Fiber Optic Technology Will Drive Next Generation Intelligent Substations

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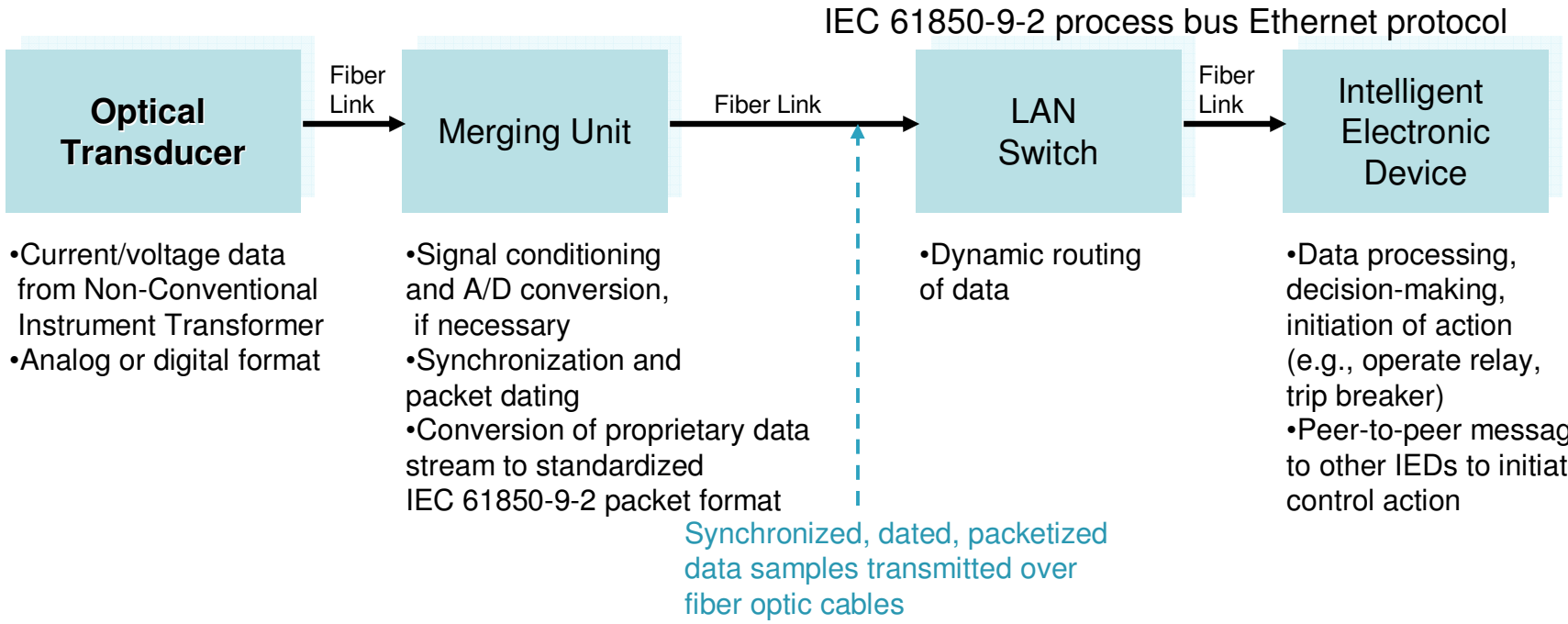
Elements of the Intelligent Substation

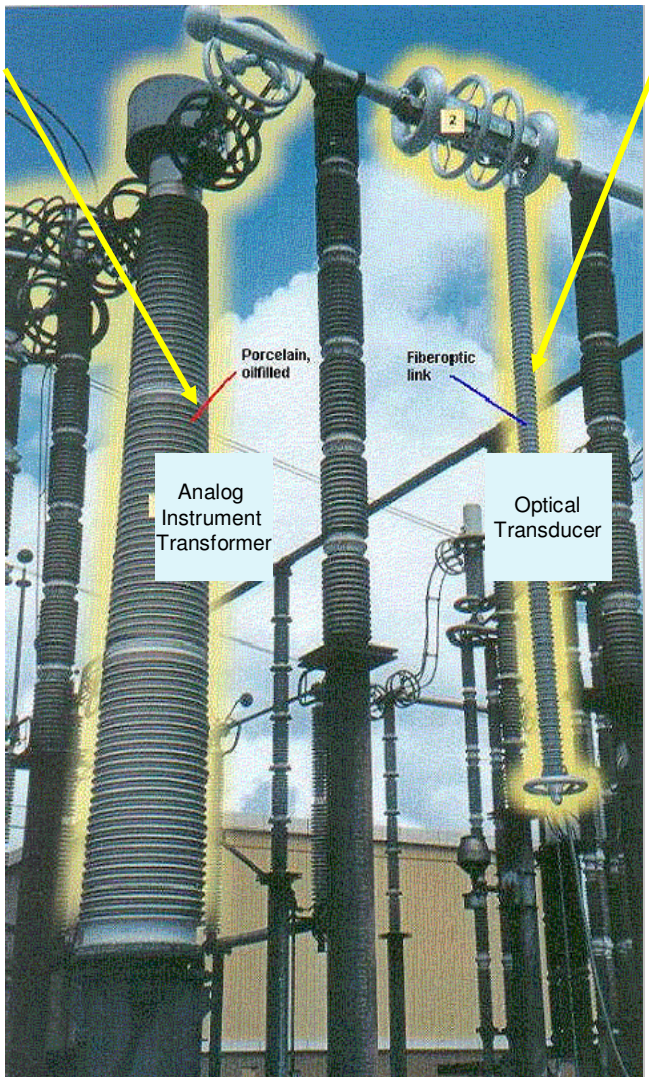


Traditional Substation	Intelligent Substation
•Electromechanical relays, programmable logic controllers and microprocessors	•Digital input from optical transducer; Ethernet communications between interchangeable IEDs
•Master-slave protocols	•Peer-to-peer messages over process bus
•Copper wire interfaces	•Small numbers of fiber optic cables replace large bundles of copper wire

Why Use Optical Transducers?

Conventional Instrument Transformer

- Proven
- Heavy and challenging to install at higher voltages
- Subject to open current circuit conditions
- Potential for explosion or leak
- Must convert analog measurement to digital format in intelligent substations



Non-Conventional Optical Transducer

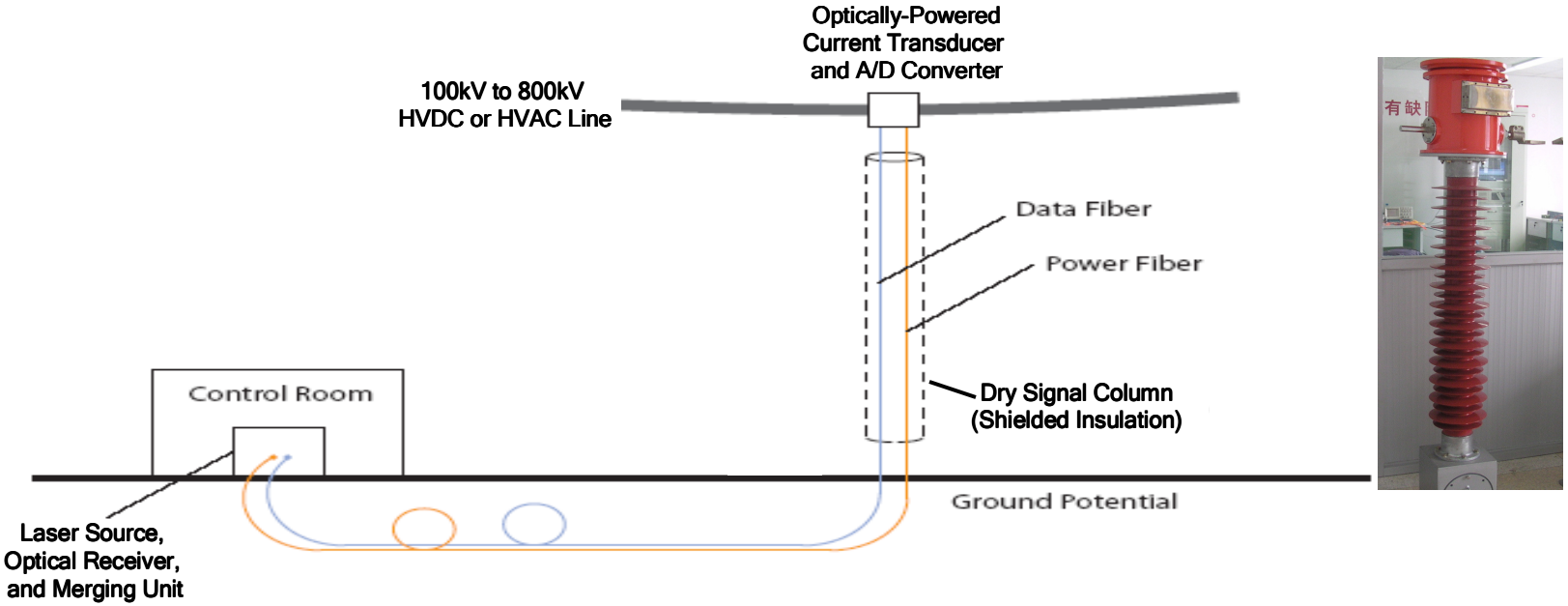
- Unaffected by high voltage, lightning or electromagnetic effects
- Small size conserves substation space and reduces seismic considerations
- Not subject to open circuit conditions
- Dry signal column eliminates possibility of explosion or leak
- Compatible with IEC 61850-9.2 digital process bus requirements

Source: Siemens Power Technologies, Areva T&D

Optical Measurement Technologies

Characteristic	Optical Current/ Voltage Sensors	All-Optical Transducers	Electro-Optical (Digital) Transducers
Application	• Current and voltage sensing on LV and MV AC Networks (up to 36 kVAC) • Primarily in distribution networks	• Current and voltage sensing on HVAC and HVDC Networks (100 kV to 550 kV) • Primarily in substations	• Current sensing on HVAC and HVDC Networks (100 kV to 800 kV+) • Primarily in substations
Measurement Technology	• Non-conductive Faraday Effect sensors and fiber cable	• Optical light source illuminates Faraday Effect sensors, photodiode measures intensity and rotation of polarized beam and converts it to analog signal	• Optical light source illuminates photovoltaic conversion device to generate electrical power • Measured current is converted to digital format on the HV line and sent optically to the control room
Typical Current Measurement Performance	• Current range 5-20,000 AAC • +/-2A accuracy (5-100A) • 2% accuracy (100A-20,000A)	• <0.2% metering accuracy from 1A to 5000A	• <0.1% metering accuracy from 1A to 1500A, and <0.2% from 1500A to 5000A
Advantages	• Simple, inexpensive system and installation • Non-conductive materials allow installation on cables or copper bars	• Wide dynamic range for protection, and good measurement accuracy for metering • Fully optical solution using one fiber	• Metering, protection and temperature measurement in one system • Electronics optically isolated from HV lines by non-conductive fiber • 18-bit digital measurement accuracy
Disadvantages	• Measurement accuracy insufficient for 100 kV and above	• Precise installation of optical sensor required to avoid environmental or temperature effects	• Requires power fiber and data fiber

Electro-Optical Transducer System Approach

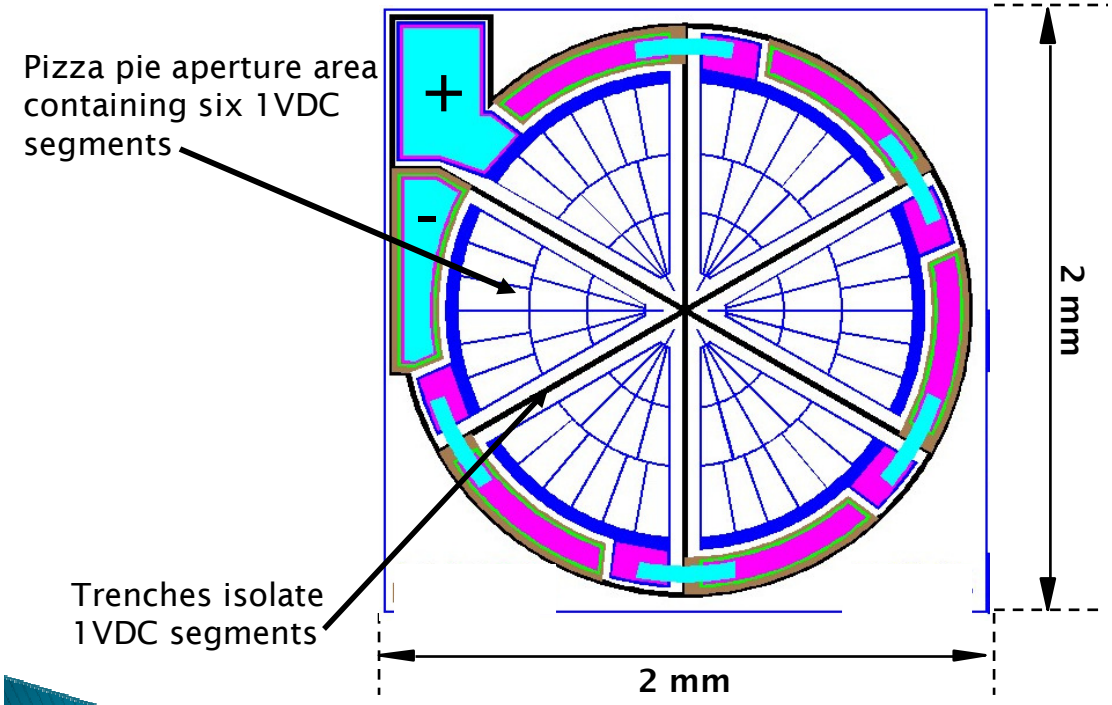


- **Application:** Current metering and protection and temperature measurement on HVDC or HVAC line
- **Enabling Technology:** Optical-to-electrical power conversion; analog signals converted to digital format on HV line and transmitted to control room via fiber optic line (or optionally over a wireless connection)
- **Key Benefit:** Non-conductive nature of fiber optic power cable isolates the electronics from ground permitting measurement electronics to mount in close proximity to the high voltage line

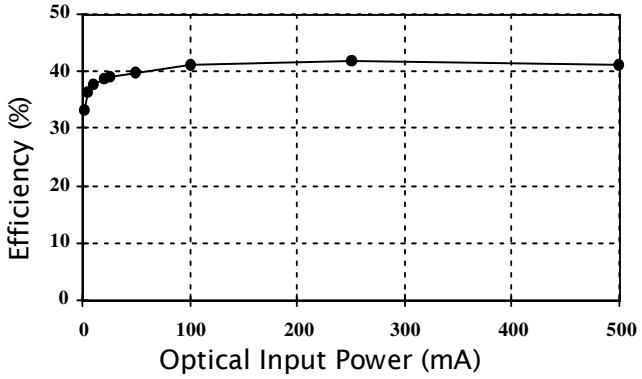
Source: JDSU Corporation

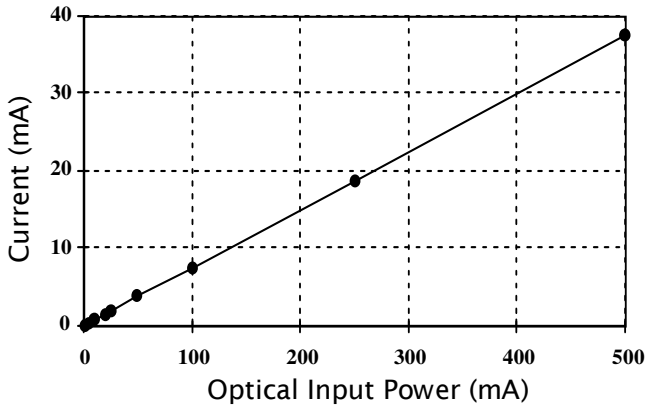
Enabling Technology: Power by Laser Light

- Single junction AlGaAs or InP semiconductor device converts laser light to electrical power with 40%+ efficiency
- Voltage from each segment of device added in series; delivered electrical current is linearly proportional to input optical power level
- 6-segment device below delivers about 220mW of electrical power
- Same functionality as solar cell, but optimized for maximum efficiency over the wavelength range of the laser source



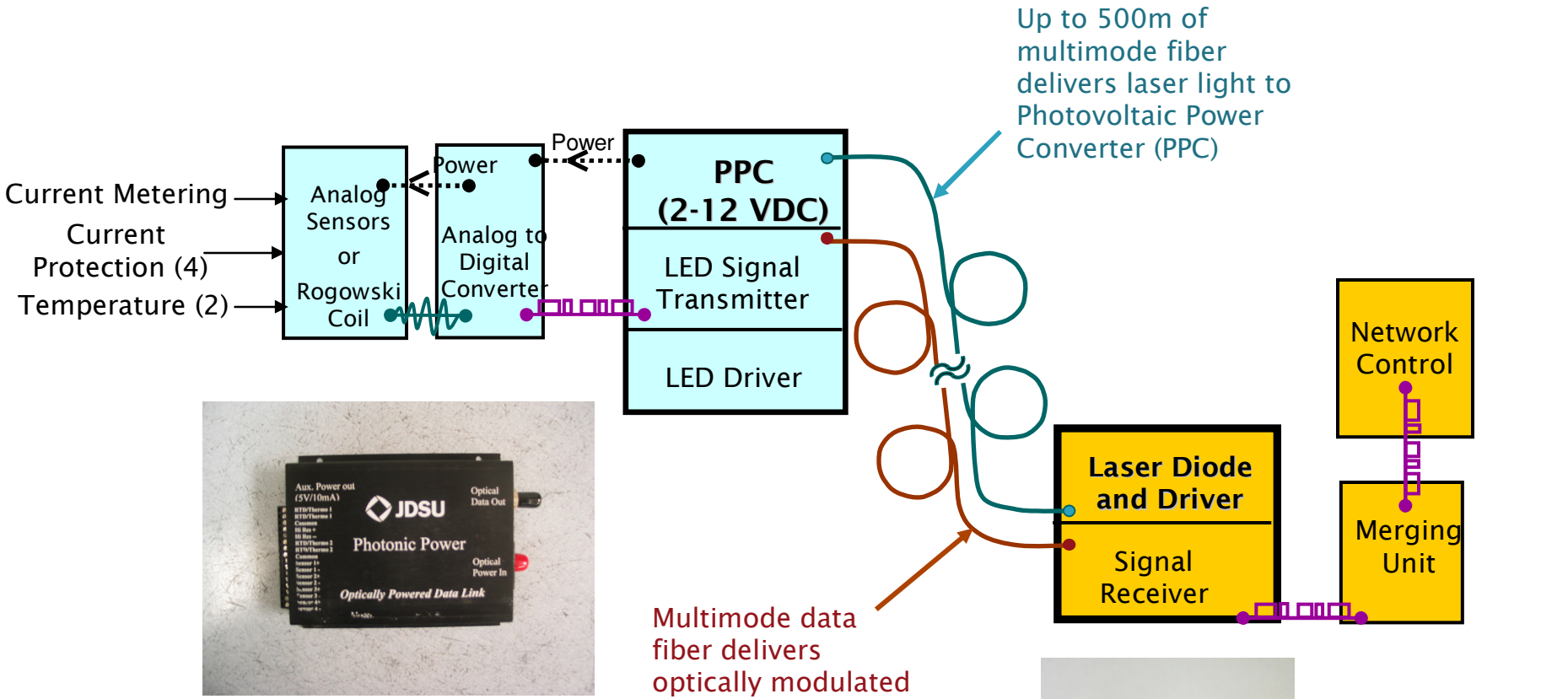
Photovoltaic Power Converter (PPC)



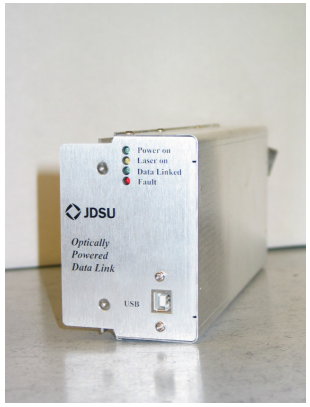


Source: JDSU Corporation

Power by Light Block Diagram (All-Fiber Solution)



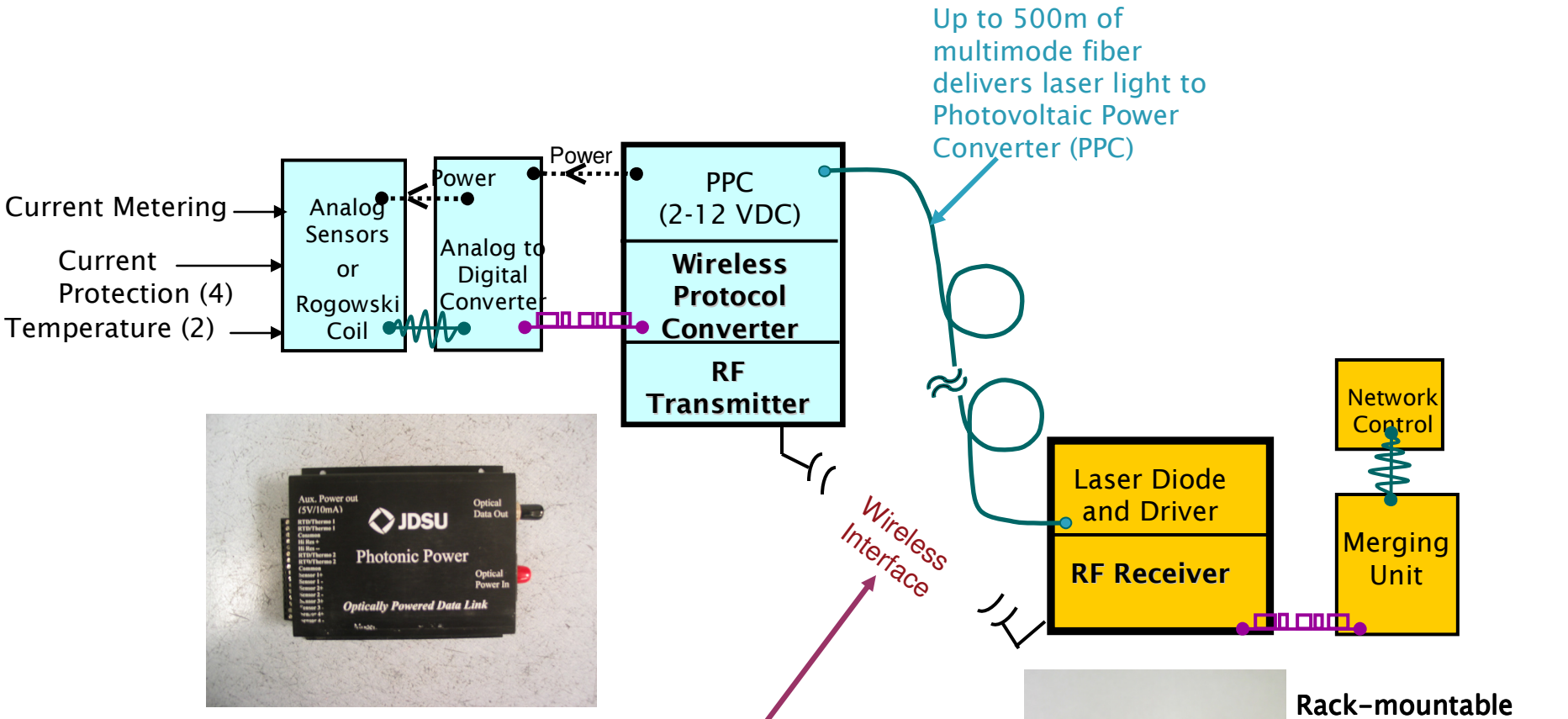
Optically-powered remote module processes up to 7 metering, protection and temperature channels simultaneously



Rack-mountable local module monitors laser output power, data link integrity and synchronization

Source: JDSU Corporation

Power by Light Block Diagram (Fiber/Wireless Solution)



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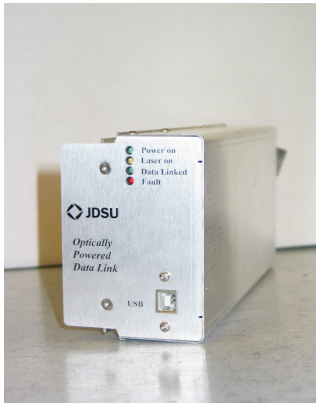

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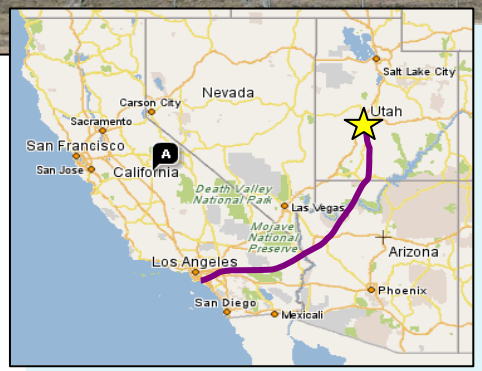
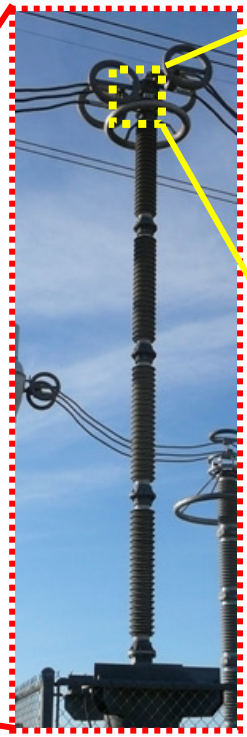
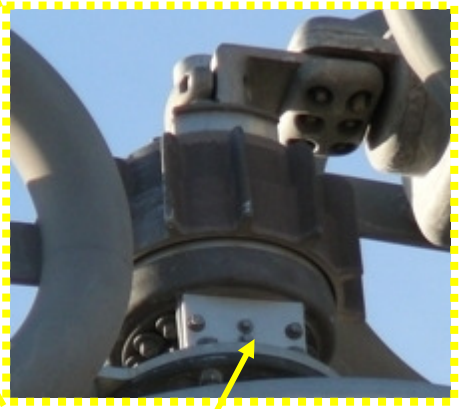
US HVDC Electro-Optical Transducer Installation

Intermountain Power Generator Station, Utah



490-mile long HVDC transmission line delivers 1600MW to Arizona and California





Optically-powered Remote Module powers the measurement electronics

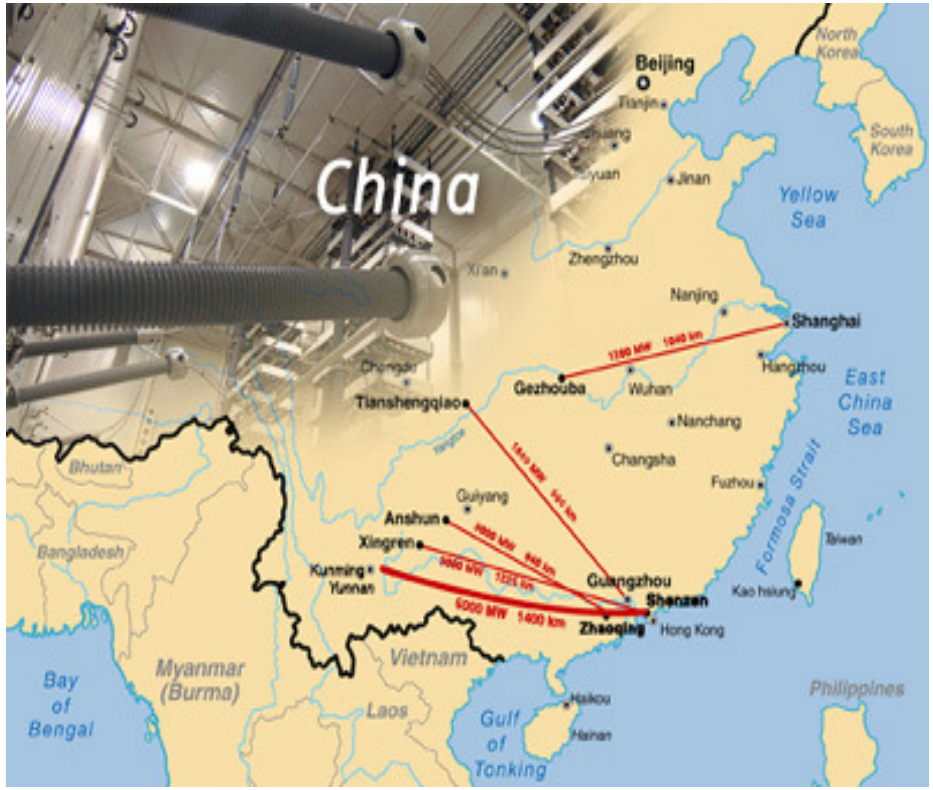
Optical CT System converts 3200 Amps of current at 500kVDC to digital data stream for metering and protection

- Intermountain is using an optically-enabled CT system for power metering and protection of its 490-mile transmission line
- Grid is reliably serving nearly four million homes in Arizona and Southern California

Source: JDSU Corporation

China is Leader in Electro-Optical Transducer Deployments

- Several HVDC ECT systems are operational in China
  - Monitoring HVDC lines carrying 1000MW to 6000MW of power over distances ranging from 500 to 1400 km
  - Several more HVDC ECT projects underway
- HVAC ECT systems being certified and field tested in China at 110kV to 550kV; higher voltages under evaluation



HVDC transmission lines utilizing electro-optical transducers shown in red

Source: Siemens Power Technologies

Enabling the Intelligent Substation with Fiber Optics

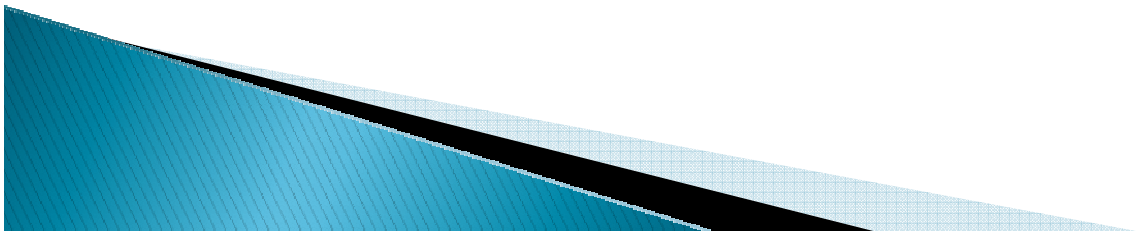
Performance Benefits

- Precise measurement and synchronization
- Better protection against current surges and open circuit conditions
- Enables digital substation process bus per IEC61850-9.2
- Impervious to electromagnetic effects, high voltages, and lightning

Operational Benefits

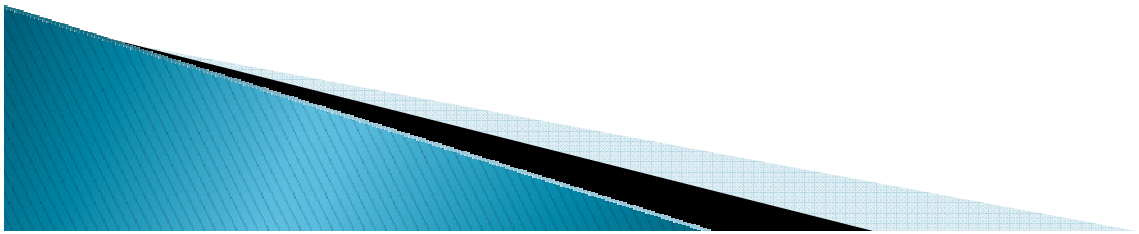
- Potential to reduce outage minutes
- Potential to allow grid to be run closer to rated capacity
- Accurate time history of events in digital format
- Eliminates potential for transformer leaks or explosion

Improved accuracy, control, response, and safety



Summary

- Fiber optic technology can be a key enabler for the Intelligent Substation
- Moving from analog to digital grid control offers benefits in performance, operation, safety and O&M
- The technology to deploy the electro-optical transducer exists and has been deployed in many HVDC applications worldwide
- China has served as the first proving ground for electro-optical transducers for HVAC applications



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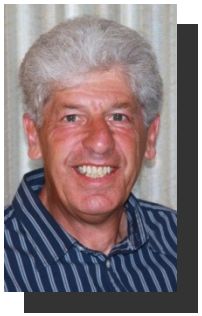

Email Mort Cohen for information on Intelligent Substations

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