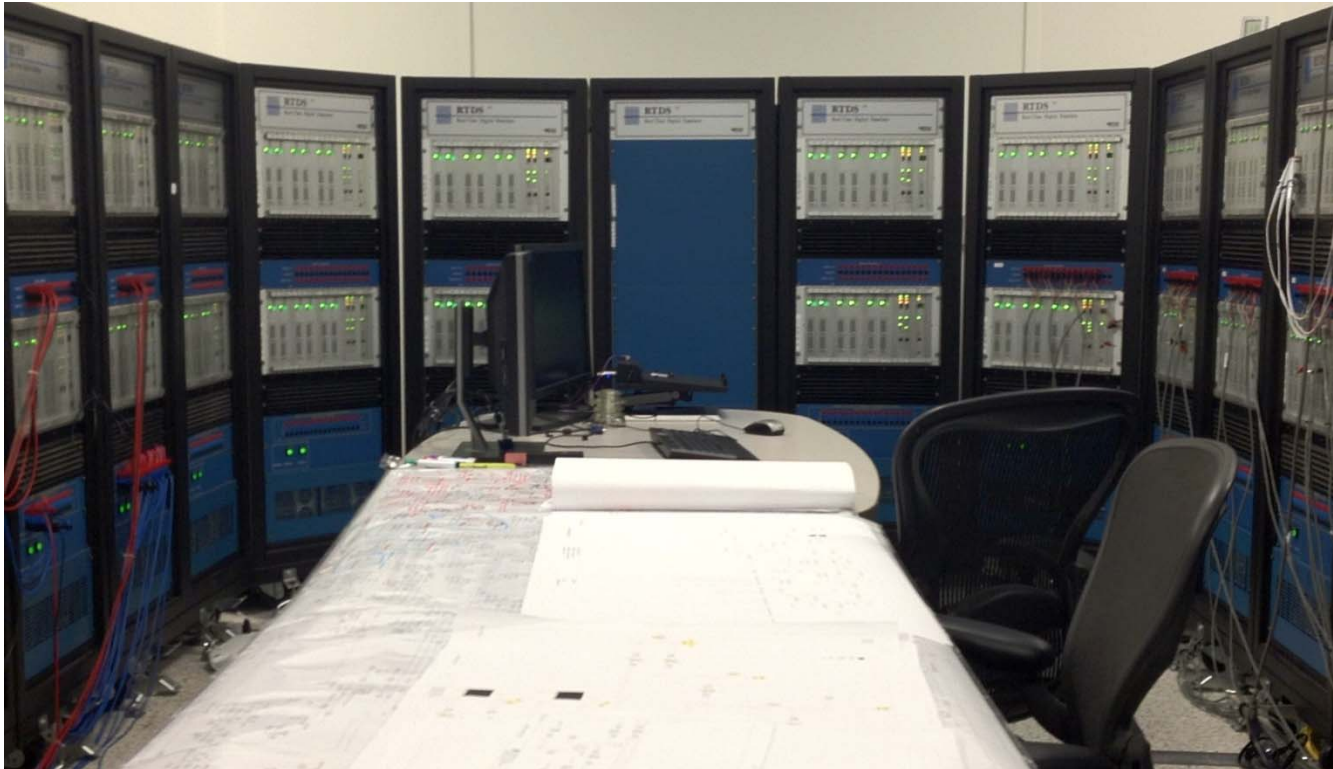# SUBSTATION AUTOMATION TESTING USING REAL TIME DIGITAL SIMULATOR (RTDS)
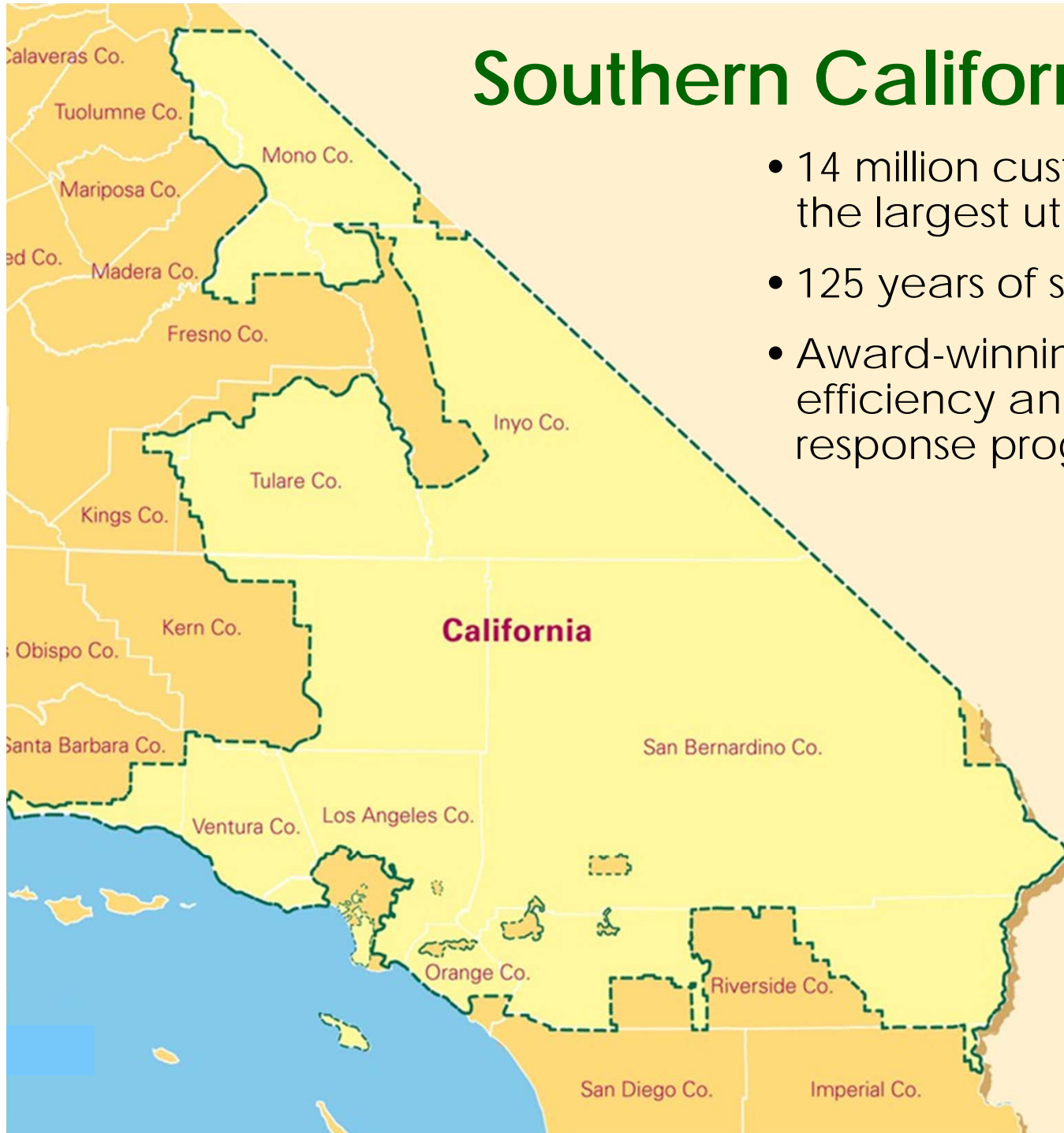

Son Le, Zeus Xioco, Southern California Edison

Southern California Edison

- 14 million customers: one of the largest utilities in US

- 125 years of service

- Award-winning energy efficiency and demand response programs

Committed to safely providing, reliable and affordable electric service

Substation Automation Efforts

- ## Substation automation 3 pilot
  - Using open standards
  - Improving engineering processes
  - Automated data collection
  - Data-driven configuration
    - Reduction in errors
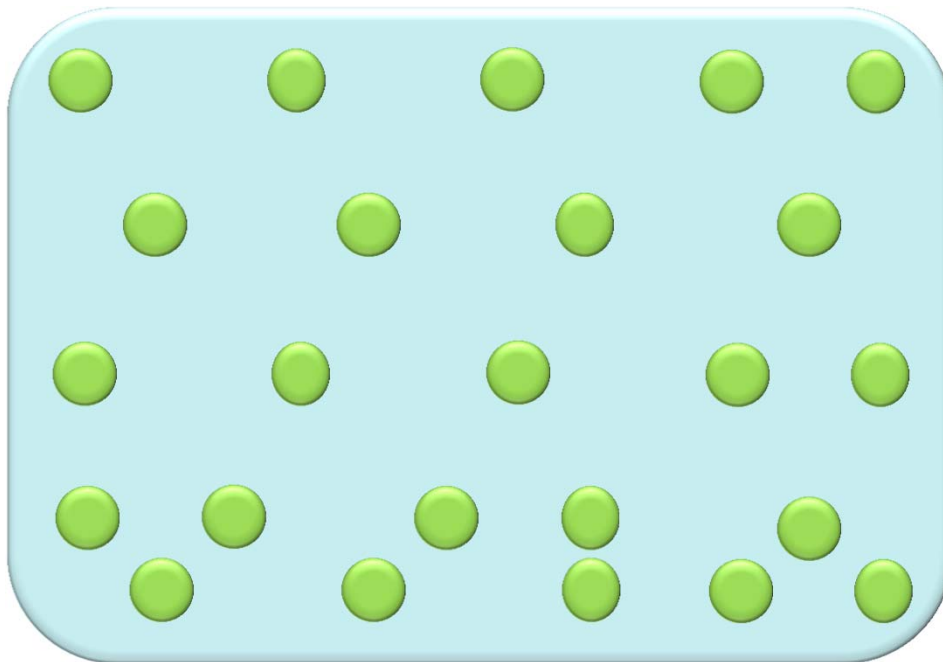   - Improved quality and consistency

Leading the Way in Electricity℠

FAT/SAT Motivation

➢Manual process

FAT/SAT Motivation

➢Manual process

➢Comprehensive, but spotty

FAT/SAT Motivation

➢Manual process

➢Comprehensive, but spotty

➢Tedious and time consuming

➢FAT is typically four to five weeks for a small station.

➢In-service testing is typically three to four weeks for a small station

FAT/SAT Motivation

➢ Manual process

➢ Comprehensive, but spotty

➢ Tedious and time consuming

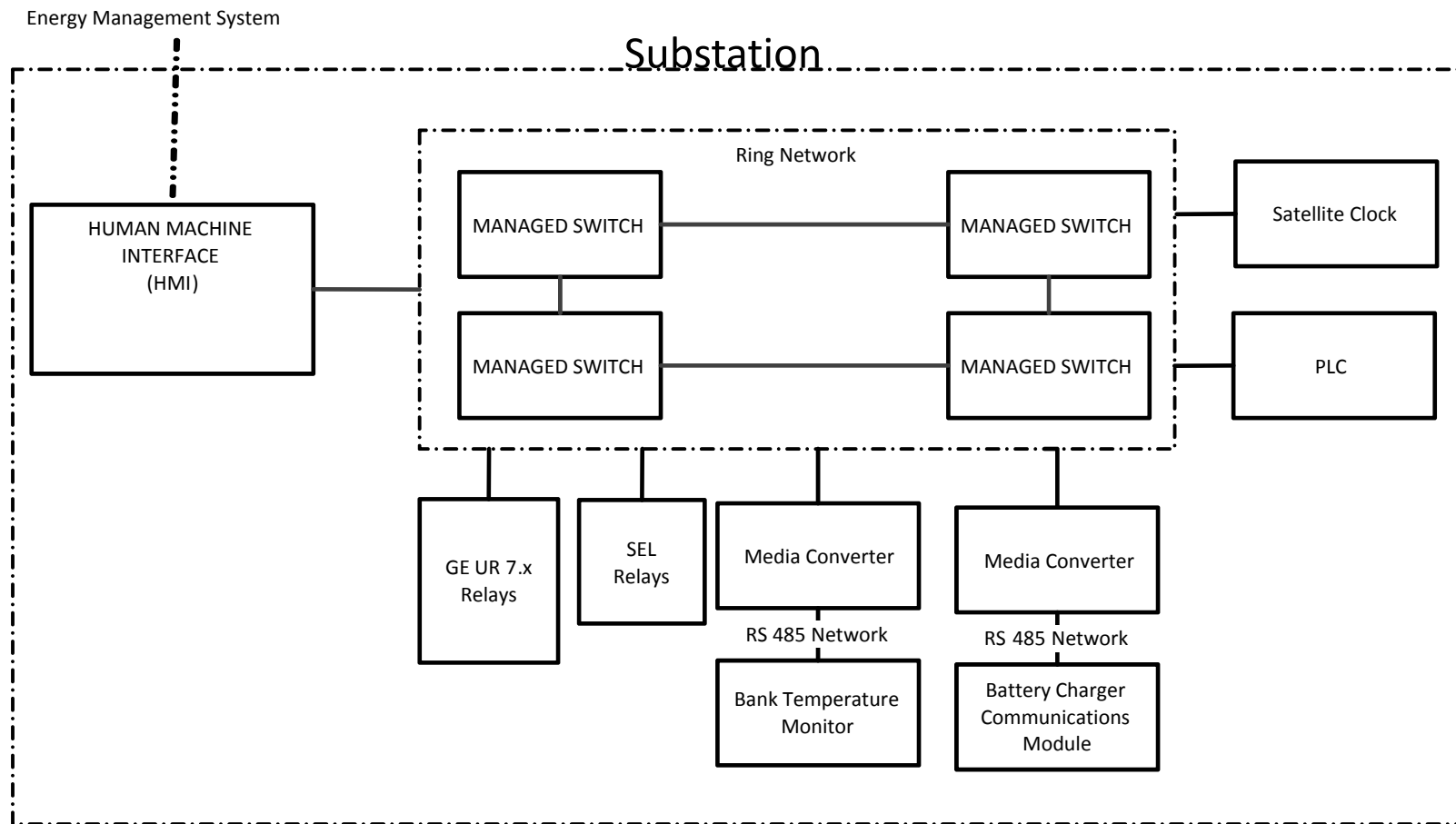➢ Large percentage of total project cost

Testing

Mobile RTDS Testing

➢ Take RTDS to the field

Distribution Substation Automation System Block Diagram

Energy Management System

Substation

Ring Network

HUMAN MACHINE INTERFACE (HMI)

MANAGED SWITCH

MANAGED SWITCH

MANAGED SWITCH

MANAGED SWITCH

Satellite Clock

PLC

GE UR 7.x Relays

SEL Relays

Media Converter

Media Converter

RS 485 Network

RS 485 Network

Bank Temperature Monitor

Battery Charger Communications Module

SOUTHERN CALIFORNIA
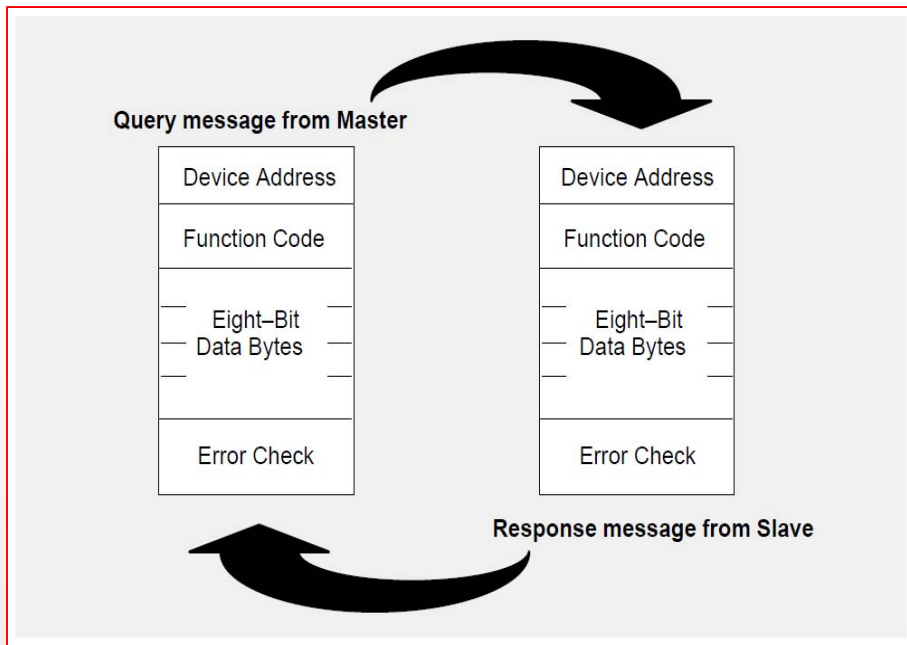EDISON®
An *EDISON INTERNATIONAL*® Company

Common Substation Automation Communication Testing
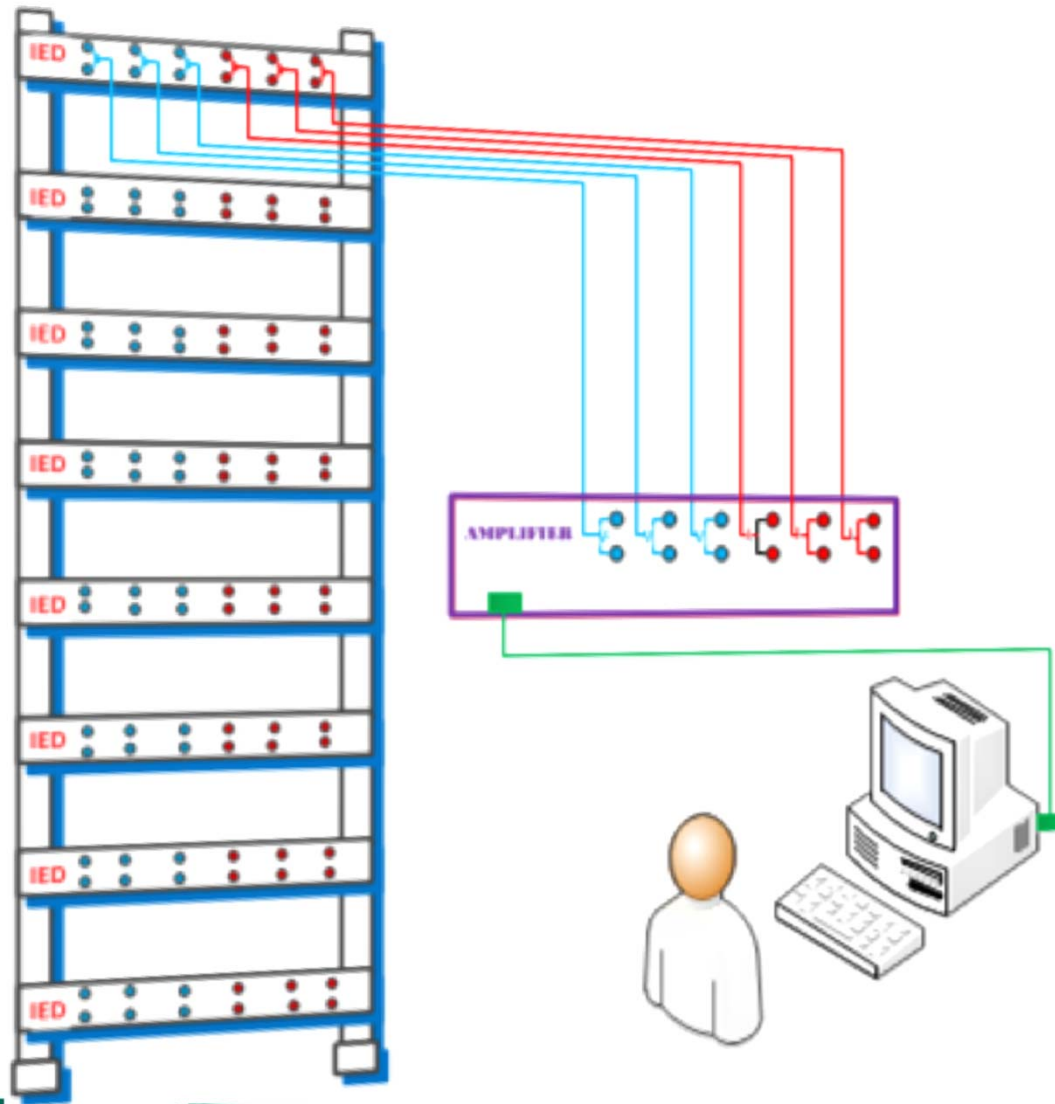
➤ **Test one relay at a time**

  ✓ **Wiring current and voltages**

  ✓ **Configuration amplifier**

  ✓ **Build test plan**

  ✓ **Check IED condition**

➤ **Hightly manual process**

Modbus in RTDS and GE Relays

➤ **Modbus protocol**

Query message from Master

| Device Address |
| Function Code |
| Eight–Bit Data Bytes |
| Error Check |

| Device Address |
| Function Code |
| Eight–Bit Data Bytes |
| Error Check |

Response message from Slave

➤ **GE Relays expose nearly all functions and values via Modbus**

➤ **RTDS Modbus scrip integration**

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# Purpose of Using Modbus Communication in RTDS and GE Relay

➢ **Simulate GE relay push buttons using RTDS script**

➢ **Can test automation function of all relay for the entire system**

➢ **Can test numerous faults and automation scenarios to check system behaviors**

➢ **Help the field personnel save time in production testing**

➢ **Help "FAT" testing save time**

66kV RTDS Model
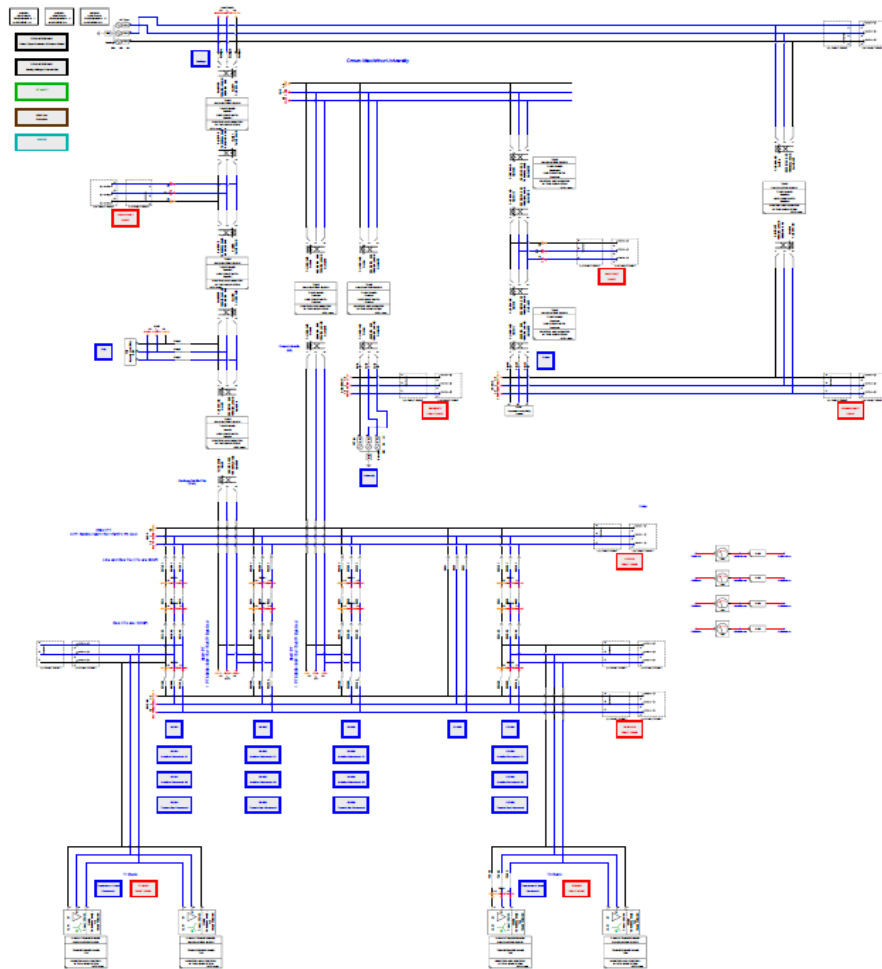
- ➢ **Represent similar substation one-line diagram**
  - ✓ **Sources lines**
  - ✓ **Operating/transfer buses**
  - ✓ **CB and disconnects**
  - ✓ **High side transformer banks**

- ➢ **Subsystem 1 for high-side (66kV) of substation**

- ➢ **Required minimum 3GPC/PB5 processing cards**

- ➢ **Faults type, location, and duration**
  - ✓ **Line to ground (AG, BG, CG)**
  - ✓ **Line to line (AB, BC, CA)**
  - ✓ **Three phase to ground (ABCG)**
  - ✓ **10 to 60 cycles**
  - ✓ **66kV source lines faults**
  - ✓ **OP/XFER buses faults**
  - ✓ **High-side banks faults**

12kV RTDS Model
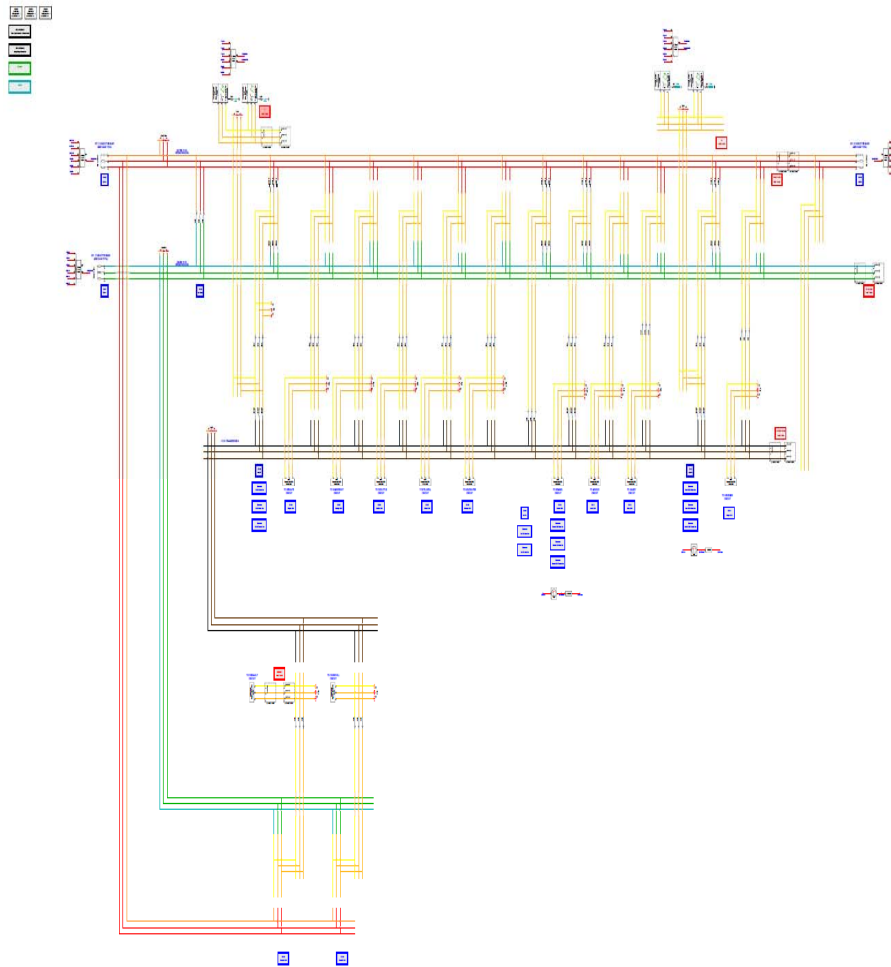
- ➤ **Represent similar substation one-line diagram**
    - ✓ **Double operating buses/transfer bus**
    - ✓ **All CB but a few disconnects**
    - ✓ **Low side transformer banks**
    - ✓ **Dynamic loads**
        - ▪ **Three phase load**
        - ▪ **Real and reactive can be changed**
- ➤ **Subsystem 2 for low-side (12kV) of substation**
- ➤ **Required minimum 3GPC/PB5 processing cards**
- ➤ **Faults Type, Location, And Duration**
    - ✓ **Line to ground (AG, BG, CG)**
    - ✓ **Line to line (AB, BC, CA)**
    - ✓ **Three phase to ground (ABCG)**
    - ✓ **10 to 60 cycles**
    - ✓ **12kV lines faults**
    - ✓ **OP/XFER buses faults**
    - ✓ **Low-side banks faults**

RTDS RunTime Model
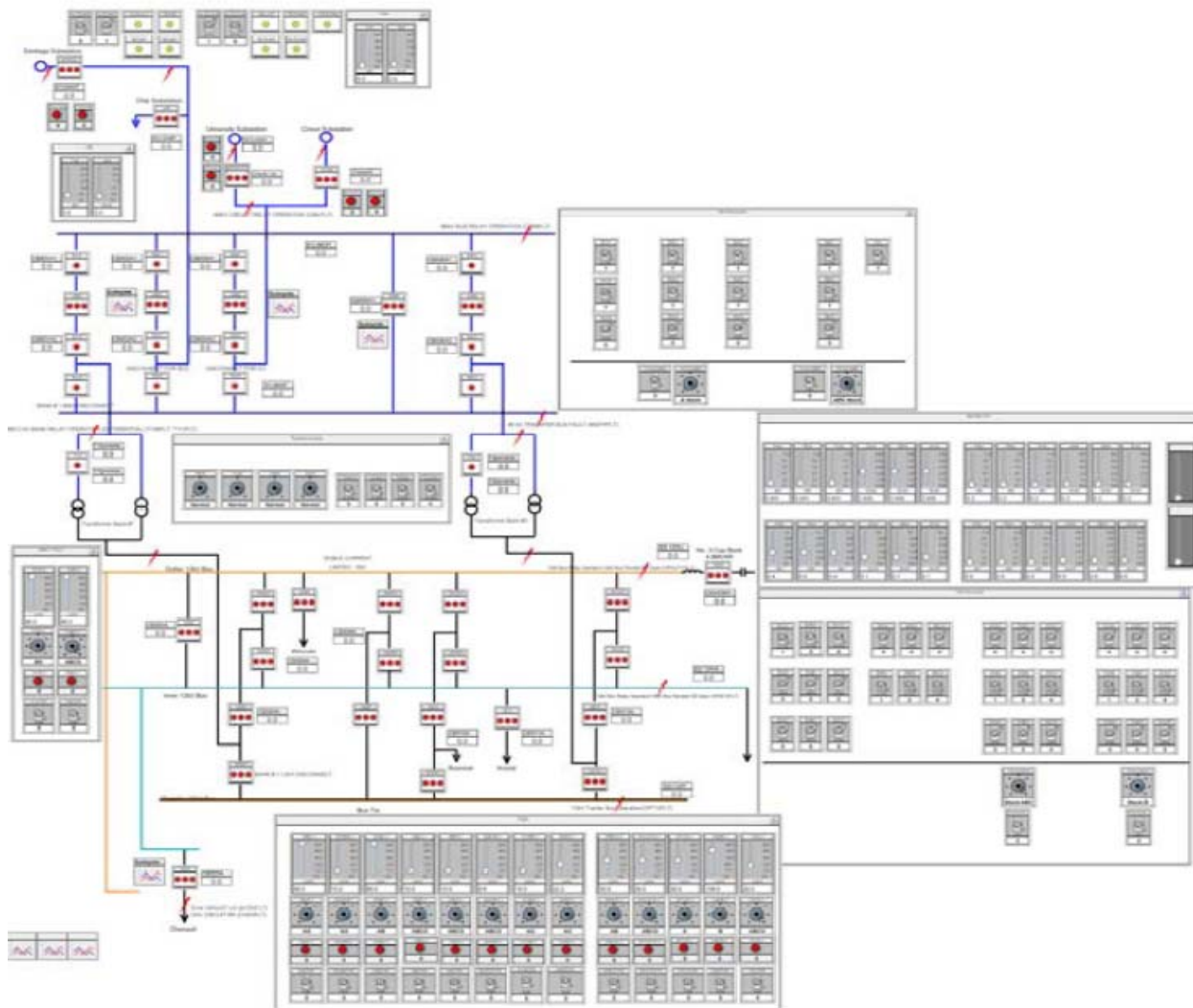
➢**CB status (read only)**

➢**Metering (analog values)**

➢**Sliders (P, Q, and time)**

➢**Switches (disconnects)**

➢**Dials (fault types, CB stuck, and banks suddent pressure etc.)**

➢**Push button (faults trigger)**

RTDS and Substation Equipment Interconnection Diagram

RTDS SYSTEM

High Voltage Digital Interface Panel

Low Voltage Digital Interface Panel

GTAO CARD
GTAO CARD
GTAO CARD

Programmable Logic Controller (PLC)

Control Signals

Status Signals

Control Signals

Status Signals

Human Machine Interface (HMI)

Analog Metering

Control Signals

SP and Transformer Failure Alarms

CB's Status

Low Level V and I

IED
IED
IED
IED

CB Simulator
CB Simulator
CB Simulator
CB Simulator

"V" And "I" Amplifier
"V" And "I" Amplifier
"V" And "I" Amplifier
"V" And "I" Amplifier

Status Signals

Secondary Voltage and Current

# RTDS and Substation Equipment Interconnection Wiring

- ➢ **Output voltages and current from each channel of GTAO cards connect to each channel of amplifier**
  - ✓ **88 channels (11 for voltages and 77 for currents)**

- ➢**Each channel of amplifier connect to buses and relays**
  - ✓ **Three phase potential transformers operating buses (both 66kV and 12kV)**
  - ✓ **Three phase current transformers (both 66kV and 12kV)**
  - ✓ **Single phase potential transformer for 66kV Hot/Dead line indication**
  - ✓ **Single phase current transformer on Ground Wye**
  - ✓ **Voltages and currents for all feeders (include bus-tie and bus diff)**

RTDS and Substation Equipment Interconnection Wiring Cont'd

➢**Low voltage digital interface panel connect to CB simulators (23 CB)**

➢**CB simulators connect to relays**
- ✓ **CB status (52a and 52b)**

➢**High voltage digital interface panel (suddent pressure and general alarm)**
- ✓ **Three states (normal, sudden pressure, fail)**
- ✓ **Alarm see in HMI (general alarm)**

➢ **HMI to relays through managed switches**

➢ **PLC to relays through managed switches**

Communication Setup
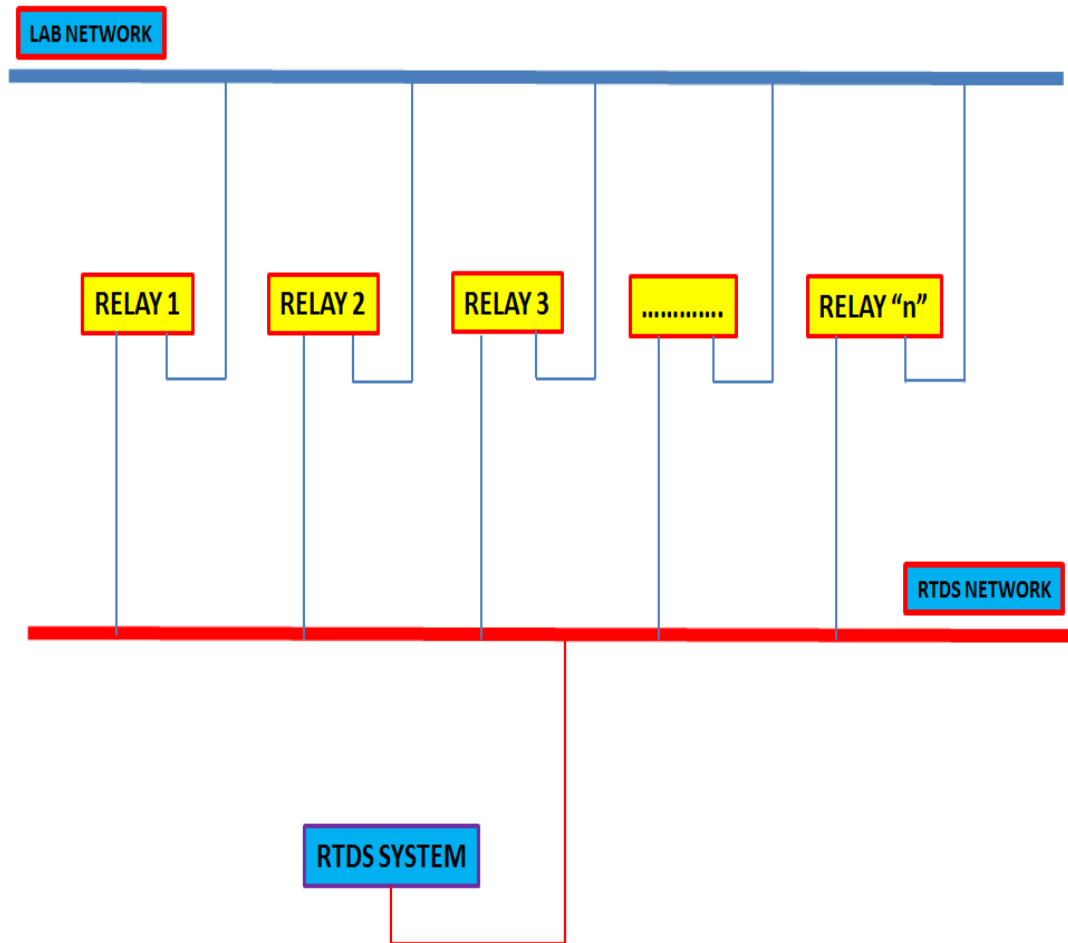
➢ **Each relay assign unique IP**
  - ✓ **Port 1 for RTDS network**
  - ✓ **Port 2 for lab network**

➢ **Check communication**
  - ✓ **command prompt**

➢**Two different networks for relays operate at the same time**

Testing Procedure

✓ **Read binary values**

✓ **RTDS can make decision based on relay status**

✓ **RTDS will simulate GE relay push buttons using ModBus**

✓ **Set the relay to initial condition**

RELAY STATUS
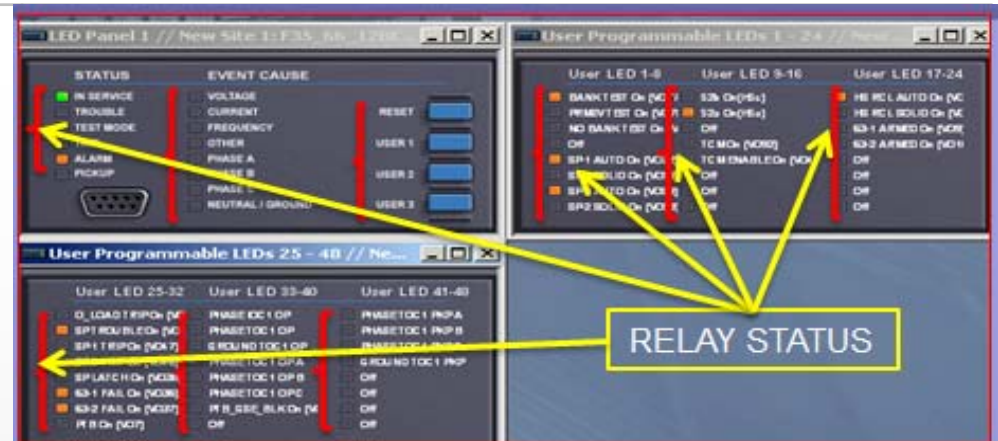
Testing Procedure Cont'd

❖ **USE SPREADSHEET CREATE ALL SCENARIOS FOR EACH RELAY**

A1 | fx | BUS TIE 12kV-F35

	A	B	C	D	E	F	G	H	I	J	K
1				BUS TIE 12kV-F35							
2				CASE 1	CASE 2	CASE 3	CASE 4	CASE 5	CASE 6	CASE 7	CASE 8
3			LED C4								
4	PB1	RCL AUTO/SOLID	SETTING GROUP ACT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	
5	PB2	SET GRP SECLECT	SETTING GROUP ACT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	
6	PB3	GRD RLY A/S	SETTING GROUP ACT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	
7	PB4	PT SELECT	SETTING GROUP ACT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	
8	PB5	CLOSE CB	SETTING GROUP ACT								On (or)
9	PB6	OPEN CB	SETTING GROUP ACT								On (or)
10	PB7	N/A	PT SECLECT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)
11	PB8	N/A	PT SECLECT	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)	On (or)
12	PB9	TMC	ModBus Holding Register	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	65,129,130,66,68,132,72,136	80,144,96,160
13	PB10	N/A	LED C5								
14	PB11	PTB GSE PUB BLOCK	52b On (CB Open)	On				On	On	On	On
15	PB12	PHASE IOC2 ENABLE	52a On (CB Close)		On	On	On				
16			Off								
17	LED C1	521	TCM On (V092)								
18	LED C2	522	TCM Enable On								
19	LED C3	523	Off								
20	LED C4	524	Off								
21	LED C5	525	Off								
22	LED C6	526	ModBus Holding Register	1	2	2	2	1	1	1	1
23	LED C7	527	LED C6								
24	LED C8	528	RCL Auto On		On		On	On		On	
25	LED C9	529	RCL Solid On	On		On			On		On
26	LED C10	530	Off								
27			Off								
28			Off								
29			GRD RLY AUTO On			On	On		On	On	
30			GRD RLY SOLID On	On	On			On			On
31			Off								
32			ModBus Holding Register	66	65	34	33	65	34	33	34

Testing Procedure Cont'd

❖ **State diagram**

➢ **Represent each relay operation block in script**

➢ **Script automatically**

✓ **Sets initial condition**

✓ **Lock out reset**

✓ **Continuously test automation functions of relays without interrupt**

✓ **Can test as many automation functions scenarios as we want through loop**
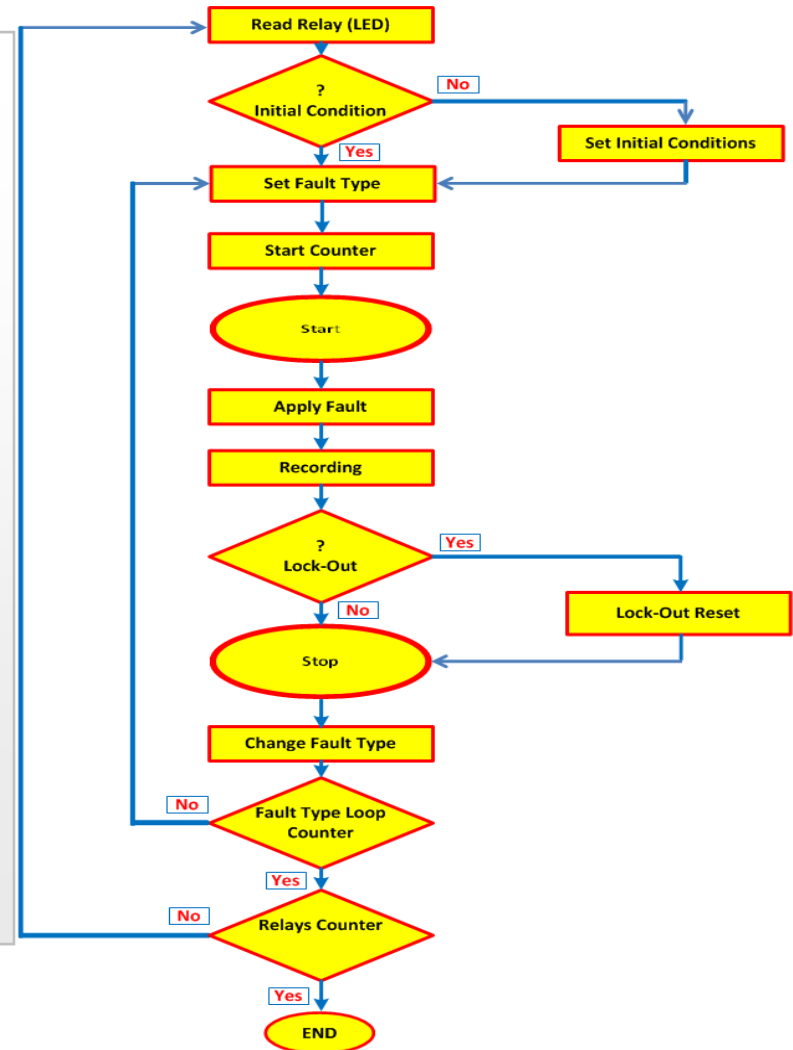
Results

- ➤ **Overall successful demonstration in the lab enviroment**
  - ➤ **Simulated entire substation using RTDS**
  - ➤ **Poved RTDS scripting capabilities can be used for automation logic testing**
  - ➤ **Viability of automated substation testing**
- ➤ **Proved to be a great development tool**
- ➤ **Enhanced the training experience**
- ➤ **Challenges**
  - ➤ **Limited to capabilities of Relays and RTDS**
  - ➤ **Amplifiers must be used**
  - ➤ **Dificult and time consuming to setup**
    - ➤ **Model**
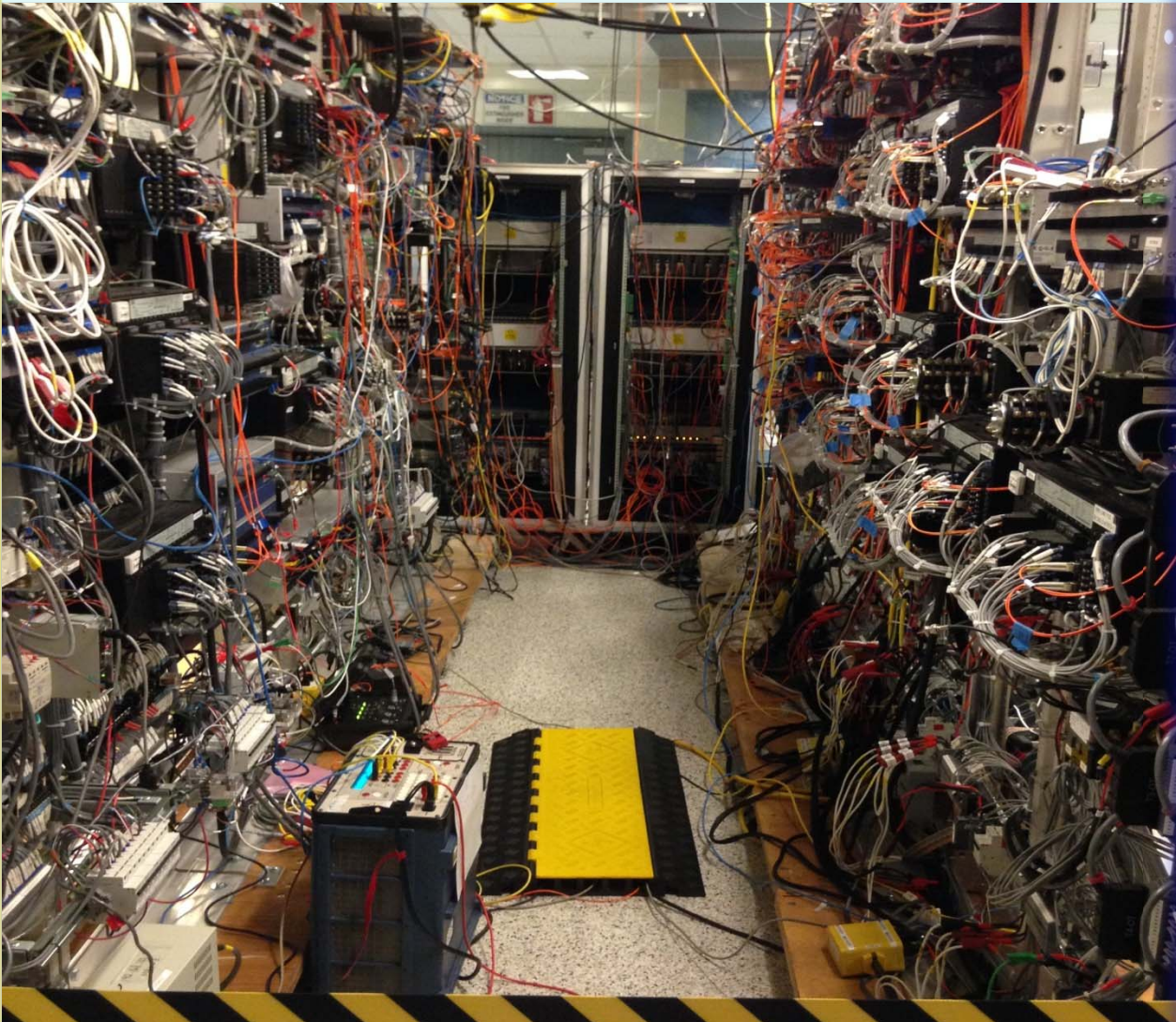   - ➤ **Hardware**
  - ➤ **Power requirements**

Next Steps

➢ **Data-driven RTDS configuration**

➢ **Data-driven RTDS Test Scripts**

➢ **Integration with SCADA Testing tools**

➢ **Single position testing**

➢ **IEC 61850 MMS protocol**

➢ **IEC 61850 process bus**

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Photos Of Lab Equipment And Setup

FRONT VIEW

Photos Of Lab Equipment And Setup Cont'd

REAR VIEW

Questions And Comments

Thank You

QUESTIONS AND COMMENTS?