



TEXAS A&M UNIVERSITY  
Engineering

# Real-time Power System Simulation with Hardware Devices through DNP3 in Cyber-Physical Testbed

Hao Huang (Presenter), C. Matthew Davis, and Katherine R. Davis  
Texas A&M University  
[hao\\_huang@tamu.edu](mailto:hao_huang@tamu.edu)

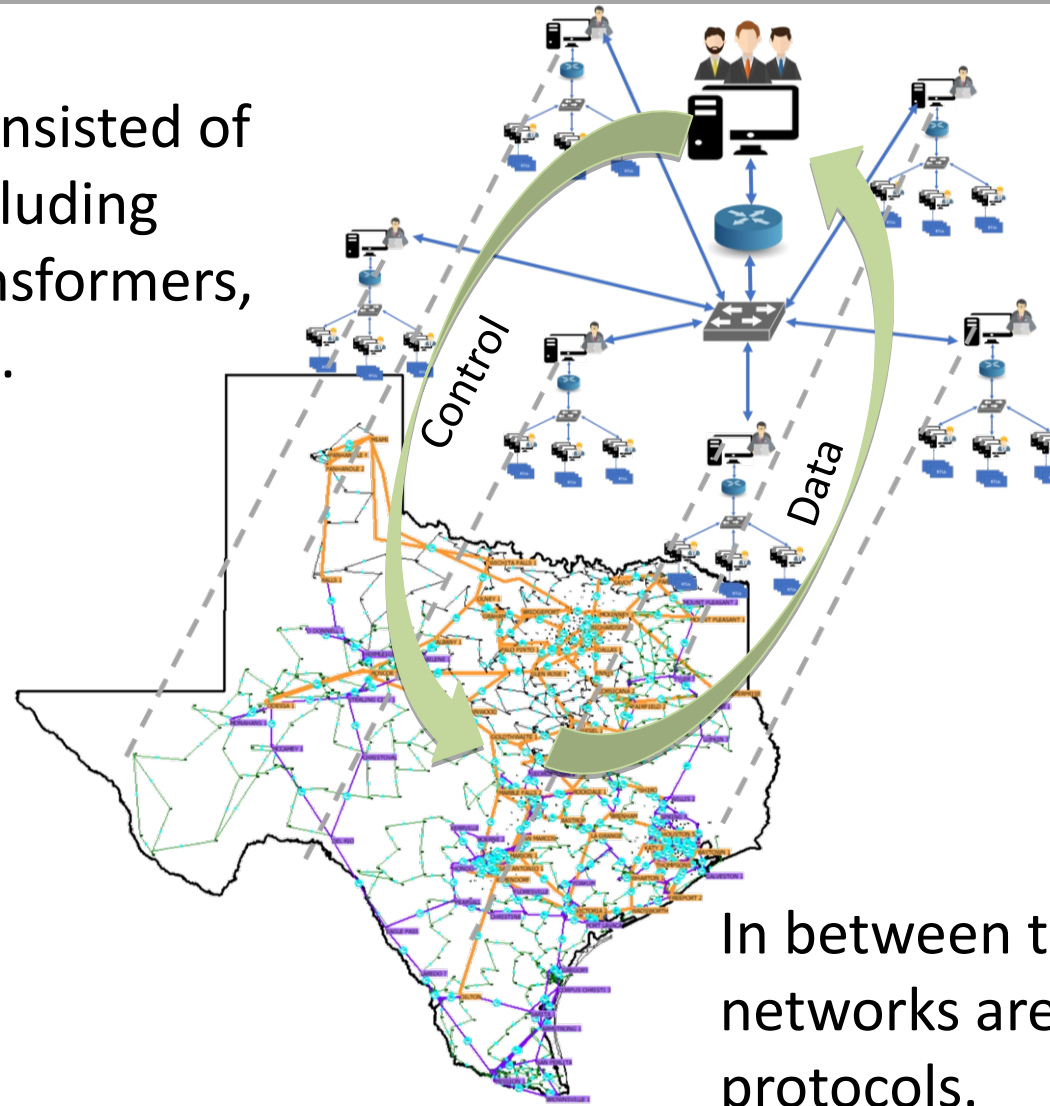
- Background of Cyber-Physical Power Systems
- Brief of DNP3 Protocol
- Hardware-in-the-loop Testbed using DNP3
- Configuration and Validation
- Exemplar of Data Acquisition and Control
- Conclusion and Future Work

# Background of Cyber-Physical Power Systems



TEXAS A&M UNIVERSITY  
Engineering

Physical Network is consisted of power equipment, including generators, loads, transformers, transmission lines, etc.



Cyber Network is consisted of communication devices and management software, including routers, switches, EMS, etc.

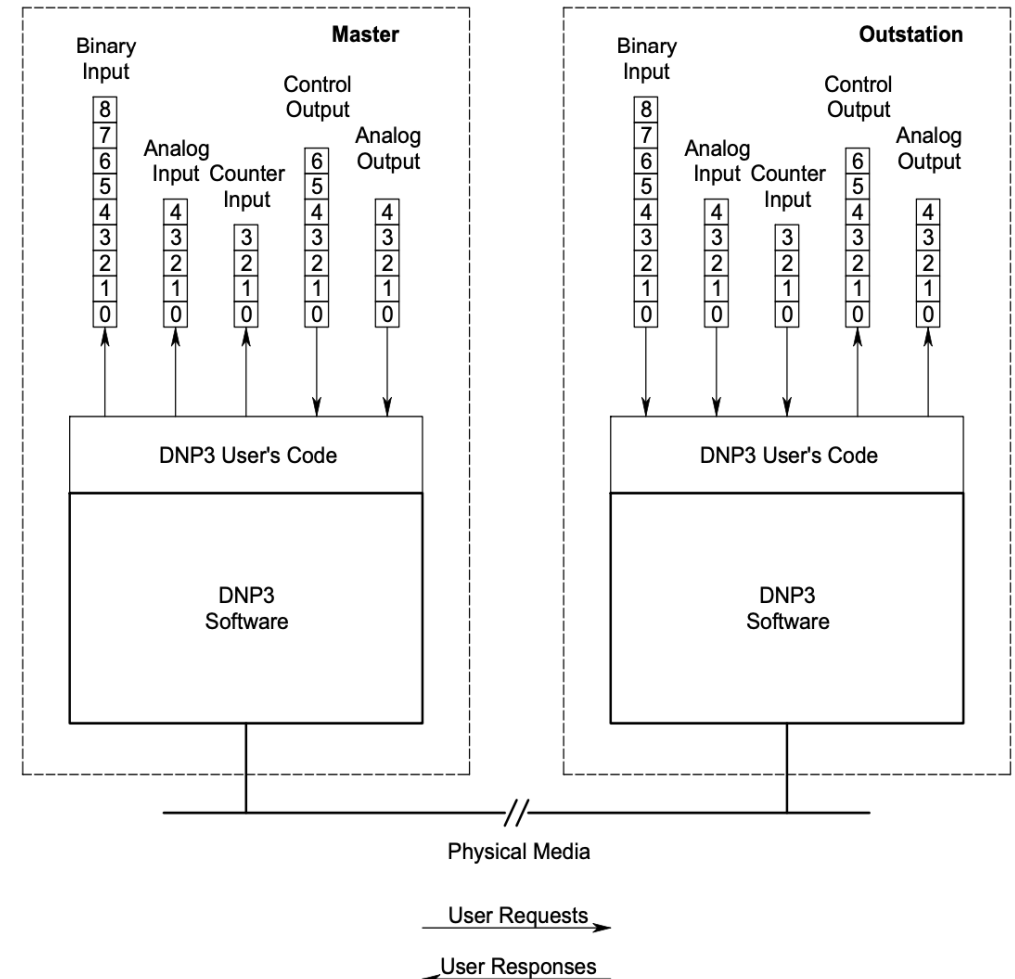
In between the cyber and physical networks are sensors, IEDs, and ICS protocols.

# Brief of DNP3 Protocol



Distributed Network Protocol 3 (DNP3) is commonly used in ICS for data acquisition and control, which is a protocol for transmission of data from point A to point B using serial and IP communications.

It provides the rules for remotely located computers and master station computers to communicate data and control commands.

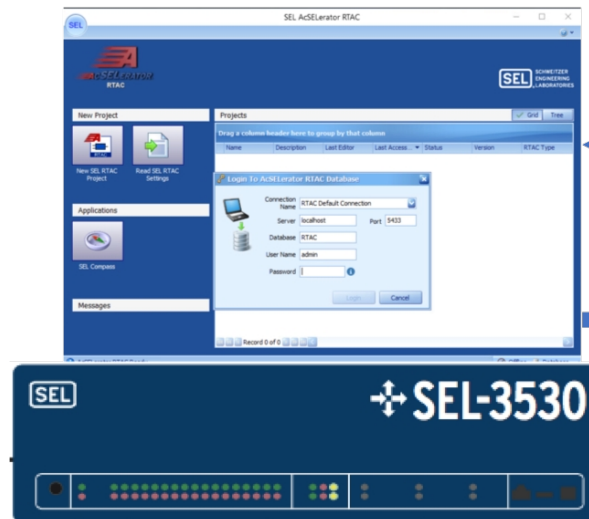


# Hardware-in-the-loop Testbed using DNP3

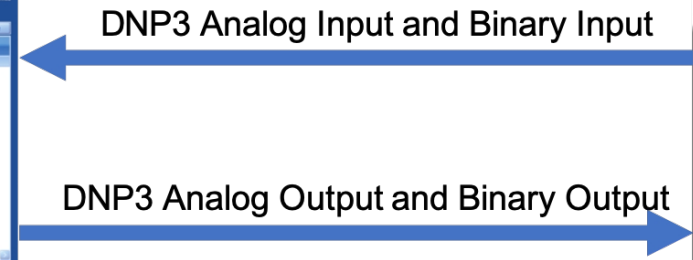


SEL Real-time Automation Controller (RTAC)

PowerWorld DynamicStudio (PWDS)



DNP3 Master/Client



DNP3 Outstation/Server

# Configuration and Validation



## Physical Information

Explore

Outstation

Filter: Advanced | DSOutstationObject

| Number | Name | All Points | Msg Count In | Msg Count Ou | IIN1 | IIN2 | Binary Input | Analog Input | Counter Input | Binary Output | Analog Output |
|--------|------|------------|--------------|--------------|------|------|--------------|--------------|---------------|---------------|---------------|
| 266    |      | 22         | 0            | 0            | 128  | 0    | 11           | 0            | 0             | 11            | 0             |
| 267    |      | 6          | 0            | 0            | 128  | 0    | 3            | 0            | 0             | 3             | 0             |
| 269    |      | 8          | 0            | 0            | 128  | 0    | 4            | 0            | 0             | 4             | 0             |
| 270    |      | 14         | 0            | 0            | 128  | 0    | 7            | 0            | 0             | 7             | 0             |
| 272    |      | 10         | 0            | 0            | 128  | 0    | 5            | 0            | 0             | 5             | 0             |
| 278    |      | 14         | 0            | 0            | 128  | 0    | 7            | 0            | 0             | 7             | 0             |
| 279    |      | 8          | 0            | 0            | 128  | 0    | 4            | 0            | 0             | 4             | 0             |

Point Object ID (also used for pasting and aux files)

Change Point Object

Point Type

Binary Input

Analog Input

Counter Input

Binary Output

Analog Output

Point Field (Depends on Object Type)

Event Class

Class 0    Class 3

Class 1    Unassigned



Number: 266   Find By Number

Name:    Find By Name

Total Points: 22

Scan Period Multiplier: 1

Point Type Counts

Binary In: 11   Binary Out: 11

Analog In: 0   Analog Out: 0

Counter In: 0

Results and Control   All Points   Binary In Points   Analog In Points   Counter In Points   Binary Out Points   Analog Out Points

|    | Outstation Number | Object Type | Object ID By Number | Field Name | Value | Point Type    |
|----|-------------------|-------------|---------------------|------------|-------|---------------|
| 1  | 266               | Bus         | 4041                | STATUS     | 0.000 | Binary Input  |
| 2  | 266               | Bus         | 4042                | STATUS     | 0.000 | Binary Input  |
| 3  | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Input  |
| 4  | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Input  |
| 5  | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Input  |
| 6  | 266               | Branch      | 4073 TO 4041        | STATUS     | 1.000 | Binary Input  |
| 7  | 266               | Branch      | 4073 TO 4041        | STATUS     | 1.000 | Binary Input  |
| 8  | 266               | Branch      | 4088 TO 4042        | STATUS     | 1.000 | Binary Input  |
| 9  | 266               | Branch      | 4088 TO 4042        | STATUS     | 1.000 | Binary Input  |
| 10 | 266               | Branch      | 4107 TO 4042        | STATUS     | 1.000 | Binary Input  |
| 11 | 266               | Branch      | 4107 TO 4042        | STATUS     | 1.000 | Binary Input  |
| 12 | 266               | Bus         | 4041                | STATUS     | 0.000 | Binary Output |
| 13 | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Output |
| 14 | 266               | Bus         | 4042                | STATUS     | 0.000 | Binary Output |
| 15 | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Output |
| 16 | 266               | Branch      | 4042 TO 4041        | STATUS     | 1.000 | Binary Output |
| 17 | 266               | Branch      | 4073 TO 4041        | STATUS     | 1.000 | Binary Output |
| 18 | 266               | Branch      | 4073 TO 4041        | STATUS     | 1.000 | Binary Output |
| 19 | 266               | Branch      | 4088 TO 4042        | STATUS     | 1.000 | Binary Output |
| 20 | 266               | Branch      | 4088 TO 4042        | STATUS     | 1.000 | Binary Output |
| 21 | 266               | Branch      | 4107 TO 4042        | STATUS     | 1.000 | Binary Output |
| 22 | 266               | Branch      | 4107 TO 4042        | STATUS     | 1.000 | Binary Output |

# Configuration and Validation



## Physical Information

PowerWorld\_RTAC\_560\_DNP  
Other, Client - Ethernet [DNP Protocol]

Settings

Drag a column header here to group by that column

| Enable | Tag Name  | Point Number | Tag Type |
|--------|---|--------------|----------|
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5047_5260_1_MWFROM   | 0            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5047_5260_1_MVARFROM | 1            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5260_5045_1_MWFROM   | 2            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5260_5045_1_MVARFROM | 3            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5260_1_MWFROM   | 4            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5260_1_MVARFROM | 5            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5262_5260_1_MWFROM   | 6            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5262_5260_1_MVARFROM | 7            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5263_5260_1_MWFROM   | 8            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5263_5260_1_MVARFROM | 9            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5317_5260_1_MWFROM   | 10           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5317_5260_1_MVARFROM | 11           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5246_1_MWFROM   | 12           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5246_1_MVARFROM | 13           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5262_1_GENMW            | 14           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5262_1_GENMVAR          | 15           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5263_1_GENMW            | 16           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5263_1_GENMVAR          | 17           | MV       |

1 of 18

# Configuration and Validation



## Physical Information

PowerWorld\_RTAC\_560\_DNP  
Other, Client - Ethernet [DNP Protocol]

Settings

Drag a column header here to group by that column

| Enable | Tag Name  | Point Number | Tag Type |
|--------|---|--------------|----------|
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5047_5260_1_MWFROM   | 0            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5047_5260_1_MVARFROM | 1            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5260_5045_1_MWFROM   | 2            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5260_5045_1_MVARFROM | 3            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5260_1_MWFROM   | 4            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5260_1_MVARFROM | 5            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5262_5260_1_MWFROM   | 6            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5262_5260_1_MVARFROM | 7            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5263_5260_1_MWFROM   | 8            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5263_5260_1_MVARFROM | 9            | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5317_5260_1_MWFROM   | 10           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5317_5260_1_MVARFROM | 11           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5246_1_MWFROM   | 12           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5261_5246_1_MVARFROM | 13           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5262_1_GENMW            | 14           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5262_1_GENMVAR          | 15           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5263_1_GENMW            | 16           | MV       |
| True   | PowerWorld_RTAC_560_DNP.AI_Substation_560_Gen_5263_1_GENMVAR          | 17           | MV       |

1 of 18

Number: 560 Find By Number  
Name: Find By Name  
Total Points: 38  
Scan Period Multiplier: 1

Point Type Counts  
Binary In: 9 Binary Out: 9  
Analog In: 18 Analog Out: 2  
Counter In: 0

Results and Control | All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

|    | Outstation Number | Zero-based Index | Object Type | Object ID By Number | Field Name | Analog Value |
|----|-------------------|------------------|-------------|---------------------|------------|--------------|
| 1  | 560               | 0                | Branch      | 5047 TO 5260        | MWFROM     | -1123.811    |
| 2  | 560               | 1                | Branch      | 5047 TO 5260        | MVARFROM   | 118.990      |
| 3  | 560               | 2                | Branch      | 5260 TO 5045        | MWFROM     | -1415.102    |
| 4  | 560               | 3                | Branch      | 5260 TO 5045        | MVARFROM   | 100.885      |
| 5  | 560               | 4                | Branch      | 5261 TO 5260        | MWFROM     | -79.822      |
| 6  | 560               | 5                | Branch      | 5261 TO 5260        | MVARFROM   | 7.186        |
| 7  | 560               | 6                | Branch      | 5262 TO 5260        | MWFROM     | 1211.673     |
| 8  | 560               | 7                | Branch      | 5262 TO 5260        | MVARFROM   | 42.978       |
| 9  | 560               | 8                | Branch      | 5263 TO 5260        | MWFROM     | 1024.005     |
| 10 | 560               | 9                | Branch      | 5263 TO 5260        | MVARFROM   | 32.873       |
| 11 | 560               | 10               | Branch      | 5317 TO 5260        | MWFROM     | -2432.873    |
| 12 | 560               | 11               | Branch      | 5317 TO 5260        | MVARFROM   | 137.137      |
| 13 | 560               | 12               | Branch      | 5261 TO 5246        | MWFROM     | 79.822       |
| 14 | 560               | 13               | Branch      | 5261 TO 5246        | MVARFROM   | -7.186       |
| 15 | 560               | 14               | Gen         | 5262 #1             | MW         | 1211.673     |
| 16 | 560               | 15               | Gen         | 5262 #1             | MVAR       | 42.978       |
| 17 | 560               | 16               | Gen         | 5263 #1             | MW         | 1024.005     |
| 18 | 560               | 17               | Gen         | 5263 #1             | MVAR       | 32.873       |

Close Help



# Configuration and Validation



## Cyber Information

PowerWorld\_RTAC\_560\_DNP

Other, Client - Ethernet [DNP Protocol]

| Setting                    | Value        | Range               | Description   |
|----------------------------|--------------|---------------------|---|
| <b>Communications</b>      |              |                     |   |
| Transport Protocol         | TCP          | TCP,UDP             | Use TCP or UDP as the ethernet transport protocol.  |
| Client IP Port             | 20010        | 23,1024-65534       | Local RTAC IP port for this DNP client session.   |
| Client UDP Broadcast Port  | 20010        | 1-65534             | Remote UDP port to which this DNP client transmits UDP broadcast messages.                |
| Server IP Address          | 172.168.2.10 | Valid IPv4 Addr...  | IP address of the remote DNP server connection.   |
| Server IP Port             | 20000        | 23,1024-65534       | IP port of the remote DNP server connection.  |
| <b>Date-Time</b>           |              |                     |   |
| UTC Offset                 | 0            | -720 to 840 (mi...  | Local Time offset from Universal Time   |
| DST Enabled                | True         | True,False          | Enable Daylight Savings Time  |
| <b>DNP</b>                 |              |                     |   |
| Client DNP Address         | 559          | 0-65519             | DNP source address. The local address of this RTAC client session. Addresses 65520-...    |
| Server DNP Address         | 560          | 0-65519             | DNP destination address. The address of the remote IED polled by this client session...   |
| Integrity Poll Period      | 60000        | 0, 100-1000000...   | Class 1,2,3,0 integrity poll period. Set to 0 to disable.                                 |
| Class 1,2,3 Polling Period | 5000         | 0, 100-1000000...   | Class 1,2,3 Polling Period. Set to 0 to disable.  |
| Poll Timeout               | 7000         | 100-65535 (milli... | Time allowed for attached DNP Server to respond to a poll. If time is exceeded, this D... |
| Number of Poll Retries     | 1            | 0-255               | The number of poll retries before the connected DNP Server is considered offline.         |

IP:172.168.2.2

Dynamic Simulator Options

Simulation Options | Display Options | Server Options | C37.118 Options | Scenario Description | Last Solution Summary | Time Schedules | DNP3 Options

Connections

PowerWorld Protocol Port: 5557

(Note, See C37.118 Options Page to set the C37.118 Port)

Server IP Address(es): 3.126, 169.254.185.18, 172.168.2.10, 0.110.215.3

Server Name: DESKTOP-TC11R49

Automatically Start Sever on Case Load

Dynamic Simulator Options

Simulation Options | Display Options | Server Options | C37.118 Options | Scenario Description | Last Solution Summary | Time Schedules | DNP3 Options

General Options

DNP3 Protocol Port: 20000

Log Outgoing Messages  Log Incoming Messages

# Configuration and Validation



## Validation

Summary

|                   |   |                         |   |
|-------------------|---|-------------------------|---|
| Connected Clients | 1 | Valid Commands Received | 0 |
| Valid Scans       | 0 | Simulation Events       | 0 |

Close

Input Contingency Actions | Simulation Actions | Simulation Events | Server Log | Connected Clients | DNP3 Log | Options

Log Outgoing DNPS Messages  Log Incoming DNPS Messages

|    | Time        | Source   | Hex Data                                  |
|----|-------------|----------|---|
| 58 |             |          | E8 C9 01 3C 02 06 3C 03 06 3C 04 06 7D AD |
| 59 | 11:16:43 PM | Outgoing | 05 64 0A 44 2F 02 30 02 48 C0             |
| 60 |             |          | C0 C9 81 00 00 5B DF                      |
| 61 | 11:16:48 PM | Incoming | 05 64 11 C4 30 02 2F 02 CE 63             |
| 62 |             |          | E9 CA 01 3C 02 06 3C 03 06 3C 04 06 08 7A |
| 63 | 11:16:48 PM | Outgoing | 05 64 0A 44 2F 02 30 02 48 C0             |
| 64 |             |          | C0 CA 81 00 00 1A D5                      |
| 65 | 11:16:53 PM | Incoming | 05 64 11 C4 30 02 2F 02 CE 63             |
| 66 |             |          | EA CB 01 3C 02 06 3C 03 06 3C 04 06 D6 14 |
| 67 | 11:16:53 PM | Outgoing | 05 64 0A 44 2F 02 30 02 48 C0             |
| 68 |             |          | C0 CB 81 00 00 F2 17                      |

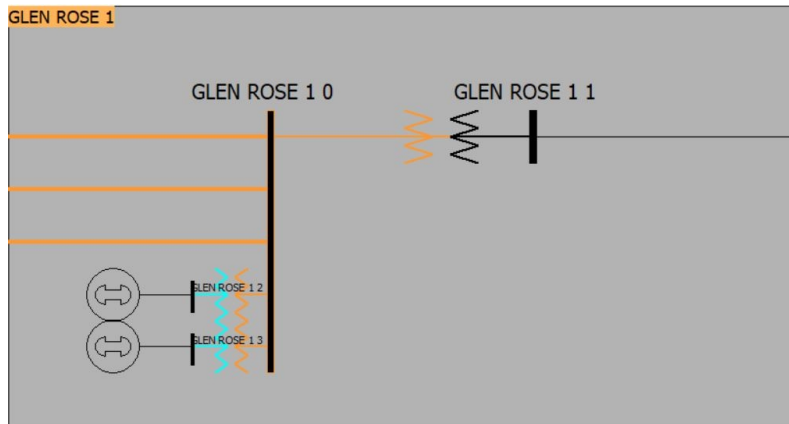
PowerWorld\_RTAC\_560\_DNP

Other, Client - Ethernet [DNP Protocol]

Settings SEL\_RTAC.Application.PowerWorld\_RTAC\_560\_DNP\_Controller

| Binary Inputs     | Expression                       | Type                            | Value |
|-------------------|----------------------------------|---------------------------------|-------|
| Double Bit Inputs | PowerWorld_RTAC_560_DNP_POU      | PowerWorld_RTAC_...             |       |
| Binary Outputs    | PowerWorld_RTAC_560_DNP_POU      |                                 | 0     |
| Counters          | PowerWorld_RTAC_560_DNP_POU_IIFE |                                 |       |
| Analog Inputs     | EN                               | ENO                             | TRUE  |
| Analog Outputs    | Disable_Tag_Updates              | Offline                         | FALSE |
|                   | Disable_Controls                 | Message_Sent_Count              | 35    |
|                   | Reset_Statistics                 | Message_Received_Count          | 35    |
|                   |                                  | Message_Failure                 | FALSE |
|                   |                                  | Message_Failure_Count           | 0     |
|                   |                                  | Message_Success_Count           | 70    |
|                   |                                  | Response_Timeout_Count          | 0     |
|                   |                                  | Data_Link_Timeout_Count         | 0     |
|                   |                                  | Buffer_Overflow                 | FALSE |
|                   |                                  | Invalid_Function_Block_Input    | FALSE |
|                   |                                  | Controls_Disabled               | FALSE |
|                   |                                  | Slow_Poll_Mode_Enabled          | FALSE |
|                   |                                  | IIN_1_1_Class_1                 | FALSE |
|                   |                                  | IIN_1_2_Class_2                 | FALSE |
|                   |                                  | IIN_1_3_Class_3                 | FALSE |
|                   |                                  | IIN_1_4_Need_Time               | FALSE |
|                   |                                  | IIN_1_5_Local                   | FALSE |
|                   |                                  | IIN_1_6_Device_Trouble          | FALSE |
|                   |                                  | IIN_1_7_Restart                 | FALSE |
|                   |                                  | IIN_2_3_Buffer_Overflow         | FALSE |
|                   |                                  | Control_Response_Code_TIMEOUT   | FALSE |
|                   |                                  | Control_Response_Code_NO_SELECT | FALSE |

# Exemplar



Substation 560 GLEN ROSE 1



Number: 560, Find By Number, Find By Name, Total Points: 38, Scan Period Multiplier: 1

Point Type Counts: Binary In: 9, Binary Out: 9, Analog In: 18, Analog Out: 2, Counter In: 0

Results and Control | All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

| Outstation Number | Zero-based Index | Object Type | Object ID By Number | Field Name | Analog Value |
|-------------------|------------------|-------------|---------------------|------------|--------------|
| 1                 | 560              | 0 Branch    | 5047 TO 5260        | MWFROM     | -1123.811    |
| 2                 | 560              |             |                     |            |              |
| 3                 | 560              |             |                     |            |              |
| 4                 | 560              |             |                     |            |              |
| 5                 | 560              |             |                     |            |              |
| 6                 | 560              |             |                     |            |              |
| 7                 | 560              |             |                     |            |              |
| 8                 | 560              |             |                     |            |              |
| 9                 | 560              |             |                     |            |              |
| 10                | 560              |             |                     |            |              |
| 11                | 560              |             |                     |            |              |
| 12                | 560              |             |                     |            |              |
| 13                | 560              |             |                     |            |              |
| 14                | 560              |             |                     |            |              |
| 15                | 560              |             |                     |            |              |
| 16                | 560              |             |                     |            |              |
| 17                | 560              |             |                     |            |              |
| 18                | 560              |             |                     |            |              |

Number: 560, Find By Number, Find By Name, Total Points: 38, Scan Period Multiplier: 1

Point Type Counts: Binary In: 9, Binary Out: 9, Analog In: 18, Analog Out: 2, Counter In: 0

Results and Control | All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

| Outstation Number | Zero-based Index | Object Type | Object ID By Number | Field Name | Analog Value |
|-------------------|------------------|-------------|---------------------|------------|--------------|
| 1                 | 560              | 0 Gen       | 5262 #1             | MWSETPOINT | 1211.633     |
| 2                 | 560              |             |                     |            |              |

Number: 560, Find By Number, Find By Name, Total Points: 38, Scan Period Multiplier: 1

Point Type Counts: Binary In: 9, Binary Out: 9, Analog In: 18, Analog Out: 2, Counter In: 0

Results and Control | All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

| Outstation Number | Zero-based Index | Object Type | Object ID By Number | Field Name | Binary Value |
|-------------------|------------------|-------------|---------------------|------------|--------------|
| 1                 | 560              | 0 Branch    | 5047 TO 5260        | STATUS     | 1            |
| 2                 | 560              | 1 Branch    | 5260 TO 5045        | STATUS     | 1            |
| 3                 | 560              | 2 Branch    | 5261 TO 5260        | STATUS     | 1            |
| 4                 | 560              | 3 Branch    | 5262 TO 5260        | STATUS     | 1            |
| 5                 | 560              | 4 Branch    | 5263 TO 5260        | STATUS     | 1            |
| 6                 | 560              | 5 Branch    | 5317 TO 5260        | STATUS     | 1            |
| 7                 | 560              | 6 Branch    | 5261 TO 5246        | STATUS     | 1            |
| 8                 | 560              | 7 Gen       | 5262 #1             | STATUS     | 1            |
| 9                 | 560              | 8 Gen       | 5263 #1             | STATUS     | 1            |

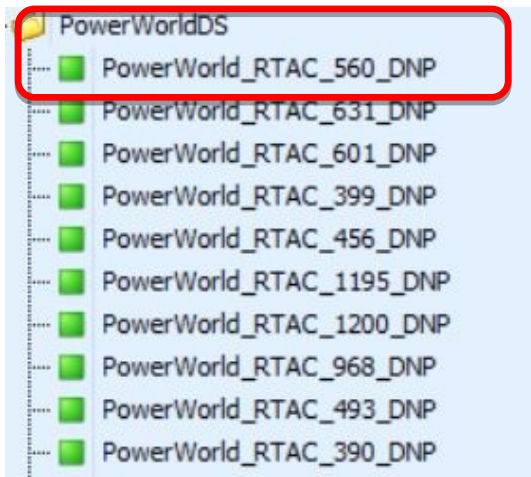
Analog Input

Analog Output

Binary Input

Binary Output

# Exemplar



PowerWorld\_RTAC\_560\_DNP  
Other, Client - Ethernet [DNP Protocol]

Settings  
Drag a column header here to group by that column

| Enable | Tag Name   | Point Number | Tag Type |
|--------|--|--------------|----------|
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.status            | 8            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.status            | 7            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5261_5246_1.status    | 6            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5317_5260_1.status    | 5            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5263_5260_1.status    | 4            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5262_5260_1.status    | 3            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5261_5260_1.status    | 2            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5260_5045_1.status    | 1            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5047_5260_1.status    | 0            | SPS      |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.operClose         | 8            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.operTrip          | 8            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.operLatchOff      | 8            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.operLatchOn       | 8            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5263_1.operPulse         | 8            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.operClose         | 7            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.operTrip          | 7            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.operLatchOff      | 7            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.operLatchOn       | 7            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Gen_5262_1.operPulse         | 7            | operSPC  |
| True   | PowerWorld_RTAC_560_DNP.BO_Substation_560_Branch_5261_5246_1.operClose | 6            | operSPC  |

Analog Input

Analog Output

Binary Input

Binary Output

# Data Collection



PowerWorld\_RTAC\_560\_DNP

Other, Client - Ethernet [DNP Protocol]

Settings

Expression

PowerWorld\_RTAC\_560\_DNP.AI\_Substation\_560\_Branch\_5047\_5260\_1\_MVARFROM

| Expression  | Type    | Value      |
|---|---------|------------|
| PowerWorld_RTAC_560_DNP.AI_Substation_560_Branch_5047_5260_1_MVARFROM | MV      |            |
| instMag   | REAL    | 118.990372 |
| mag   | REAL    | 118.990372 |
| range   | RANGE_T | normal     |

Number: 560

Name: [ ]

Total Points: 38

Scan Period Multiplier: 1

Point Type Counts: Binary In: 9, Binary Out: 9, Analog In: 18, Analog Out: 2, Counter In: 0

Results and Control: All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

Outstation Number: 560

Zero-based Index: [ ]

Object Type: [ ]

Object ID By Number: [ ]

Field Name: [ ]

Analog Value: [ ]

WFROM: -1123.811

Number: 560

Name: [ ]

Total Points: 38

Scan Period Multiplier: 1

Point Type Counts: Binary In: 9, Binary Out: 9, Analog In: 18, Analog Out: 2, Counter In: 0

Results and Control: All Points | Binary In Points | Analog In Points | Counter In Points | Binary Out Points | Analog Out Points

Outstation Number: 560

Zero-based Index: [ ]

Object Type: [ ]

Object ID By Number: [ ]

Field Name: [ ]

Binary Value: [ ]

| Outstation Number | Zero-based Index | Object Type | Object ID By Number | Field Name | Binary Value |
|-------------------|------------------|-------------|---------------------|------------|--------------|
| 1                 | 560              | 0 Branch    | 5047 TO 5260        | STATUS     | 1            |
| 2                 | 560              | 1 Branch    | 5260 TO 5045        | STATUS     | 1            |
| 3                 | 560              | 2 Branch    | 5261 TO 5260        | STATUS     | 1            |
| 4                 | 560              | 3 Branch    | 5262 TO 5260        | STATUS     | 1            |
| 5                 | 560              | 4 Branch    | 5263 TO 5260        | STATUS     | 1            |
| 6                 | 560              | 5 Branch    | 5317 TO 5260        | STATUS     | 1            |
| 7                 | 560              | 6 Branch    | 5261 TO 5246        | STATUS     | 1            |
| 8                 | 560              | 7 Gen       | 5262 #1             | STATUS     | 1            |
| 9                 | 560              | 8 Gen       | 5263 #1             | STATUS     | 1            |

PowerWorld\_RTAC\_560\_DNP

Other, Client - Ethernet [DNP Protocol]

Settings

Expression

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5047\_5260\_1

| Expression   | Type         | Value   |
|--|--------------|---------|
| PowerWorld_RTAC_560_DNP.BI_Substation_560_Branch_5047_5260_1 | SPS          |         |
| stVal  | BOOL         | TRUE    |
| q  | quality_t    |         |
| validity   | VALIDITY_T   | good    |
| detailQual   | detailQual_t |         |
| source   | SOURCE_T     | process |
| test   | BOOL         | FALSE   |
| operatorBlocked  | BOOL         | FALSE   |
| t  | timeStamp_t  |         |

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5260\_5045\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5261\_5246\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5261\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5262\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5263\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Branch\_5317\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Gen\_5262\_1

PowerWorld\_RTAC\_560\_DNP.BI\_Substation\_560\_Gen\_5263\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5047\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5260\_5045\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5261\_5246\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5261\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5262\_5260\_1

PowerWorld\_RTAC\_560\_DNP.BO\_Substation\_560\_Branch\_5263\_5260\_1



This paper presents a cyber-physical testbed implementation of new DNP3 communication functionality of PWDS with SEL RTAC, mimicking the interactive control and response between real-time power system simulation and hardware devices in real world.

For future work, we can incorporate real or emulated communication network between PWDS and industrial hardware and software. Cyber intrusions can then be performed in the communication network, and the power system impacts can be observed in PWDS with real-time simulation; hardware devices can also detect such events with pre-defined alerts and control logic.

# Acknowledgement



TEXAS A&M UNIVERSITY  
Engineering

The work described in this paper was supported by funds from the US Department of Energy under award DE-OE0000895 and the National Science Foundation under Grant 1916142.



INTEGRITY  
EXCELLENCE LEADERSHIP



TEXAS A&M UNIVERSITY  
Engineering

**Thank you**

