Digital Substation Technology Enables Advanced Transformer Monitoring Application

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Agenda

• Introduction to Vaughan TS4 project
• Discuss the challenges of applying the transformer monitoring system
• Introduction to Digital Secondary Systems and overview of technologies that were considered
• Review the implementation of the Digital Secondary System technology deployed to solve the challenges
• Deploying synchronism check using Synchrophasor Technology
• Summary and Questions
About Alectra Utilities Corporation

• Part of the Alectra family of companies.

• Distributes electricity to approximately one million customers in Ontario’s Greater Golden Horseshoe Area.

• Owns and operates 13 transformer stations and 159 municipal stations.
Schweitzer Engineering Laboratories Inc.

• SEL designs, manufactures, and supports a complete line of products and services for the protection, monitoring, control, automation, and metering of electric power systems

• SEL solutions range from comprehensive generator and transmission protection to distribution automation and control systems.
Vaughan TS4

- The Vaughan TS4 project was approved in 2013 for construction in the northern area of Vaughan to meet the growth in that area
- The location is on Kirby Road west of Kipling Avenue next to the Hydro One 230kV Minden Line
VTS4 Components

Bermondsey configuration transformer station consisting of:

- Qty 2 – 75/100/125 MVA power transformers, 230kV – 27.6kV
- Gas Insulated Switchgear line-up:
  - Qty 4 – transformer breakers
  - Qty 2 – tie breakers
  - Qty 12 – feeder breakers
  - Qty 2 – capacitor breakers
- Qty 3 – 5-way 27.6kV tie switches
Bushing Monitoring

• New requirement to monitor the capacitance values of the capacitance taps of the high voltage 230kV transformer bushings for detection of bushing insulation deterioration

• Elected to use the Doble IDD on-line bushing monitor system
230kV Voltage Signal for P&C

- Traditional back up line protection relay used bushing potential devices for line voltage measurements
- 230kV transformer capacitive bushing and bushing potential devices have challenges in providing the critical voltage signal to the protection and control system
- Calibration, reliability and maintenance issues
Alternative Source for 230kV Voltage Signal

• Reliable and accurate ‘spare’ secondary winding of the potential transformer unit in the Combined High Voltage 230kV Revenue Metering Instrument Transformer Unit

• This could be used to provide the voltage signal to the Protection & Control and Monitoring System of the Transformer Station
Wholesale Revenue Metering System

- IESO Regulated System
- The ‘spare’ secondary winding of the voltage transformer unit in the Combined High Voltage 230kV Revenue Metering Instrument Transformer Unit would be utilized
- The current transformer unit in the Combined High Voltage 230kV Revenue Metering Instrument Transformer Unit will remain dedicated to the Wholesale Revenue Metering System
- Only fiber optic communications permitted to leave the Wholesale Revenue Metering System
Digital Secondary Systems (DSS)

- Enable the transfer of current and voltage signals over fiber optic media
- Remote acquisition module and protection relay required
- IEC 61850 9-2 Sampled Values
- SEL TiDL Technology
Data Acquisition Systems

Traditional Relay

Remote Acquisition Module + Relay

Remote Acquisition Module + Relay
Splitting Functions adds Latency

Latency = $T_{\text{RELAY}}$

Latency = $T_{\text{RELAY}} + 1.5 \text{ ms}$

Consider Network Delay
Modern switchgear that publishes breaker status
Modern CT and VT that publishes sampled values
IEC 61850 9-2 Sampled Value Applications

• Measure and digitize voltages and currents
  - Merging units in yard cabinet
  - IEC 61850-9-2-compliant instrument transformers
  - Merging units require time source for sample synchronization

• Subscribe to data streams
  - Data shared among multiple relay systems
  - Network connections versus discrete wiring
  - Limited to 4.8 kHz sampling rate (9-2 LE)
Time-Domain Link (TiDL) Technology

Control House

Process Bus
(IEC 61158 EtherCAT®)

Station Bus
(IP, GOOSE, MMS, DNP3, and so on)
TiDL Applications Advantages

- IEC 61158 EtherCAT-based transport
- Point-to-point connections
- Synchronous 24 kHz sampling
- Inherently cybersecure technology
- Only one additional setting
- Direct fiber access
- Available in SEL 421 Line Protection Relay
- Perfect fit for application
• Top view is relay with traditional screw terminals used to connect the hard wired voltage and current signals

• Bottom view shows the traditional current and voltage inputs are replaced with fiber optic connectors
Simple to use Commissioning and Status Tools

- Simply connect the remote nodes in a supported topology and depress the commissioning button to learn and lock in on that topology
- Commissioning and Network LED provide system status
- Individual LED’s provide status of each Remote Node
Remote Node Connections

- Connections to the remote node are made by Direct fiber optics
- Protection-Rated AC input module for direct connection to instrument transformers
- Digital input and digital output modules available but not required in this application
- 4 slot or 10 slot panel and surface mount options available
No Remote Time Source Required

Synchronized Relative Time-Domain Island
Implementation of Solution at Vaughan TS4

- TiDL technology provided the simplest approach to solving this problem
- Direct fiber connection
- No remote time source required
Installation of SEL 421 TiDL Relay

- 421 Protection relay with TiDL node for current connections located in relay panel
- Traditional protection settings with same relay algorithms used in previous designs
- Traditional test switches
- Benefit of not completely deviating from proven utility standards used on previous stations
Installation of Node for Line Voltage Connections

- Front View of remote node
- Status of unit provided by simple LED’s indicating enabled or commissioning errors
- No settings in remote device
- Traditional test switches
Connection View of Remote Node

- View inside panel
- Direct Fiber connection to TiDL relay board
- Status of unit provided by simple LED’s indicating enabled or commissioning errors
One Challenge Remaining

- Breakers capable of connecting different sources require synchronism check functions.
- The synchronism check algorithm in the relay compares the magnitude and angle of the voltages on each side to ensure it is safe to close the breaker.
- Prevents closing during out of phase or dead bus conditions as required.
- Essential for the safe operation of the power system equipment.
Previous Design Used 230kV Primary Voltages

- Past designs had wired voltage signals from the primary side that were now replaced with the TiDL Digital System.
- Installing additional potential transformers on the Transformer secondary side is not practical.
- Make secondary breaker a TiDL relay.
- IEC 61850 9-2 would require a network to share the digital voltages.
- What about Synchrophasors?
What is a Synchrophasor?

- Satellite-based time-keeping systems allow measurements, such as voltage phasors, current phasors, and frequency, to within synchronized within 1 µs.
- Allows for precise comparison of magnitudes and angles across the power system.
Relays Send and Receive Synchrophasors

- Modern relays can both send and receive Synchrophasors
- Direct fiber optic connection between two relays allows exchange of C37.118 data stream on a client-server relationship
- Client relay time aligns the received measurements with its own measurements
- Time aligned data can be used for computations and logic for control systems
Example Application of Synchrophasor RTC
Implementation of Solution at VTS4

- SEL 421 TiDL relay is a C37.118 server and direct fiber connected to the SEL 451 Transformer Secondary Breaker Relay
- SEL 451 relay time aligns transformer primary voltages from the C37.118 stream with the directly connected bus voltages
- Magnitude and angle comparisons are completed and supervise the closing of the breaker
Wholesale Revenue Metering Cabinet

• Due to space limitations in the metering cabinet an additional cabinet to house the remote acquisition equipment was required

• The auxiliary protection panels were located adjacent to the metering cabinets and locked and sealed as part of the wholesale metering installation
Summary

• Evaluating new technology for traditional designs can provide benefits in cost, functionality, maintenance and reliability.

• Proof of concept testing and evaluation of new technologies early in the design process provides successful project deployment.

• Negotiations with the IESO required to allow the Metering Seal on L1 & L2 auxiliary protection cabinet to house the remote data acquisition equipment.

• Vaughan TS4 was successfully placed into service in December of 2017.

• Design can be used to retrofit existing stations and allow the deployment of the Doble IDD on-line bushing monitor system to protect critical transformer station assets.
Questions