A Practical Approach to Implementing IEC 61850 and Real-Time HIL Testing of Virtualized Applications

Presented by:

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About Tesco Automation

- Design & Test IEC 61850 Protection, Automation, and Control (PAC) systems for end users
- IEC 61850 standards development
- IEC 61850 in-depth training
- Forefront on the application of Virtualized PAC systems
- System Modeling with Hardware-In-The-Loop (HIL) testing

Intention of this Presentation

Provide a vision of what digitalization looks like

Present a strategy for getting there

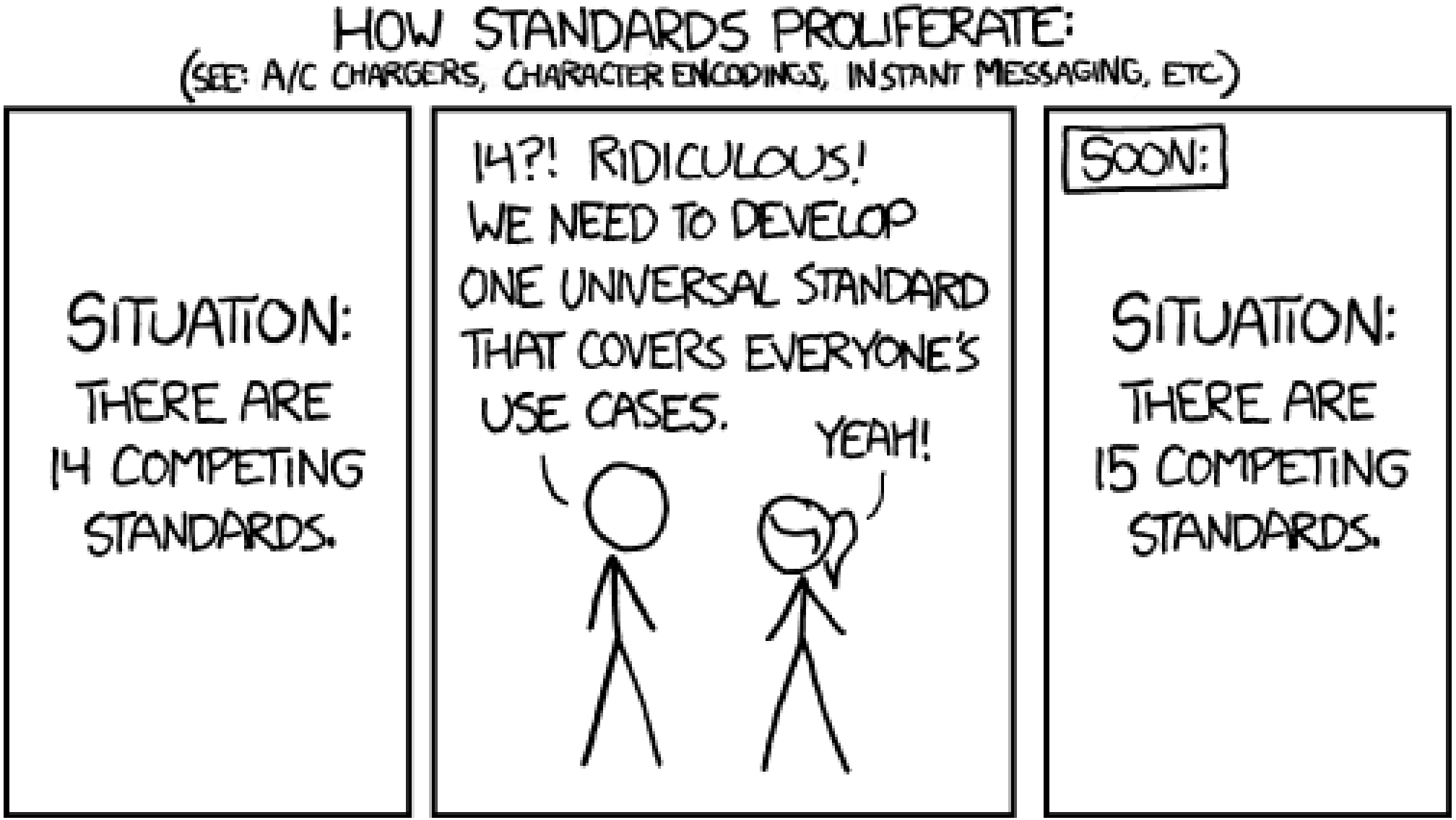
Present ideas for tools to help gain confidence in the transition

Market Trends

- Distributed Energy Resources
- Demand due to electrification of transportation, heating/cooling, etc
- Growth of cloud computing
- Machine Learning & AI

Market Trend Response

- Flexible, data-driven grid evolution
- Protection, Automation, and Controls of power systems need to adapt
- Ideal solution incorporates open, interoperable standards with emphasis on a Software defined approach



https://xkcd.com/927/

What does Digitalization Look Like

- IEC 61850
  - International standard defining communication protocols for intelligent electronic devices
  - Standardized framework for interoperability
  - Machine-Readable Standard
  - Foundation for telemetry, protection-speed signals, and digitized streams of sensor information

Enables the Shift from Hardware to Software

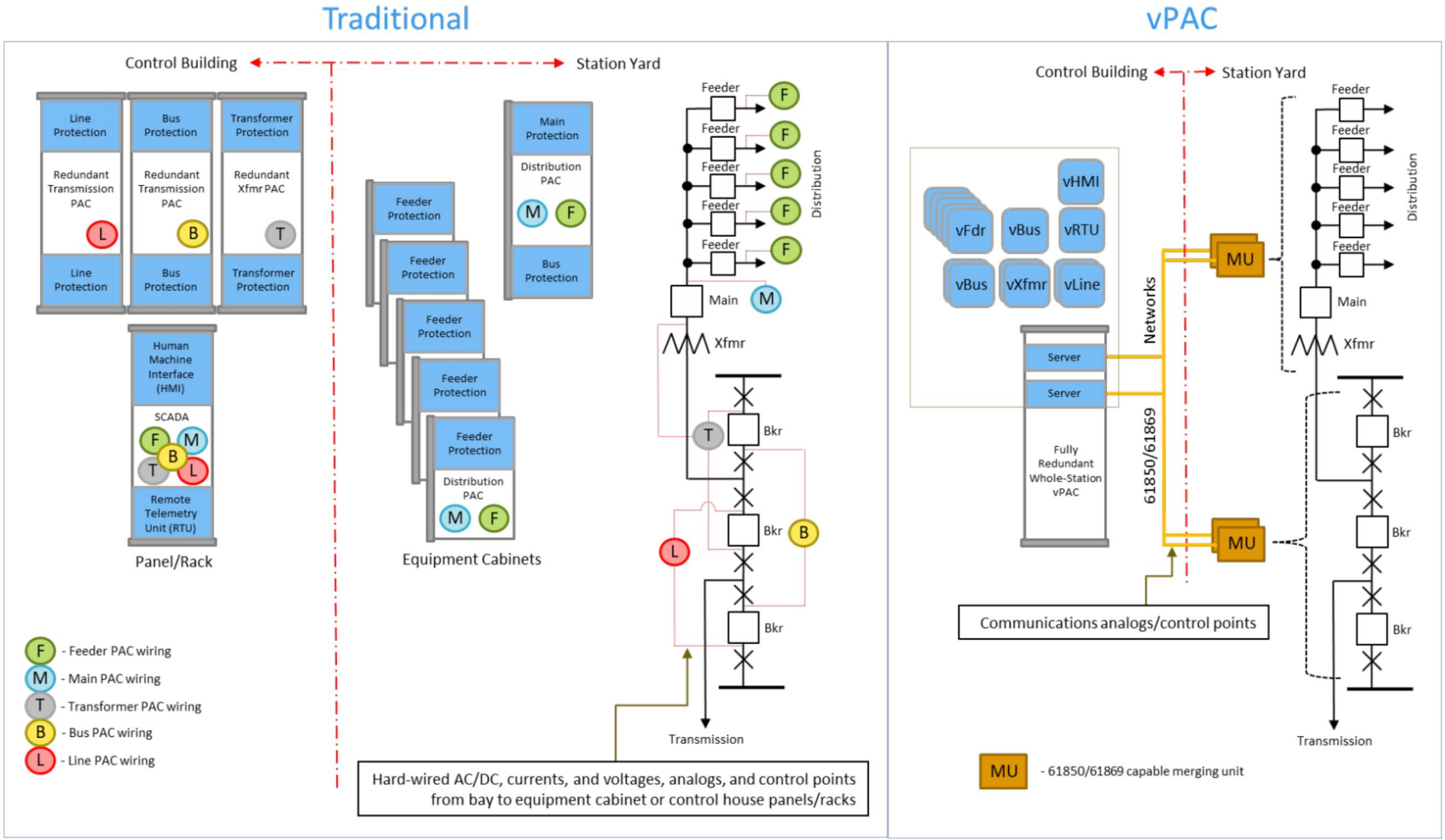
What does Digitalization Look Like

- vPAC Alliance – Virtual Protection Automation and Control Alliance
  - Established to advocate for standards that promote flexible, manageable, and interoperable platforms within the energy sector
  - Focuses on advancing the adoption of virtualization within substations

Enables the Software to Scale

Take all of this (and more)…

...Place it on this


Traditional
Control Building
Station Yard
Line Protection
Redundant Transmission PAC
L
Line Protection
Bus Protection
Redundant Transmission PAC
B
Bus Protection
Transformer Protection
Redundant Xfmr PAC
T
Transformer Protection
Human Machine Interface (HMI)
SCADA
F
M
B
T
L
Remote Telemetry Unit (RTU)
Panel/Rack
Feeder Protection
Feeder Protection
Feeder Protection
Feeder Protection
Feeder Protection
Distribution PAC
M
F
Equipment Cabinets
Main Protection
Distribution PAC
M
F
Bus Protection
Feeder
F
Distribution
Main
M
Xfmr
T
Bkr
Bkr
B
L
Bkr
Transmission
F - Feeder PAC wiring
M - Main PAC wiring
T - Transformer PAC wiring
B - Bus PAC wiring
L - Line PAC wiring
Hard-wired AC/DC, currents, and voltages, analogs, and control points from bay to equipment cabinet or control house panels/racks
vPAC
Control Building
Station Yard
vHMI
vFdr
vBus
vRTU
vBus
vXfmr
vLine
Server
Server
Fully Redundant Whole-Station vPAC
Networks
61850/61869
MU
MU
Communications analogs/control points
Feeder
Distribution
Main
Xfmr
Bkr
Bkr
Bkr
Transmission
MU - 61850/61869 capable merging unit

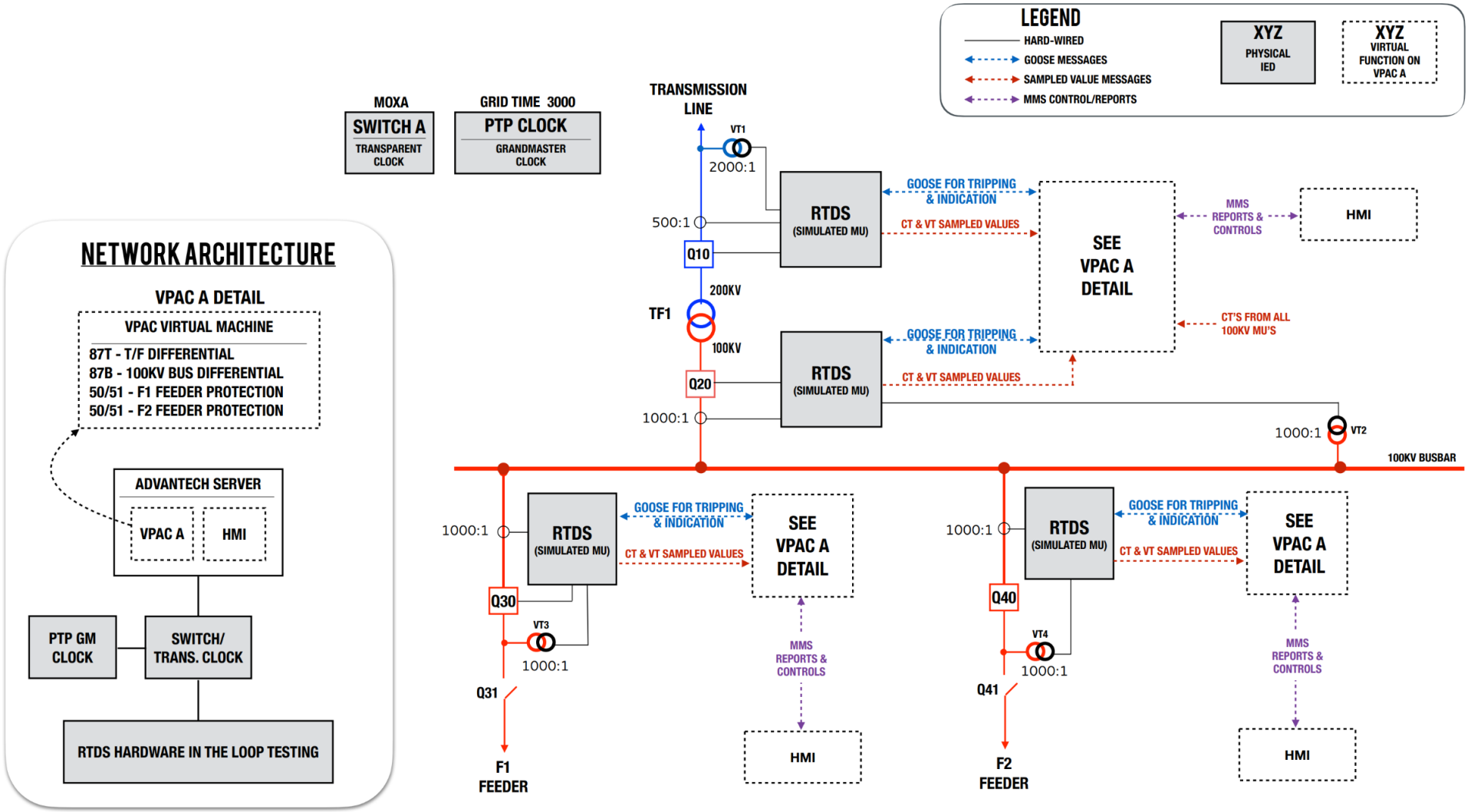
Strategic Thinking

High Level Strategy for Digitalization

1. Appropriate training at the appropriate time
   - Includes engineers, technicians, operators, and managers
2. Embrace IT Partners
3. Test, Test, Test
   - Evaluate in a lab environment
   - Run VMs in parallel as regression testing
   - Introduce HIL testing as a means for testing
4. Build it!
   - Realize the first build is going to include many lessons learned

Demo Setup

Tesco VPAC Demonstration System



Hardware Setup

- GPS Clock providing PTP time source
- Server configured with 24 core Intel Xeon processor, 128GB RAM
- Real Time Simulator with Network Interfaces for Sampled Value streams
- Network Switch with 28 ports

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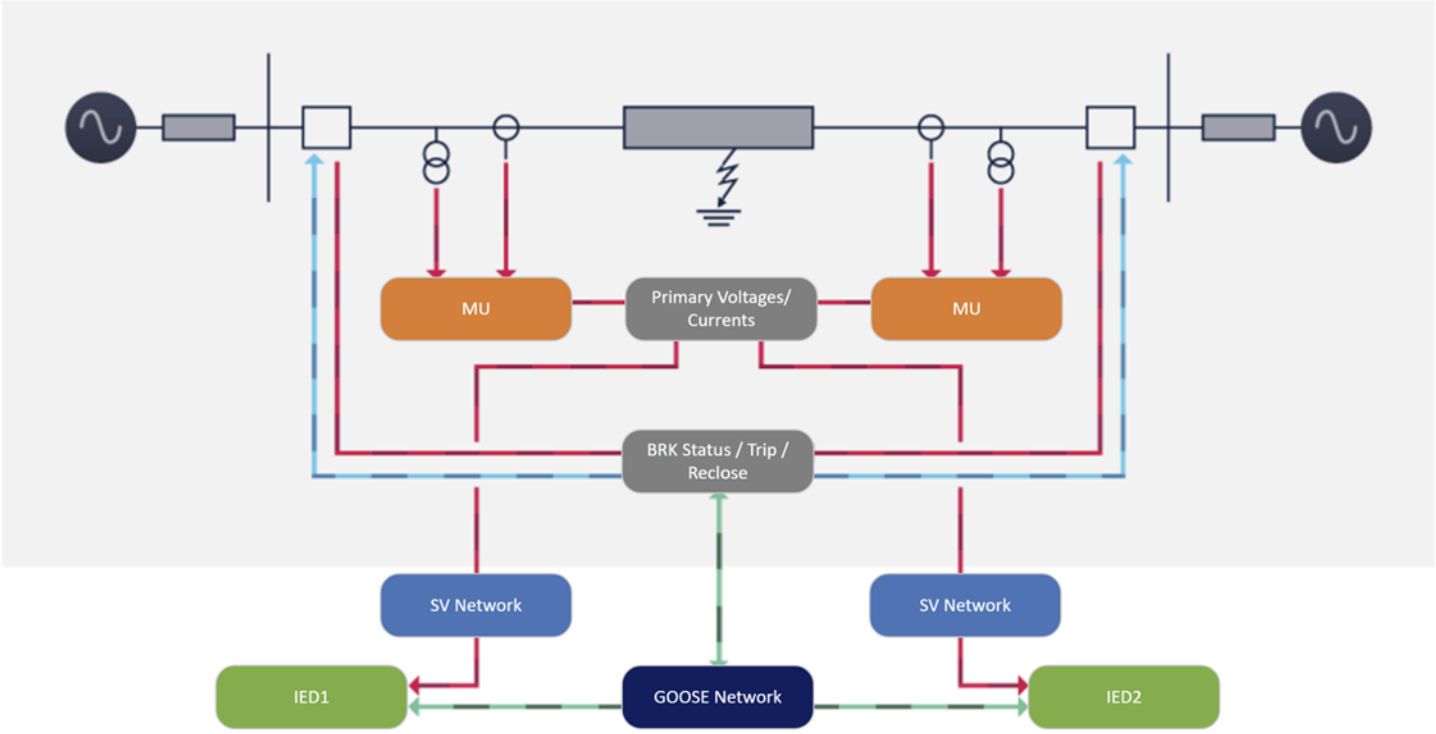
Software Setup

- Server Side - DUT
  - VMWare ESXi Hypervisor
  - ABB SSC600 Centralized Protection Platform as a VM
  - Windows VM for management and configuration
- Test Side
  - Test Computer running RTDS RSCAD
  - Web browser for interface to SSC600

Real Time HIL Testing

Real-Time HIL Testing

- Simulate -
  - Physical Primary system
  - Secondary systems like MU
- Output -
  - Bus voltages and line currents
  - Status of the breaker
- Receive -
  - Trip and reclose

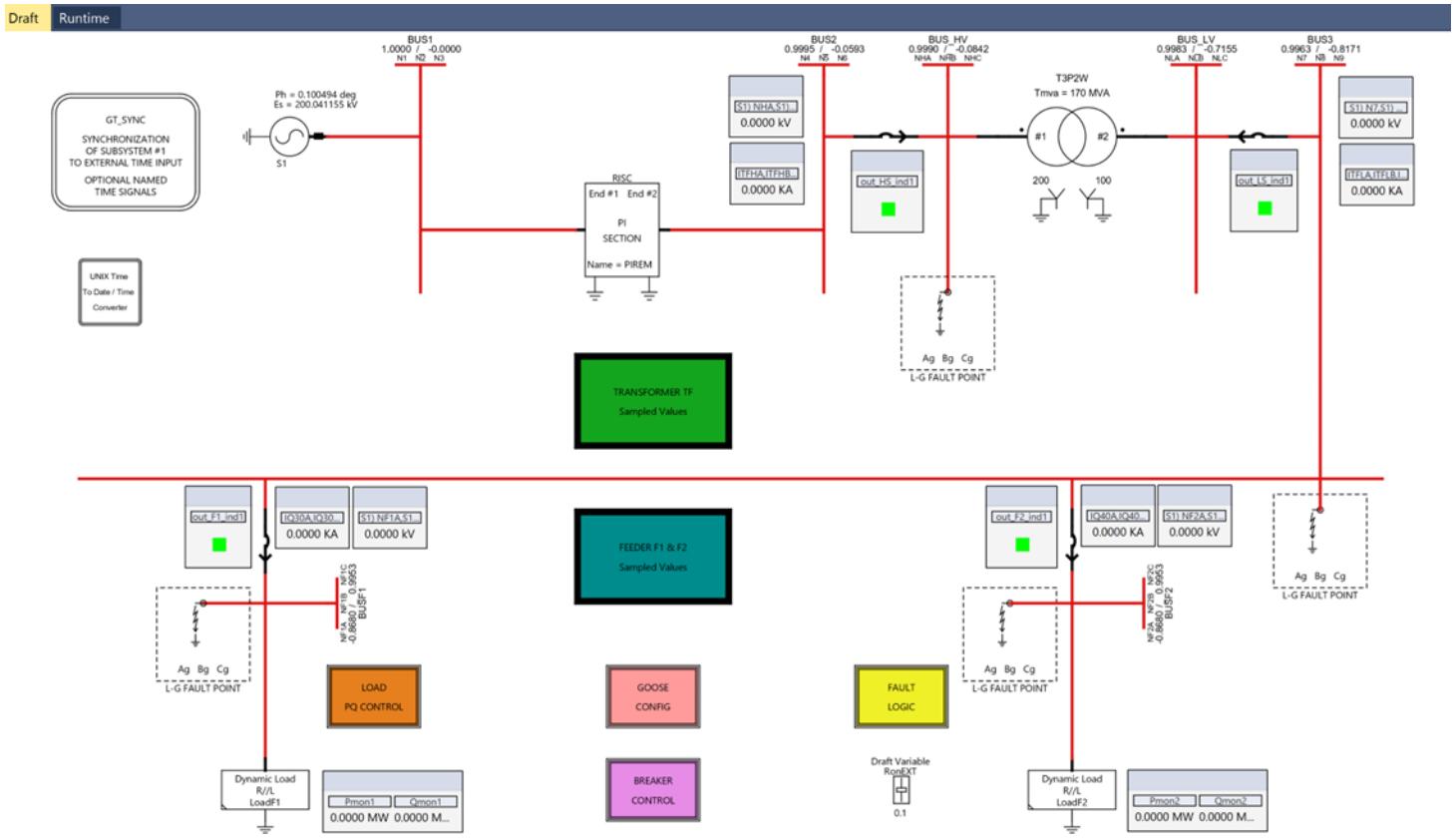


Benefits of Real-Time HIL testing

- Gain insights into the performance of PAC applications and the dynamic response of the power system
- Test interoperability of protection and control IEDs from multiple vendors with communication protocols
- Test novel protection algorithm in real-time before the release of the target hardware
- Develop and pre-commission protection schemes for utilities.
- Automate real-time testing with Script

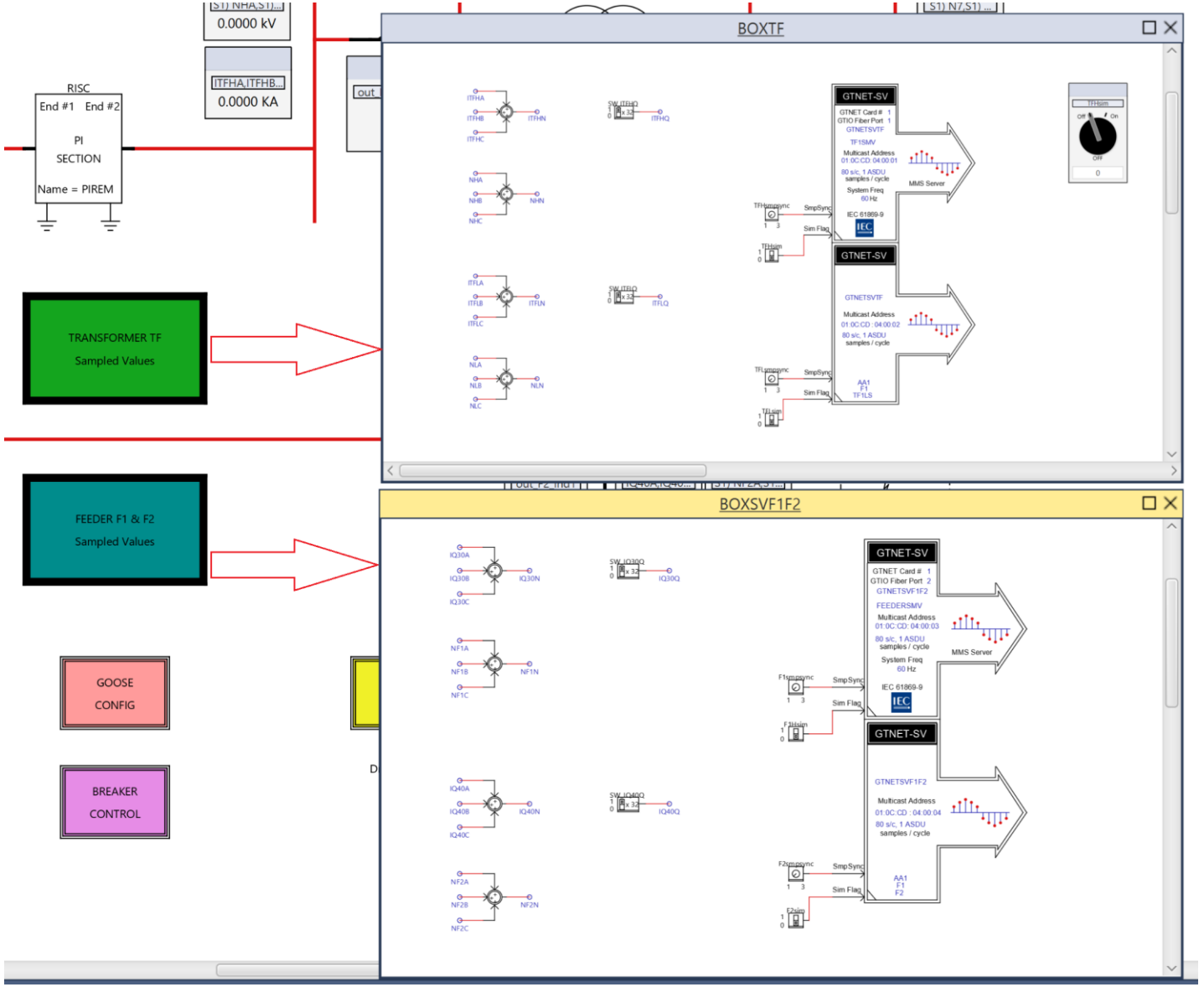
Virtualized Application - Modeling

- Both the primary system and MUs are modeled in the Real-Time Digital Simulator
- The simulated system Interfaces with external vPAC using IEC 61850 protocol
  - 4 SV streams are subscribed by vPAC
  - The status of all 4 CBs are subscribed by vPAC using GOOSE
  - Controls from vPAC are subscribed by the simulator using GOOSE



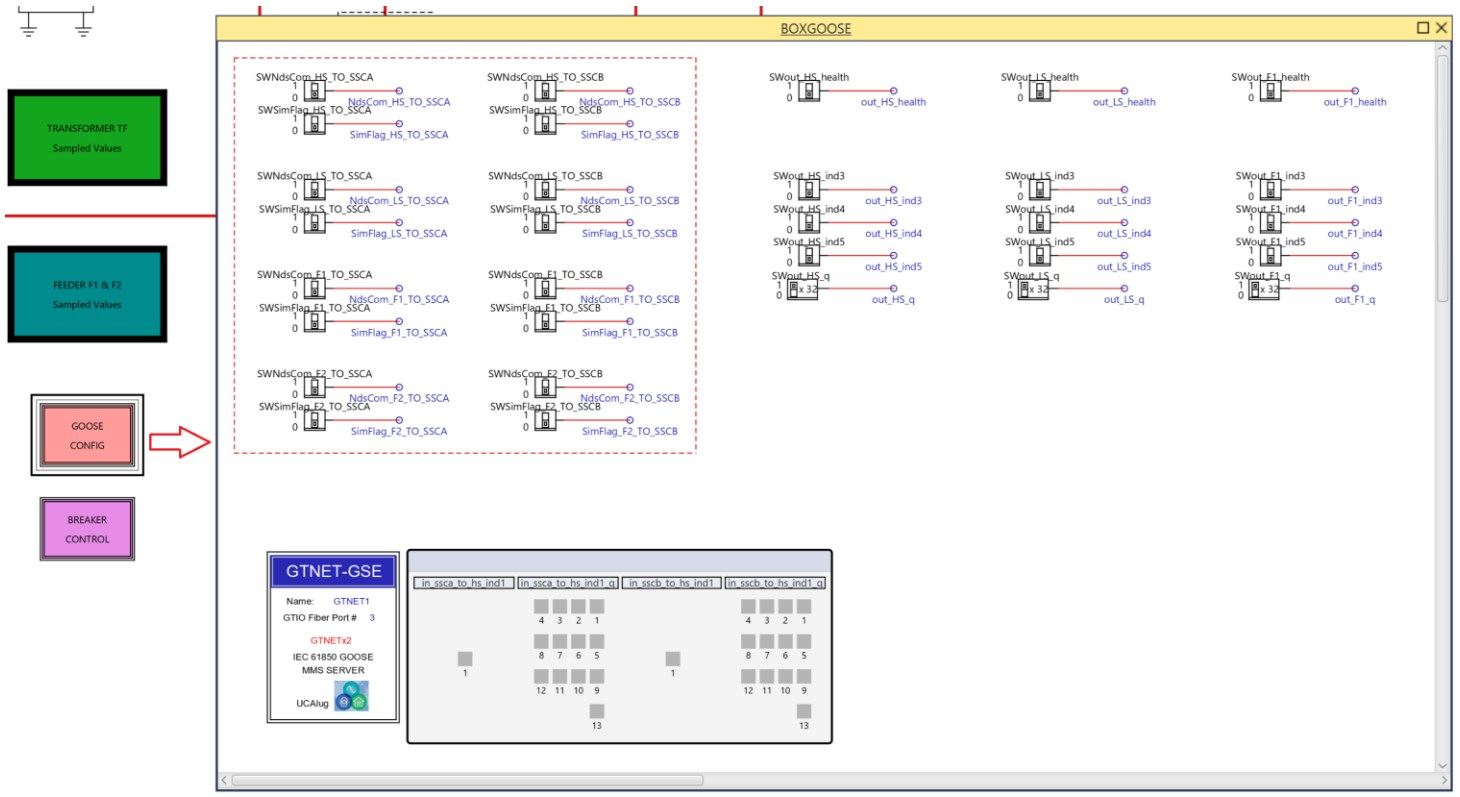
Virtualized Application - Modeling: MUs

- IEC 61850-9-2 LE SV streams for -
  - Transformer High & Low side
  - Feeder F1 & F2



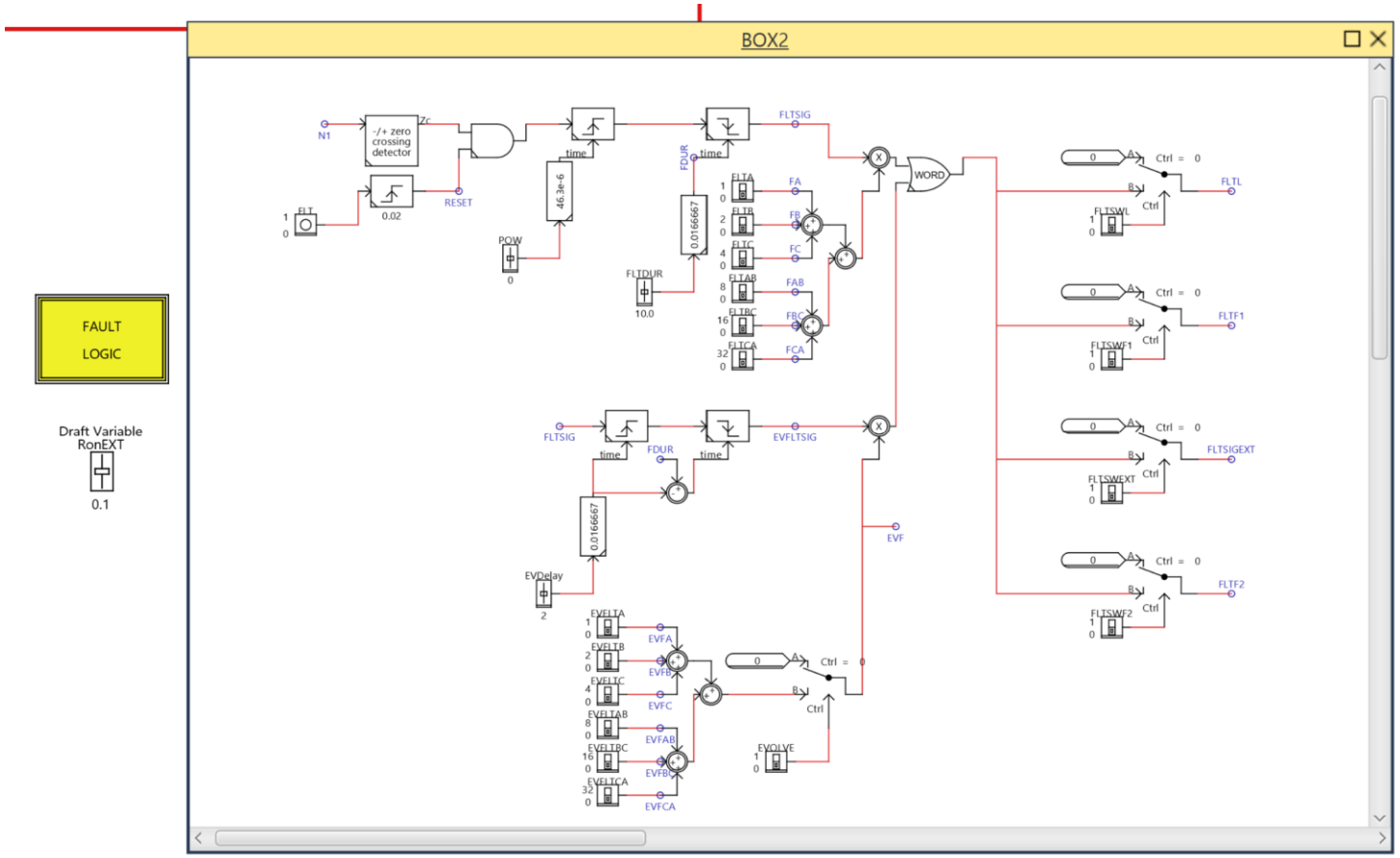
Virtualized Application - Modeling: CBs

- IEC 61850-8-1 GOOSE streams for -
  - Transformer High & Low side CB status
  - Feeder F1 & F2 CB status
  - Trips & Reclose from external vPAC



Virtualized Application - Modeling: Faults

- Various fault scenarios are available to be simulated for testing the external vPAC



Virtualized Application - Scripting

- C-like programming language
- Adaptive via if, for, while statements
- User-defined subroutines
- Customized results reporting
- Automated plot printing

```
Stop;

setfaultswitch();

SetSlider "Subsystem #1 : CTLs : Inputs : FON" = 0.0;
SetSlider "Subsystem #1 : CTLs : Inputs : FLTDUR" = 10.0;
SetSwitch "Subsystem #1 : CTLs : Inputs : SWint_or_ext" = 1.0;

SUSPEND 3.0;

//SetPlotSeconds 1.25,1,5;


/*********** Print the Test header to the test results file **********/
fprintf(fname, "*****************************************************************\n");
fprintf(fname, "* VPAC HIL TESTS USING RTDS SIMULATION SYSTEM\n");
fprintf(fname, "*\n");
fprintf(fname, "* SSC600 TEST PERFORMANCE SUMMARY\n");
fprintf(fname, "*\n");
fprintf(fname, "* TEST STARTED: %s\n",date());
fprintf(fname, "*****************************************************************\n");
fprintf(fname, "\n");
fprintf(fname, "Test%s",delim);
fprintf(fname, "Type%s",delim);
fprintf(fname, "Location%s",delim);
fprintf(fname, "RON%s",delim);
fprintf(fname, "FON%s",delim);
fprintf(fname, "HSTrip%s",delim);
fprintf(fname, "LSTrip%s",delim);
fprintf(fname, "F1Trip%s",delim);
fprintf(fname, "F2Trip%s",delim);
fprintf(fname, "HStripTime%s",delim);
fprintf(fname, "LStripTime%s",delim);
fprintf(fname, "F1tripTime%s",delim);
fprintf(fname, "F2tripTime%s",delim);
fprintf(fname, "Pass/Fail%s",delim);


/***************************** TESTING LOOP *********************************/
fprintf(stdmsg, "* VPAC HIL TESTS USING RTDS SIMULATION SYSTEM \n");
Wait 3.0;

Start;

for (iff=0;iff<4;iff++)
{
    /* test counter */
    itc=itc+1;

    setfaultlocation();

    fprintf(fname, "%d%s%s%s%s%s%f%s%f%s",itc,delim,seq[10],delim,ffloc[iff],delim,0.1,delim,angle[0],delim);
    fprintf(stdmsg, "Test Case Number: %d\tFault Type set to: %s\tFault Location: %s\tFault Resistance for this case is set to: %f ohms\tPoint on wave for this case is set to: %f degrees",itc,seq[10],ffloc[iff],0.1,angle[0]);

    Wait 5.0;

    applyfault();

    getfaultdata();

    reset_brk();
}

fprintf(fname, "TEST FINISHED: %s\n",date());
fprintf(stdmsg, "Testing Finished, Total Test Cases performed: %d",itc);

Stop;

/***************************** END OF TESTING LOOP **************************/

/***************************** USER FUNCTIONS *******************************/
function applyfault()
{
    //Start ;

    fprintf(stdmsg, "Waiting 5 sec For Steady State Condition");
    SUSPEND 5.0;

    PushButton "Subsystem #1 : CTLs : Inputs : FLT";
    ReleaseButton "Subsystem #1 : CTLs : Inputs : FLT";

    return 0;
}

function getfaultdata()
{
    fprintf(stdmsg, "Saving Fault Voltages and Currents and Relay Operate TImes");

    SUSPEND 5.0;

    TT_HS = MeterCapture("TTHS");
    TT_LS = MeterCapture("TTLS");
    TT_F1 = MeterCapture("TTF1");
    TT_F2 = MeterCapture("TTF2");
```

Main Takeaways

Conclusion

- Digitalization of power systems is possible TODAY
- Plan your strategy on how to get there
- Learn and leverage interoperable standard tools and software

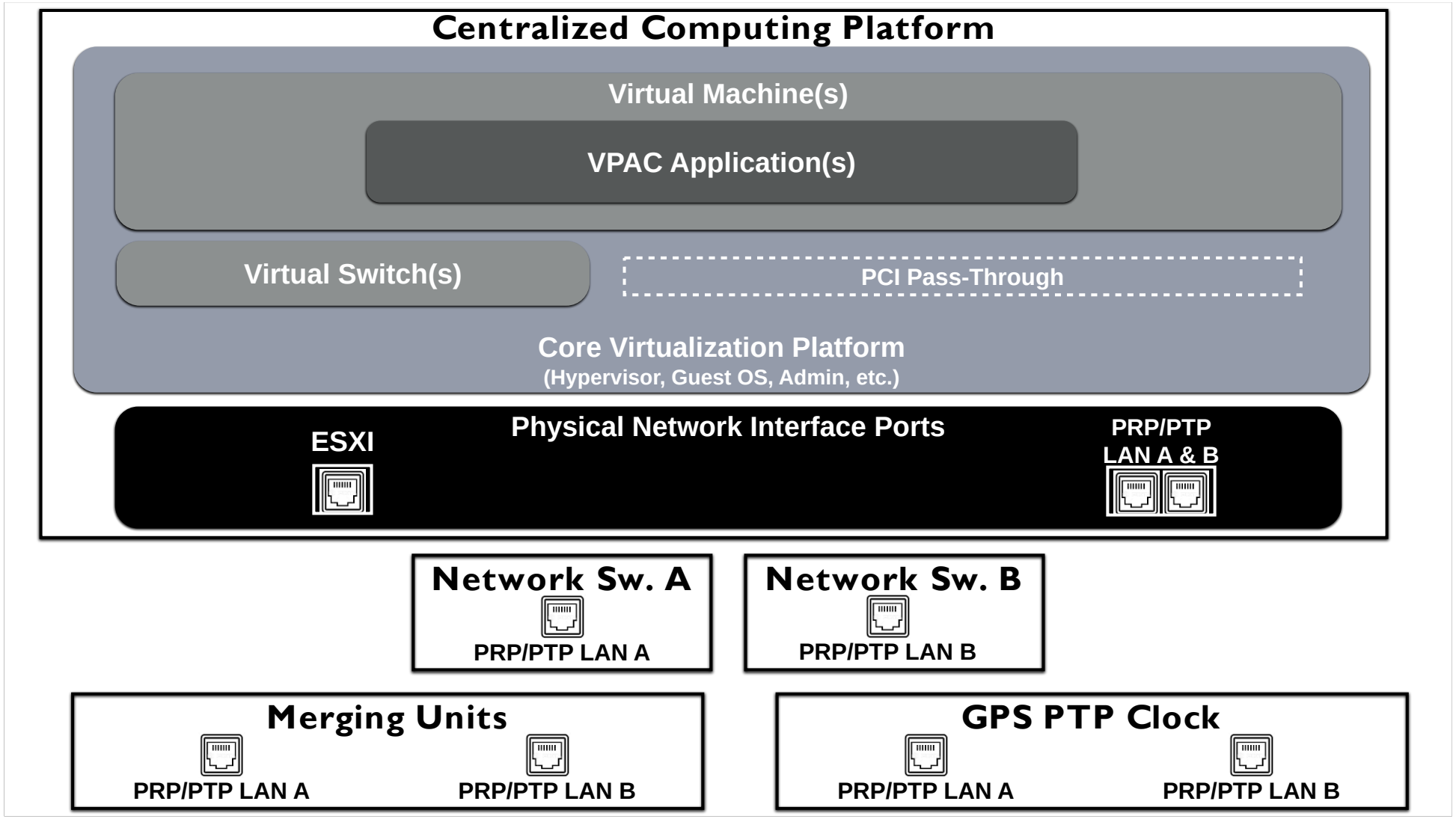

IEC 61850
UNIVERSITY
TRAINING • TESTING • CONSULTING
61850university.com


TESCO
TescoAutomation.com


Digital Substations
USER TASK FORCE
DigitalSubstations.com

Questions?

Backup slides


Centralized Computing Platform
Virtual Machine(s)
VPAC Application(s)
Virtual Switch(s)
PCI Pass-Through
Core Virtualization Platform
(Hypervisor, Guest OS, Admin, etc.)
ESXI
Physical Network Interface Ports
PRP/PTP
LAN A & B
Network Sw. A
PRP/PTP LAN A
Network Sw. B
PRP/PTP LAN B
Merging Units
PRP/PTP LAN A
PRP/PTP LAN B
GPS PTP Clock
PRP/PTP LAN A
PRP/PTP LAN B