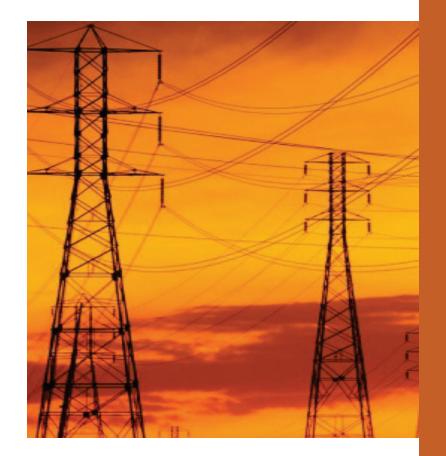
## Hardware-in-the-Loop Testing of a Completely Digital IEC 61850-Based Teleprotection Scheme Using the RTDS Simulator

## A.C. Adewole R. Tzoneva

RTDS Applications and Technology Conference May 16-19, 2017 Winnipeg, Canada



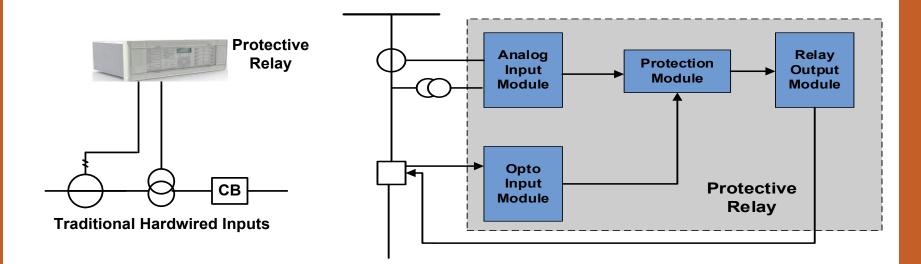
- Background
- Objectives
- Methodology
- Experimental Results
- Conclusion
- Bibliography





## Protection in conventional power systems

- Analogue current and voltage inputs from CTs and VTs
- Analogue inputs protection relays
- Inter-wiring required





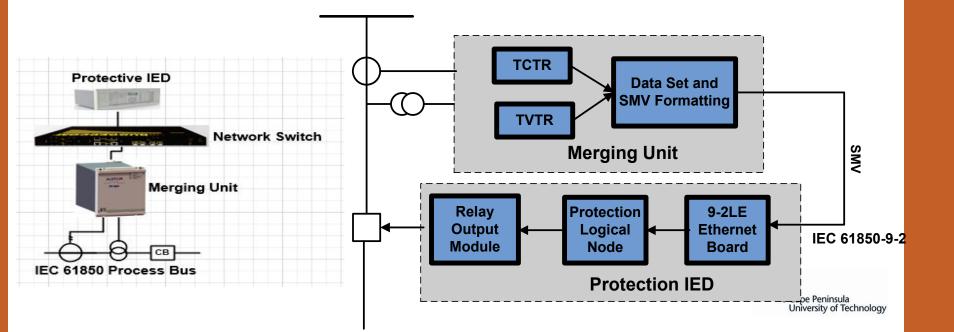
## Shortcomings:

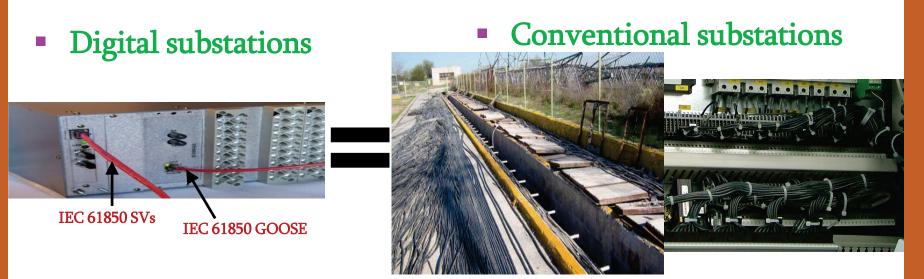
- Multiple cable runs between CTs/VTs and relays
- Inter-wiring amongst devices is required
- Multiple protocols are in use
- Interoperability between multi-vendor devices is difficult
- Expensive protocol converters required
- Lack of harmonization and standardization
- Reconfiguration and maintenance difficult



## Protection in a completely digital power system

- Digitized current and voltage inputs from NCITs/Merging Units (MUs)
  - NCITs: Optical sensor loops/capacitive voltage dividers
  - MUs: LNs, merging of V & I datasets, and frame formatting
  - P/M: 80 samples/cyc., PQ: 256 samples/cyc. (IEC 61850-9-2LE)
- Protection relays with digital interface
- Communication-based link between the process/bay/station levels





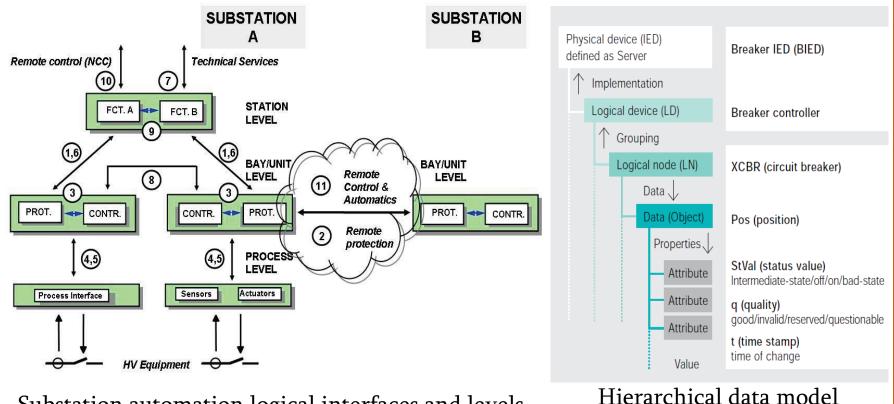
## Advantages of IEC 618550-based digital substations:

- Allows for standardization & interoperability
- Less cabling required from CTs/VTs & between devices
- Lifecycle cost savings
- Less installation and outage time
- Increased safety
- Easy reconfiguration and maintenance



## IEC 61850: Automation and control in power systems

- Object-oriented data modelling
  - Logical device | logical nodes | data objects | data attributes
- Substation configuration language (SCL)



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Substation automation logical interfaces and levels

#### Features of tele-protection schemes

- Substation-to-Substation (SS-SS) exchange of information by relays
- High-speed simultaneous fault clearing compared to time-stepped distance protection

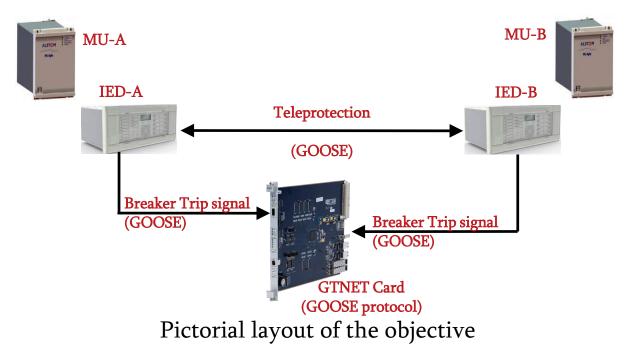
#### Benefits of tele-protection schemes

- Improves system stability (power transfer) of healthy lines
- Reduces voltage sag duration
- Reduces damage to insulators/through-fault duty time on transformers
- Permits quicker reclosing



#### **OBJECTIVES**

#### Teleprotection (POTT) Scheme Logic

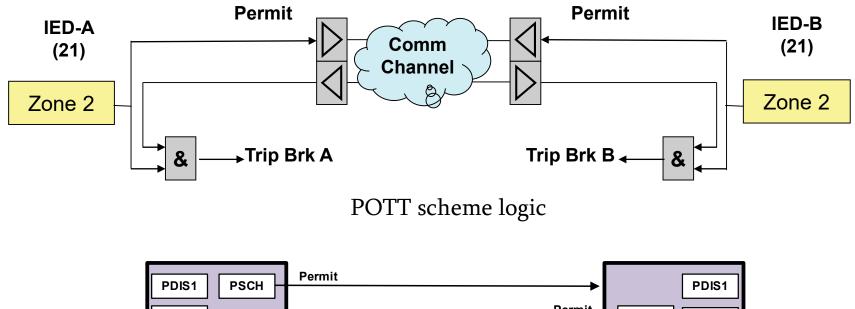


- Use IEC 61850-9-2LE inputs
- Use an over-reaching Zone-2 distance element
- Send a key (POTT TX) via GOOSE to the remote end
- Transfer trip is supervised by the over-reaching (Zone-2) element of the remote end
- Issue breaker trip signals using IEC 61850-8-1 GOOSE messages



#### OBJECTIVES

#### Teleprotection (POTT) Scheme Logic



POTT scheme logic using IEC 61850 logical nodes



#### **OBJECTIVES**

## Objectives

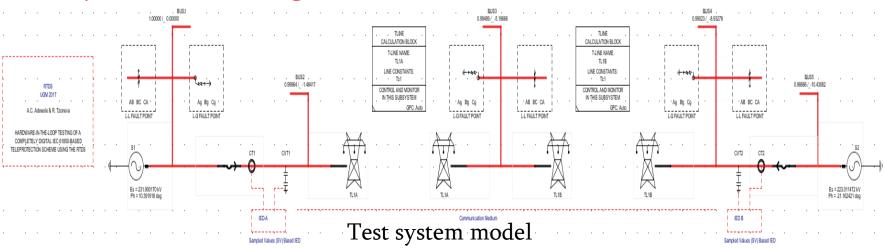
- Conformance testing
- Performance testing
  - Testing of the MU measurement (accuracy) function
  - Testing of the protection function (speed, dependability, security)
- Interoperability testing
- Interchangeability testing



- Test system modelling in RSCAD
- Three case study setups using industrial-grade hardware
- System engineering process
- Hardware-in-the-loop simulations using the RTDS



## **Test System Modelling**



#### Protection zones and zone times

| Protection Zones | Zone Phase and Ground Reach Settings       | Time Delay | ×                                       |
|------------------|--|------------|---|
|                  |  | /(ms)      | /                                       |
| Zone-1 (forward) | 80% of Line-1                              | 0          |   |
| Zone-2 (forward) | (Line-1 impedance) + 20% Line- 2 impedance | 200        | H Zone 2<br>distance<br>protection      |
| Zone-3 (reverse) | 20% of Line-1                              | 400        | Line Zone 1<br>distance<br>protection R |

#### Simulation parameters

| Fault Location /(%)   | 20, 40, 60, 75, 115 (forward), 20 (reverse)                        |
|-----------------------|--|
| Fault Resistance /(Ω) | 0.1, 1.0, 5.0, 10.0  |
| Fault Type            | Phase-to-Ground (A-G), Phase-to-Phase (AB) and Three Phase (3 Ph.) |

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- **Testbed setup for 3 case studies RTDS**
- Two merging units from the same vendor
  - Same model used
- Two IEDs from the same vendor
  - Same model used
  - Distance protection function (Mho characteristics)
  - Zones 1-3 elements (forward and reverse directionality)
- Communication network switches
- GPS satellite clock



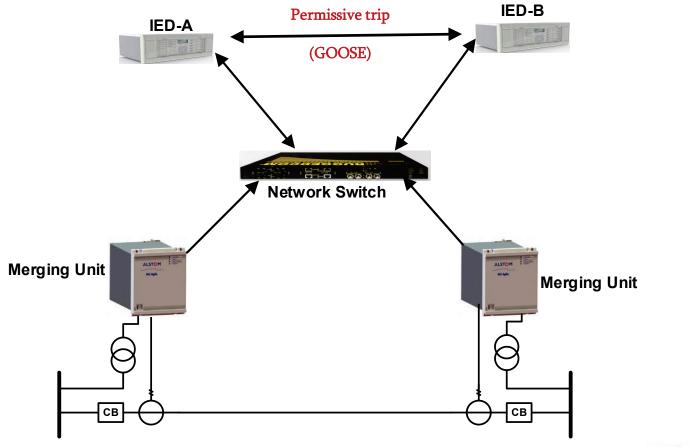
## **Testbed at CSAEMS-CPUT**



Implemented testbed for hardware-in-the-loop simulations

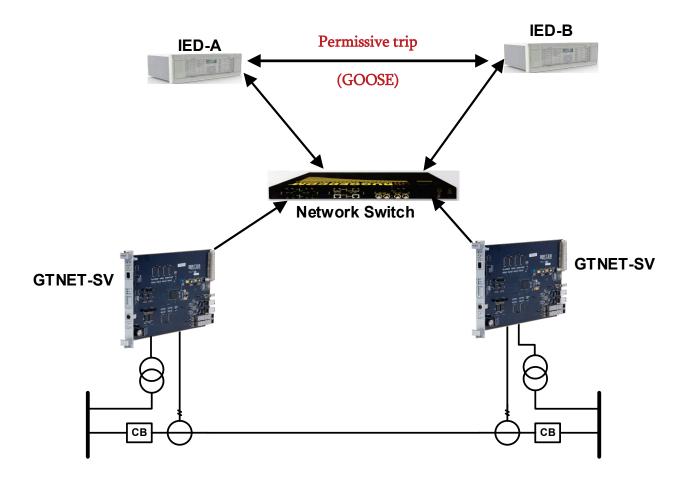


## Case Study-1



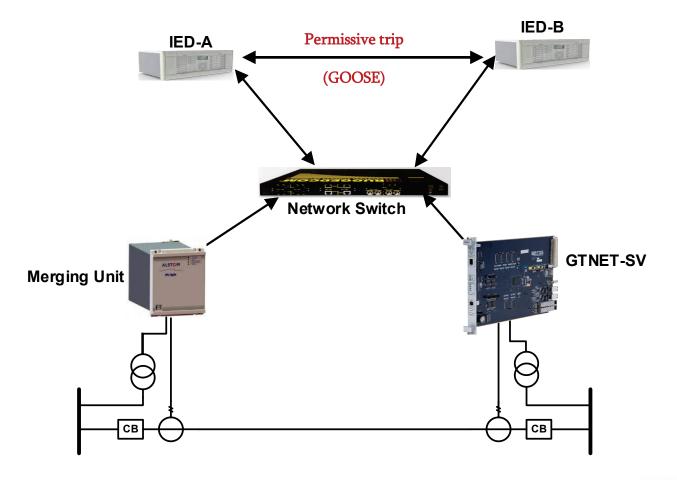


## Case Study-2





## Case Study-3



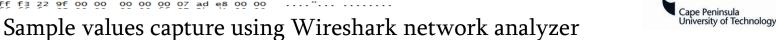


#### Measurement accuracy

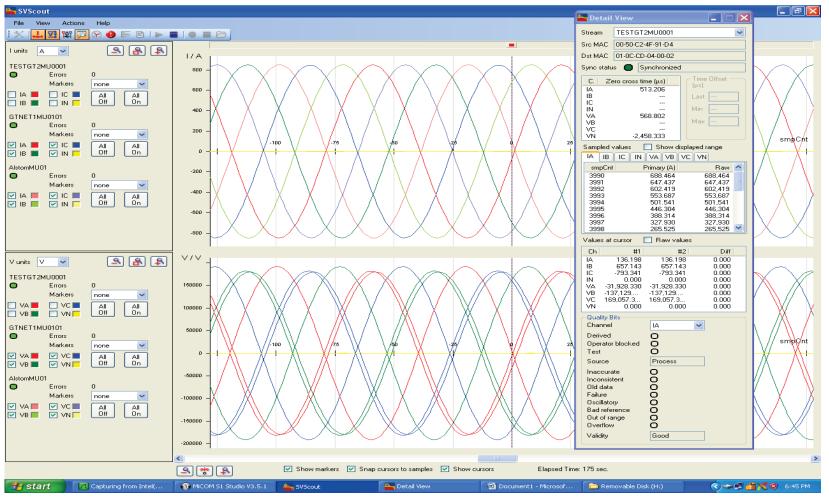
Line currents: Maximum relative error

- Sampled Values from MU: 0.13% | GTNET-SV: 0.067% Voltages:
  - Sampled Values from MU: 0.81% | GTNET-SV: 0.021%

| <pre>1 0.000000 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEc61850 Sampled Val 2 0.000001 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 4 0.000251 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 5 0.000252 80:b3:2a:09:4C:c6 Iec-Tc57_04:00:01 IEc61850 Sampled Val 6 0.000253 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 7 0.000494 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEc61850 Sampled Val 9 0.000494 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 0.000750 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 1 0.000750 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 1 0.000750 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 1 0.000750 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:01 IEc61850 Sampled Val 1 1 0.000750 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:01 IEc61850 Sampled Val 1 2 0.000998 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 3 0.000998 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 4 0.009998 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 5 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 4 0.009998 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 5 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 5 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 9 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 9 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 9 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled Val 1 1 0.0007 1 IEC61850 Sampled Val 1 1 0.00140 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 1 1 0.00140 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 1 1 0.00140 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 1 9 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 1 1 0.000750 IEC61850 Sampled Val 1 1 0.000750 IEC61850</pre>  | . 00         | 0000                    |                | rce                  |                      |                |                       |                | De              | stina          | tion              |                           |     | Protocol        |            |     | Info |
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| <pre>8 0.000494 80:b3:22:09:4c:c6 Iec-TC57_04:00:04 IEC61850 Sampled Val<br/>9 0.000494 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br/>10 0.000750 80:b3:22:09:4c:c6 Iec-TC57_04:00:04 IEC61850 Sampled Val<br/>12 0.000751 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br/>13 0.000998 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>14 0.000999 80:b3:22:09:4c:c6 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>15 0.000999 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>16 0.001243 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>17 0.001243 80:b3:22:09:4c:c6 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>18 0.001244 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br/>19 0.001496 RtdSTechno_02:d5 IEC61850 Sampled Val<br/>10</pre>      | . 00         | 0253                    | Rtd            | sTe                  | chn                  | o_01           | L:d4                  | 4              | Ie              | C-T            | c57_0             | 4:00:03                   | 2   | IEC61850        | Sampled    | Va  | 1    |
| 9 0.000494 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>10 0.000750 80:b3:2a:09:4c:c6 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>12 0.000751 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>13 0.000998 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>14 0.000999 80:b3:2a:09:4c:c6 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>14 0.000999 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>16 0.001243 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>17 0.001243 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>18 0.001244 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>18 0.001244 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled Val<br>18 0.001245 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>18 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled Val<br>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:04 (01:0c:cd<br>IEC61850 Sampled Value<br>APPID: 0x4000<br>Length: 108<br>Reserved 1: 0x0000 (0)<br>Reserved 2: 0x0000 (0)<br>8 savPdu<br>noASDU: 1<br>SvID: AlstomMU02<br>smpCnt: 721<br>confRef: 1<br>smpSynch: global (2)<br>Phismeas1<br>value: 342772<br>B quality: 0x00000000, validity: good, source: process<br>value: -843105<br>B quality: 0x00000000, validity: good, source: process<br>value: 503272   | . 00         | 0494                    | Rtd            | IsTer                | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | c 57_0            | 4:00:03                   | 1   | IEC61850        | Sampled    | va  | 1    |
| <pre>10 0.000749 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val 12 0.000750 RtdsTechno_01:d4 Iec-Tc57_04:00:04 IEC61850 Sampled Val 13 0.000998 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val 14 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val 15 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 16 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val 17 0.001243 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:02 IEC61850 Sampled Val 19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Iec-Tc57_04:00:04 (01:0c:cd IEC61850 Sampled Val 19 0.001496 RtdsTechno_0000 (0) B savPdu noASDU: 1 B seqASDU: 1 item B ASDU SVTD: AlstomMu02 SmpCnt: 721 ConfRef: 1 SmpSynch: global (2) B PhsMeasI value: 342772 B quality: 0x00000000, validity: good, source: process value: -84300 B quality: 0x00000000, validity: good, source: process value: -503272 </pre>   | . 00         | 0494                    | 80:            | b3:2                 | 2a:(                 | 09:4           | 4c:0                  | c6             | Ie              | C-T            | c57_0             | 4:00:04                   | 4   | IEC61850        | Sampled    | va  | 1    |
| <pre>11 0.000750 80:b3:22:09:4c:c6 Iec-Tc57_04:00:04 IEC61850 Sampled Val<br/>12 0.000751 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val<br/>13 0.000998 RtdsTechno_01:d4 Iec-Tc57_04:00:04 IEC61850 Sampled Val<br/>14 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:04 IEC61850 Sampled Val<br/>15 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val<br/>16 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val<br/>17 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val<br/>18 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled Val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled Val<br/>10 Sampled Values<br/>APPID: 0x4000<br/>Length: 108<br/>Reserved 1: 0x0000 (0)<br/>Reserved 2: 0x0000 (0)<br/>B savPdu</pre>   | . 00         | 0494                    | Rtd            | Ister                | chn                  | 0_01           | L : d4                | 4              | Ie              | C-T            | c 57_0            | 4:00:03                   | 2   | IEC61850        | sampled    | va  | 1    |
| 12 0.000751 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>13 0.000998 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>14 0.000999 80:b3:2a:09:4c:c6 Iec-TC57_04:00:01 IEC61850 Sampled val<br>15 0.000999 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>16 0.001243 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>17 0.001243 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>18 0.001244 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>19 0.001496 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>19 0.001496 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>11 EC61850 Sampled values<br>APPID: 0x4000<br>Length: 108<br>Reserved 1: 0x0000 (0)<br>B savPdu<br>nOASDU: 1<br>B seqASDU: 1 item<br>B ASDU<br>SVID: AlstomMU02<br>smpCnt: 721<br>confRef: 1<br>smpSynch: global (2)<br>PhSMeas1<br>value: 342772<br>B quality: 0x00000000, validity: good, source: process<br>value: -843105<br>B quality: 0x0000000, validity: good, source: process<br>value: 0x0000, validity: good, source: process<br>value: 0x0000, validity: good, source: process  | . 00         | 0749                    | Rtd            | ste                  | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | c57_0             | 4:00:03                   | 1   | IEC61850        | sampled    | va  | 1    |
| <pre>13 0.000998 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>14 0.000999 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:04 IEC61850 Sampled val<br/>15 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>16 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>17 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>18 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:04 (01:0c:cd<br/>19 0.000</pre>      | . 00         | 0750                    | 80:            | b3:2                 | 2a:(                 | 09:4           | 4c:c                  | c6             | Ie              | C-T            | c 57_0            | 4:00:04                   | 4   | IEC61850        | Sampled    | va  | 1    |
| 14 0.000999 80:b3:22:09:4C:c6 Iec-TC57_04:00:04 IEC61850 Sampled val<br>15 0.000999 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>16 0.001243 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>17 0.001243 80:b3:22:09:4C:c6 Iec-TC57_04:00:02 IEC61850 Sampled val<br>18 0.001244 RtdSTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val<br>19 0.001496 RtdSTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val<br>10 0.00140 IEC61850 Sampled val<br>10 0.00140 IEC61850 Sampled val<br>10 0.00140 IEC61850 Sampled val<br>10 0.0010 IEC61850 Sampled val<br>10 0.000000 (0)<br>10 SavPdu<br>10 0.00000000 (0)<br>10 SavPdu<br>10 0.00000000 (0)<br>11 IEC61850 Sampled val<br>12 0.00000000 (0)<br>13 SavPdu<br>14 0.00000000 (0)<br>14 0.00000000 (0)<br>15 0.   | . 00         | 0751                    | Rtd            | ster                 | chno                 | o_01           | L : d4                | 4              | Ie              | C-T            | c57_0             | 4:00:03                   | 2   | IEC61850        | Sampled    | val | 1    |
| <pre>15 0.000999 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>16 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>17 0.001243 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>18 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-Tc57_04:00:04 (01:0c:cd<br/>IEC61850 Sampled values<br/>APPID: 0x4000<br/>Length: 108<br/>Reserved 1: 0x0000 (0)<br/>Reserved 2: 0x0000 (0)<br/>B savPdu<br/>noASDU: 1<br/>B seqASDU: 1 item<br/>B ASDU<br/>SvID: AlstomMU02<br/>smpCnt: 721<br/>confRef: 1<br/>smpSynch: global (2)<br/>B PhsMeas1<br/>value: 342772<br/>B quality: 0x00000000, validity: good, source: process<br/>value: -843105<br/>B quality: 0x00000000, validity: good, source: process<br/>value: 503272</pre>   | . 00         | 0998                    | Rtd            | ste                  | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | <57_0             | 4:00:03                   | 1   | IEC61850        | Sampled    | va  | 1    |
| <pre>16 0.001243 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEc61850 Sampled val<br/>17 0.001243 80:b3:2a:09:4c:c6 Iec-Tc57_04:00:04 IEc61850 Sampled val<br/>18 0.001244 RtdsTechno_01:d4 Iec-Tc57_04:00:02 IEc61850 Sampled val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>19 0.001496 RtdsTechno_01:d4 Iec-Tc57_04:00:04 (01:0c:cd<br/>IEC61850 Sampled values<br/>APPID: 0x4000<br/>Length: 108<br/>Reserved 1: 0x0000 (0)<br/>E savPdu<br/>noASDU: 1<br/>E seqASDU: 1 item<br/>E ASDU<br/>SvID: AlstomMU02<br/>smpCnt: 721<br/>confRef: 1<br/>smpSynch: global (2)<br/>E PhsMeas1<br/>value: 342772<br/>E quality: 0x00000000, validity: good, source: process<br/>value: -843105<br/>E quality: 0x00000000, validity: good, source: process<br/>value: 0x0000000, validity: good, source: process</pre>   | . 00         | 0999                    | 80:            | b3:2                 | 2a:(                 | 09:4           | lc:0                  | c6             | Ie              | C-T            | c57_0             | 4:00:04                   | 4   | IEC61850        | Sampled    | va  | 1    |
| <pre>17 0.001243 80:b3:22:09:4C:c6 Iec-Tc57_04:00:04 IEC61850 Sampled val<br/>18 0.001244 Rtd5Techno_01:d4 Iec-Tc57_04:00:02 IEC61850 Sampled val<br/>19 0.001496 Rtd5Techno_01:d4 Iec-Tc57_04:00:01 IEC61850 Sampled val<br/>Frame 5: 122 bytes on wire (976 bits), 122 bytes captured (976 bits)<br/>Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-Tc57_04:00:04 (01:0c:cd<br/>IEC61850 Sampled values<br/>APPID: 0x4000<br/>Length: 108<br/>Reserved 1: 0x0000 (0)<br/>Reserved 2: 0x0000 (0)<br/>B savPdu<br/>noASDU: 1<br/>Souther Souther S</pre>  | . 00         | 0999                    | Rtd            | sTer                 | chno                 | o_01           | L : d4                | 4              | Ie              | C-T            | c57_0             | 4:00:03                   | 2   | IEC61850        | Sampled    | va  | 1    |
| <pre>18 0.001244 RtdsTechno_01:d4 Iec-TC57_04:00:02 IEC61850 Sampled val 19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val  Frame 5: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-TC57_04:00:04 (01:0c:cd IEC61850 Sampled values APPID: 0x4000 Length: 108 Reserved 1: 0x0000 (0) Reserved 2: 0x0000 (0) B savPdu noASDU: 1 B seqASDU: 1 item B ASDU SvID: AlstomMU02 SmpCrt: 721 confRef: 1 SmpSynch: global (2) B PhsMeas1 value: 342772 B quality: 0x00000000, validity: good, source: process value: -843105 B quality: 0x00000000, validity: good, source: process value: 503272</pre>  | . 00         | L243                    | Rtd            | IsTee                | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | <pre>c 57_0</pre> | 4:00:03                   | 1   | IEC61850        | Sampled    | va  | 1    |
| <pre>19 0.001496 RtdsTechno_01:d4 Iec-TC57_04:00:01 IEC61850 Sampled val Frame 5: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-TC57_04:00:04 (01:0c:cd IEC61850 Sampled values APPID: 0x4000 Length: 108 Reserved 1: 0x0000 (0) Reserved 2: 0x0000 (0) B savPdu noASDU: 1 B seqASDU: 1 item ASDU SvID: AlstomMU02 smpCnt: 721 confRef: 1 smpSynch: global (2) PhsMeas1 value: 342772 B quality: 0x00000000, validity: good, source: process value: -843105 B quality: 0x00000000, validity: good, source: process value: 0x00000000, validity: good, source: process value: 0x00000000, validity: good, source: process</pre>   | . 00         | L243                    | 80:            | b3:2                 | 2a:(                 | 09:4           | 4 <b>c</b> : <b>c</b> | c6             | Ie              | C-T            | <57_0             | 4:00:04                   | 4   | IEC61850        | Sampled    | va  | 1    |
| <pre>Frame 5: 122 bytes on wire (976 bits), 122 bytes captured (976 bits) Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-Tc57_04:00:04 (01:0c:cd IEc61850 sampled values APPID: 0x4000 Length: 108 Reserved 1: 0x0000 (0) Reserved 2: 0x000 (0) SavPdu noASDU: 1 SeqASDU: 1 SeqASDU: 1 SvID: AlstomMU02 smpcnt: 721 confRef: 1 smpSynch: global (2) PhsMeas1 value: 342772 Quality: 0x00000000, validity: good, source: process value: -843105 Quality: 0x00000000, validity: good, source: process value: 0x00000000, validity: good, source: process value: 0x00000000, validity: good, source: process value: 0x00000000, validity: good, source: process</pre>  | . 00         | L244                    | Rtd            | ste                  | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | c57_0             | 4:00:03                   | 2   | IEC61850        | Sampled    | va  | 1    |
| <pre>Frame 5: 122 bytes on wire (976 bits), 122 bytes captured (976 bits)<br/>Ethernet II, Src: 80:b3:2a:09:4c:c6 (80:b3:2a:09:4c:c6), Dst: Iec-Tc57_04:00:04 (01:0c:cd<br/>APPID: 0x4000<br/>Length: 108<br/>Reserved 1: 0x0000 (0)<br/>B savPdu<br/>noASDU: 1<br/>B seqASDU: 1 item<br/>ASDU<br/>SvID: AlstomMU02<br/>smpCnt: 721<br/>confRef: 1<br/>smpSynch: global (2)<br/>PhsMeas1<br/>value: 342772<br/>B quality: 0x0000000, validity: good, source: process<br/>value: -843105<br/>B quality: 0x0000000, validity: good, source: process<br/>value: 0x0272</pre>  | . 00         | L496                    | Rtd            | sTe                  | chn                  | o_01           | L : d4                | 4              | Ie              | C-T            | c 57_0            | 4:00:03                   | 1   | IEC61850        | Sampled    | va  | 1    |
| <pre>svID: AlstomMU02 smpCnt: 721 confRef: 1 smpSynch: global (2) B PhsMeas1 value: 342772 @ quality: 0x00000000, validity: good, source: process value: -843105 B quality: 0x00000000, validity: good, source: process value: 503272</pre>  | oAS<br>eqA   | SDU: 1                  | iten           |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| <pre>svID: AlstomMU02 smpCnt: 721 confRef: 1 smpSynch: global (2) B PhsMeas1 value: 342772 @ quality: 0x00000000, validity: good, source: process value: -843105 B quality: 0x00000000, validity: good, source: process value: 503272</pre>  |              |                         |                |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| <pre>confRef: 1 smpSynch: global (2) PhsMeas1 value: 342772 guality: 0x00000000, validity: good, source: process value: -843105 guality: 0x00000000, validity: good, source: process value: 503272</pre>   |              | svID: /                 | lsto           | OMMO                 | 02                   |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| <pre>smpSynch: global (2)</pre>  |              | smpCnt                  | 721            | L                    |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| <ul> <li>PhsMeas1</li> <li>value: 342772</li> <li>quality: 0x00000000, validity: good, source: process</li> <li>value: -843105</li> <li>quality: 0x00000000, validity: good, source: process</li> <li>value: 503272</li> </ul>   |              | confRet                 | : 1            |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| value: 342772<br>⊕ quality: 0x00000000, validity: good, source: process<br>value: -843105<br>⊕ quality: 0x00000000, validity: good, source: process<br>value: 503272   |              | smpsynd                 | :h: g          | JOP                  | al                   | (2)            |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| <ul> <li>              quality: 0x00000000, validity: good, source: process             value: -843105      </li> <li>             quality: 0x00000000, validity: good, source: process             value: 503272      </li> </ul>   |              |                         |                |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| value: -843105<br>⊕ quality: 0x00000000, validity: good, source: process<br>value: 503272  |              |                         |                |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
|  |              |                         |                |                      |                      | 0000           | ), v                  | val            | idi             | ty:            | good              | , sour                    | ce: | process         |            |     |      |
| value: 503272  |              |                         |                |                      |                      |                | _                     | -              |                 |                |                   |                           |     |                 |            |     |      |
|  |              |                         |                |                      |                      | 0000           | ), v                  | val            | ıdi             | ty:            | good              | , sour                    | ce: | process         |            |     |      |
|  |              |                         |                |                      |                      |                | -                     | -              |                 |                |                   |                           |     |                 |            |     |      |
| 🗄 quality: 0x00000000, validity: good, source: process   |              |                         |                |                      | 000                  | 0000           | <i>,</i> , ۱          | val            | idi             | ty:            | good              | , sour                    | ce: | process         |            |     |      |
| value: -411  |              |                         |                |                      | 000                  | 0000           |                       |                |                 | +              | a                 |                           |     |                 |            |     |      |
| guality: 0x00000000, validity: good, source: process     galues: Z018620   |              |                         |                |                      |                      |                | ۰, <i>۱</i>           | val            | 101             | cy:            | good              | , sour                    | ce: | process         |            |     |      |
| value: -7918639  |              |                         |                |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
| ⊞ quality: 0x00000000, validity: good, source: process   |              |                         |                |                      |                      |                | , <b>`</b>            | vati           | ran             | cy:            | good              | , sourc                   | Ce: | process         |            |     |      |
| value: 18839203<br>⊡ quality: 0x00000000, validity: good, source: process  |              |                         |                |                      |                      |                | <u>.</u>              |                | i dii           | ÷              | good              | FOUR                      |     | process         |            |     |      |
|  |              |                         |                |                      |                      |                | ·, `                  | vall           | iui             | cy:            | good              | , sourc                   | ce. | process         |            |     |      |
|  |              |                         |                |                      |                      |                | •                     | val            | idi             | tv.            | dood              | Source                    |     |                 |            |     |      |
| value: -10920089   |              |                         |                |                      |                      |                |                       |                |                 |                |                   |                           |     |                 |            |     |      |
|  |              | - quai                  |                |                      | 000                  | 0000           | ,                     |                |                 | - , -          | 9004              | , 504.                    | ce: | process         |            |     |      |
| value: -10920089<br>⊡ quality: 0x00000000, validity: good, source: process   | L 00         | cd 04                   | 00             | 04 ε                 | 30 b                 | b3             | 2a                    | 09             | 4c              | c6             | 88 bi             | a 40 00                   |     | •               | *.L@       | L.  |      |
| value: -10920089   | L 00         | cd 04                   | 00             | 04 8<br>00 6         | 80 k                 | b3<br>62       | 2a<br>80              | 09<br>01       | 4c<br>01        | c6<br>a2       | 88 ba             | a 40 00<br>5 5 80         | }   | .1              | ]0[        | -   |      |
| value: -10920089<br>⊡ quality: 0x00000000, validity: good, source: process   | L 00<br>0 60 | cd 04<br>00 00<br>6c 73 | 00<br>00<br>74 | 04 8<br>00 6<br>6f 6 | 80 b<br>50 6<br>5d 4 | b3<br>62<br>4d | 2a<br>80<br>55        | 09<br>01<br>30 | 4 c<br>01<br>32 | c6<br>a2<br>82 | 88 bi<br>5d 30    | 40 00<br>55 80<br>2 d1 83 |     | .1b<br>.AlstomM | ]0[<br>U02 | :   |      |



#### Measurement Analysis: MU with GTNET-SV as reference

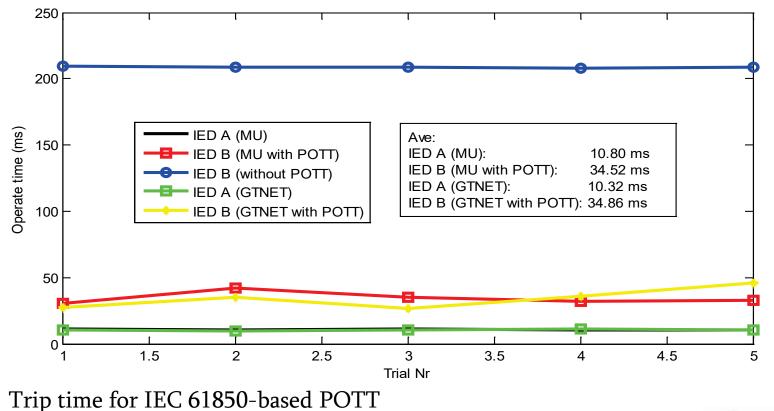


SV capture using SVScout



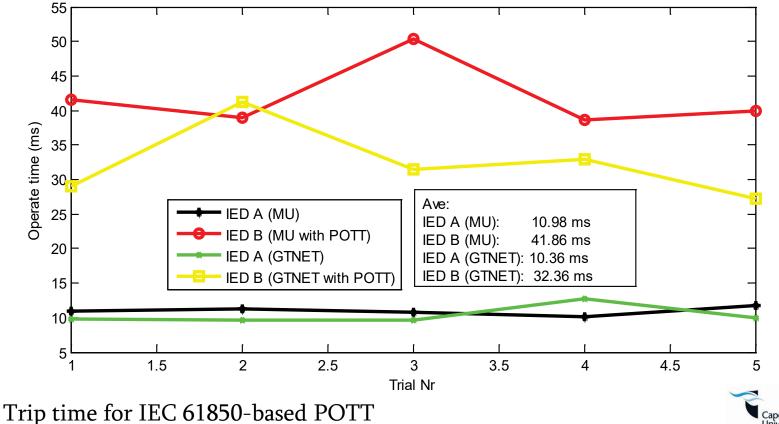
## IEC 61850-GOOSE Based POTT using SVs from 2 MiCOM & 2 RTDS GTNET MUs (A-G Fault)

Relay Operate Time: Time from fault inception to when a trip signal was issued





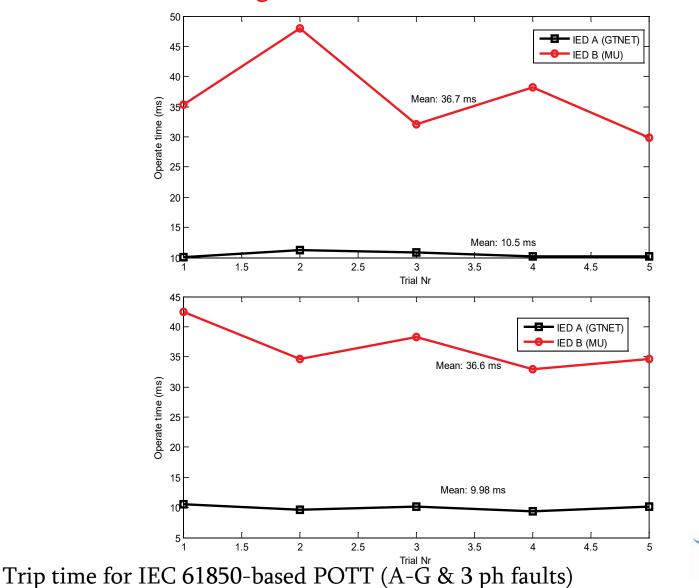
## IEC 61850-GOOSE Based POTT using SVs from 2 MiCOM & 2 RTDS GTNET MUs (3 Phase fault)



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#### **Interchangeability**

GOOSE Based POTT using SVs from 1 MiCOM & 1 RTDS GTNET MUs



Cape Peninsula University of Technology

#### CONCLUSION

- Validation of product and system functionality
- Conformance testing
- Functional testing:
  - IED measurement accuracy
  - Speed
  - Security
  - Dependability tests carried out
- IEC 61850 interoperability testing
- IEC 61850 interchangeability testing





# Thank you Questions?



#### Bibliography

- Adewole, A.C., Tzoneva, R. (2014). Impact of IEC 61850-9-2 Standard-Based Process Bus on the Operating Performance of Protection IEDS: Comparative Study. 19th IFAC World Congress (IFAC WC 2014), Cape Town, South Africa, August 24-29, 2014, pp. 2245-2252.
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