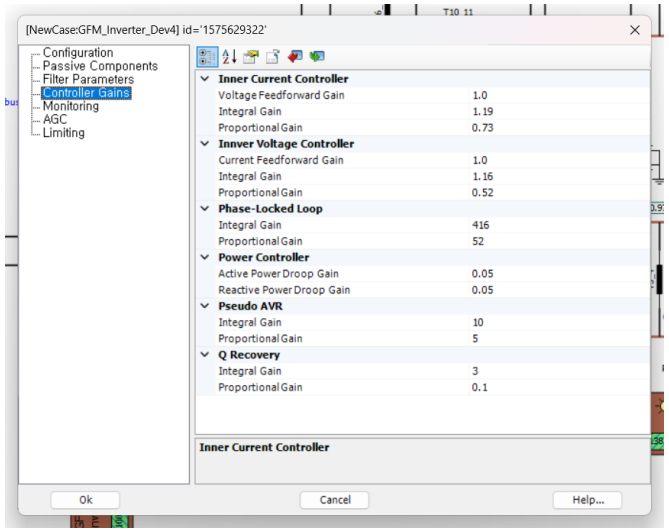


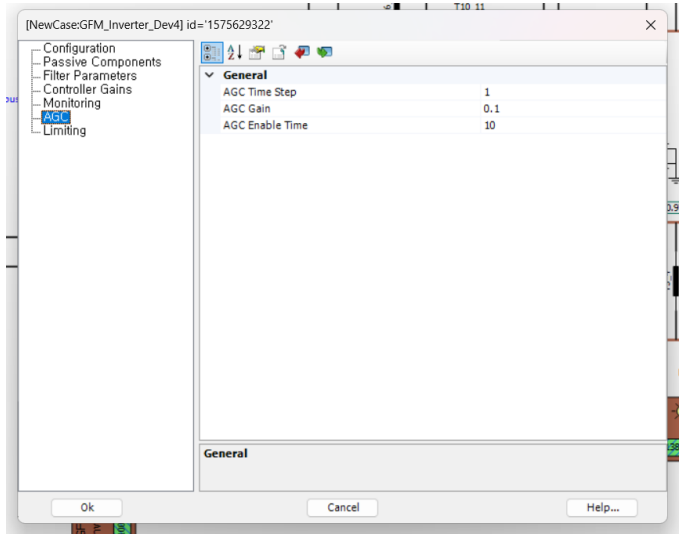
GFM B (PV Generator)

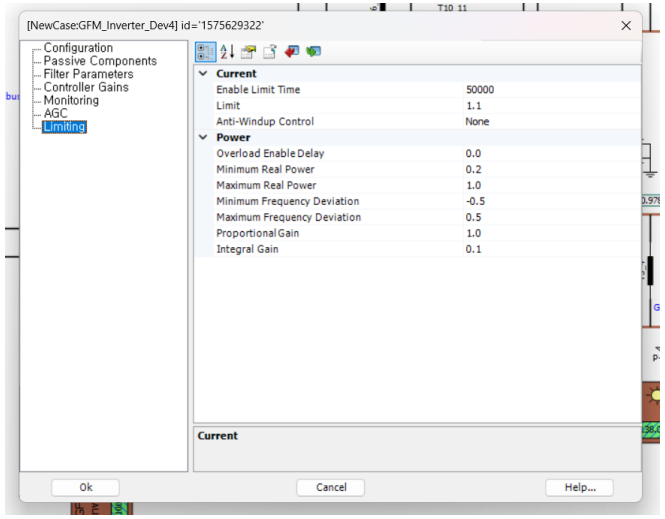




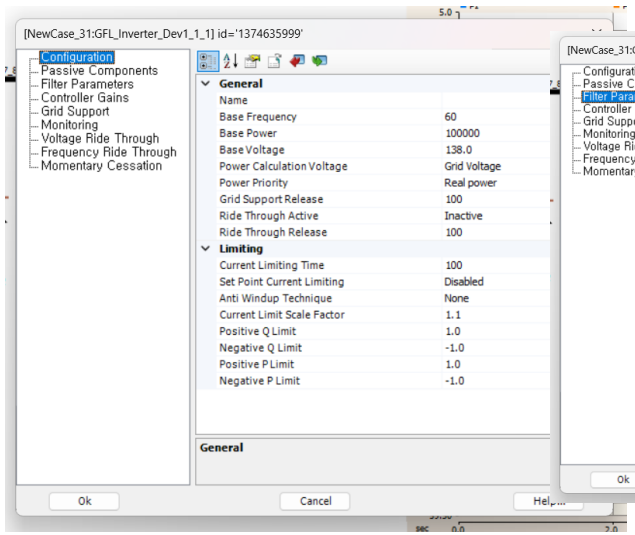








GFL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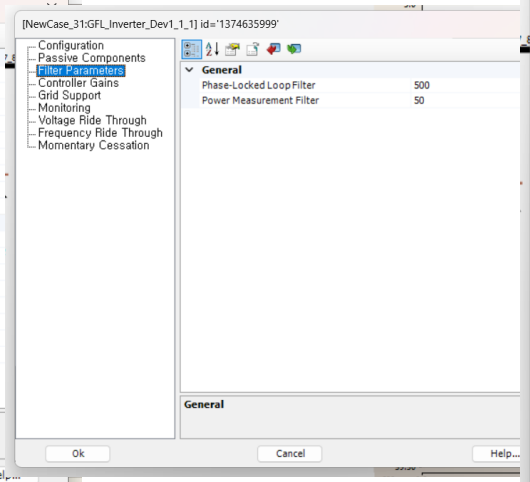
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
General
Name
Base Frequency 60
Base Power 100000
Base Voltage 138.0
Power Calculation Voltage Grid Voltage
Power Priority Real power
Grid Support Release 100
Ride Through Active Inactive
Ride Through Release 100
Limiting
Current Limiting Time 100
Set Point Current Limiting Disabled
Anti Windup Technique None
Current Limit Scale Factor 1.1
Positive Q Limit 1.0
Negative Q Limit -1.0
Positive P Limit 1.0
Negative P Limit -1.0
General
Ok
Cancel
Help...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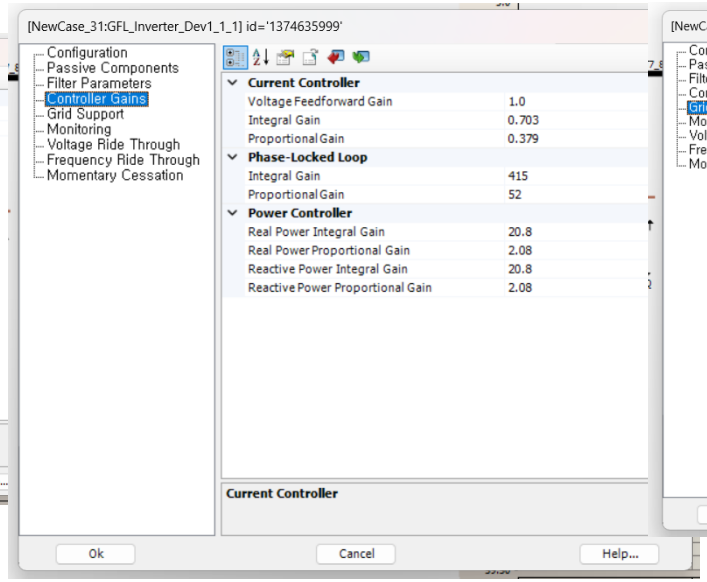
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
General
Phase-Locked Loop Filter 500
Power Measurement Filter 50
General
Ok
Cancel
Help...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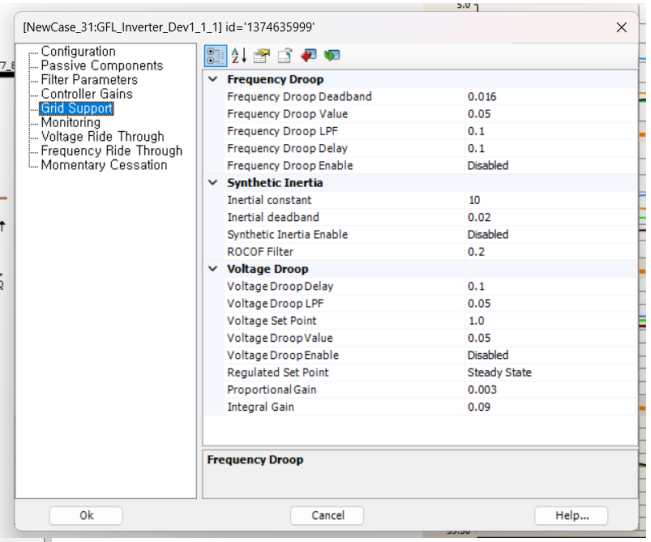
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
Current Controller
Voltage Feedforward Gain 1.0
Integral Gain 0.703
Proportional Gain 0.379
Phase-Locked Loop
Integral Gain 415
Proportional Gain 52
Power Controller
Real Power Integral Gain 20.8
Real Power Proportional Gain 2.08
Reactive Power Integral Gain 20.8
Reactive Power Proportional Gain 2.08
Current Controller
Ok
Cancel
Help...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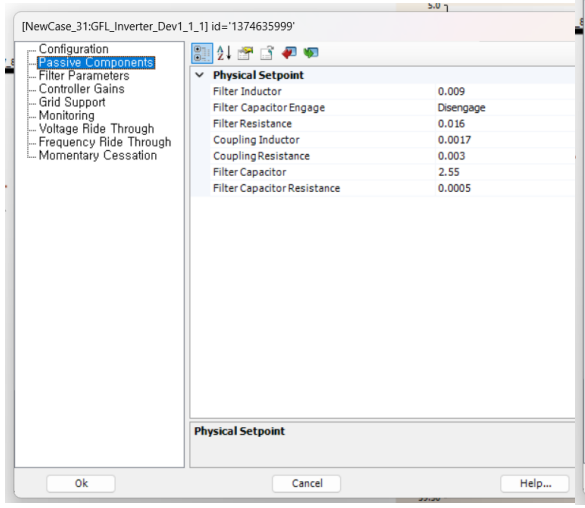
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
Frequency Droop
Frequency Droop Deadband 0.016
Frequency Droop Value 0.05
Frequency Droop LPF 0.1
Frequency Droop Delay 0.1
Frequency Droop Enable Disabled
Synthetic Inertia
Inertial constant 10
Inertial deadband 0.02
Synthetic Inertia Enable Disabled
ROCOF Filter 0.2
Voltage Droop
Voltage Droop Delay 0.1
Voltage Droop LPF 0.05
Voltage Set Point 1.0
Voltage Droop Value 0.05
Voltage Droop Enable Disabled
Regulated Set Point Steady State
Proportional Gain 0.003
Integral Gain 0.09
Frequency Droop
Ok
Cancel
Help...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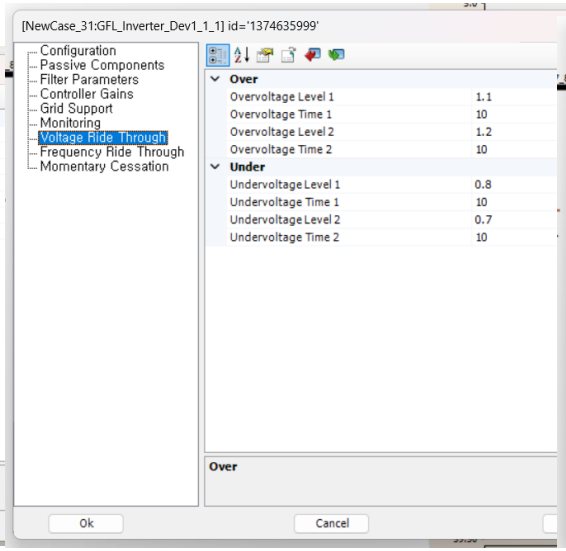
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
Physical Setpoint
Filter Inductor 0.009
Filter Capacitor Engage Disengage
Filter Resistance 0.016
Coupling Inductor 0.0017
Coupling Resistance 0.003
Filter Capacitor 2.55
Filter Capacitor Resistance 0.0005
Physical Setpoint
Ok
Cancel
Help...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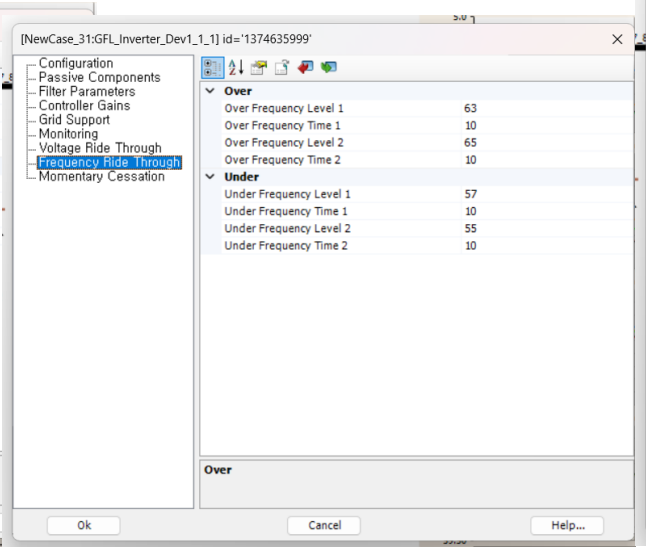
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
Over
Overvoltage Level 1 1.1
Overvoltage Time 1 10
Overvoltage Level 2 1.2
Overvoltage Time 2 10
Under
Undervoltage Level 1 0.8
Undervoltage Time 1 10
Undervoltage Level 2 0.7
Undervoltage Time 2 10
Over
Ok
Cancel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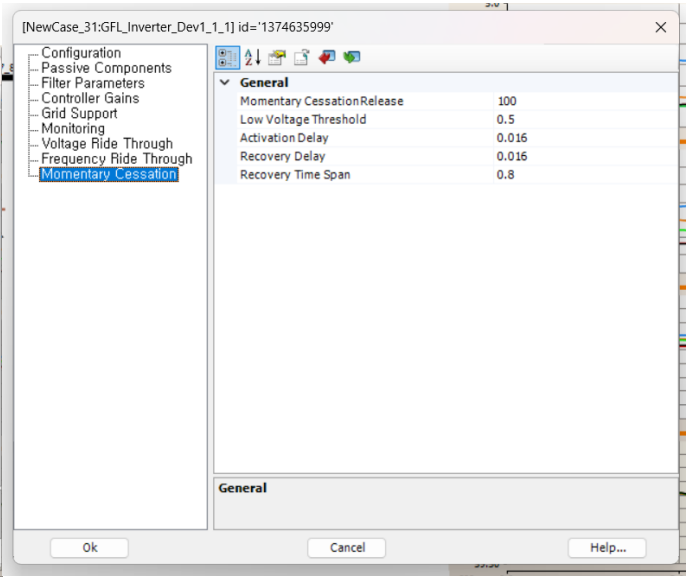
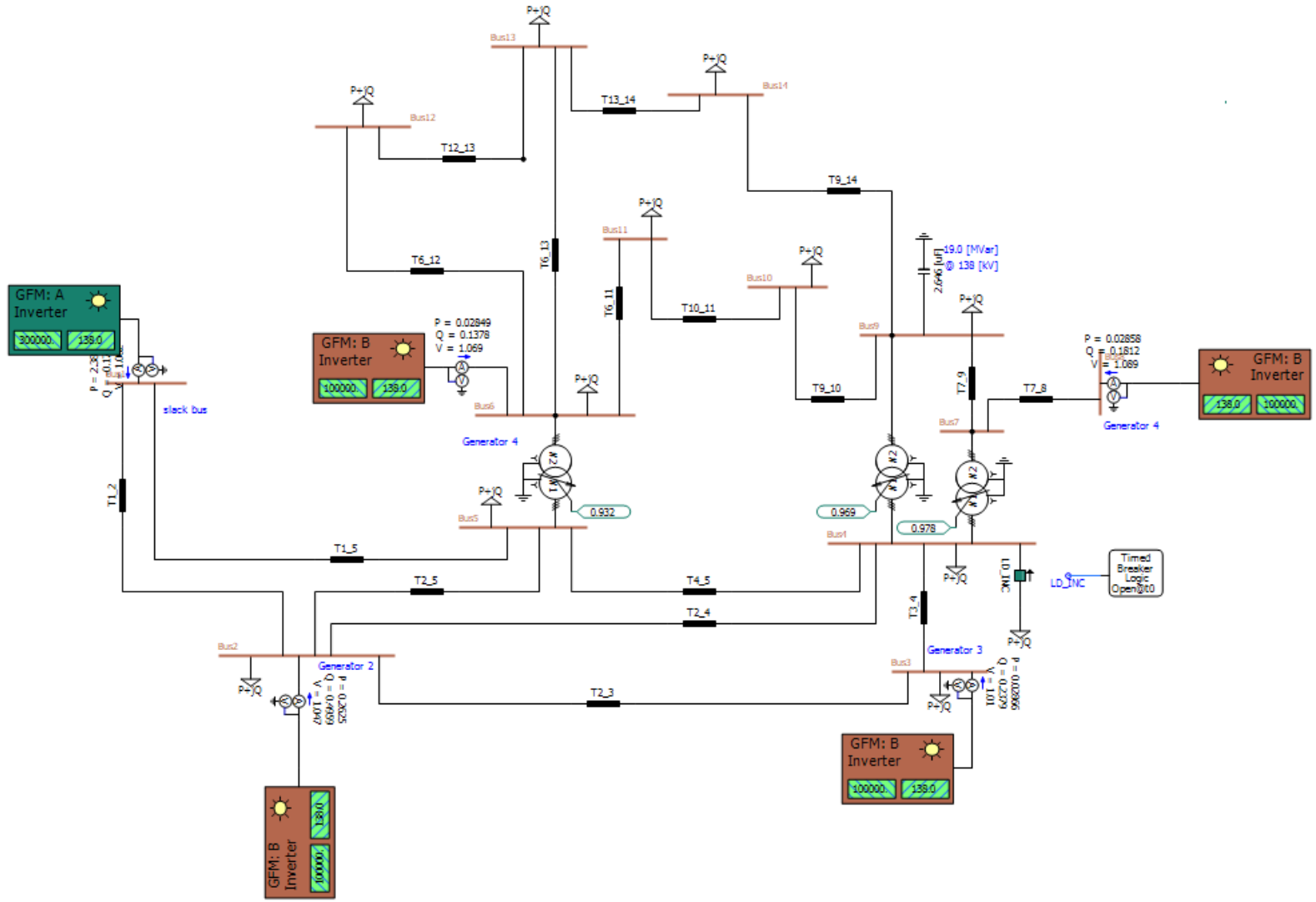
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
Over
Over Frequency Level 1 63
Over Frequency Time 1 10
Over Frequency Level 2 65
Over Frequency Time 2 10
Under
Under Frequency Level 1 57
Under Frequency Time 1 10
Under Frequency Level 2 55
Under Frequency Time 2 10
Over
Ok
Cancel
Help...

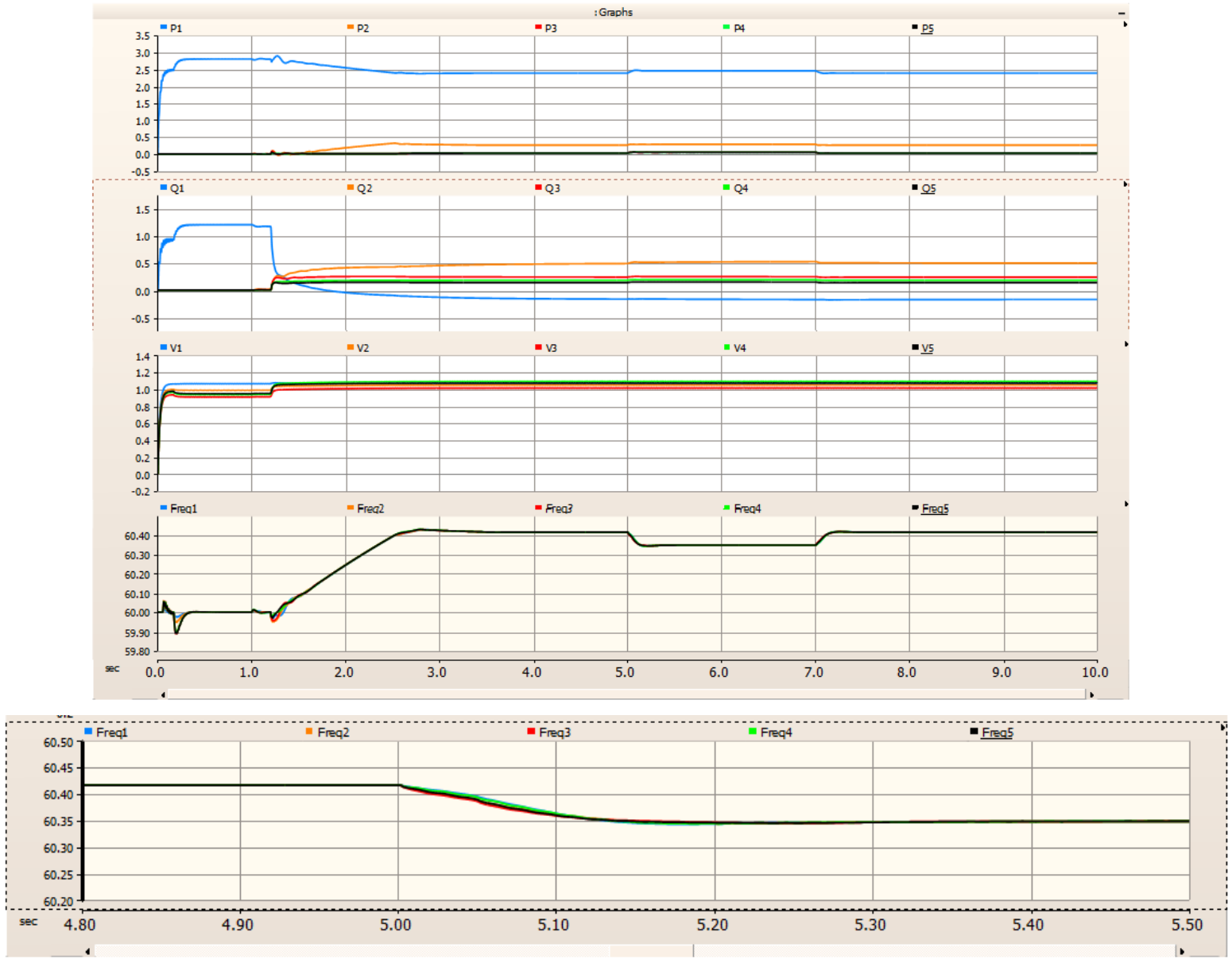

[NewCase_31:GFL_Inverter_Dev1_1_1] id='1374635999'
Configuration
Passive Components
Filter Parameters
Controller Gains
Grid Support
Monitoring
Voltage Ride Through
Frequency Ride Through
Momentary Cessation
General
Momentary Cessation Release 100
Low Voltage Threshold 0.5
Activation Delay 0.016
Recovery Delay 0.016
Recovery Time Span 0.8
General
Ok
Cancel
Help...

Zero Inertia (GFM A Slack)

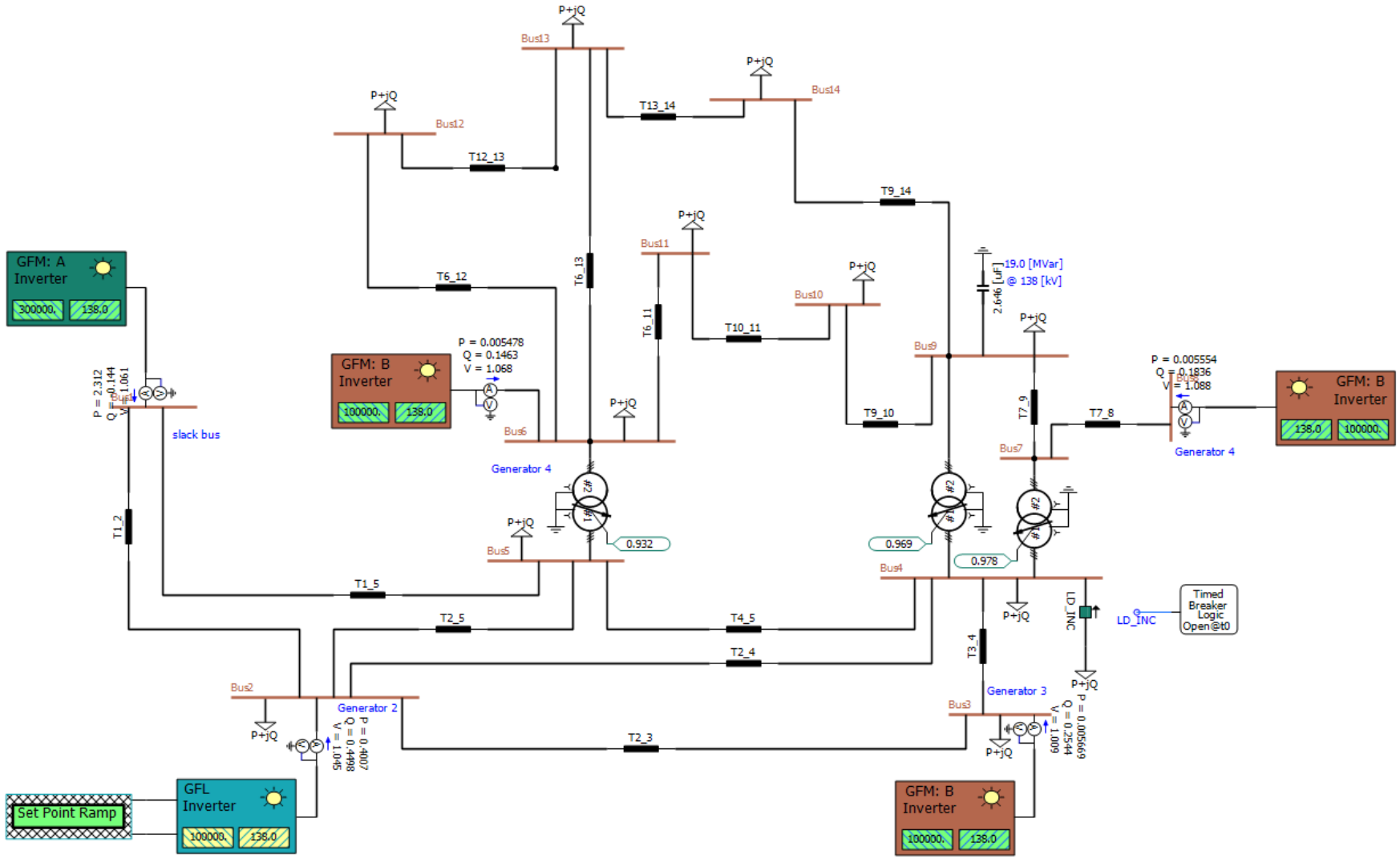
Zero Inertia (All Inverter): GFM5 : GFL 0



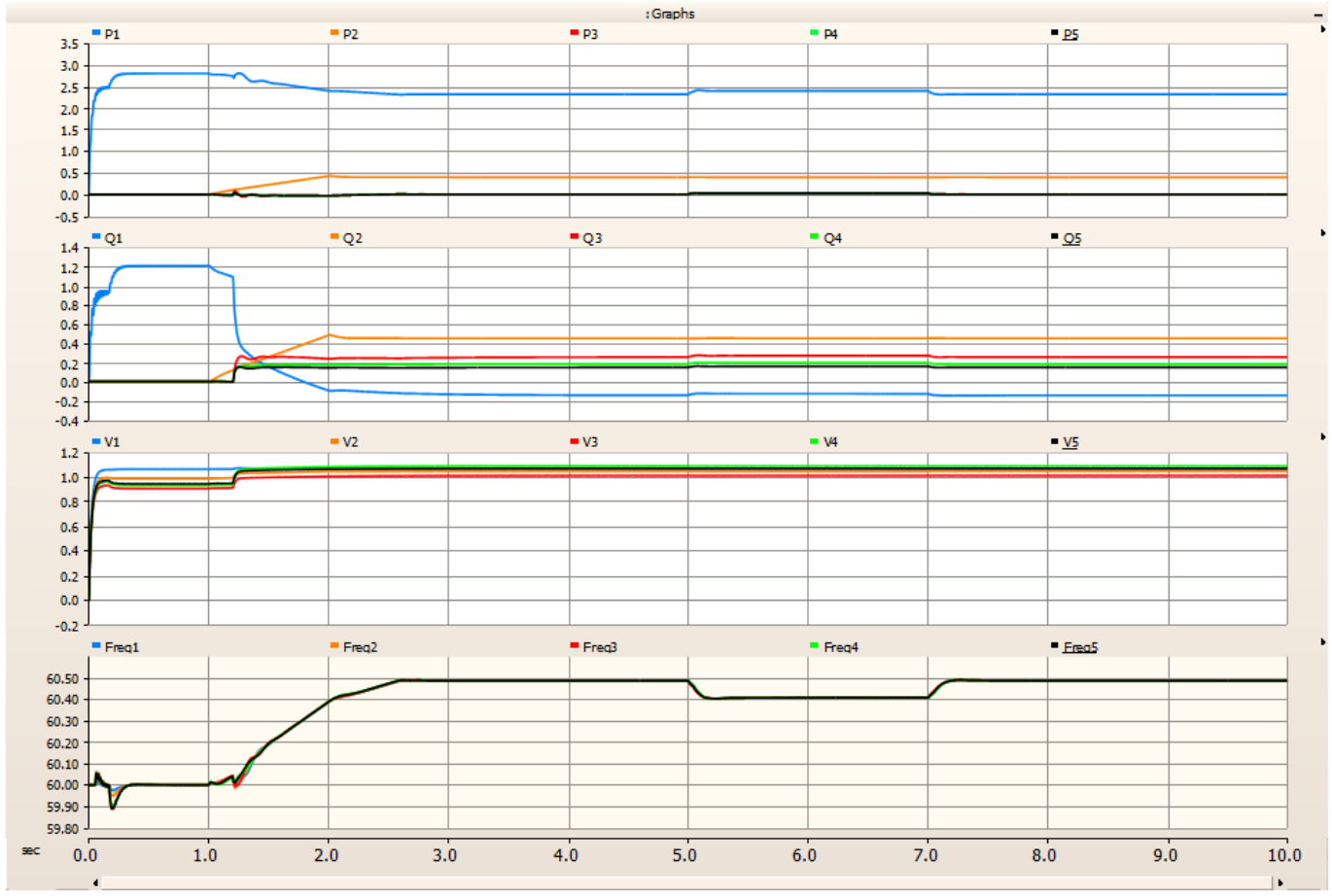
Zero Inertia (All Inverter): GFM5 : GFL 0

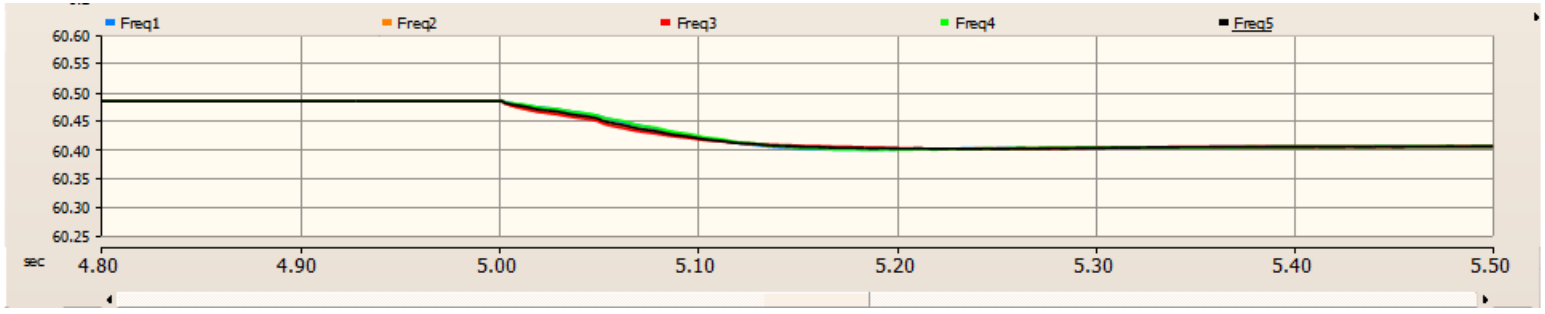


Zero Inertia (All Inverter): GFM4 : GFL 1

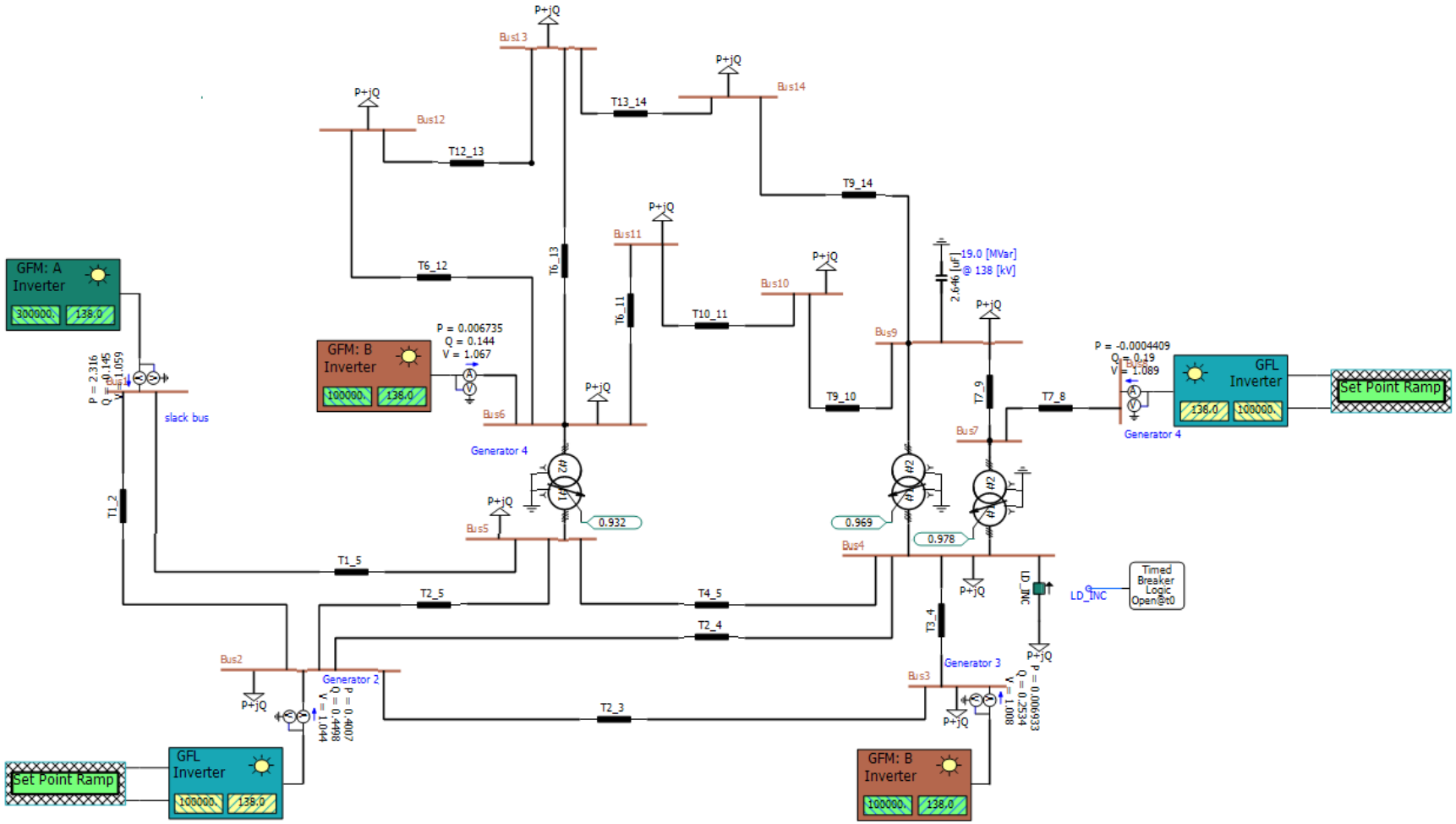


Zero Inertia (All Inverter): GFM4 : GFL 1

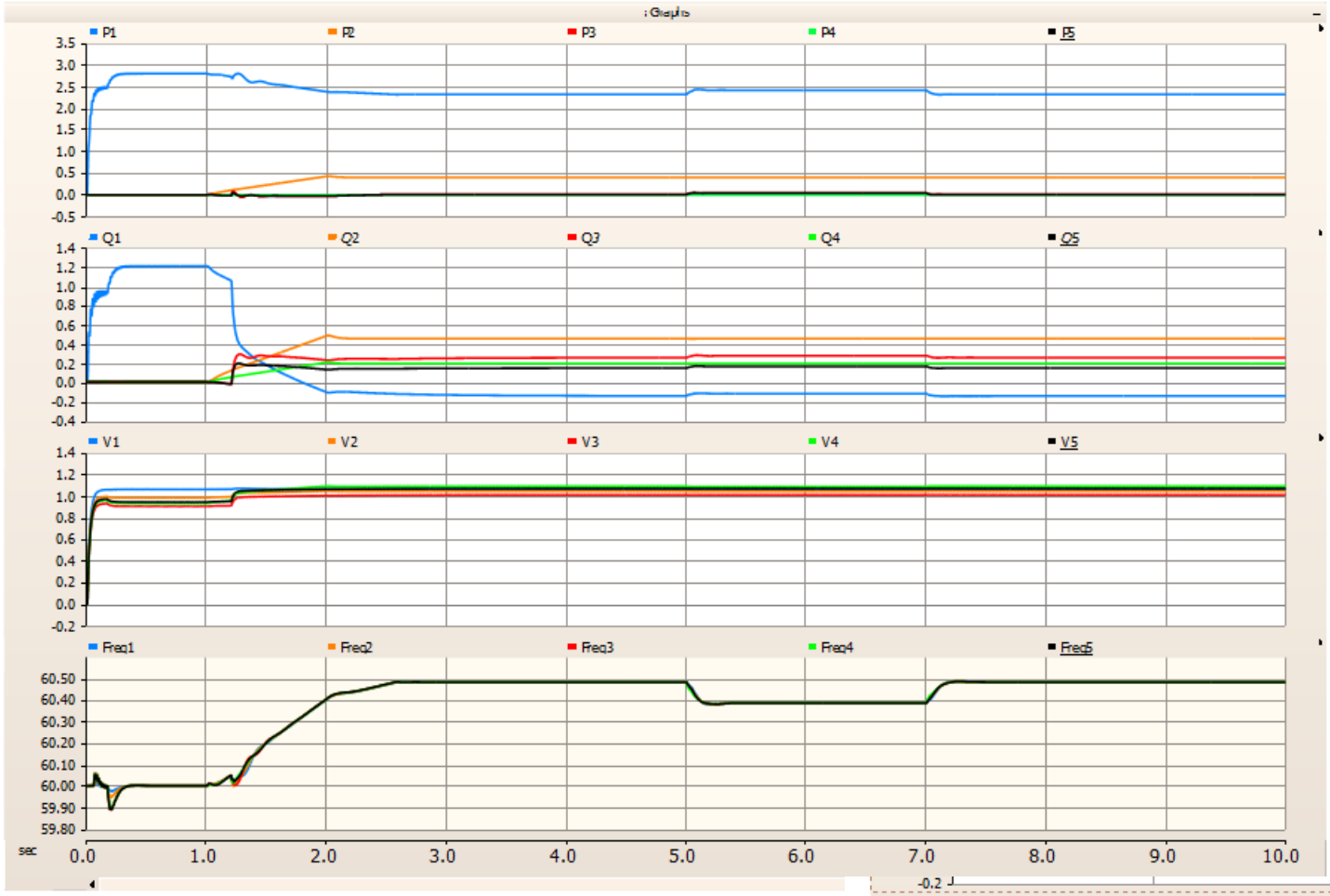


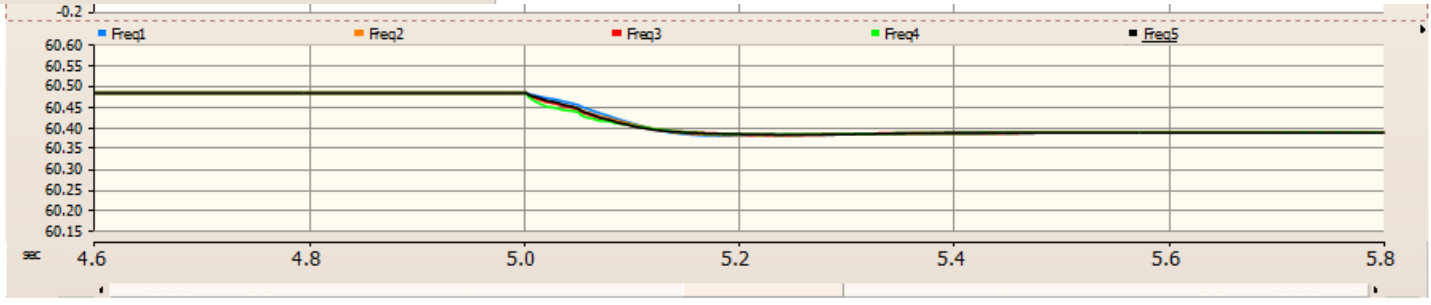


Zero Inertia (All Inverter): GFM3 : GFL 2

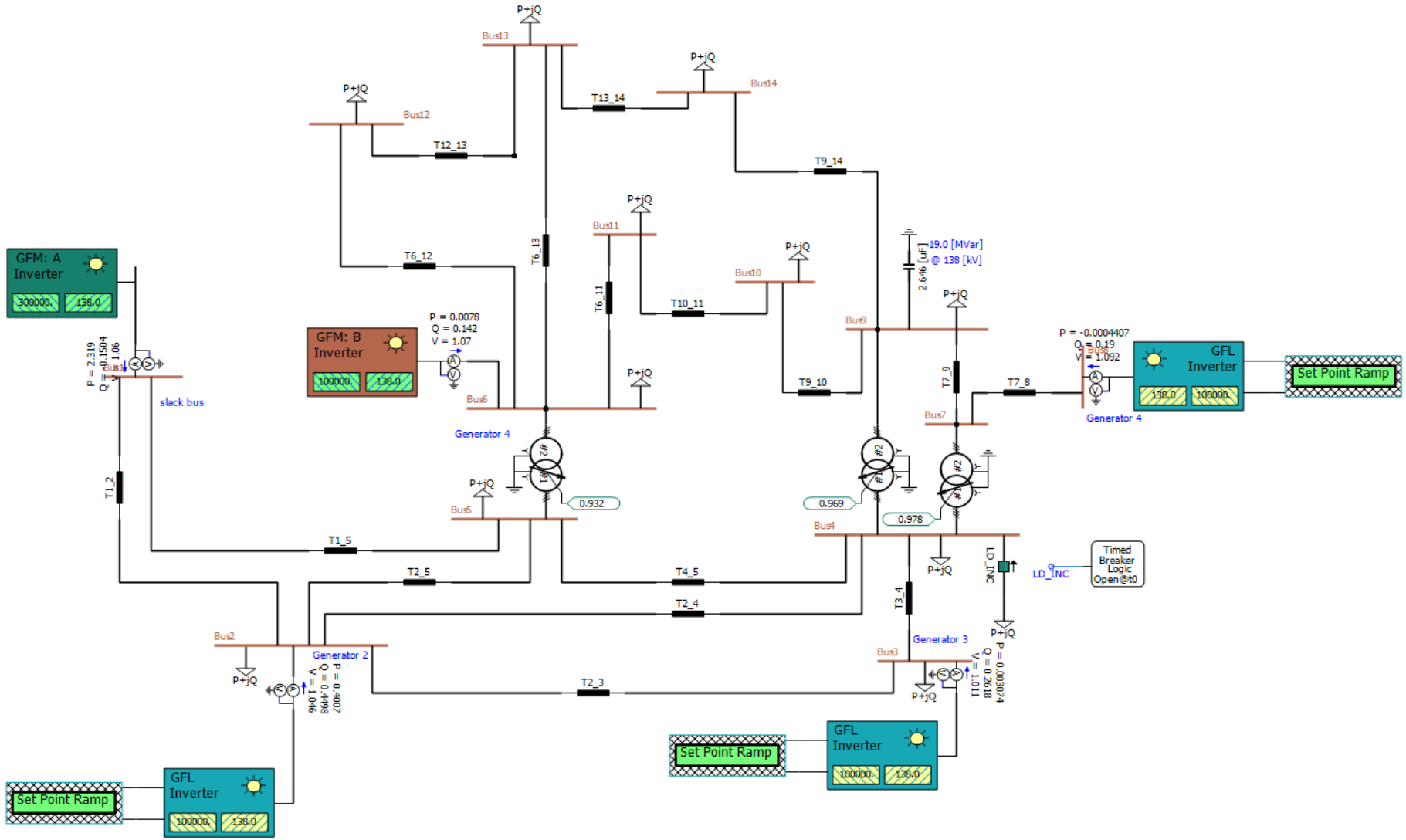


Zero Inertia (All Inverter): GFM3 : GFL 2

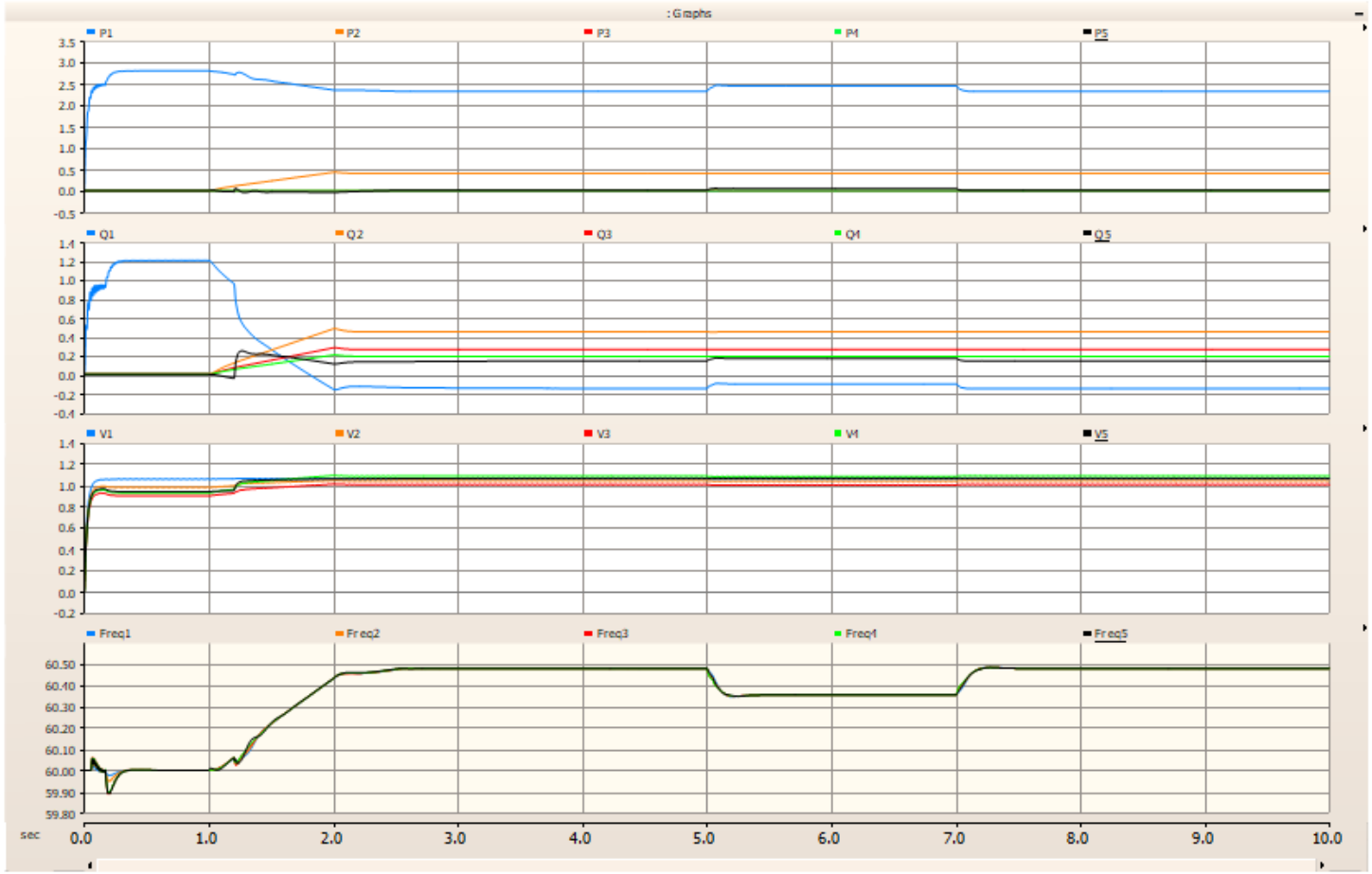


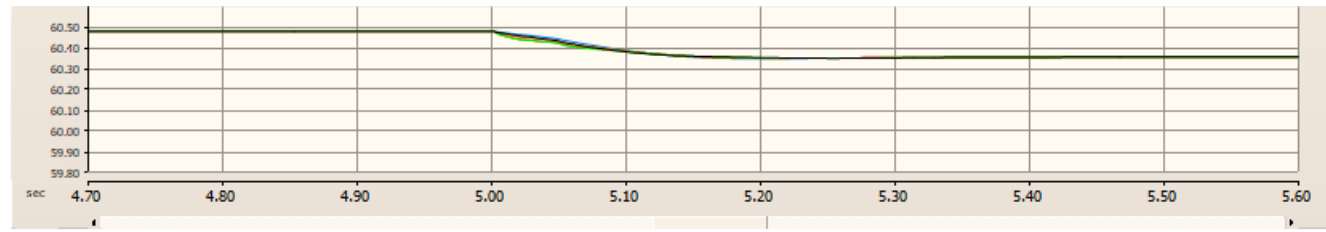


Zero Inertia (All Inverter): GFM2 : GFL 3

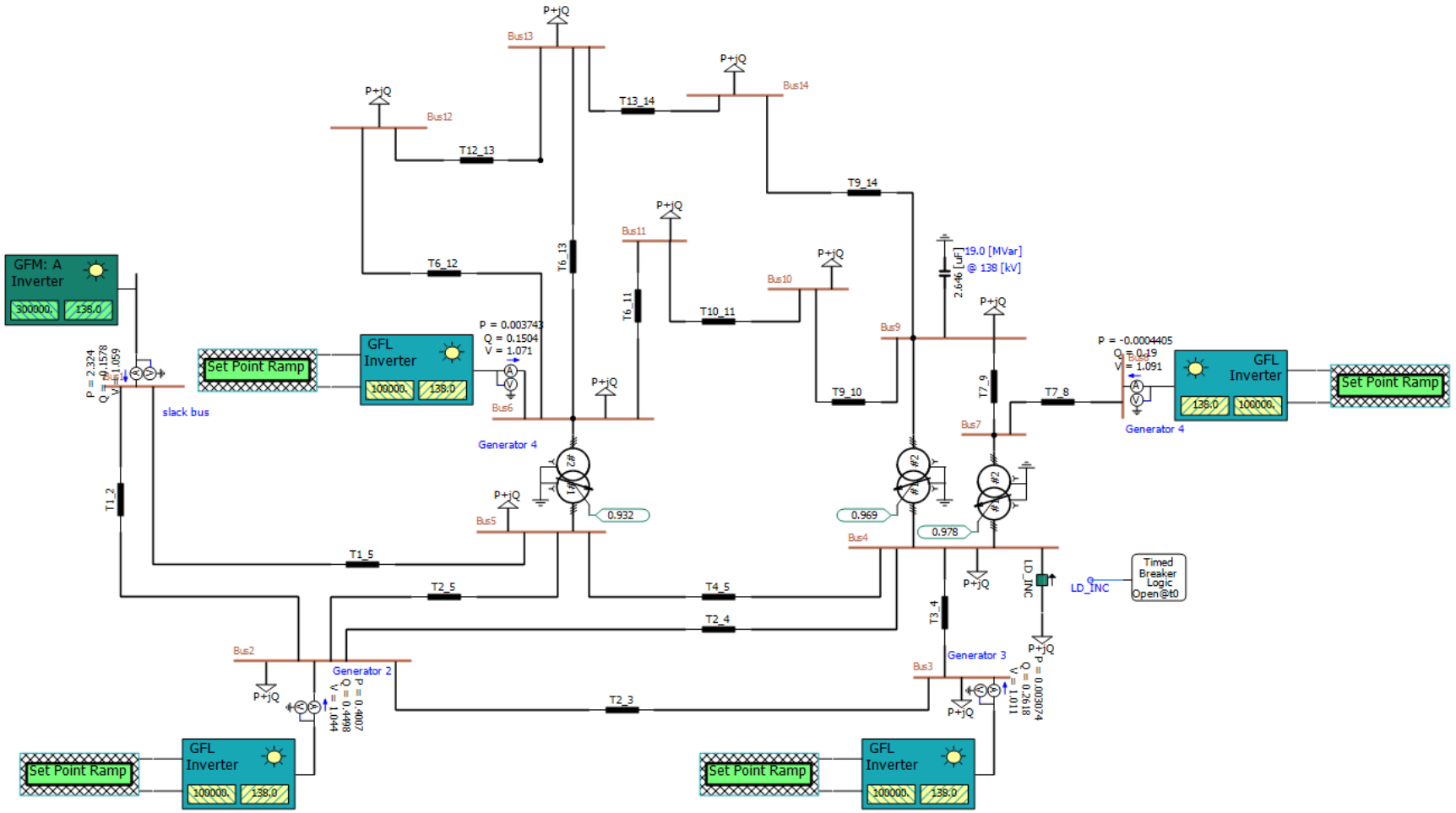


Zero Inertia (All Inverter): GFM2 : GFL 3

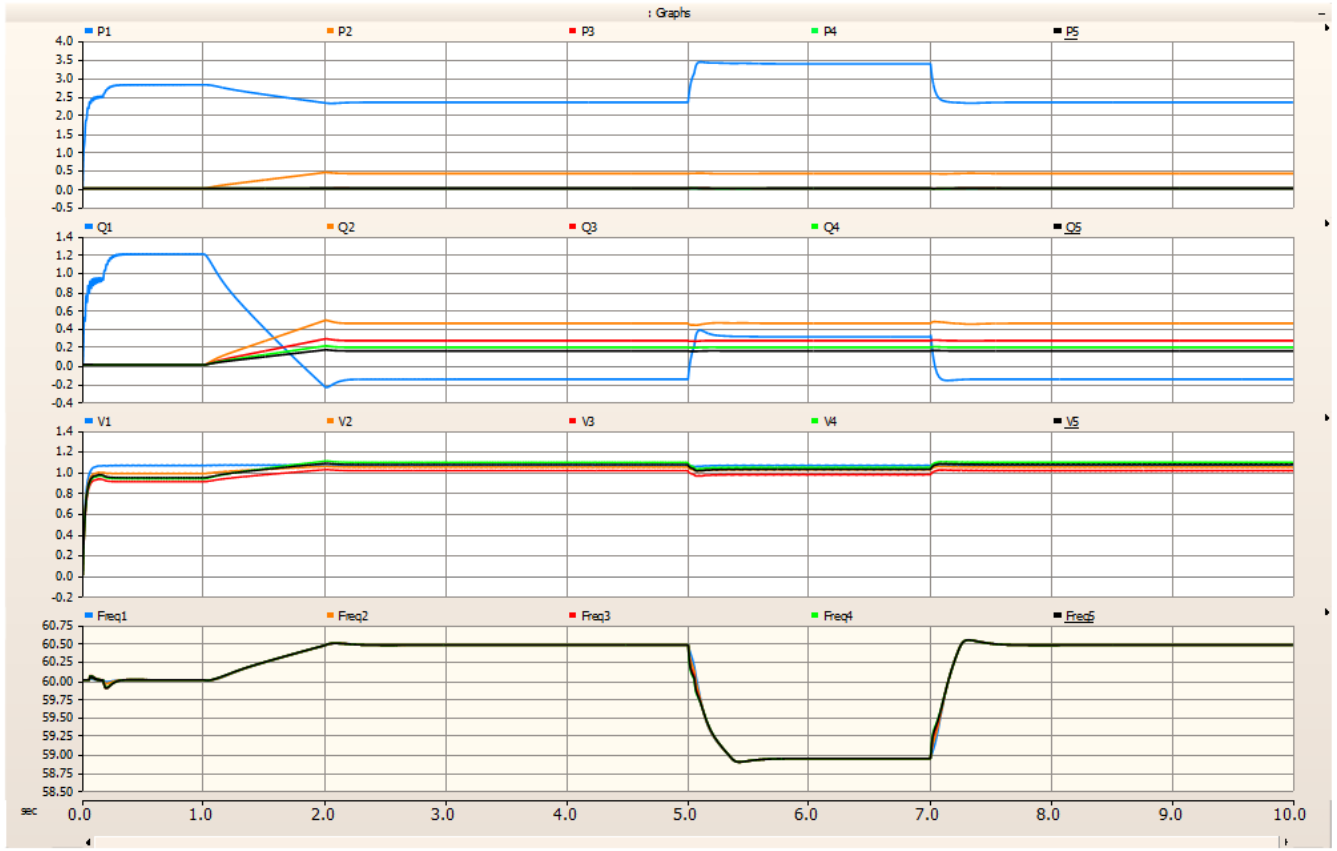




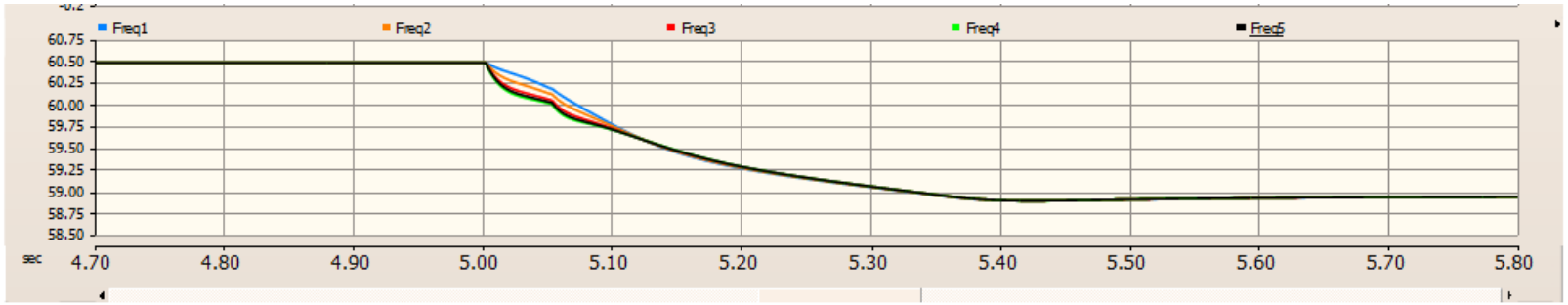
Zero Inertia (All Inverter): GFM1 : GFL 4



Zero Inertia (All Inverter): GFM1 : GFL 4

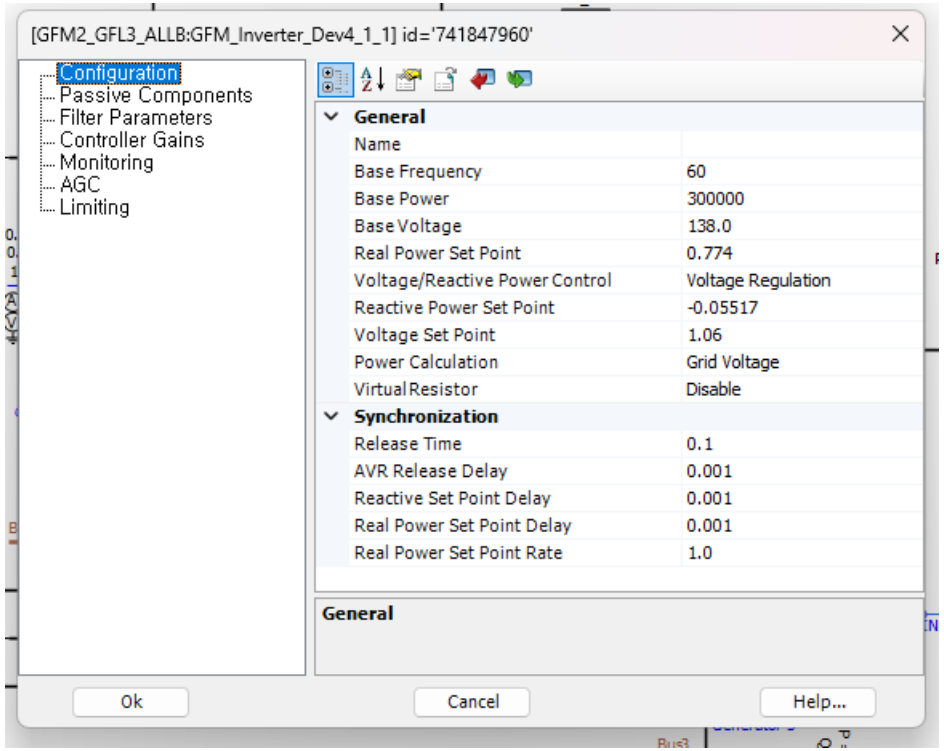


Collapse!

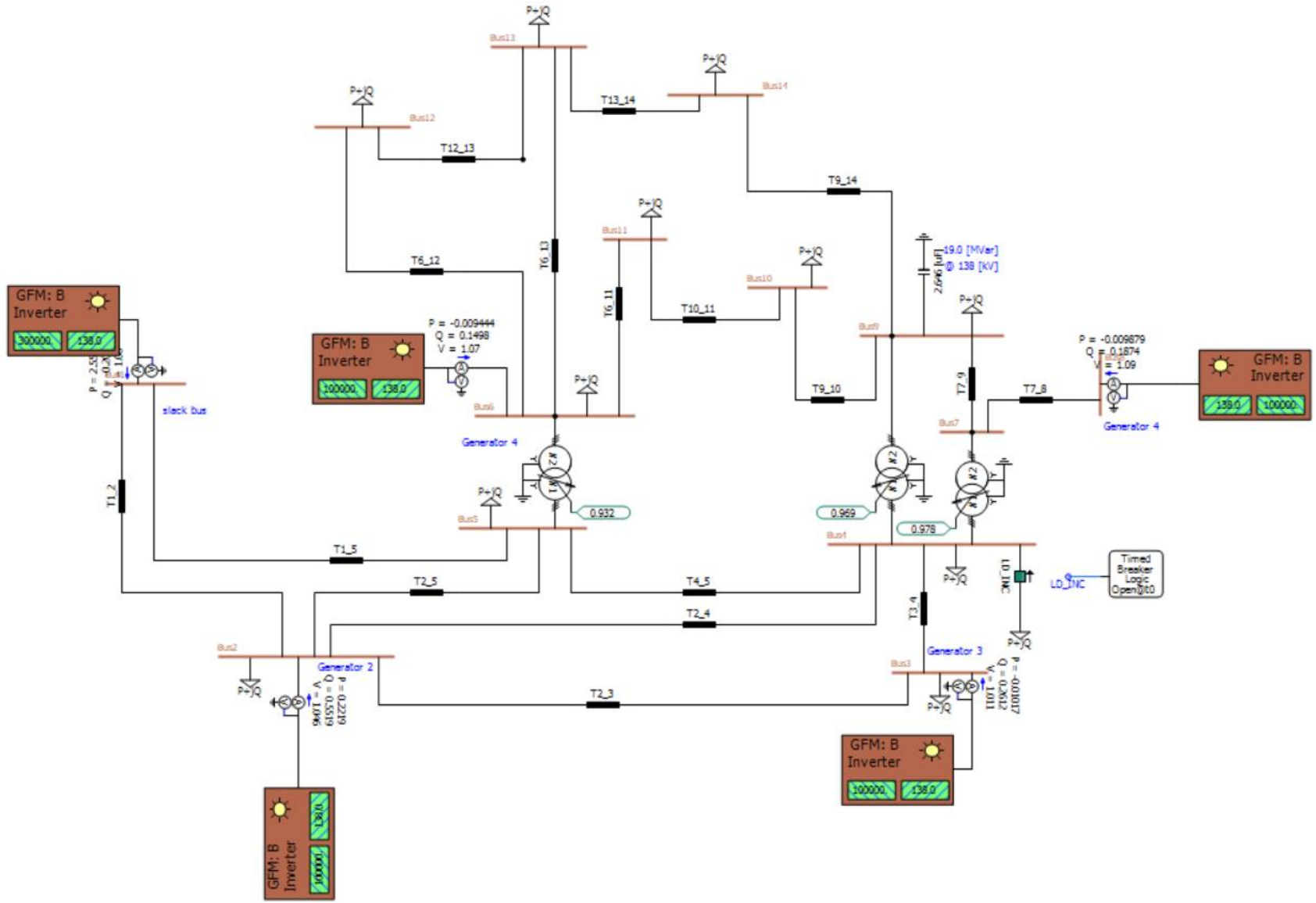


Zero Inertia Kenyon GFM B Model

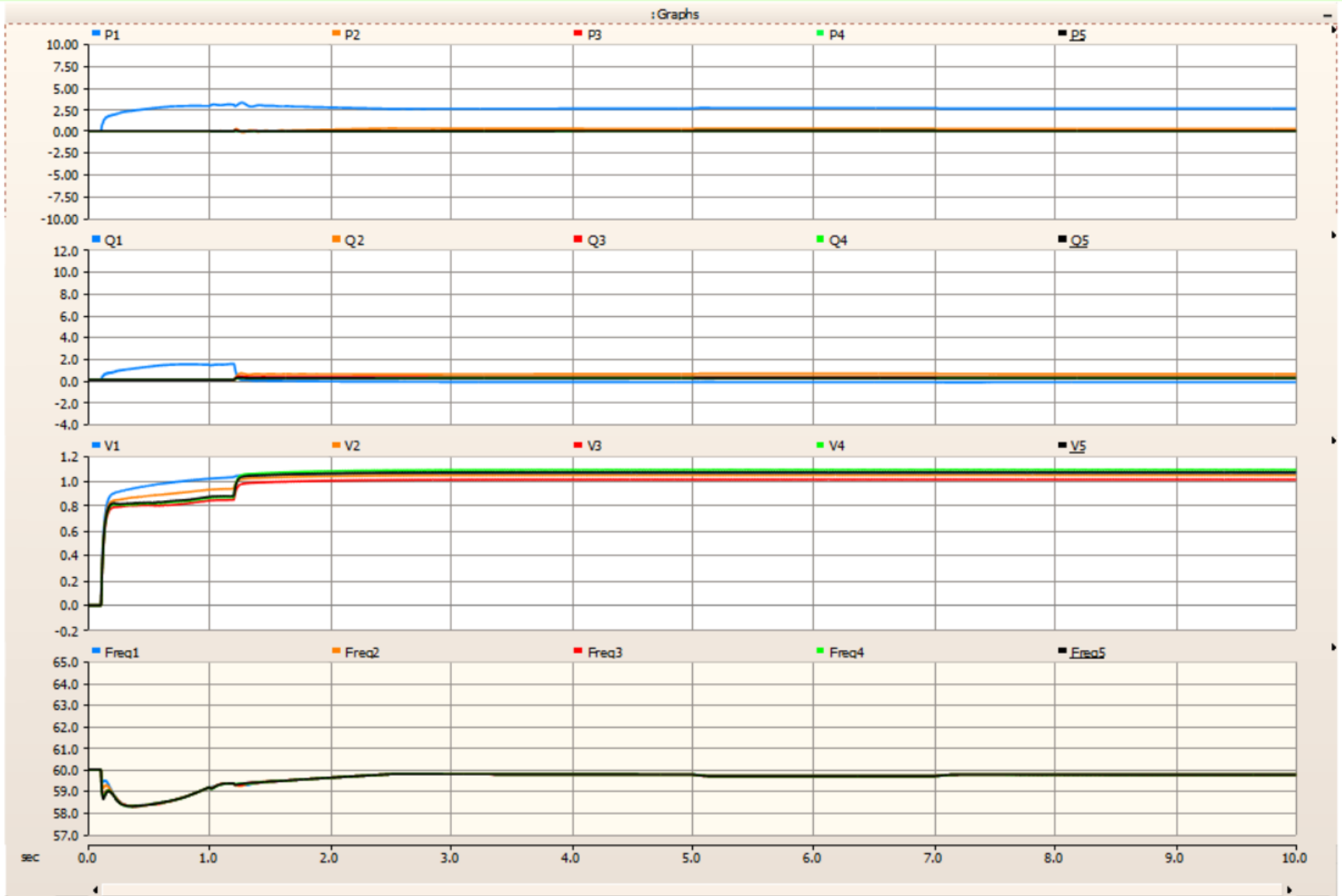
Slack GFM B Synchronization is earlier than other GFM buses (similar to ideal case)



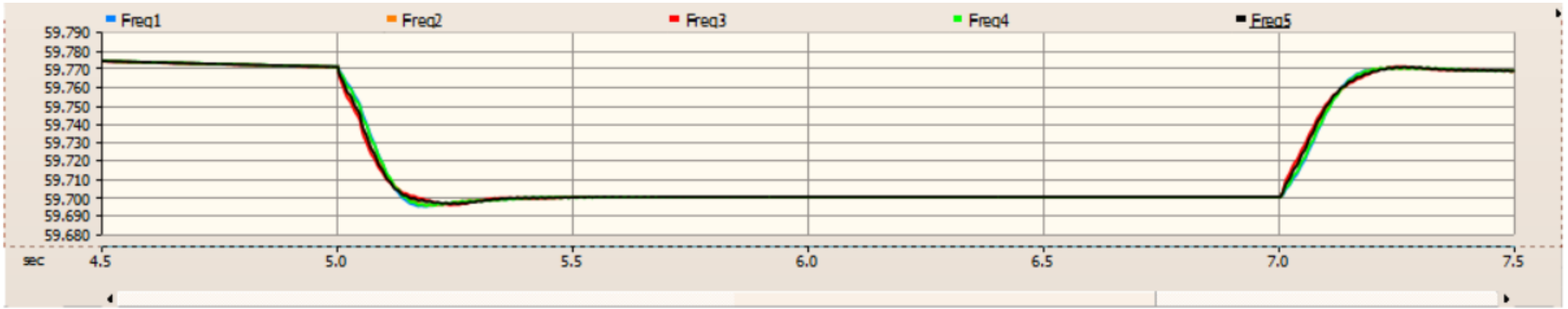
Zero Inertia (All Inverter): GFM5 : GFL 0 (GFM B Slack)



Zero Inertia (All Inverter): GFM5 : GFL 0 (GFM B Slack)

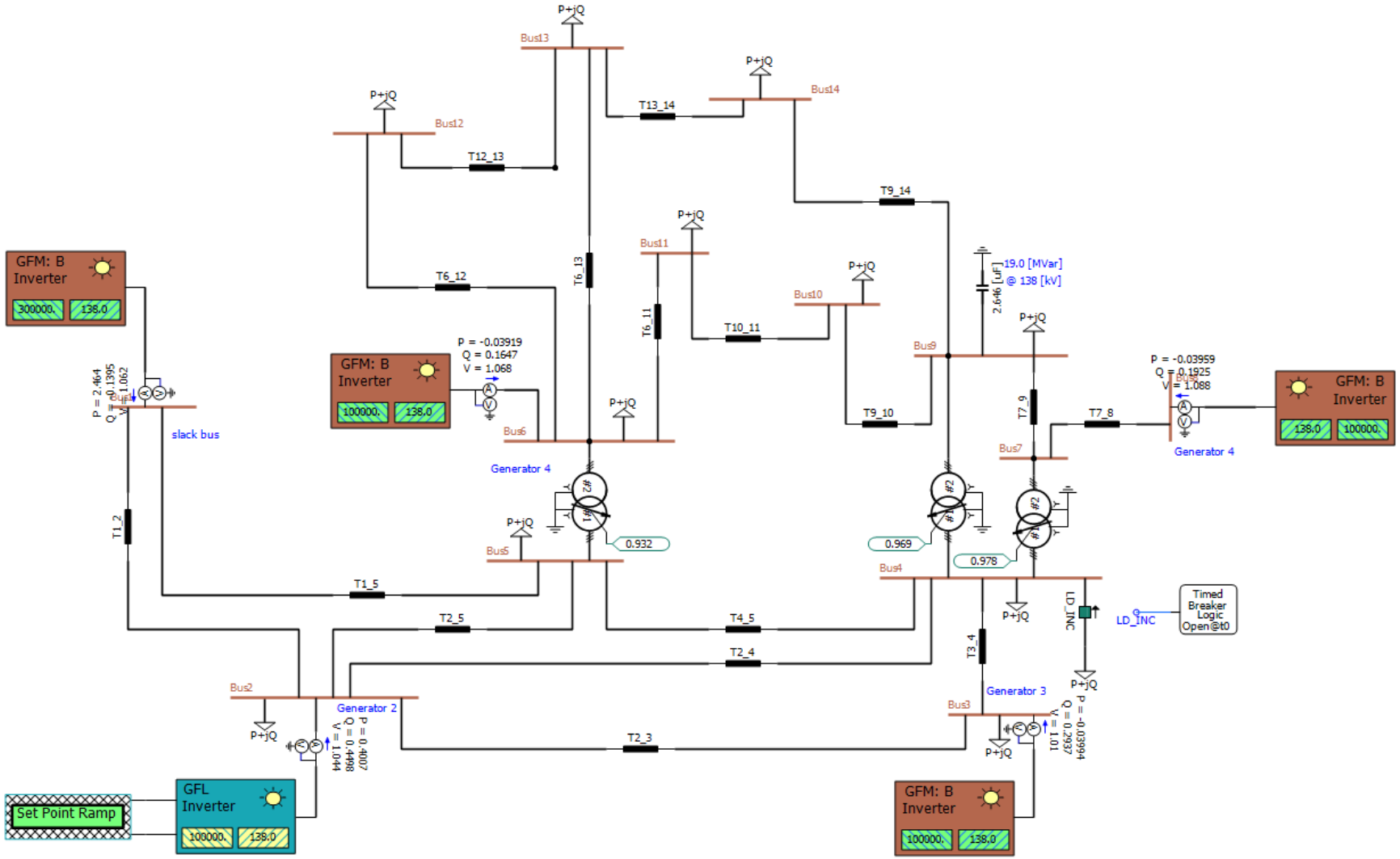


Zero Inertia (All Inverter): GFM5 : GFL 0 (GFM B Slack)

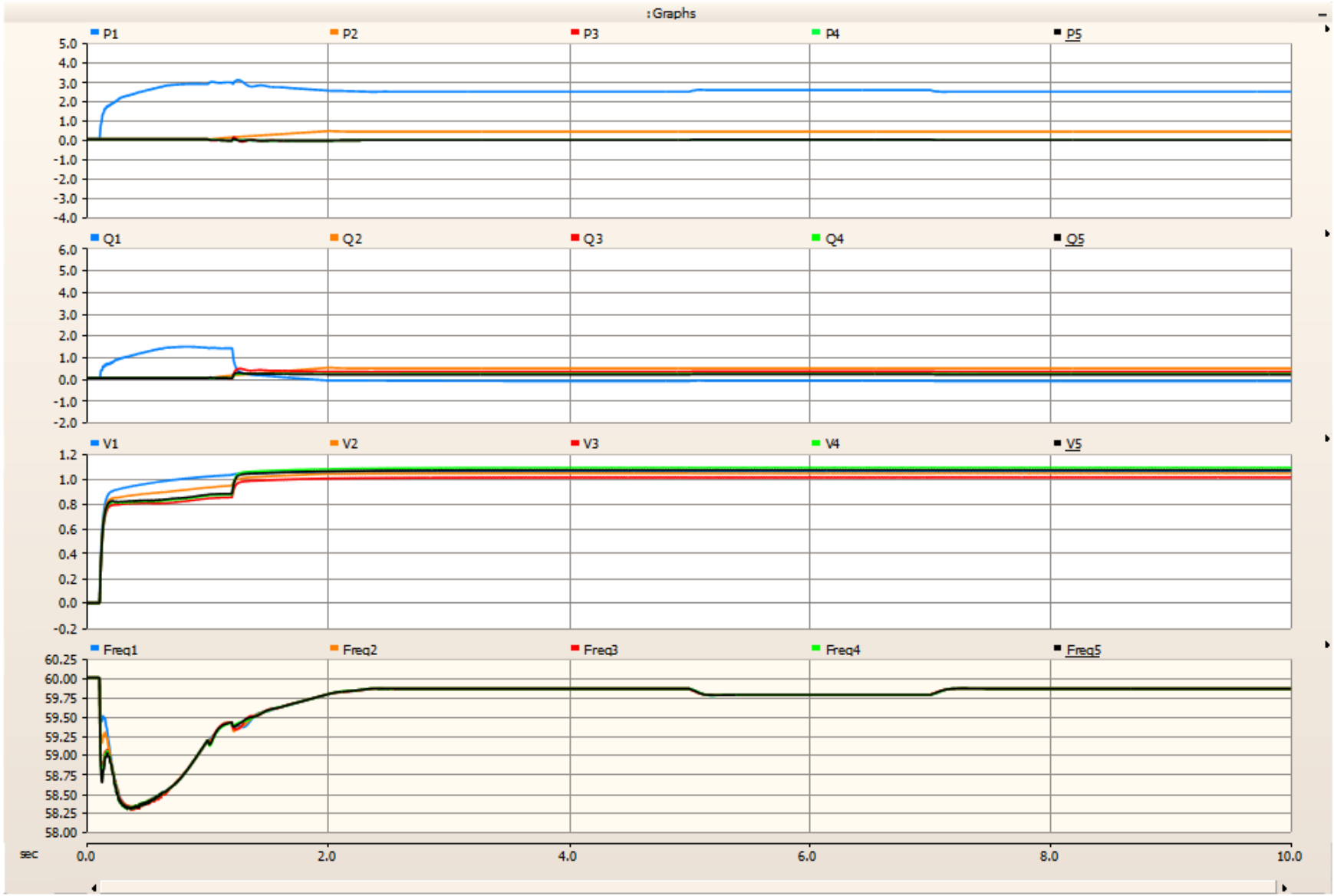


59.775 – 59.695 = 0.08

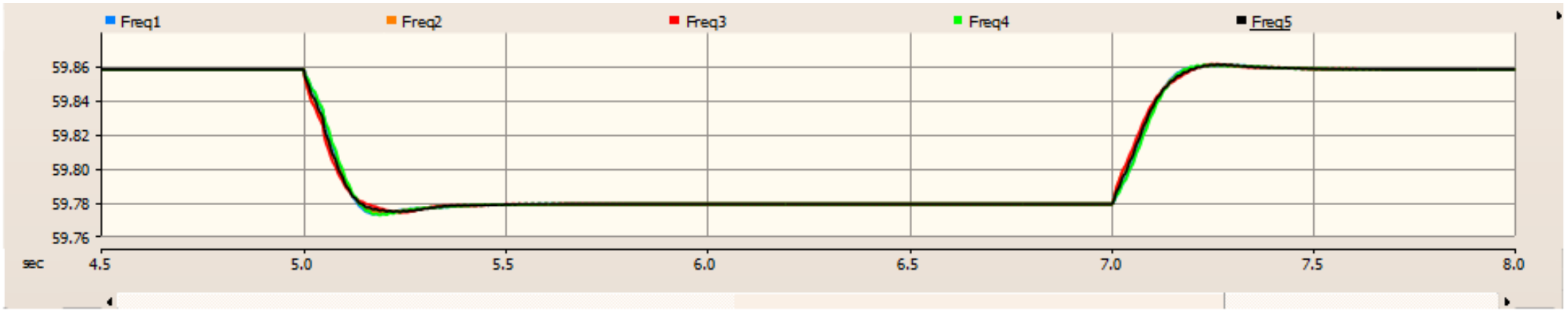
Zero Inertia (All Inverter): GFM4 : GFL 1 (GFM B Slack)



Zero Inertia (All Inverter): GFM4 : GFL 1 (GFM B Slack)

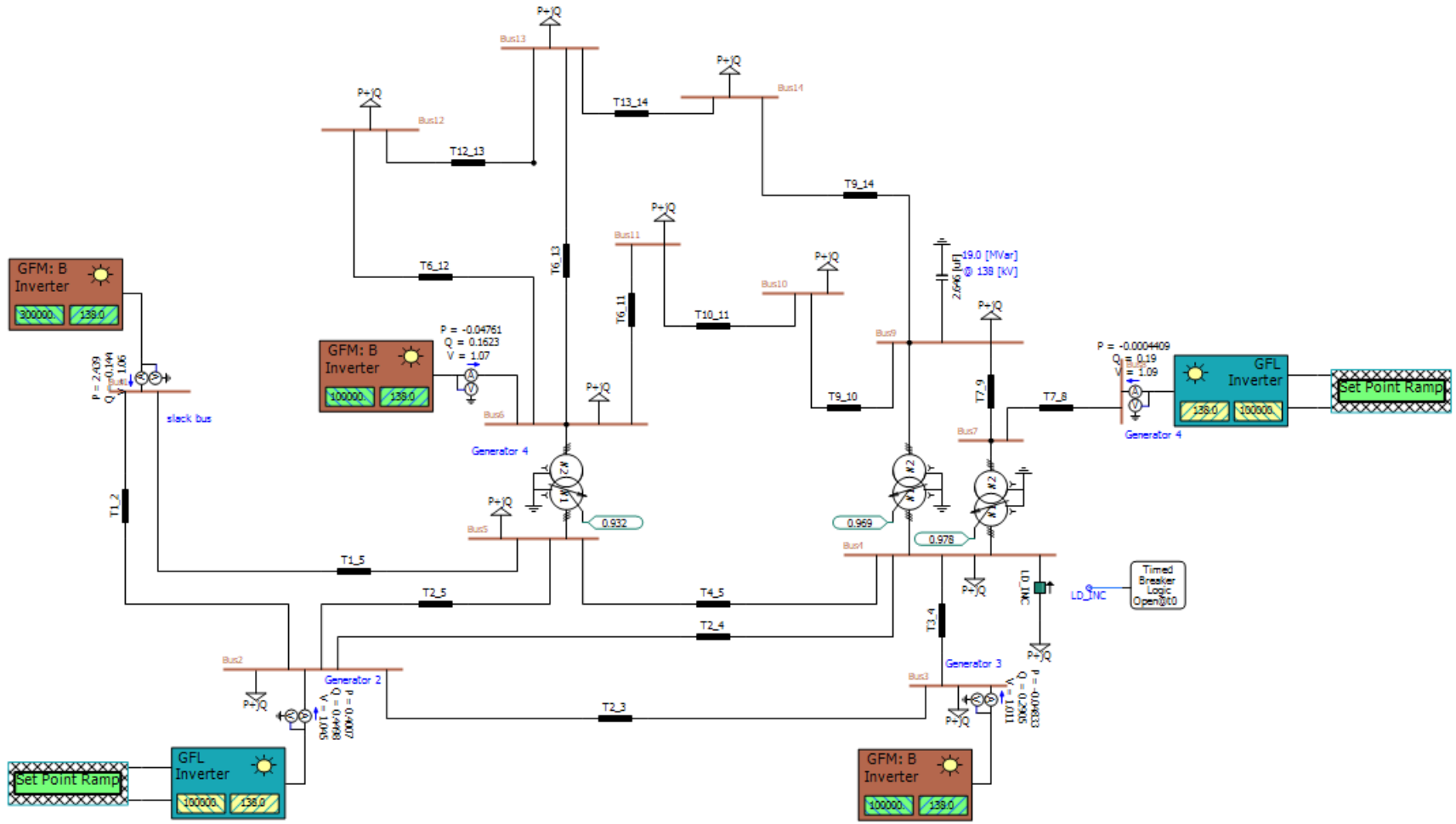


Zero Inertia (All Inverter): GFM4 : GFL 1 (GFM B Slack)

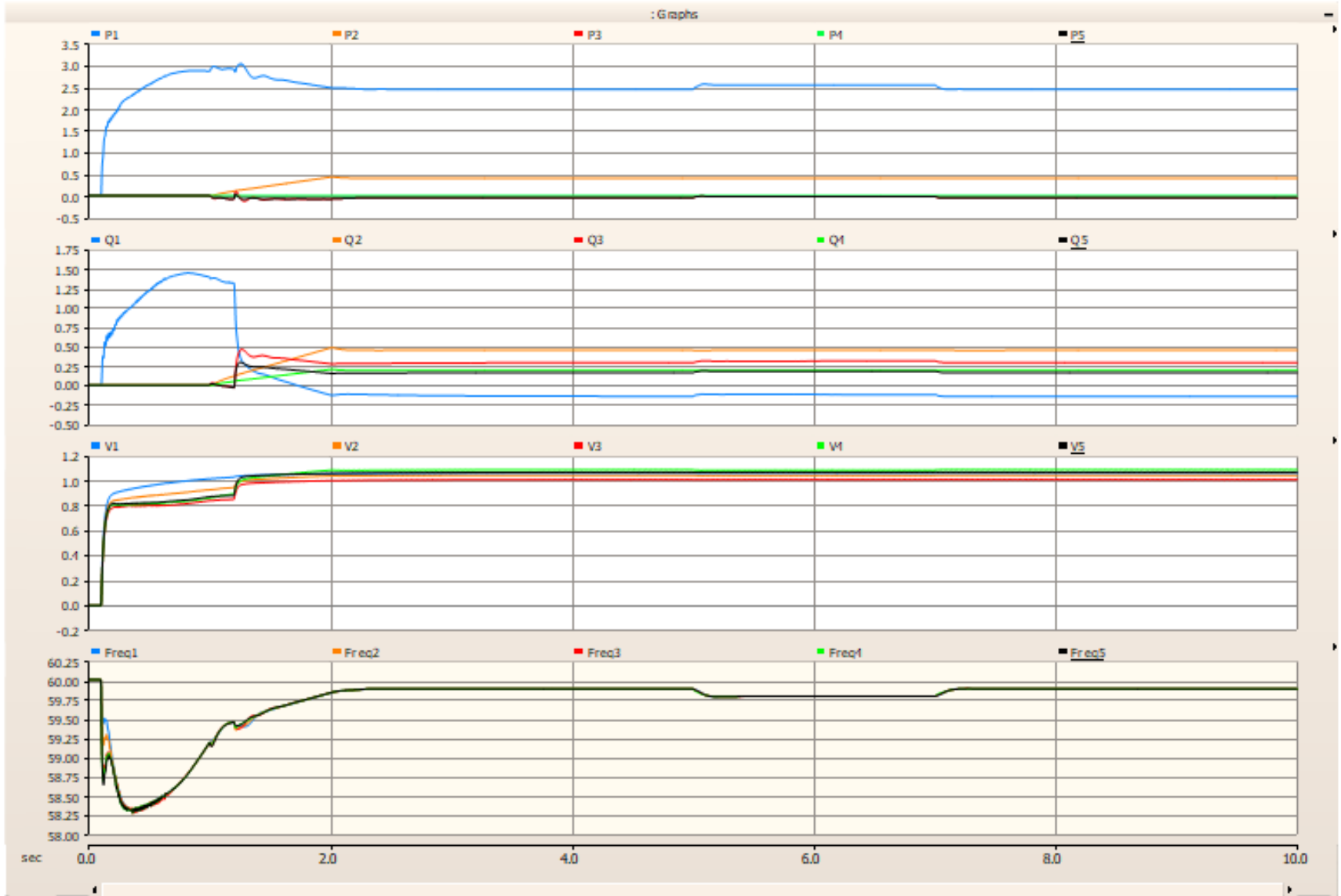


59.86 – 59.778 = 0.82

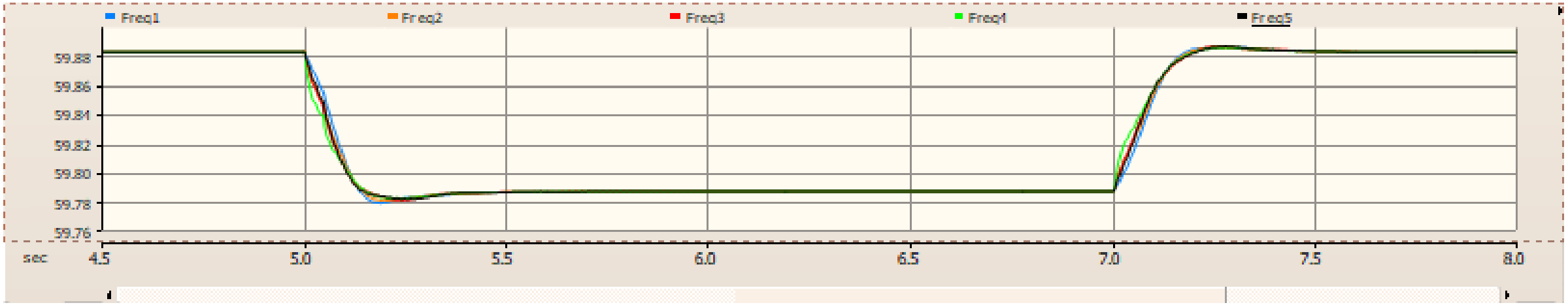
Zero Inertia (All Inverter): GFM3 : GFL 2 (GFM B Slack)



Zero Inertia (All Inverter): GFM3 : GFL 2 (GFM B Slack)

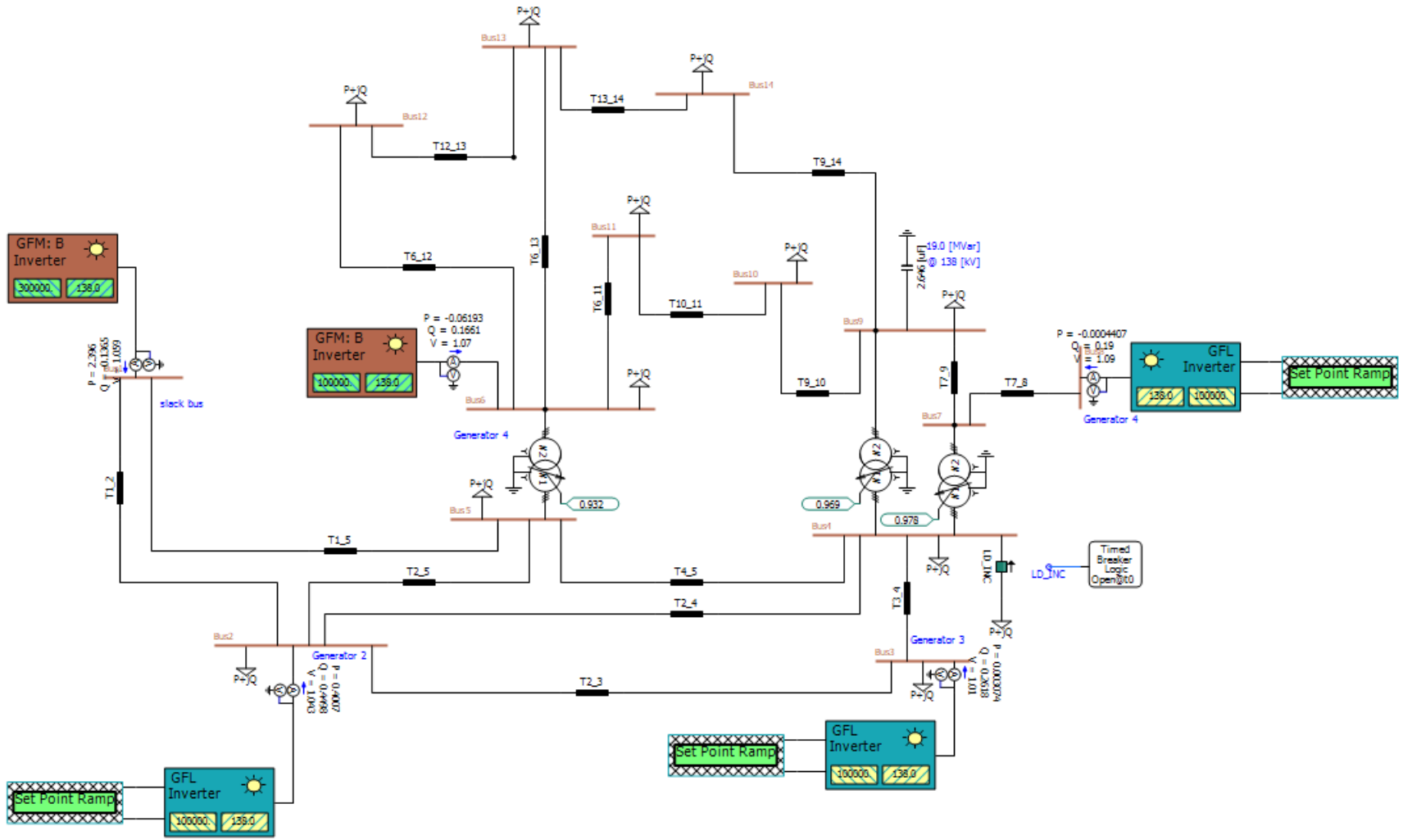


Zero Inertia (All Inverter): GFM3 : GFL 2 (GFM B Slack)

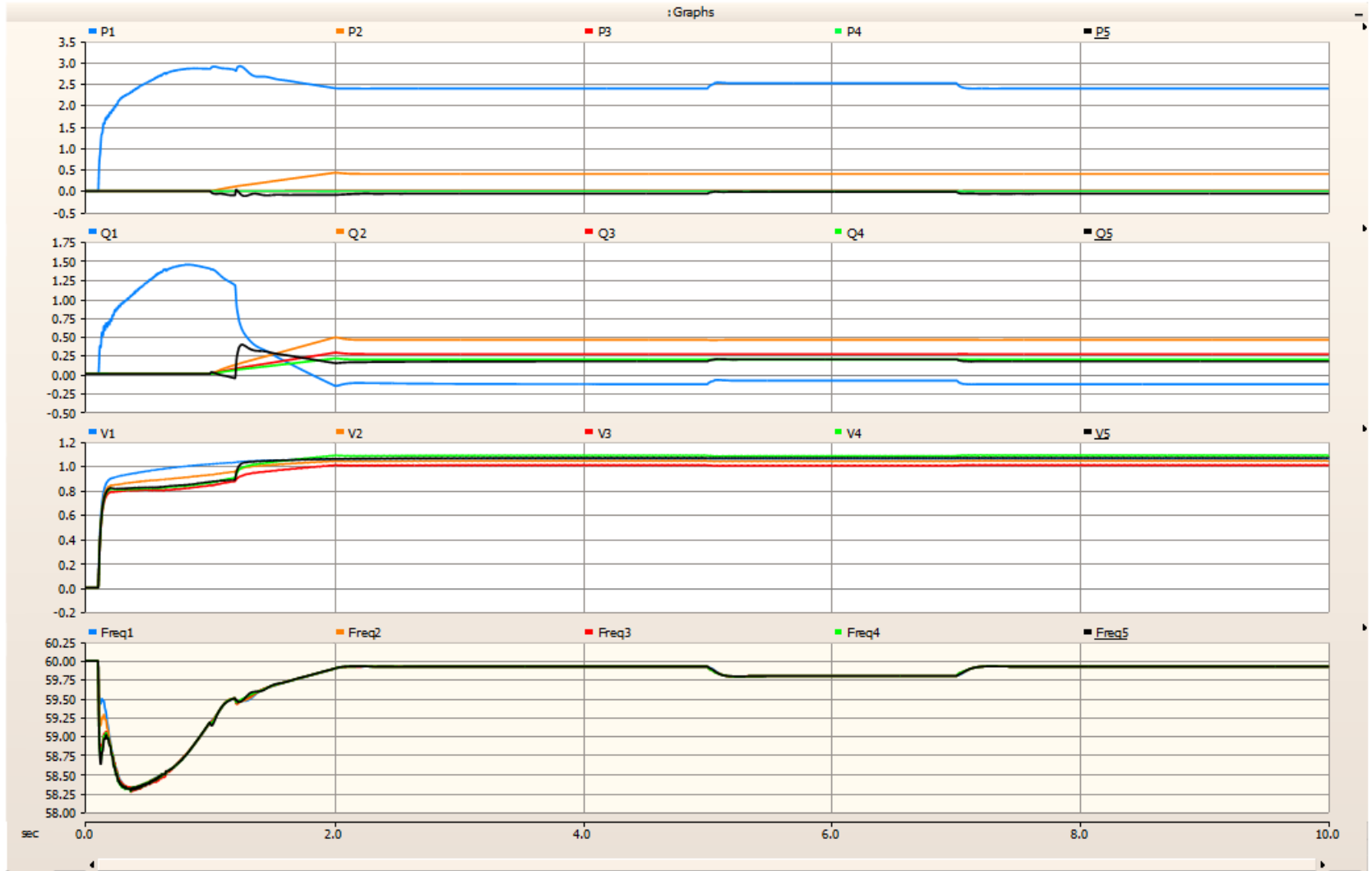


59.88 – 59.78 = 0.10

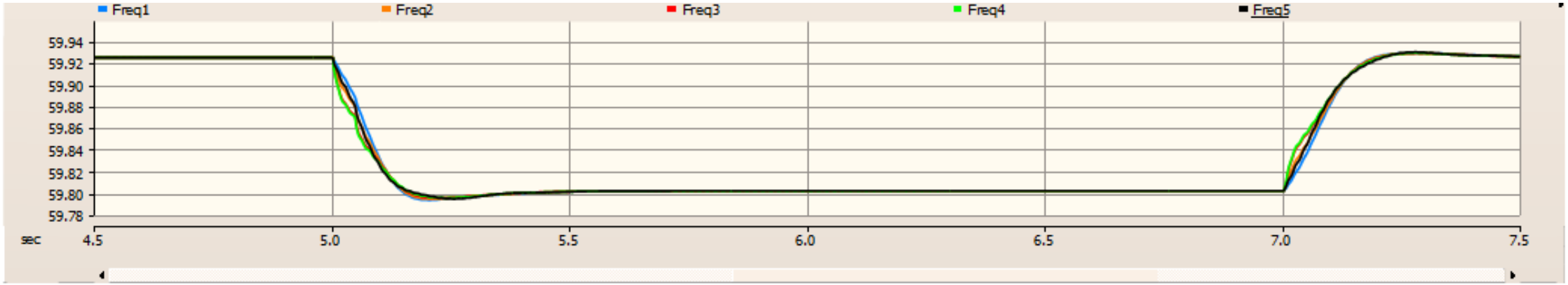
Zero Inertia (All Inverter): GFM2 : GFL 3 (GFM B Slack)



Zero Inertia (All Inverter): GFM2 : GFL 3 (GFM B Slack)

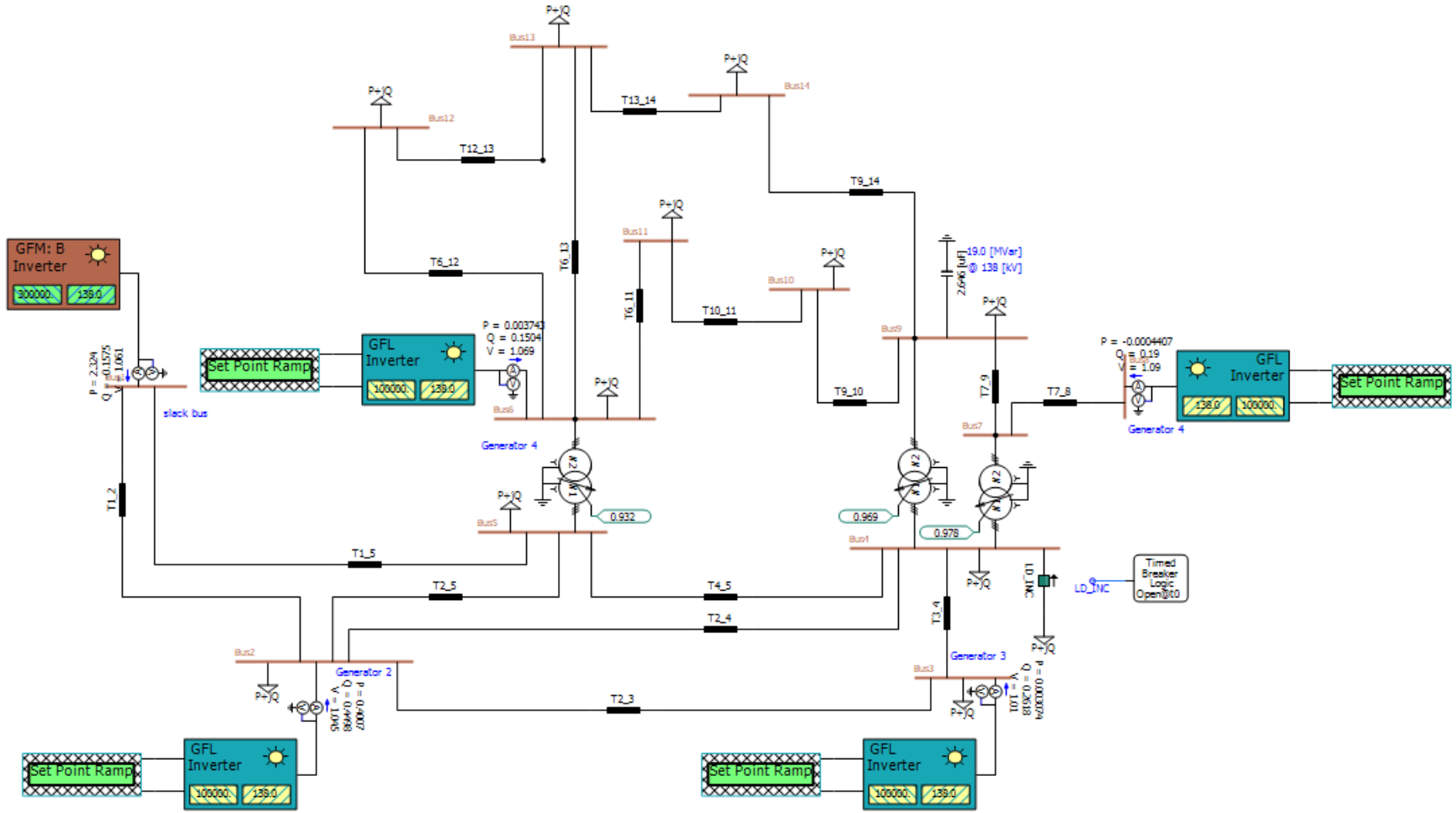


Zero Inertia (All Inverter): GFM2 : GFL 3 (GFM B Slack)

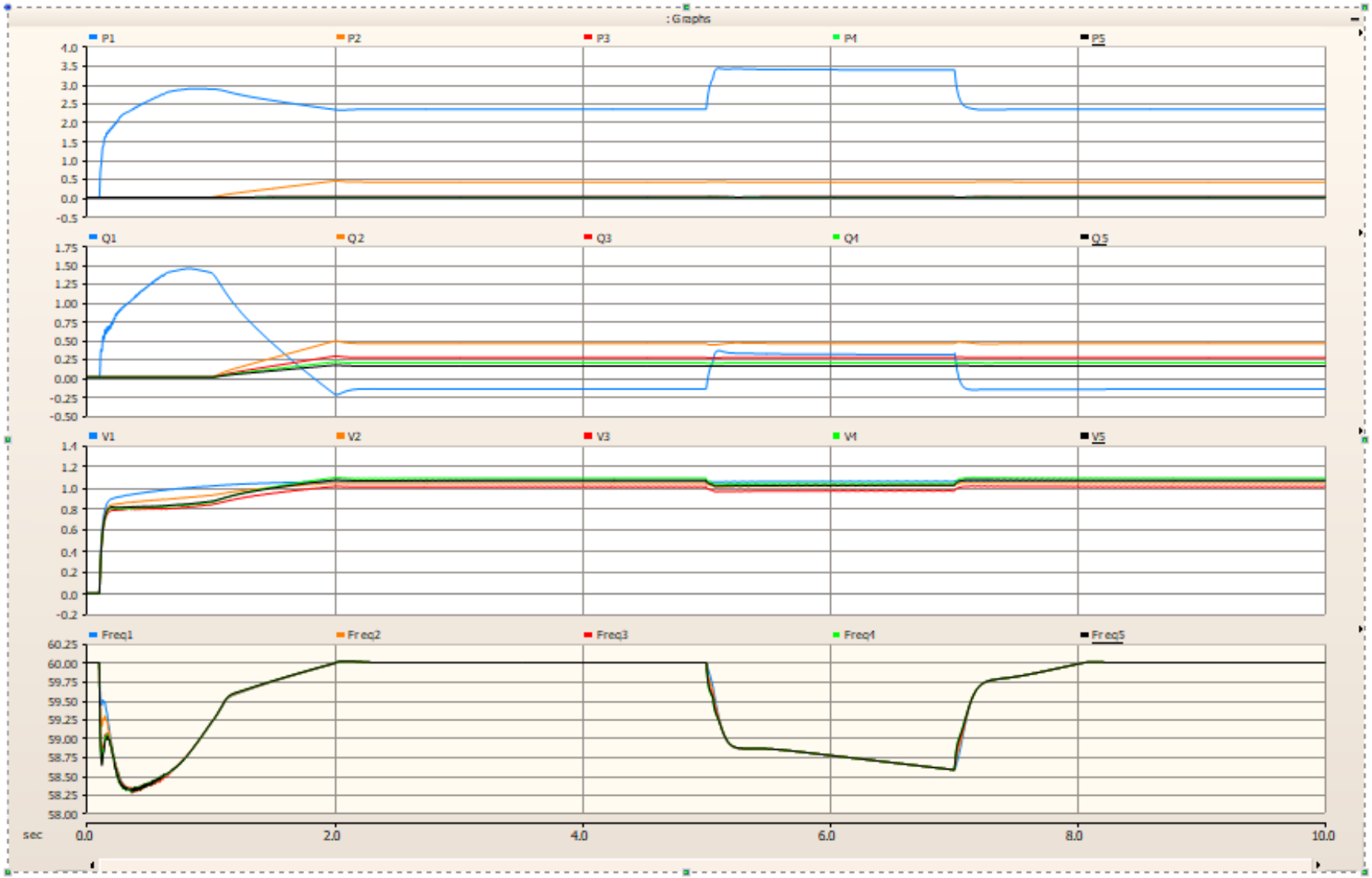


59.926 – 59.796 = 0.130

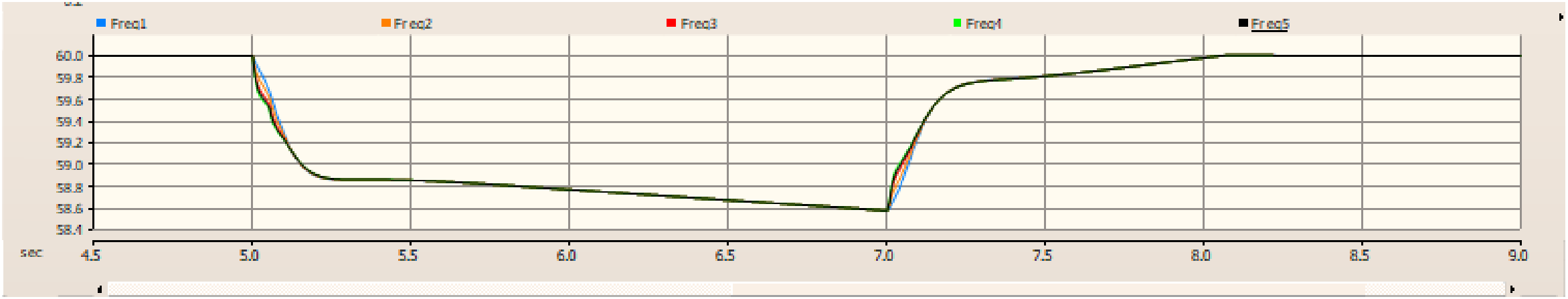
Zero Inertia (All Inverter): GFM1 : GFL 4 (GFM B Slack)



Zero Inertia (All Inverter): GFM0 : GFL 3 (GFM B Slack)



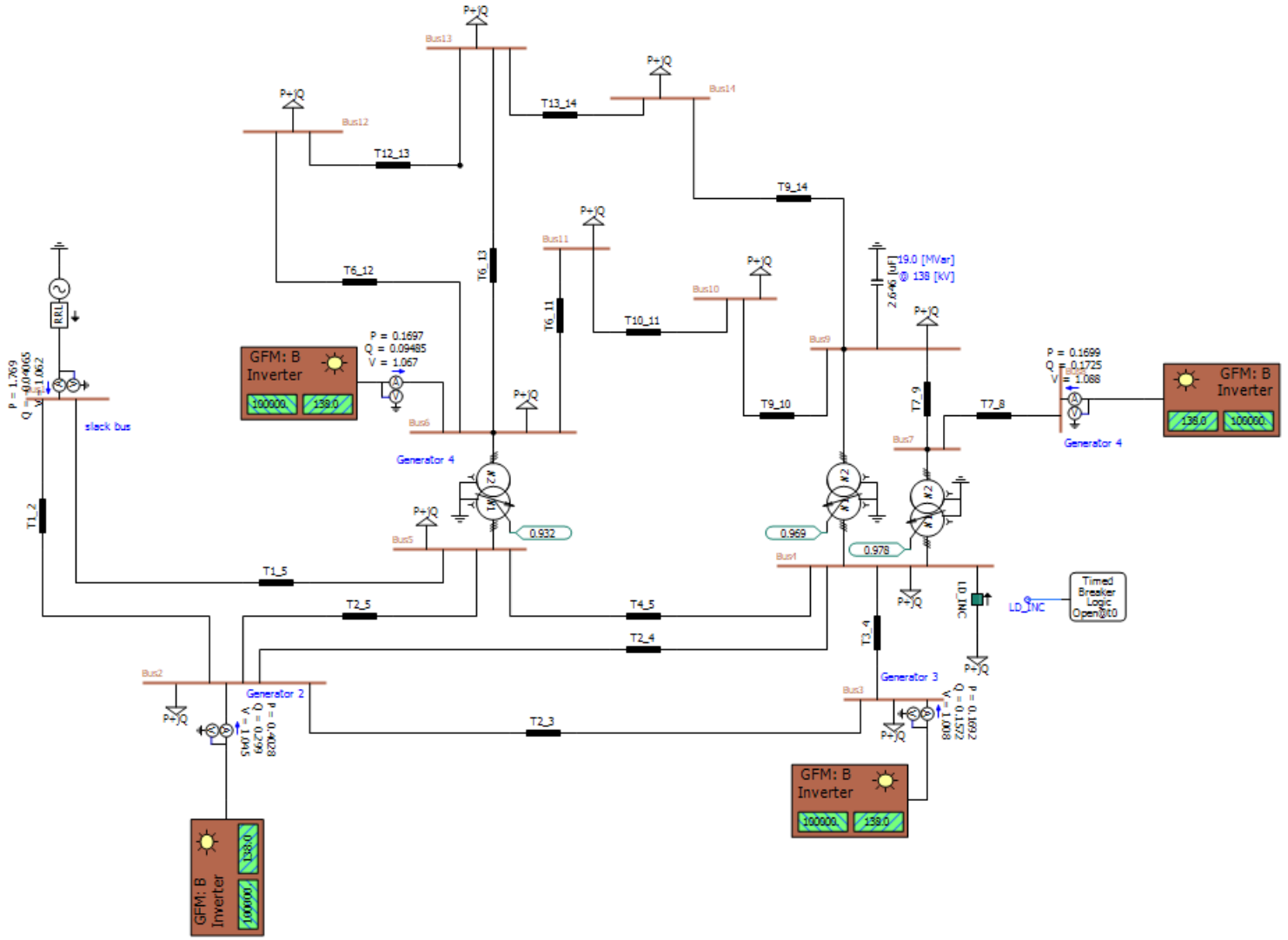
Zero Inertia (All Inverter): GFM0 : GFL 3 (GFM B Slack)



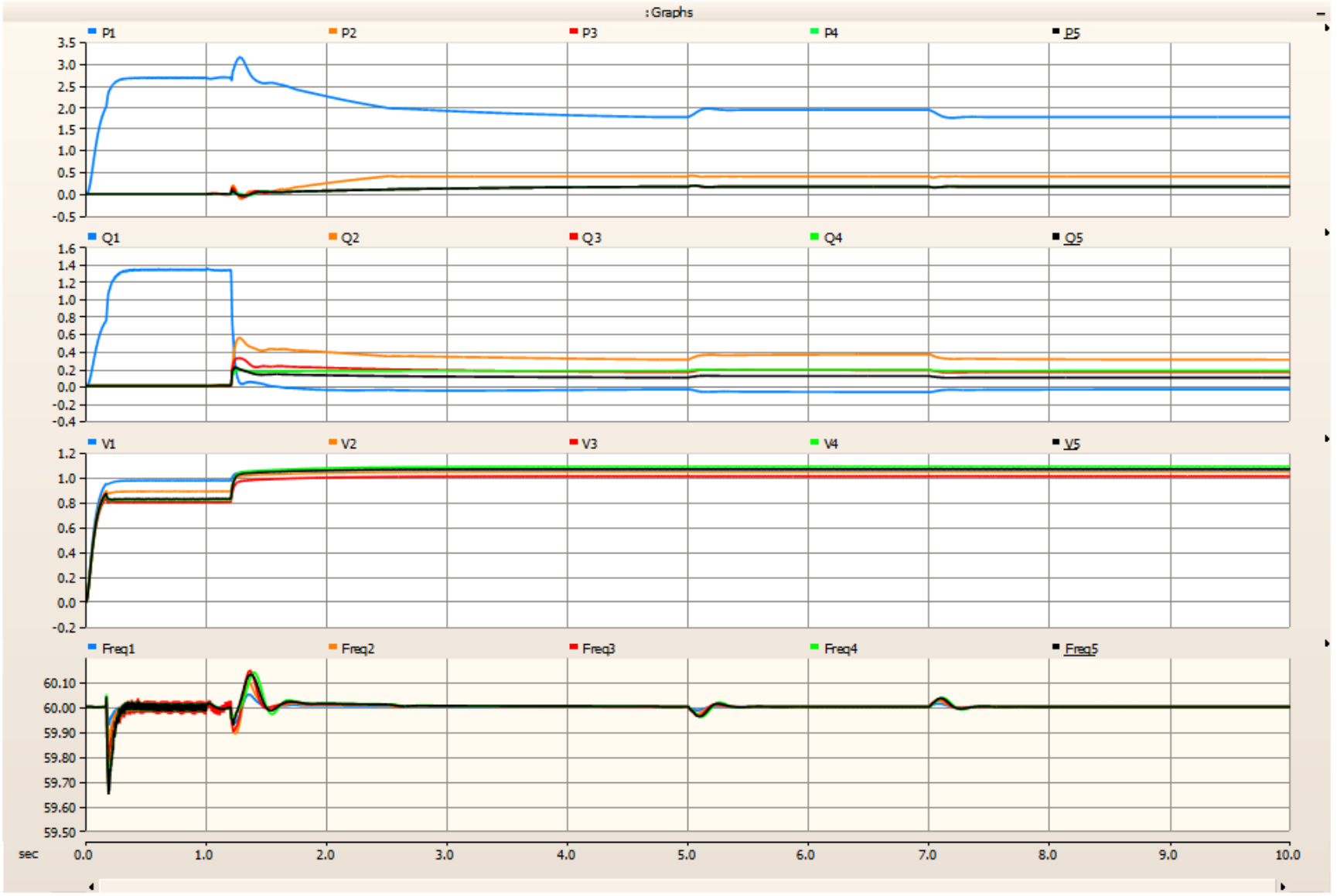
60.00 – 58.867 = 1.133 → Unstable

Ideal Slack Simulations

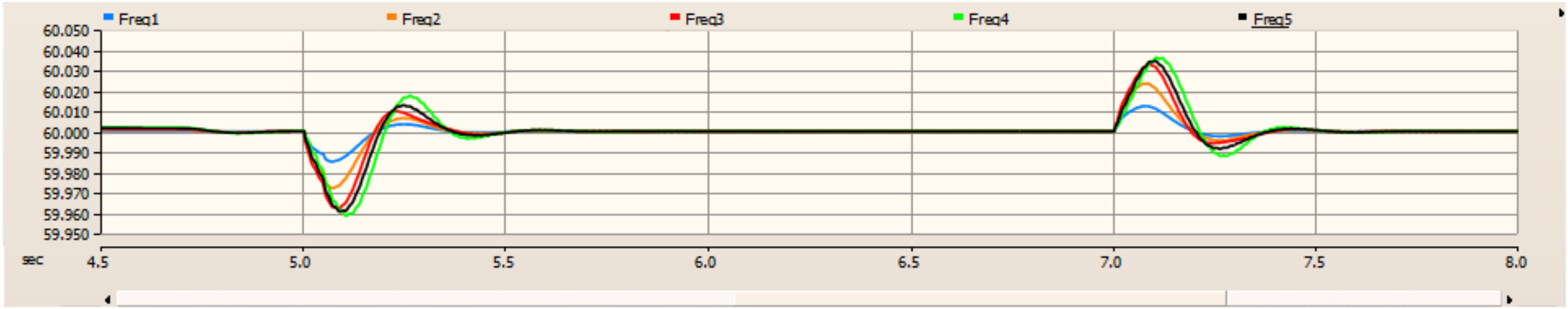
GFM4_GFL0_SLACK



GFM4_GFL0_SLACK

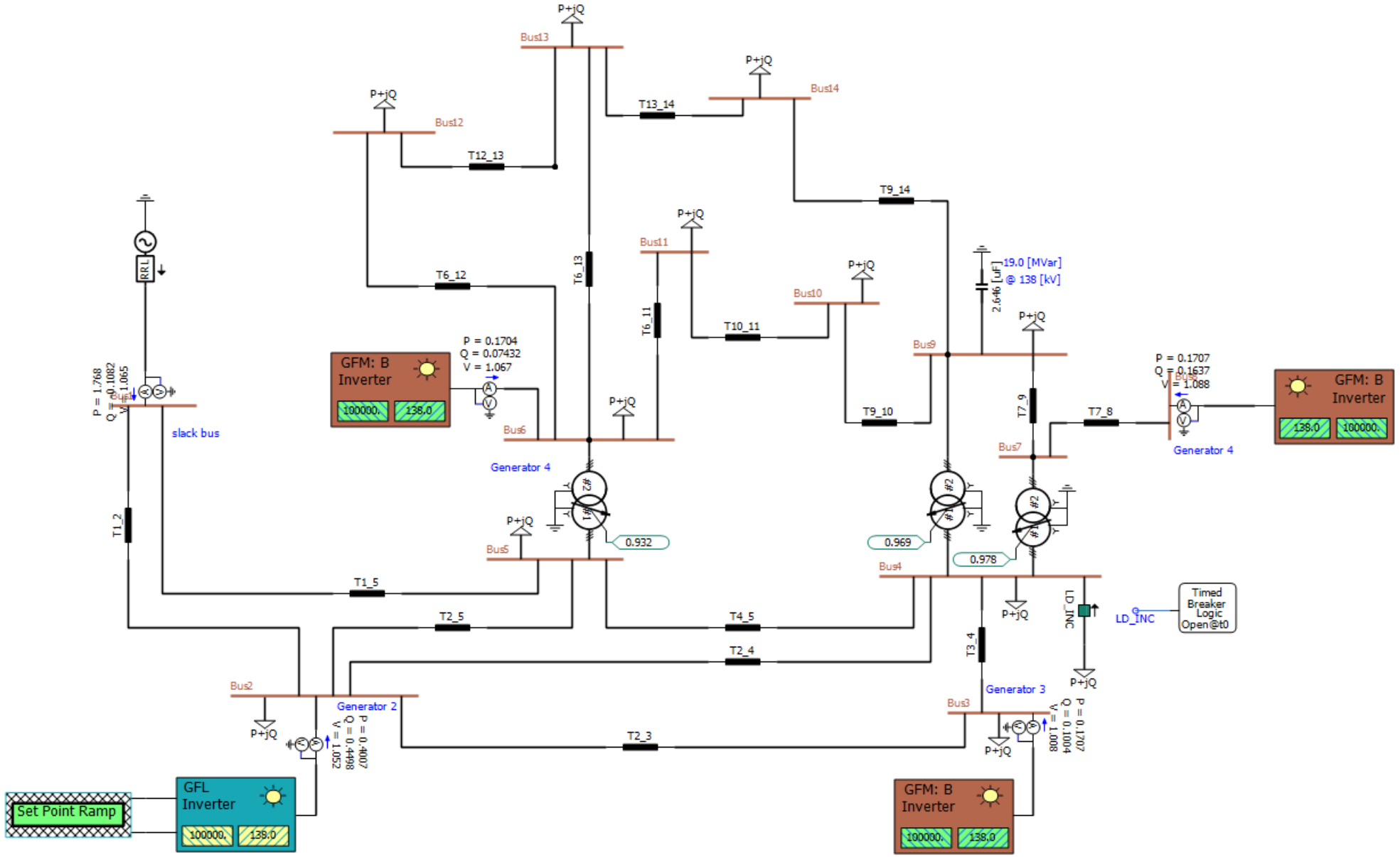


GFM4_GFL0_SLACK

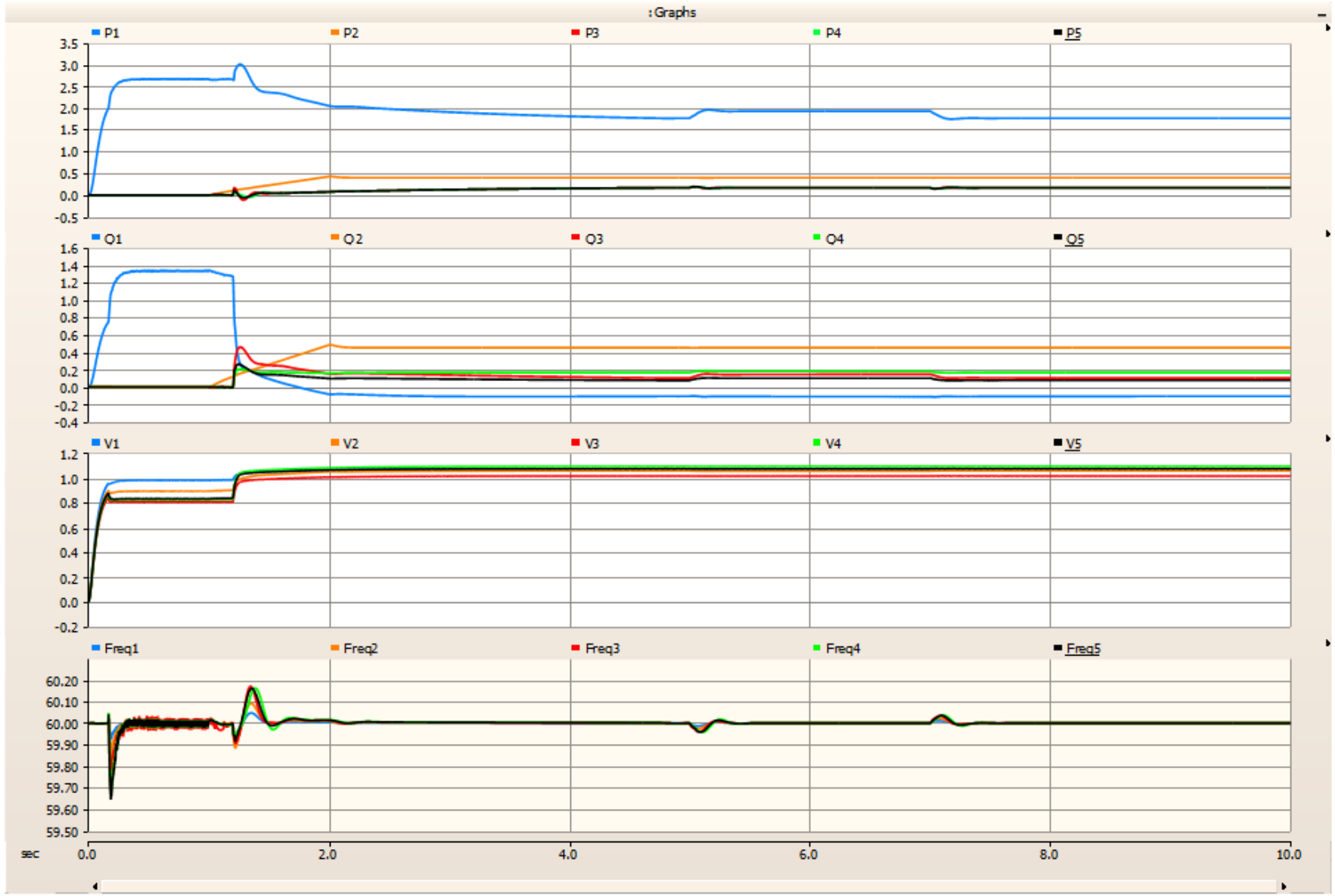


60.00 – 59.96 = 0.04

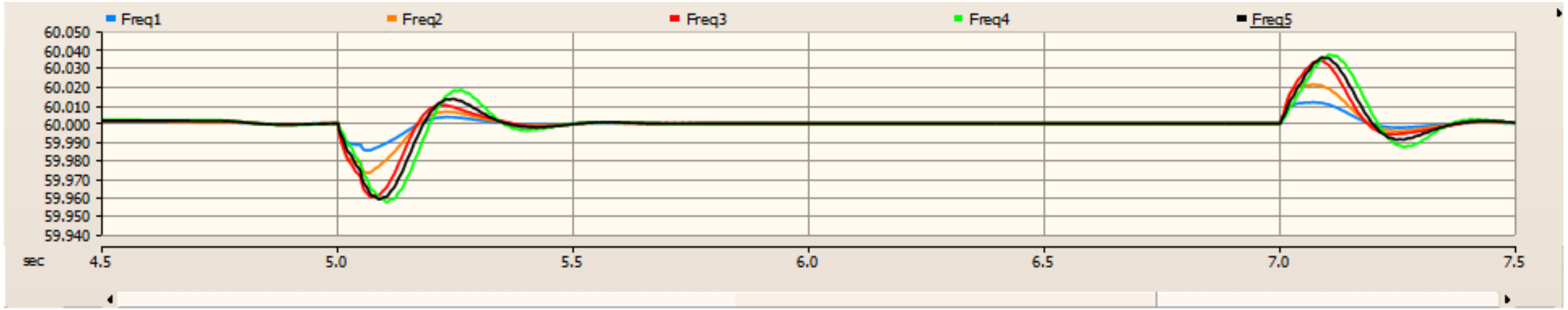
GFM3_GFL1_SLACK



GFM3_GFL1_SLACK

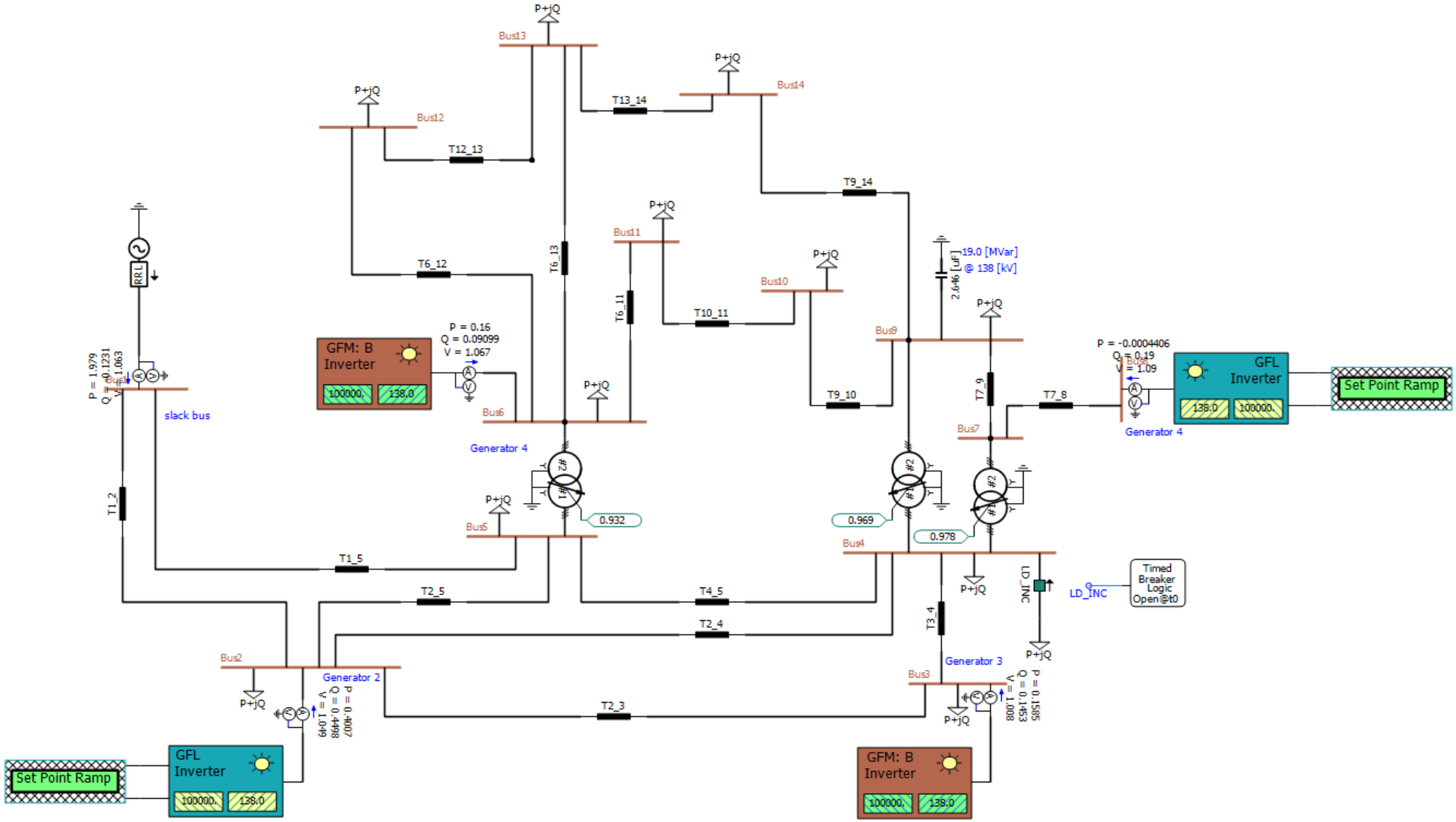


GFM3_GFL1_SLACK

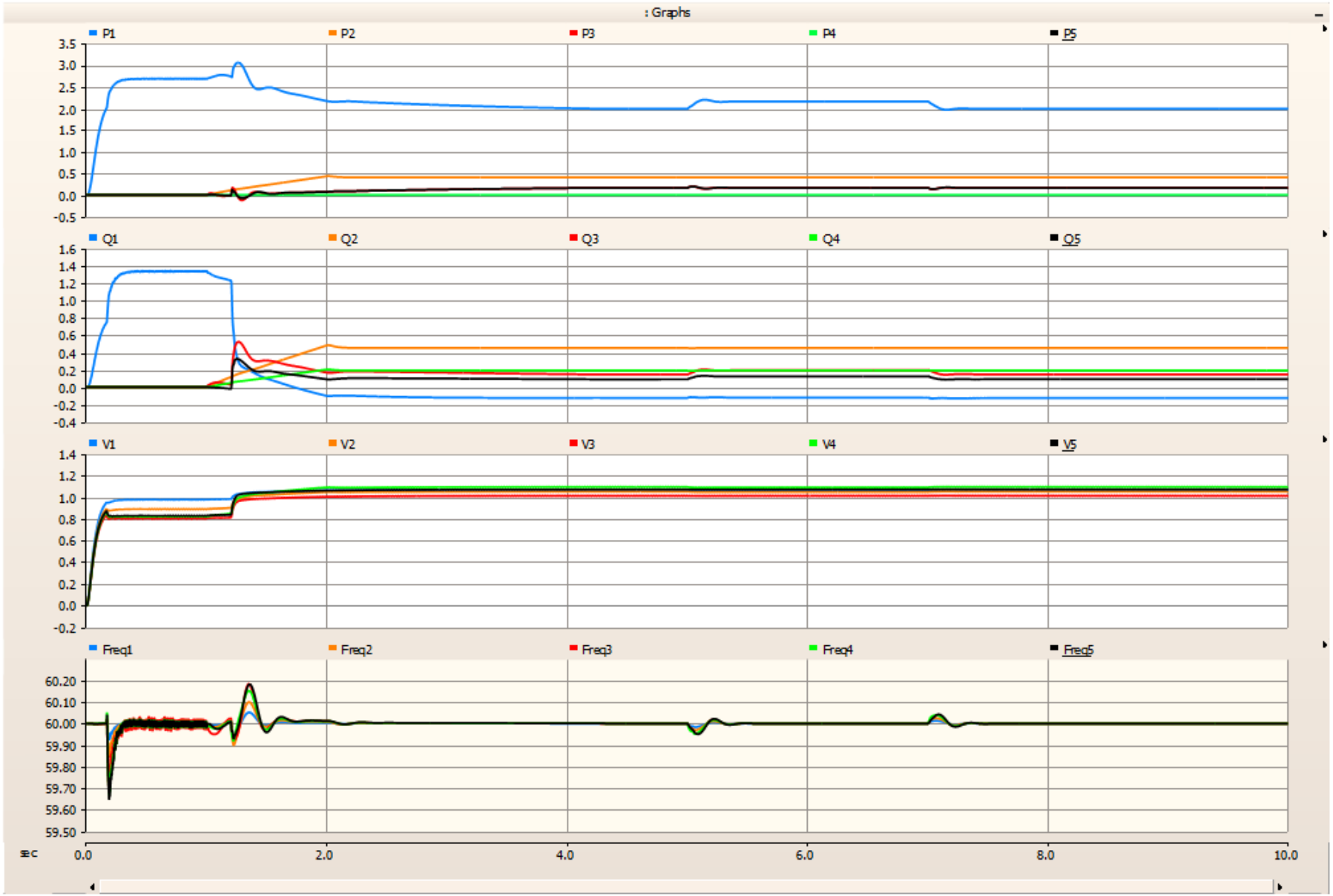


60.00 – 59.96 = 0.04 (same as previous)

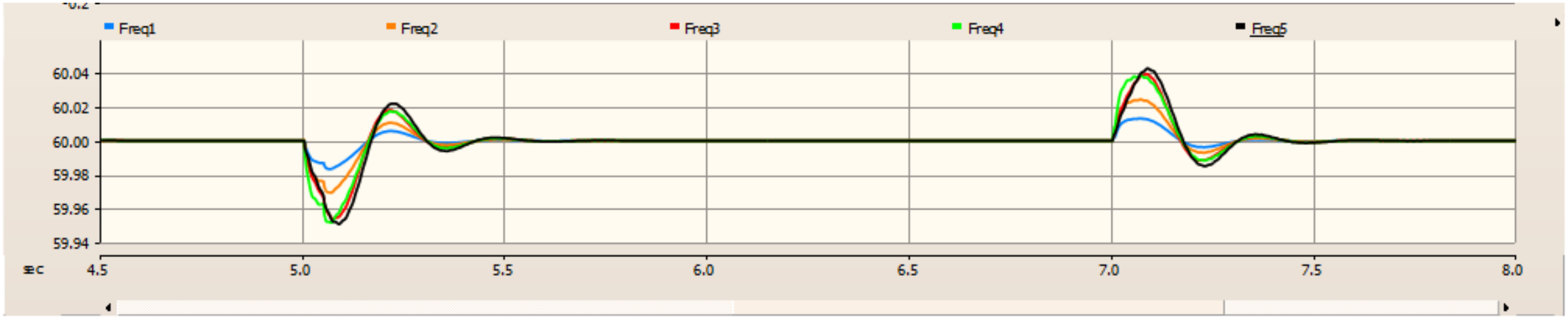
GFM2_GFL2_SLACK



GFM2_GFL2_SLACK

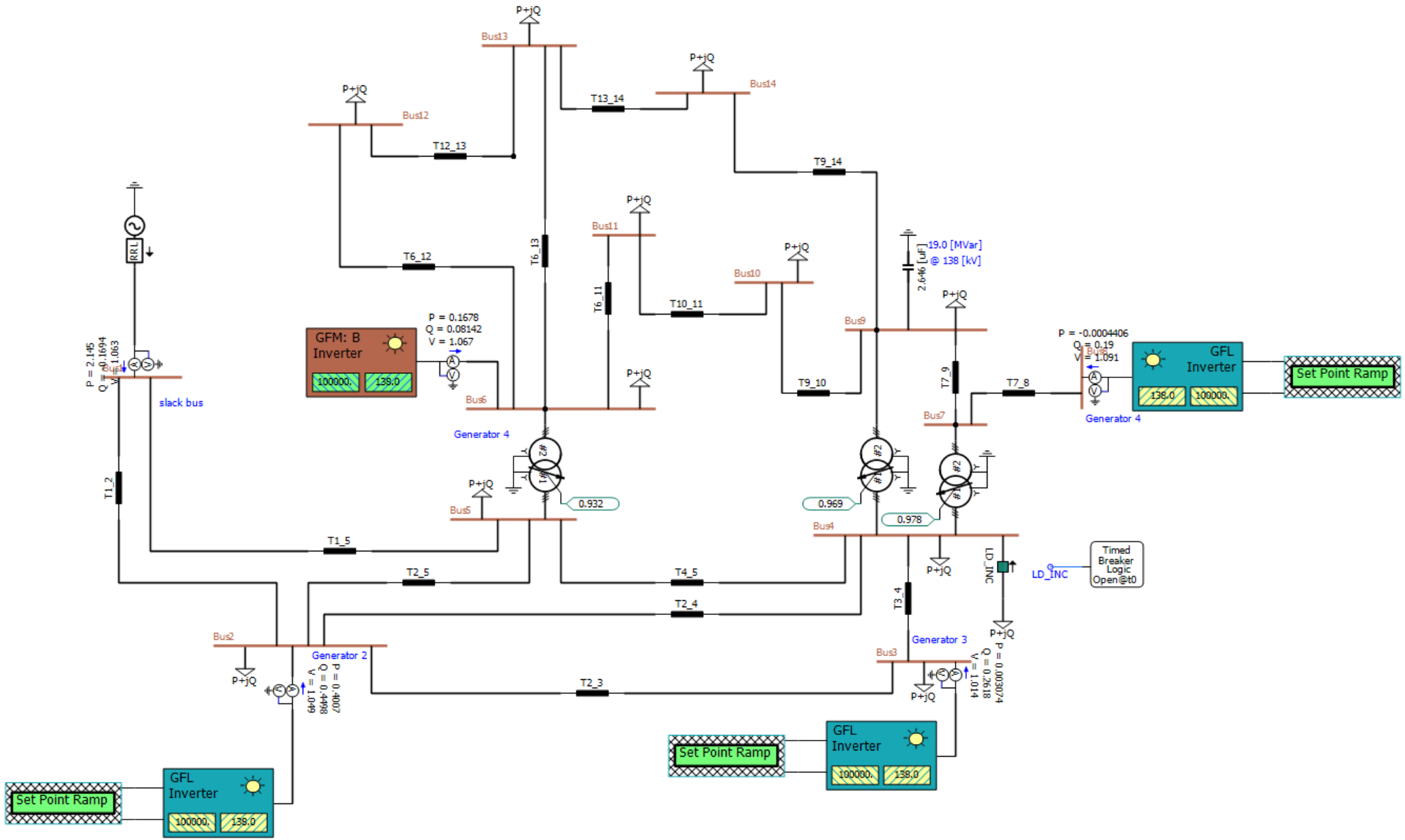


GFM2_GFL2_SLACK

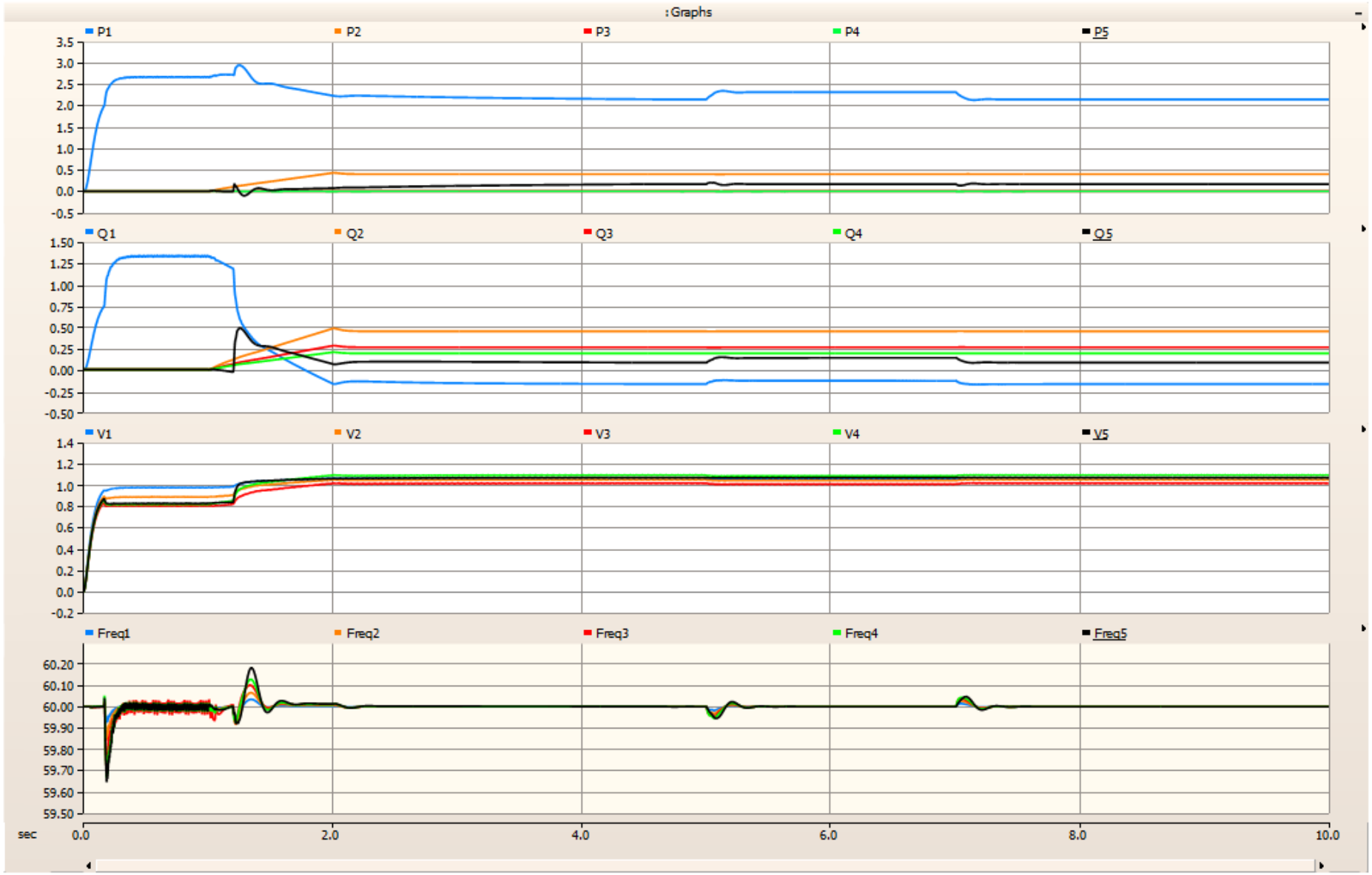


60.00 – 59.95 = 0.05

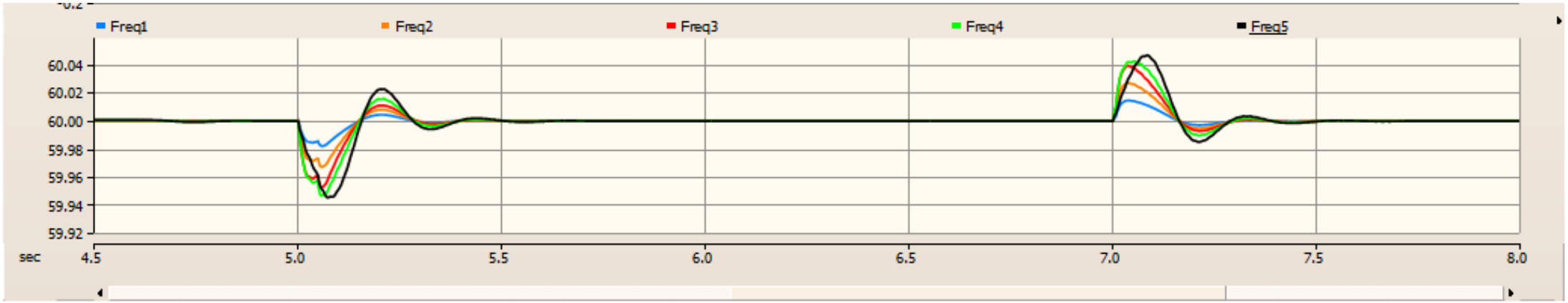
GFM1_GFL3_SLACK



GFM1_GFL3_SLACK

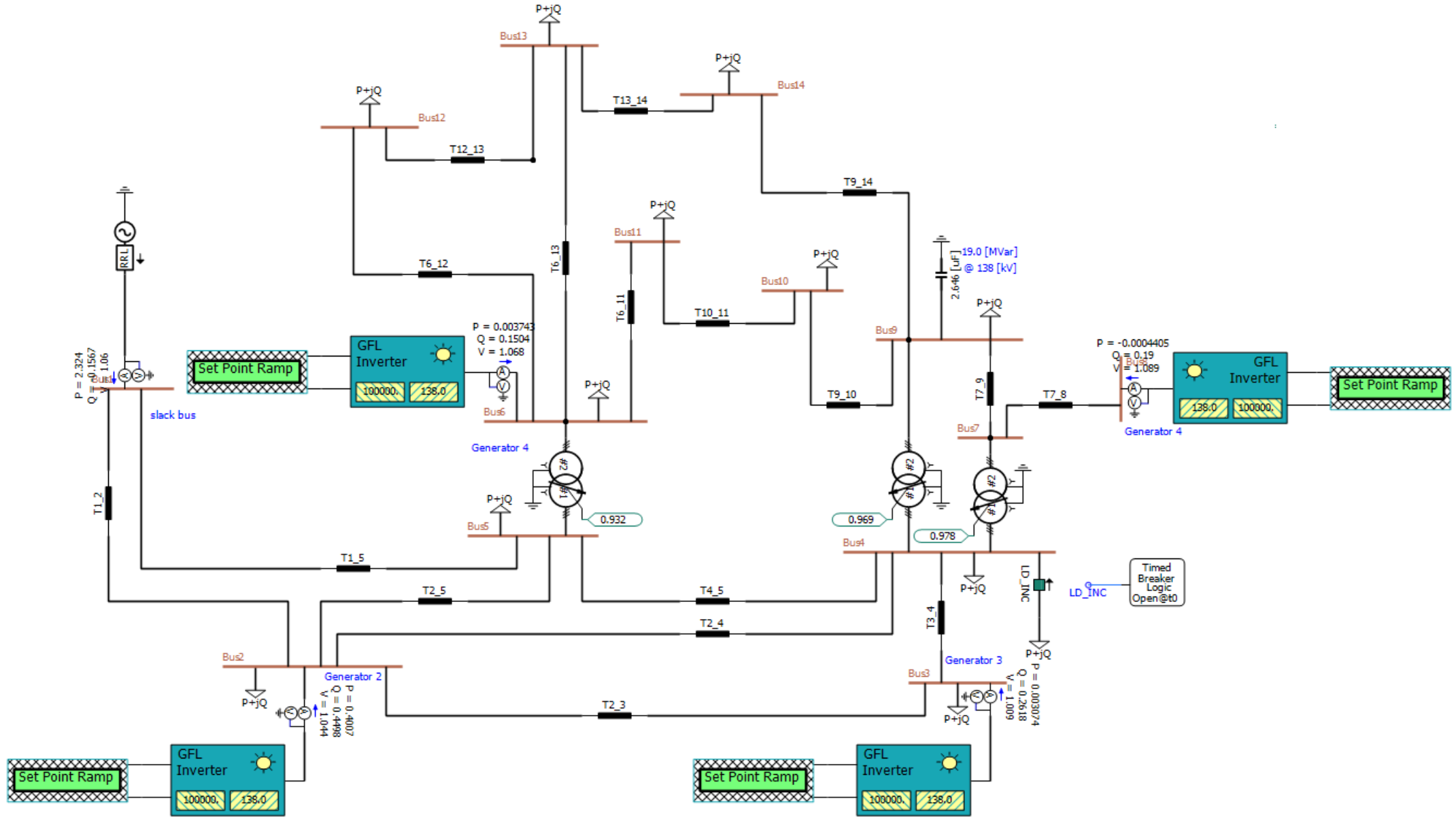


GFM1_GFL3_SLACK

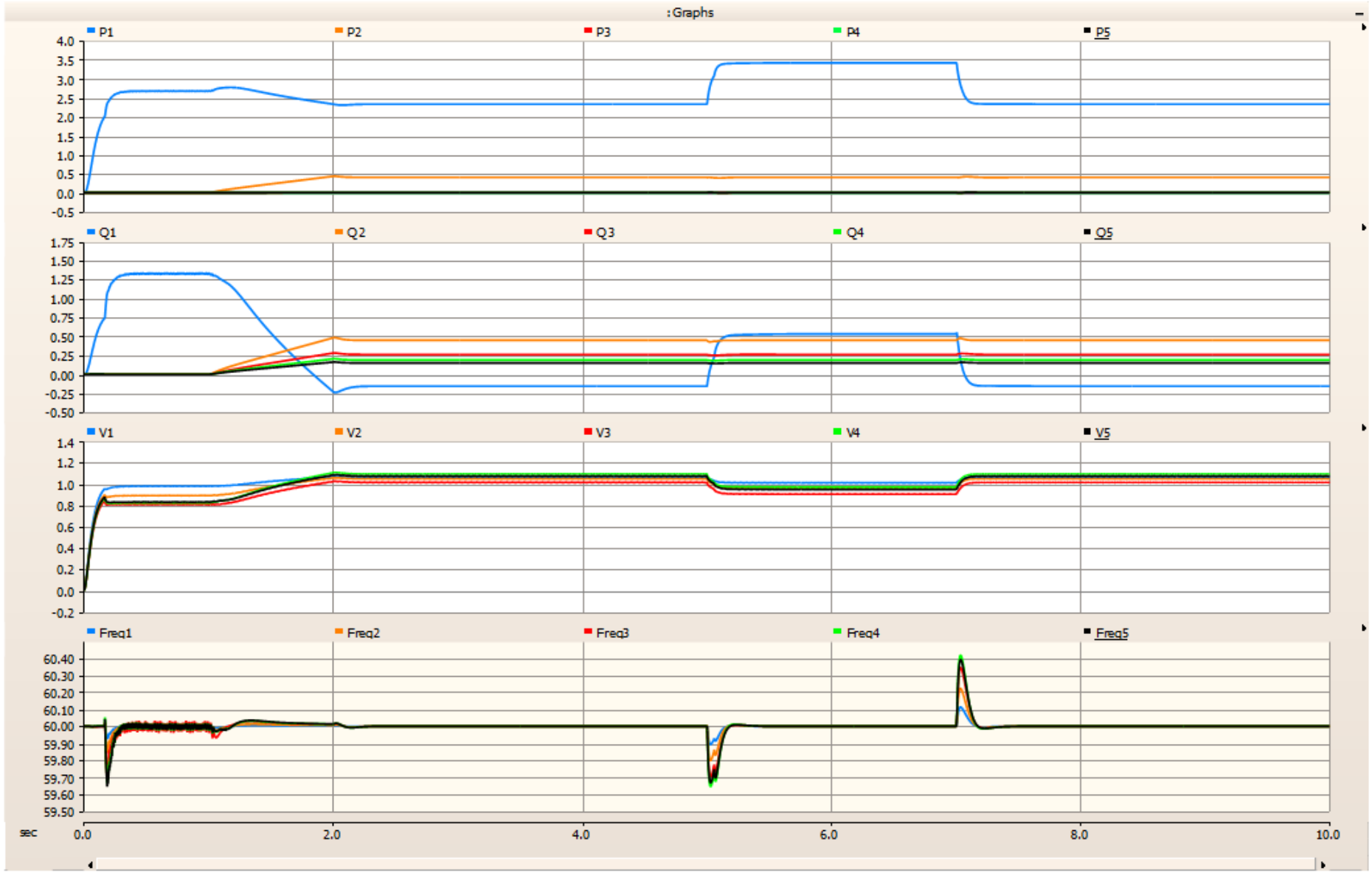


60.00 – 59.94 = 0.06

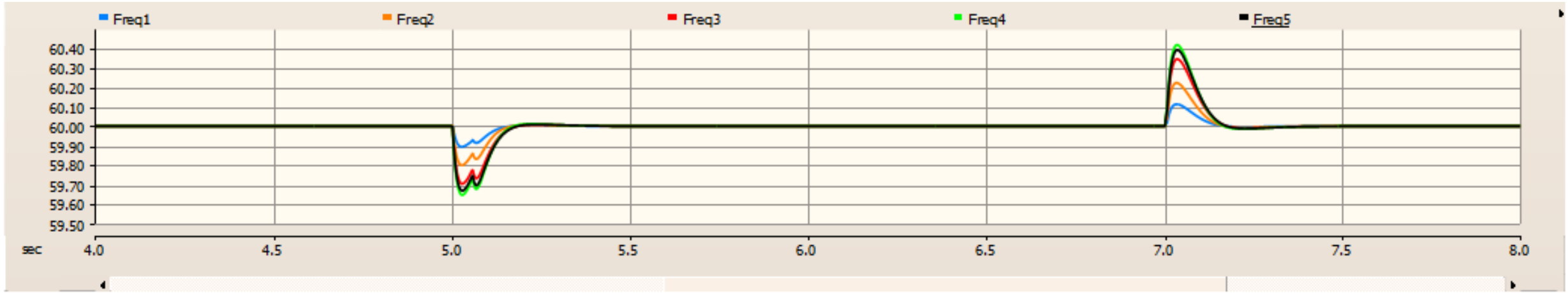
GFM0_GFL4_SLACK



GFM0_GFL4_SLACK



GFM0_GFL4_SLACK



60.00 – 59.65 = 0.35

Zero Inertia Observations:

- GFM:GFL ratio cannot be lower than 2:3
  - 1:4 frequency collapse for a small load change
  - Slightly stable 5:0, 4:1, 3:2, and 2:3 with 5:0 at best.

Using Ideal Voltage Source as Slack:

- Frequency changes, but returns back to 60 Hz
  - May not reflect actual grid behavior

- Next Week:
  - Fault analysis
  - Slight changes in load and PQ setting using data from PowerWorld