

HELICS T+C Use Case

**The Impact of Communication Delay on Wide-Area Control:
a MatLab Power System Tool and NS3 Integrated Simulation**

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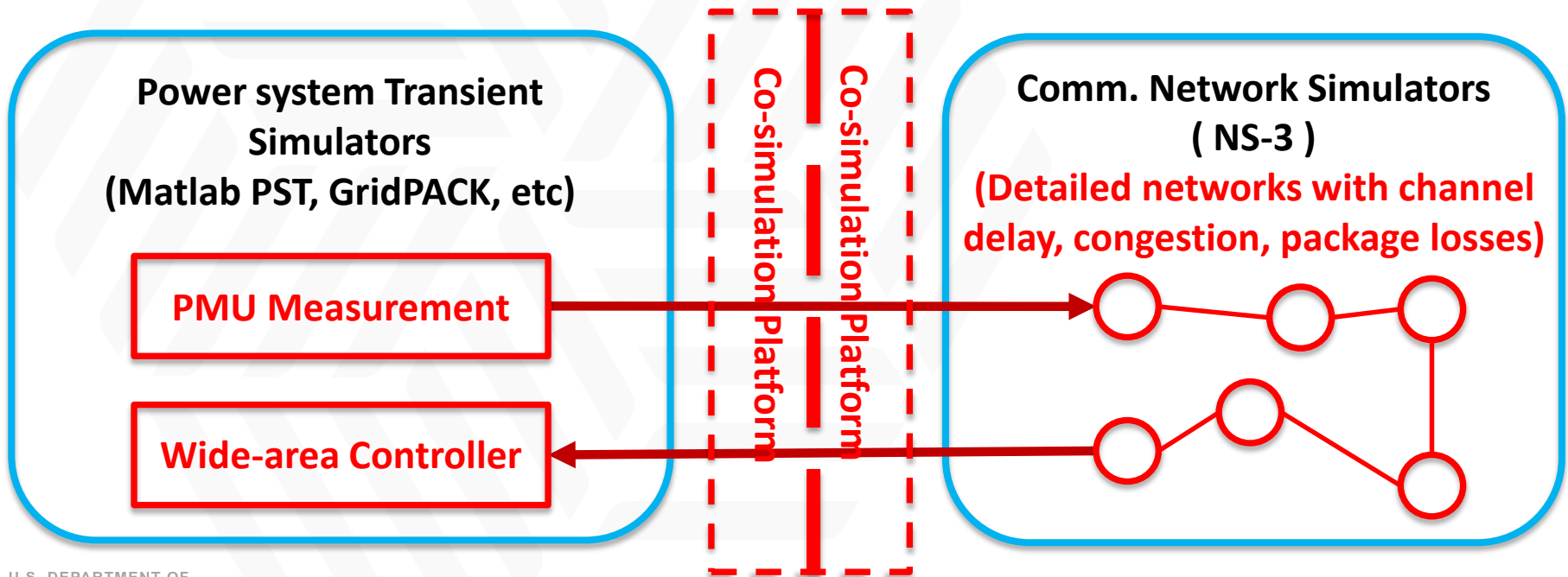
Background



- More PMUs in the power systems makes **wide-area control** available.
- Industries are interested in wide-area controls.
- Communication networks are vulnerable to disruptions, leading to the risk of destabilizing power grids.
- Simulation tools exists, but lack flexibility and scalability.

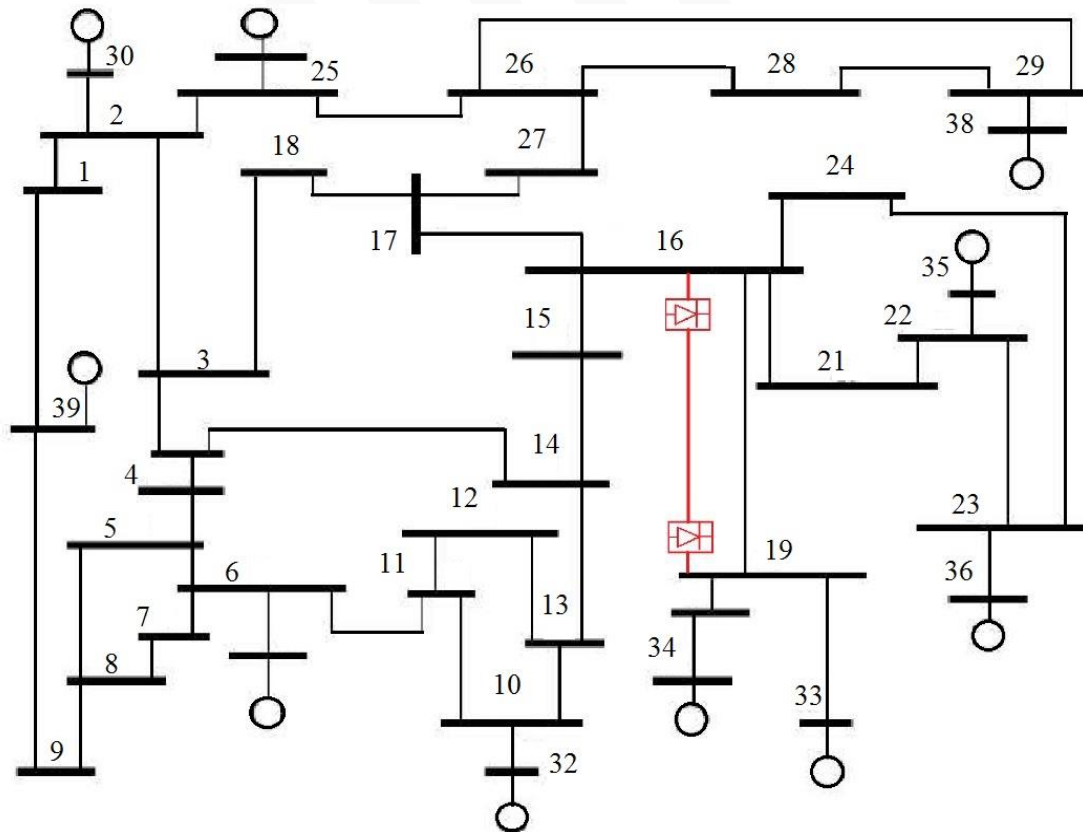
Use Case: Objective

- Investigating impact of communication network on the wide-area control and power system stability.
- Co-simulation between well-known Power system transient stability simulators and communication network simulators.

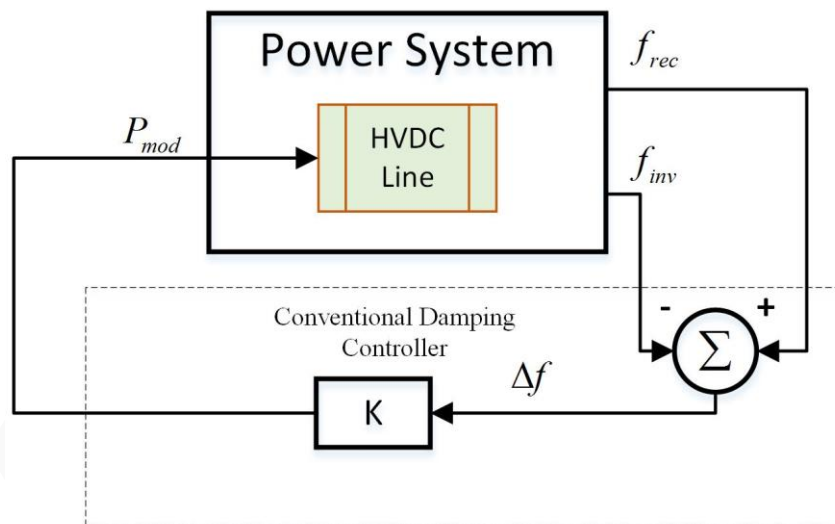


IEEE New England 39-Bus Test System

- Study the impact of communication delay on wide-area HVDC damping controls.
- A 850 MW 500-kV rated HVDC line is added between bus 16 and 19, connecting the **northeastern area** with the **southeastern area**.

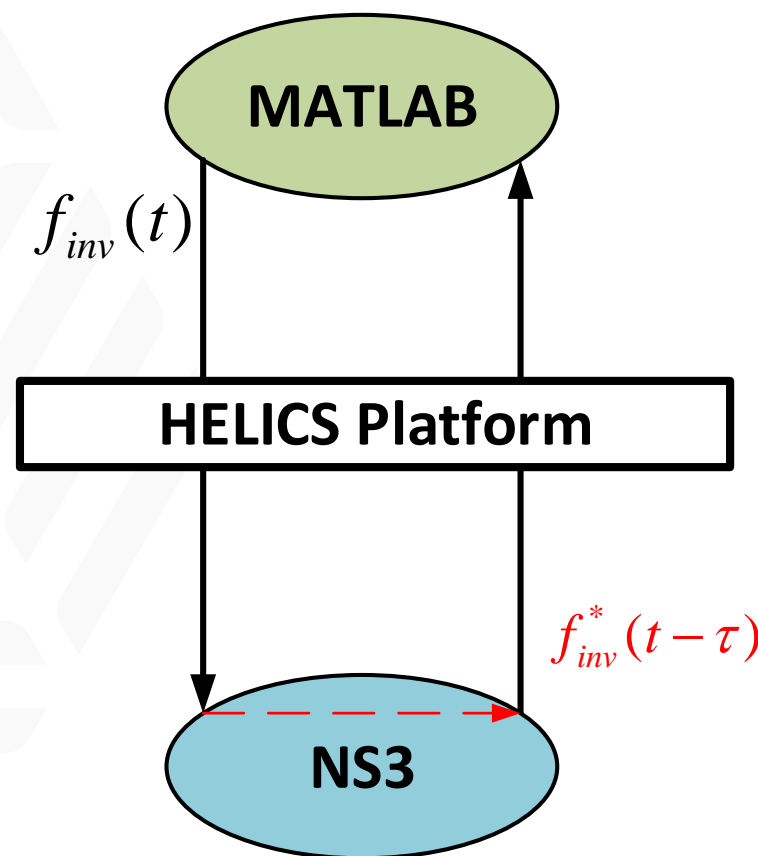


HVDC Damping Control



$$P_{mod}(t) = K(f_{rec}(t) - f_{inv}(t))$$

$$P_{mod}(t) = K(f_{rec}(t) - f_{inv}^*(t - \tau))$$

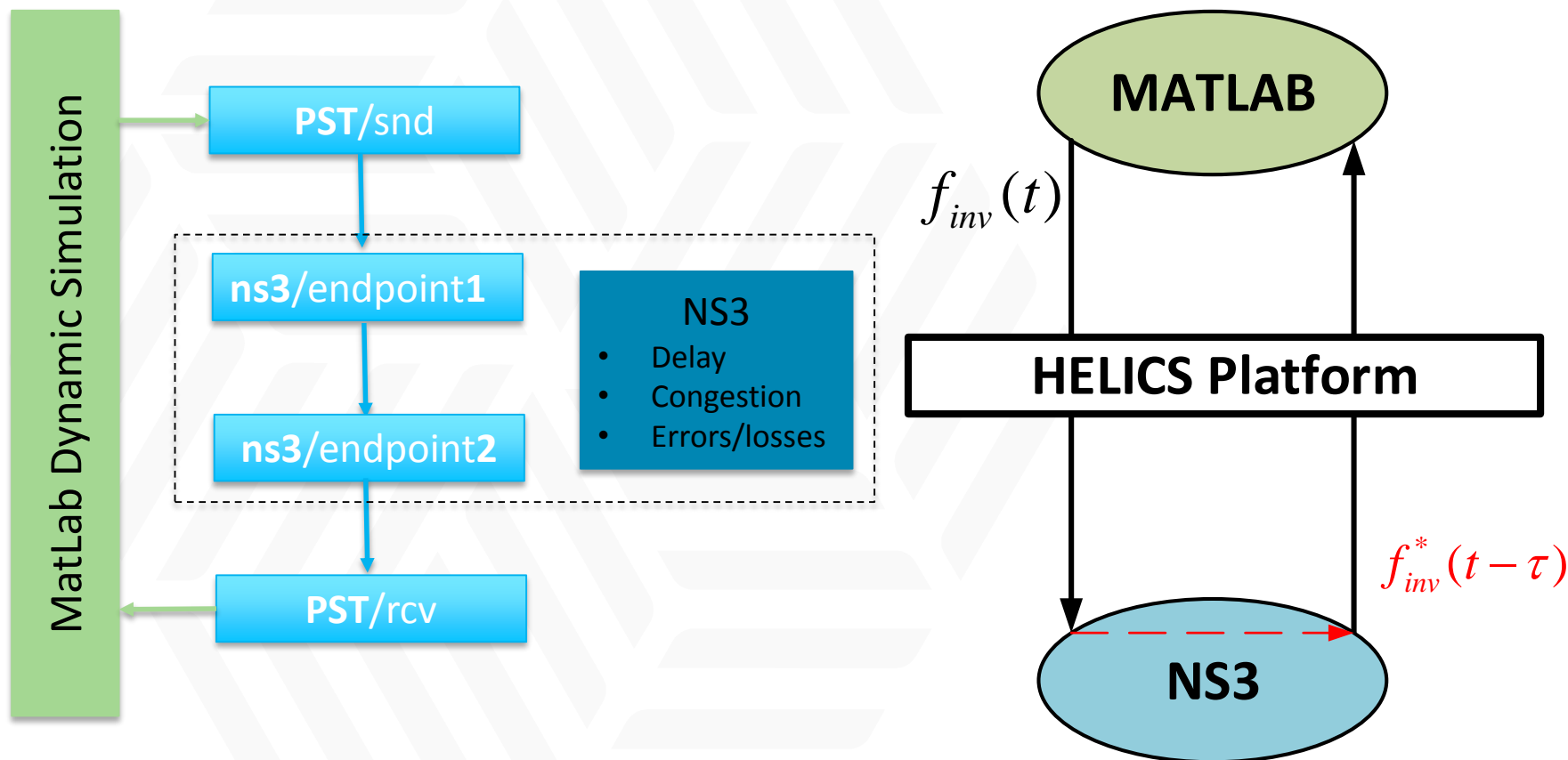


MatLab Communicate with NS3

MatLab Side: message federate named 'PST'

NS3 Side: message federate named 'ns3'

$$P_{mod}(t) = K \left(f_{rec}(t) - f_{inv}^*(t - \tau) \right)$$



Setup HELICS for Matlab + NS3 Co-Simu

- Matlab Mex supports gcc 4.9, while NS3 needs gcc 5.4 to build. Solution is to build two HELICS versions separately for Matlab and NS3.
 - HELICS for Matlab: gcc 4.9, BOOST needs also to be built with gcc 4.9
 - HELICS for NS3: gcc 5.4, BOOST needs also to be built with gcc 5.4

```
export LD_LIBRARY_PATH="$HOME/helics-test/helics-install/lib:$LD_LIBRARY_PATH"

# activate the following two, block the above if running ns-3 with HELICS???
#export LD_LIBRARY_PATH="$HOME/helics-ns3/helics-ns3-install/lib:$LD_LIBRARY_PATH"
#export LD_LIBRARY_PATH="$HOME/boost_1_66_0_install_ns3/lib:$LD_LIBRARY_PATH"
```

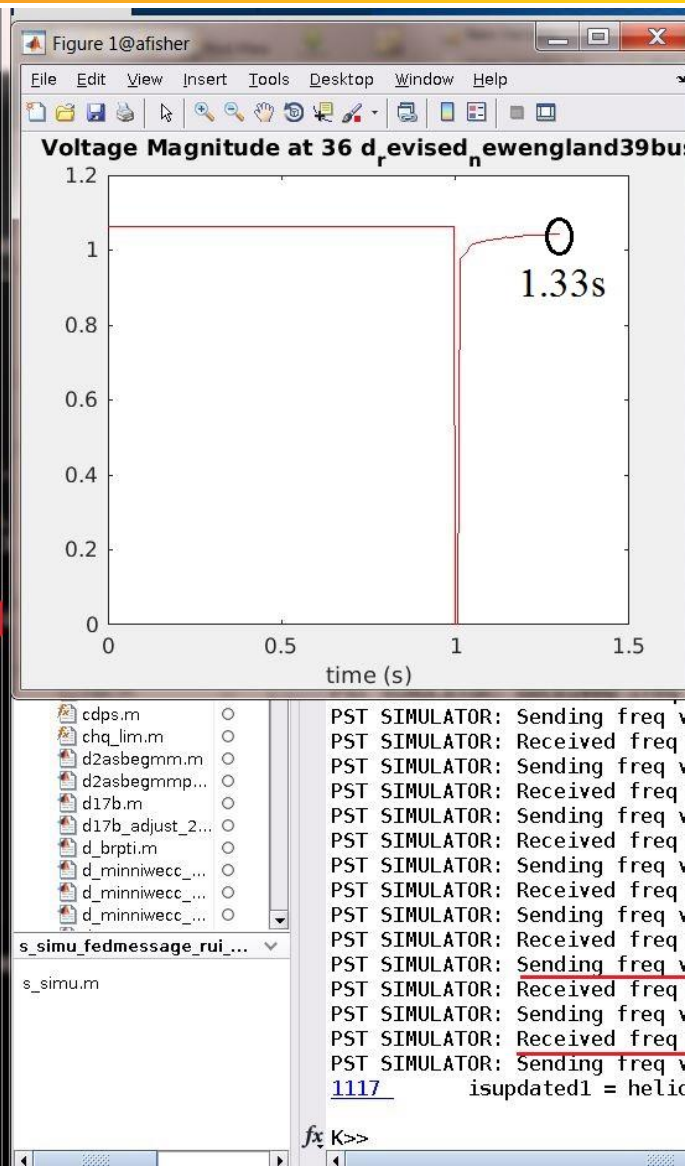
```
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```

Thanks for all the help and Support from Trevor, Ryan, Philip and Dheepak.

MatLab, ns-3 co-simulation

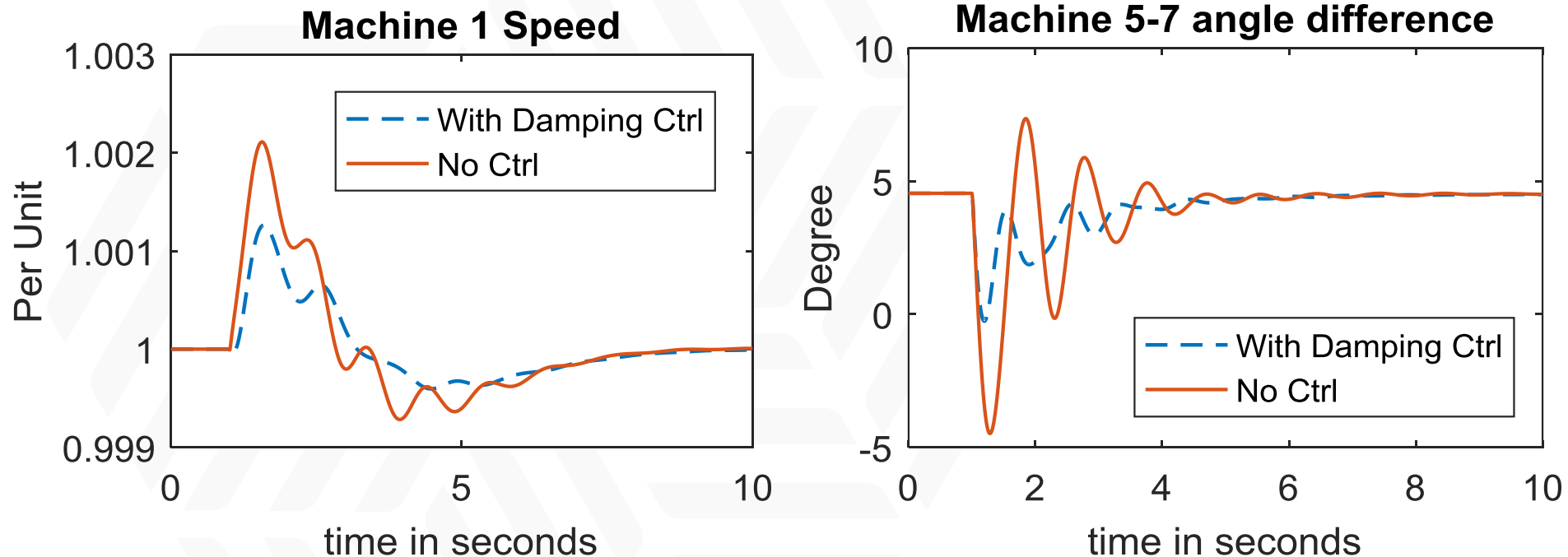
```
2. @afisher.pnl.gov (fanr254) 4. @afisher.pnl.gov (fanr254)
Outer: Granted time helics: +1335807806.0ns
Outer: nextTime <= grantedTime: 1
HelicsSimulatorImpl:ProcessOneEvent(0x1e415d0)
handle 1335807805
HelicsApplication:HandleRead(0x1e49610, 0x1e506b0)
At time '1335807805'ns 'endpoint2' received 7 bytes at ad
HelicsStaticSourceApplication:DoRead(0x1e49610, Message(1
sending message on to PST/recv_freq
Inner: m_events->IsEmpty(): 0
Inner: m_stop: 0
Inner: Next time ns-3: +1340808365.0ns
Inner: Granted time helics: +1335807806.0ns
Inner: nextTime <= grantedTime: 0
Request: Requesting time: 1.34081
HelicsApplication:EndpointCallback(0x1e48d80, "endpoint1"
HelicsApplication:DoEndpoint(0x1e48d80, 1, 1.34)
HelicsStaticSinkApplication:DoEndpoint(0x1e48d80, 1, 1.34
HelicsApplication:Send(0x1e48d80, "endpoint2", Message(1.
buffer='0x1e51730'
HelicsApplication:GetLocalInet(0x1e49610)
At time '1335851592'ns 'endpoint1' sent 7 bytes to 'endpo
HelicsSimulatorImpl:Schedule(0x1e415d0, 43786, 0x1e58ab0)
m_currentTs='1335807806' tAbsolute='+1335851592.0ns'
Request: Granted time helics: 1.34
Request: Granted time ns-3: +1340000000.0ns
Outer: m_events->IsEmpty(): 0
Outer: m_stop: 0
Outer: Next time ns-3: +1335851592.0ns
Outer: Granted time helics: +1340000000.0ns
Outer: nextTime <= grantedTime: 1
HelicsSimulatorImpl:ProcessOneEvent(0x1e415d0)
handle 1335851592
HelicsSimulatorImpl:Schedule(0x1e415d0, 59200, 0x1e11170)
m_currentTs='1335851592' tAbsolute='+1335910792.0ns'
HelicsSimulatorImpl:ScheduleWithContext(0x1e415d0, 1, 150
Inner: m_events->IsEmpty(): 0
Inner: m_stop: 0
Inner: Next time ns-3: +1335910792.0ns
Inner: Granted time helics: +1340000000.0ns
Inner: nextTime <= grantedTime: 1
HelicsSimulatorImpl:ProcessOneEvent(0x1e415d0)
handle 1335910792
Inner: m_events->IsEmpty(): 0
```



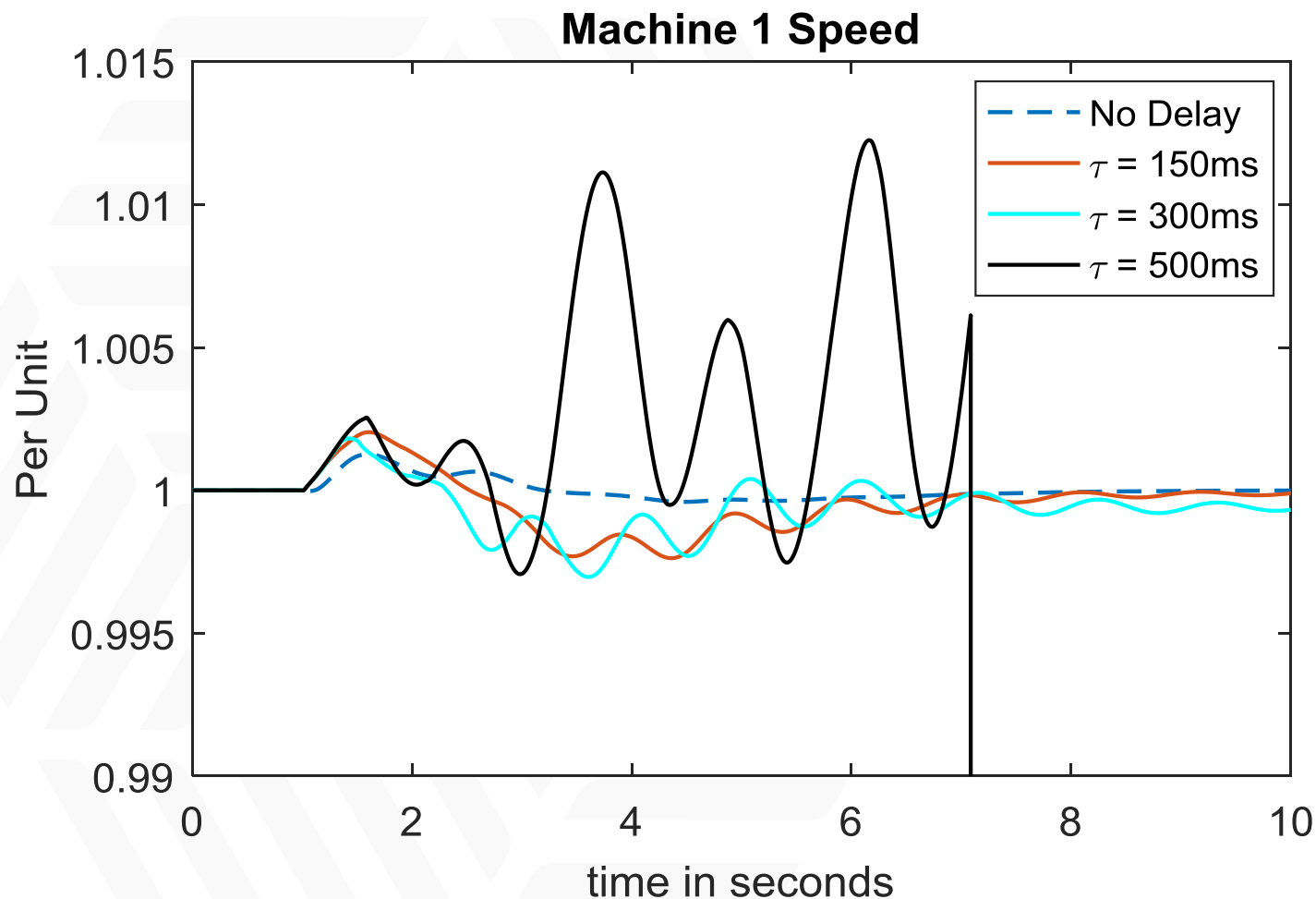
```
Code
Time
Commands
Simulink
Layout
Preferences
Set Path
Add-Ons
Parallel
ENVIRONMENT
pstv3
tue = 60.0024 to LOAD SENDER at time1.
alue = 59.998 at time 1.255 from ns3
lue = 60.0024 to LOAD SENDER at time1.
alue = 59.9982 at time 1.26 from ns3
lue = 60.0023 to LOAD SENDER at time1.
alue = 59.9984 at time 1.265 from ns3
lue = 60.0023 to LOAD SENDER at time1.
alue = 59.9986 at time 1.27 from ns3
lue = 60.0023 to LOAD SENDER at time1.
alue = 59.9988 at time 1.275 from ns3
lue = 60.0023 to LOAD SENDER at time1.
alue = 59.999 at time 1.28 from ns3
lue = 60.0022 to LOAD SENDER at time1.
alue = 59.9992 at time 1.285 from ns3
lue = 60.0022 to LOAD SENDER at time1.
alue = 59.9994 at time 1.29 from ns3
lue = 60.0022 to LOAD SENDER at time1.
alue = 59.9996 at time 1.295 from ns3
lue = 60.0021 to LOAD SENDER at time1.
alue = 59.9997 at time 1.3 from ns3
PST SIMULATOR: Sending freq value = 60.0021 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 59.9999 at time 1.305 from ns3
PST SIMULATOR: Sending freq value = 60.0021 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 59.9591 at time 1.31 from ns3
PST SIMULATOR: Sending freq value = 59.9937 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 60.0434 at time 1.315 from ns3
PST SIMULATOR: Sending freq value = 60.0116 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 60.0061 at time 1.32 from ns3
PST SIMULATOR: Sending freq value = 59.9959 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 59.9886 at time 1.325 from ns3
PST SIMULATOR: Sending freq value = 60.0021 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 59.977 at time 1.33 from ns3
PST SIMULATOR: Sending freq value = 60.0019 to LOAD SENDER at time1.
PST SIMULATOR: Received freq value = 60.0022 at time 1.335 from ns3
PST SIMULATOR: Sending freq value = 60.0018 to LOAD SENDER at time1.
1117 isupdated1 = helics.helicsEndpointHasMessage(subpreal);
```


Preliminary Results (No Delay)

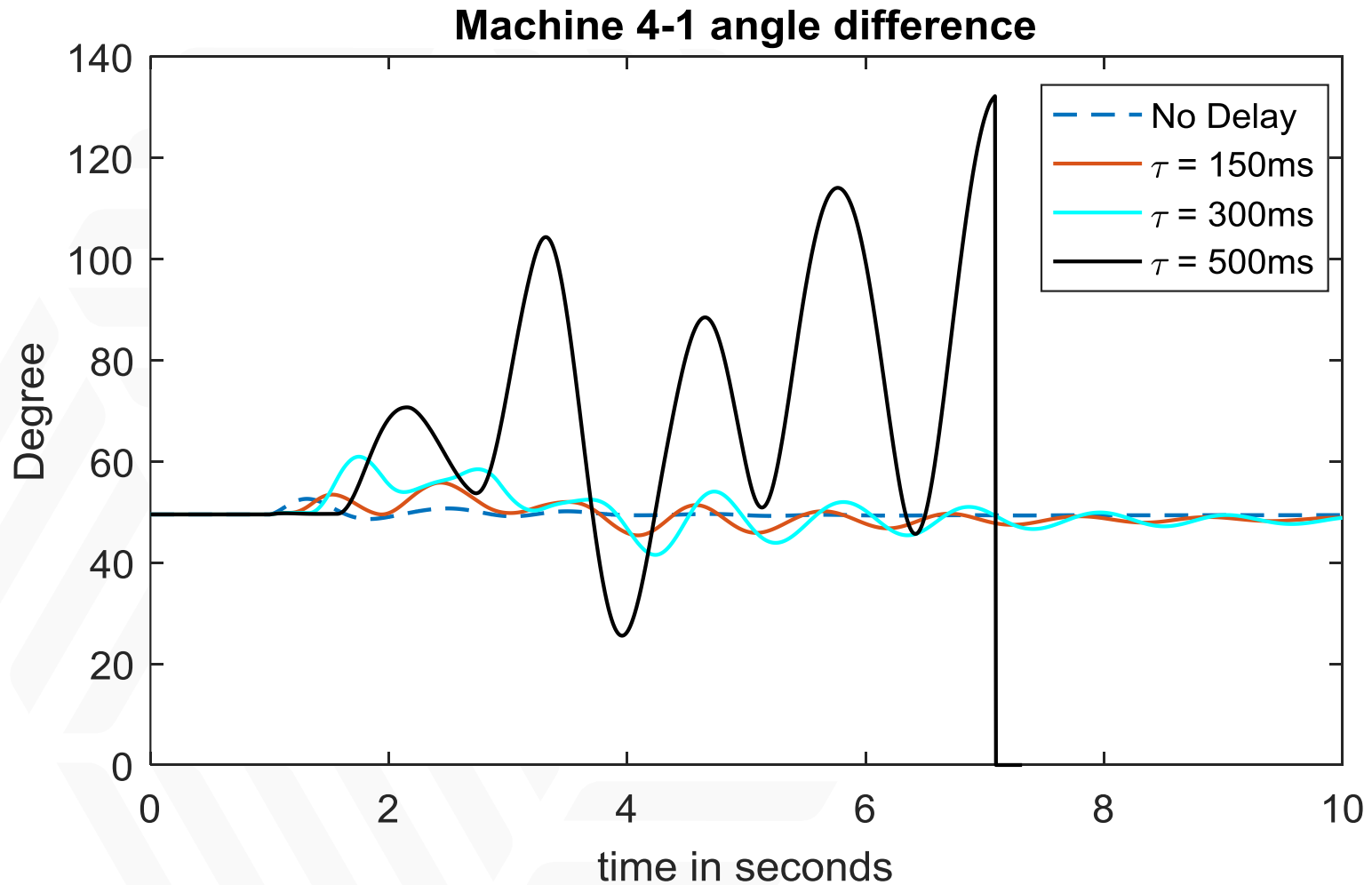
At time 1.0 sec, a temporary three-phase fault occurred on the transmission line between Bus 23 and Bus 36. The fault is tripped 1.5 cycles later.



Preliminary Results (With Delay)



Preliminary Results (With Delay)



Future Path

- Test the impact on wide-area control on a large-scale power system.
- Test multiple wide-area controllers on one system.
- Evaluate or quantify the impact of communication issues.
- Test compensation methodologies for communication issues.