NxtPhase T&D Corporation
Optical Current and Voltage Transformers

Digital and fiber optic solutions for the electric power industry.
Agenda

• Introduction
• Optical technology and experience
• Interface
• Discussion of the flexible form factor (F3) optical CT
• Certification and economics
Introduction

• Digital & optical solutions for electric power industry
  – Optical Sensors: Current, Voltage & Combined
  – Relays & Recorders
• Offices
  – Vancouver
  – Winnipeg
  – Phoenix
• The Vision: “all-digital integrated substation”
NxtPhase was formed by combining industry leading teams in:

- Optical current sensing
- Optical voltage sensing
- Protection & recording solutions
The Pieces

Control Room
Optical Sensors Benefits

• Performance Features
  – Accuracy exceeds ANSI/IEEE class 0.15/IEC class 0.2S
  – Wide dynamic range
  – Bandwidth from dc to 100\textsuperscript{th}+ harmonic
  – Seismic performance
  – User-adjustable turn-ratio
  – No CT Saturation
  – Excellent phase accuracy

• Safety & Environmental Concerns
  – Uses dry nitrogen as insulating gas not oil, cellulose, or SF\textsubscript{6}
  – No open secondaries
  – No ferro-resonance
  – Galvanic isolation from HV line
Optical Sensors Benefits (2)

• Installation Savings & Retrofit Capability
  – Weight is 10% of conventional device
  – Voltage & current in one device
  – Zero footprint CT is possible
  – Metering & protection relaying in one device

• Self Monitoring

• Simple and Flexible Setting
  – Graphical User Interface provides a user-friendly interface to permit system health monitoring and parameter modification
  – Simplifies substation design by allowing a simple template design for multiple applications

• Leads to digital communications & data acquisition
## Installations

<table>
<thead>
<tr>
<th>Utility / Customer</th>
<th>Product</th>
<th>Voltage</th>
<th>Application</th>
<th>Location</th>
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<tbody>
<tr>
<td>BC Hydro</td>
<td>NXVCT</td>
<td>230 kV</td>
<td>Protection Trial</td>
<td>Ingledow Substation, Surrey, BC, Canada</td>
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<tr>
<td>Hydro Quebec</td>
<td>NXVCT</td>
<td>138 kV</td>
<td>Revenue Metering</td>
<td>Rolls Royce gas-turbine station, Montreal, PQ</td>
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<td>Metering &amp; Protection</td>
<td>Deer Valley Substation, Phoenix, AZ</td>
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<td>BC Hydro</td>
<td>NXVT</td>
<td>500kV</td>
<td>Calibration</td>
<td>Powertech Testing Lab</td>
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<td>230 kV</td>
<td>Revenue Metering</td>
<td>Geothermal Plant, Sonoma County, CA</td>
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<td>American Electric Power</td>
<td>NXVCT</td>
<td>345 kV</td>
<td>Metering &amp; Protection</td>
<td>PSERC Project, Columbus, Ohio</td>
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<td>Portland General Electric</td>
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<td>Calibration</td>
<td>Portland, Oregon</td>
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<td>Revenue Metering</td>
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<td>Monitoring Transients (PQ)</td>
<td>Glengrove Substation, Toronto, ON</td>
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<td>Alabama Power</td>
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<td>NXCT</td>
<td>LV</td>
<td>Calibration CTs</td>
<td>Gaithersburg, MD</td>
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<td>Entergy</td>
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<td>Revenue Metering</td>
<td>3 systems in Orange, TX</td>
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<td>EKA Chemicals</td>
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<td>P&amp;C, and metering</td>
<td>Magog, Quebec, 6 installations</td>
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<td>P&amp;C, and metering</td>
<td>Laterrié, Quebec, Canada, 2 systems</td>
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<td>VA TECH - ENEL</td>
<td>NXCT</td>
<td>420 kV</td>
<td>Breaker/Protection</td>
<td>Italy, Tema (Candia)</td>
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<tr>
<td>VA TECH - NGT UK</td>
<td>NXCT</td>
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<td>Breaker/Protection</td>
<td>UK, Sundon</td>
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<td>VA TECH - Wienstrom</td>
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<td>420 kV</td>
<td>Metering &amp; Protection</td>
<td>Austria</td>
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<td>DynAmp - Alcan</td>
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<td>80 kA</td>
<td>P&amp;C, and metering</td>
<td>Beauhamois, Quebec, Canada</td>
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<td>DynAmp - Rusal</td>
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<td>350 kA</td>
<td>P&amp;C, and metering</td>
<td>Sayanagorsk, Russia</td>
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<td>Portland General Electric</td>
<td>NXVCT</td>
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<td>Metering &amp; Protection</td>
<td>Portland, OR</td>
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<td>APS</td>
<td>NXVT</td>
<td>230 kV</td>
<td>Metering &amp; Protection</td>
<td>Phoenix, Arizona</td>
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<td>AltaLink</td>
<td>NXCT</td>
<td>230 kV</td>
<td>Shunt Cap Protection, 4 sys</td>
<td>Alberta, Canada, 4 systems</td>
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<td>Areva/Hydro Quebec</td>
<td>NXCT-DC</td>
<td>69 kV</td>
<td>HVDC in Static VAR Comp</td>
<td>Quebec Canada, De-Icer project</td>
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</table>
Installation Example  NXVCT-115

Hydro Quebec’s Rolls-Royce Substation – 115kV
Combined Voltage & Current Optical Sensor
Arizona Public Service, Deer Valley Substation – 230 kV Combined Voltage & Current Optical Sensor

BC Hydro, Ingledow Substation – 500 kV Combined Voltage & Current Optical Sensor

National Grid (UK) Sundon Substation NXCT - 420 kV

CANDIA Enel, Terna Substation NXCT – 420 kV
VA-Tech, Wienstrom, Austria

GIS-NXCT-420

Portugal

Entergy Gulfrich Substation – 69 kV Optical Current Sensor

EKA Chemicals, Magog, Quebec

Portable optical VT for Calibration
NXVT-500 kV, BC Hydro

NXCT-F3-DC 25 kA

BC Hydro

NXVT-500 kV, BC Hydro
Fiber Optic Current Sensor

- Light Source
- Modulator
- Polarizer
- Circular Polarizer
- Mirror
- Current Carrying Conductor
- Fiber Optic Loop
- Photo Detector
- Digital Intelligence

data
The NXCT

CT Head – can have Multiple Sets of Fiber Wound Around Head

Various primary connections

Composite Insulator No gas/oil inside!!!
NXCT Accuracy - Linearity over Dynamic Range

![Graphs showing accuracy and linearity over dynamic range for NXCT.](image-url)
The Pockels Effect

Electric field produces a birefringence that is linearly proportional to the magnitude of the electric field.
NXVCT & NXVT

VT: Multiple Electric Field Sensors

Internal Shielding to Moderate Surface Perturbation Effects

Composite Insulator

CT Head – can have Multiple Sets of Fiber Sensors

Low pressure dry nitrogen
NXVT Accuracy - Linearity

IEC 0.2% Accuracy Class

IEEE 0.3% Accuracy Class

Ratio Error (%) vs. Percent of Rated Voltage (%)

Phase Error (minutes of arc) vs. Applied Voltage (kV)

- Ratio Error (%)
- Phase Error (minutes)

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NXVT Accuracy over Temperature

The graphs depict the accuracy of NXVT over temperature changes. The x-axis represents time (in hours) ranging from 0:00 to 24:00. The y-axis on the left graph shows the ratio error (%) ranging from -1.0 to 0.0, and the y-axis on the right graph shows the phase error (minutes) ranging from -60.0 to 0.0. Both graphs feature temperature (°C) as a variable on the x-axis.

The graphs illustrate the performance of the NXVT system under varying temperature conditions, emphasizing its accuracy within specified limits. The data points indicate that the system maintains a high level of accuracy across different temperature fluctuations.
## AIS-NXCT Specifications

<table>
<thead>
<tr>
<th>Voltage Classes</th>
<th>AC / DC: Up to to 800 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metering Accuracy</td>
<td>Exceeds IEC Class 0.2S, Exceeds IEEE Class 0.15S</td>
</tr>
<tr>
<td>Protection Accuracy</td>
<td>IEC Class 5P/IEEE 10%</td>
</tr>
<tr>
<td>Dynamic Range</td>
<td>1 A to 4000 A for metering</td>
</tr>
<tr>
<td>Short-time Current</td>
<td>80 kA rms, 216 kA peak</td>
</tr>
<tr>
<td>Temperature Range</td>
<td>-50°C to +65°C</td>
</tr>
<tr>
<td>Bandwidth</td>
<td>DC to 6 kHz</td>
</tr>
</tbody>
</table>
## AIS-NXVT Specifications

<table>
<thead>
<tr>
<th>Specification</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Voltage Classes</strong></td>
<td>Up to 550 kV</td>
</tr>
<tr>
<td><strong>Metering Accuracy</strong></td>
<td>Exceeds IEC Class 0.2, Exceeds IEEE Class 0.15</td>
</tr>
<tr>
<td><strong>Protection Accuracy</strong></td>
<td>IEC Class 3P, IEEE Class 10%</td>
</tr>
<tr>
<td><strong>Dynamic Range</strong></td>
<td>&lt;2% to &gt;200% of rated voltage</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td>-50°C to +55°C</td>
</tr>
<tr>
<td><strong>Bandwidth</strong></td>
<td>0.001Hz to 6 kHz</td>
</tr>
</tbody>
</table>
Many types of interface are available:

- **Conventional CT**
- **Fibers & cables**
- **IEC 61850-9-2-lt**
- **2.5 VA Voltage Amplifier (HEA)**
- **1 VA 1A Metering Current Amplifier (HEA) (B-0.1)**
- **L25 5A Protection Current Amplifier (HEA) (B-0.25)**
- **More 5A Current Amplifiers (HEA) if required**
- **5 A Relay 1**
- **5 A Relay 2**
- **115 V Meter**
- **4 V Fibers**
- **5 A Relay 3**

**Interface (One-line diagram)**

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Electronics Modules (all 3-phase)

- Splice tray
- Electro-optics chassis
- Combined power supply & 1A metering amplifier chassis
Preferred Meter Interface

Meters Types
Any Class II commercially available meter with conventional inputs:

- Landis & Gyr
- Elster
- Power Measurement
- Itron
NXCT-F3

125 V dc Power
Output: ±10 V @ Full Scale
Optical Fiber Cable
Low Voltage Modulator Drive - Shielded Twisted pair

CT Electronics
Optical Modulator box
Optical Modulator box
Optical Modulator box

Sensing Loop(s)
Current A
Current B
Current C

3-Phase NXCT-F3 Block Diagram
# NXCT-F3 Technical Specifications

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full scale bus current</td>
<td></td>
<td></td>
</tr>
<tr>
<td>NXCT-F3-AC</td>
<td>Up to 100 kA-turn AC</td>
<td>AC only (no DC)</td>
</tr>
<tr>
<td>NXCT-F3-DC</td>
<td>Up to 600 kA-turn DC</td>
<td>DC and AC</td>
</tr>
<tr>
<td><strong>Output</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Voltage output</td>
<td>±10 V max</td>
<td>Resistive load &gt; 5 kΩ</td>
</tr>
<tr>
<td>Optional current output</td>
<td>±1 A rated (X 2) for metering</td>
<td>Maximum burden 0.25 Ω</td>
</tr>
<tr>
<td></td>
<td>±5 A rated (X 20) for protection</td>
<td>Separate chassis for amplifiers</td>
</tr>
<tr>
<td>Current measurement accuracy</td>
<td>Down to ± 0.1%</td>
<td>Depending on current level, temperature, AC or DC</td>
</tr>
<tr>
<td>Current measurement Bandwidth</td>
<td>DC to 6 kHz</td>
<td>AC or DC option</td>
</tr>
<tr>
<td><strong>Environmental</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating temperature, electronics</td>
<td>-5 to 40 °C</td>
<td>Temperature specification over which accuracy specification is maintained.</td>
</tr>
<tr>
<td>Operating temperature, sensing head</td>
<td>-40°C to +60 °C</td>
<td>Narrower temperature range for higher accuracies</td>
</tr>
</tbody>
</table>
NXCT-F3

Accuracy over frequency

Ideal for:
- retrofit,
- temporary metering installation
- line monitoring (including power quality)
- portable live calibration, and
- high-current generation applications.
NXCT-F3

NXCT-F3-DC-50kA, EKA Chemicals, Sep 2004, Magog, Quebec. Sensing heads and modulator boxes.
NXCT-F3, Sensing head (cable) and Modulator Box
NXCT-F3

Complete Single-Phase System
NXCT-F3

SM fiber pigtail

Shielded twisted pair

Sensing-head end (removable)

Sensing-head beginning (fixed)
NXCT-F3

Various temporary installation configurations around bushings - measuring current through the bushing and/or calibrating magnetic bushing CTs
Measurement Canada Approval

- Started approval process in 2000
- Successfully collected and demonstrated performance for over two years in hot, cold, and wet climates
- Have established verification and re-verification procedures
- Expect conditional approval for the CT by the end of the year
  - Cover the entire system, including the electronics and amplifiers
- Can have an exemption from certification for > 3MW applications
Medium Voltage Application Economics

- Economic benefits are realized with more widespread use.
- Even though the instrument transformers may still be more expensive at medium voltage, total solution cost can be significantly lower today.
- BC Hydro studied metering at 25 kV, at 400 points between transmission and distribution.
  - Conclusion: Combined optical VT/CT sensors from NxtPhase will result in the lowest cost solution (by 25%) for metering this interface when considering total solution cost, including instrument transformers, project management, engineering, civil work, meters, communication, commissioning, …
Other Practicalities

- CT and VT ratios are chosen at time of order, similar to conventional instrument transformers
  - VT rated secondary is usually ~115 V
  - CT rated secondary is usually 1 A (as opposed to 5 A)
- Ratios can be changed via software only after breaking Measurement Canada Seal
- Rated burdens are usually quite low (< 1 VA), but quite sufficient for connection to multiple electronic meters
- Over-current up to RF=2 is available (2 A output)
- Cable runs between the high-energy outputs (from the amplifiers) and the meters are usually quite short
  - Typically same cubical
- Verification of accuracy similar to magnetic instrument transformers