



HVDC Development Process



**Designated Entity Design
Standards Task Force**

September 7, 2017
Audubon, PA



- Since 2005:
 - 1320 MW of power transmission infrastructure development, financing, construction and operation
 - \$1.5 billion in private investment
- Flagship Projects, both On Budget and Ahead of Schedule:
 - Neptune RTS: 2007; 660 MW; \$650 million
 - Hudson: 2013; 660 MW; \$850 million
- Actively pursuing additional, complementary projects

NEPTUNE

Regional Transmission System

- 65- Mile-Long, 660-MW HVDC Cable Linking PJM Electricity Market with Long Island Power Authority (“LIPA”)
- 51 Miles of Cable are Buried Undersea
- 14 Miles Underground
- Selected by LIPA in June 2004 Via Competitive RFP Process
- Financial Close July 2005 with Investment-Grade Rating
- Completed June 2007 – On Budget and Ahead of Schedule



Neptune RTS Project Team



Project management, permitting,
financing, operations

The logo for SIEMENS, featuring the word "SIEMENS" in a bold, teal, sans-serif font.



Principal Contractors:
Top global companies in HVDC and
cable technology



Two Terminal Monopolar System Metallic Return



- **Advantages of HVDC Transmission**
 - Controlled Power Exchange
 - Limitation of Short Circuit Currents
 - Transmission at variable voltages
 - No fault cascading

Cables Installed in Multiple Campaigns

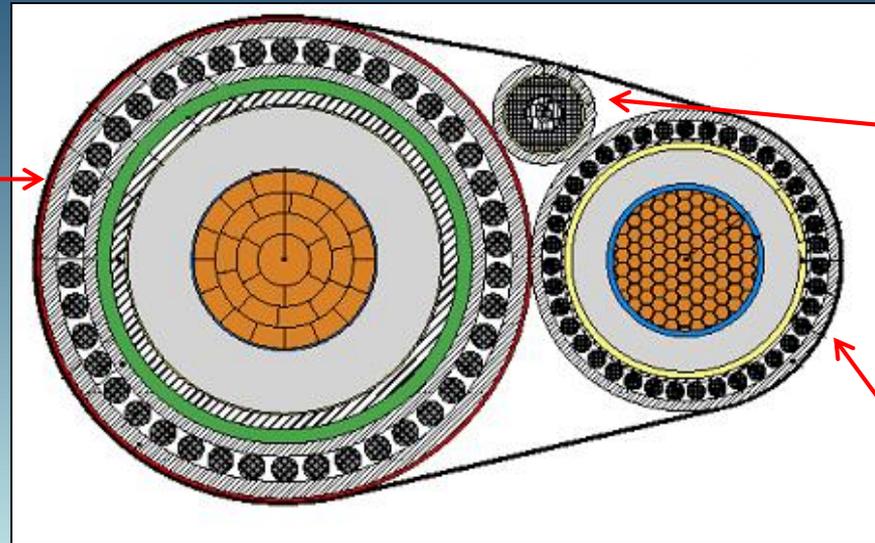


Sayreville Converter Station



Neptune DC Cable

High Voltage Main Cable (Copper Core)



Fiber Optic Cable

Medium Voltage Return Cable





Converter Transformer (Single Phase)

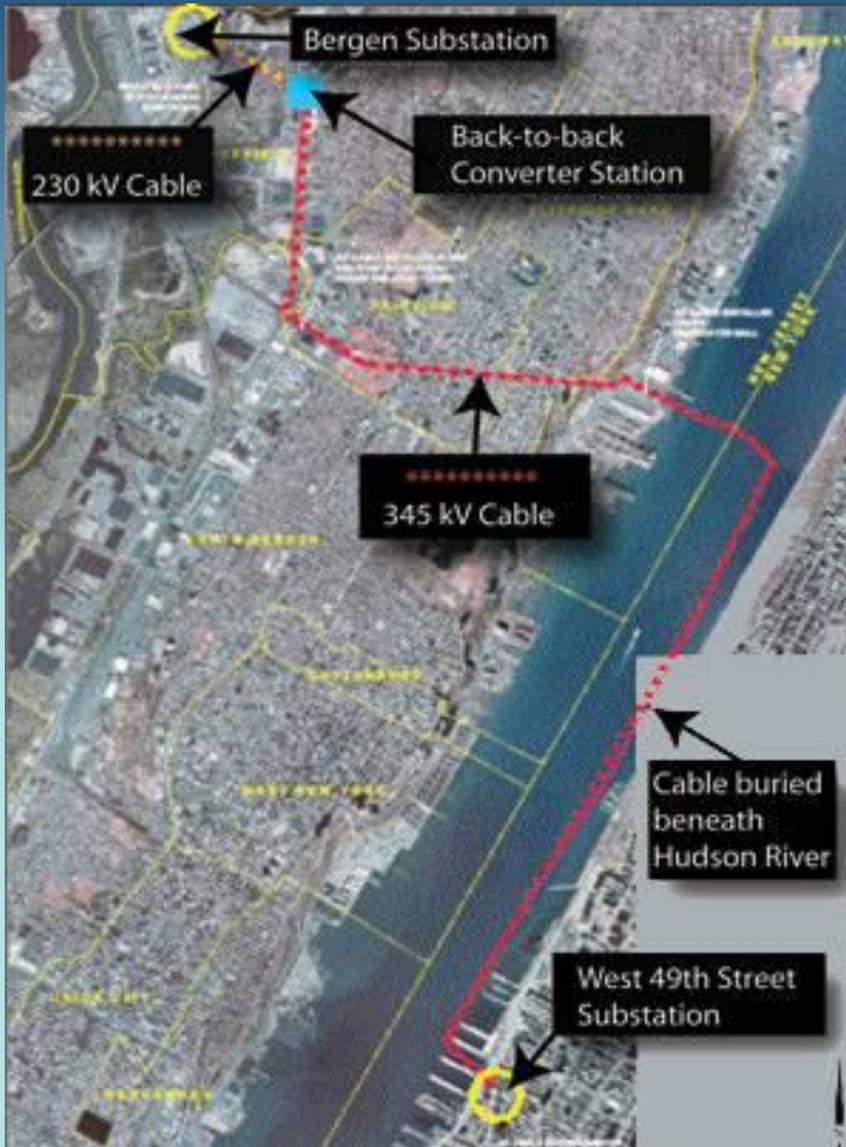




DC Smoothing Reactor

500 kV Cable Termination





- 8-mile underground and underwater power cable linking PJM and NY power grids between Ridgefield, New Jersey and West 49th St. Substation in NYC
- Single back-to-back converter station (AC-DC-AC) located in Ridgefield, NJ
- Project commencement in May 2011
- Completed ahead of schedule and under budget May 2013

Hudson Transmission Project Team

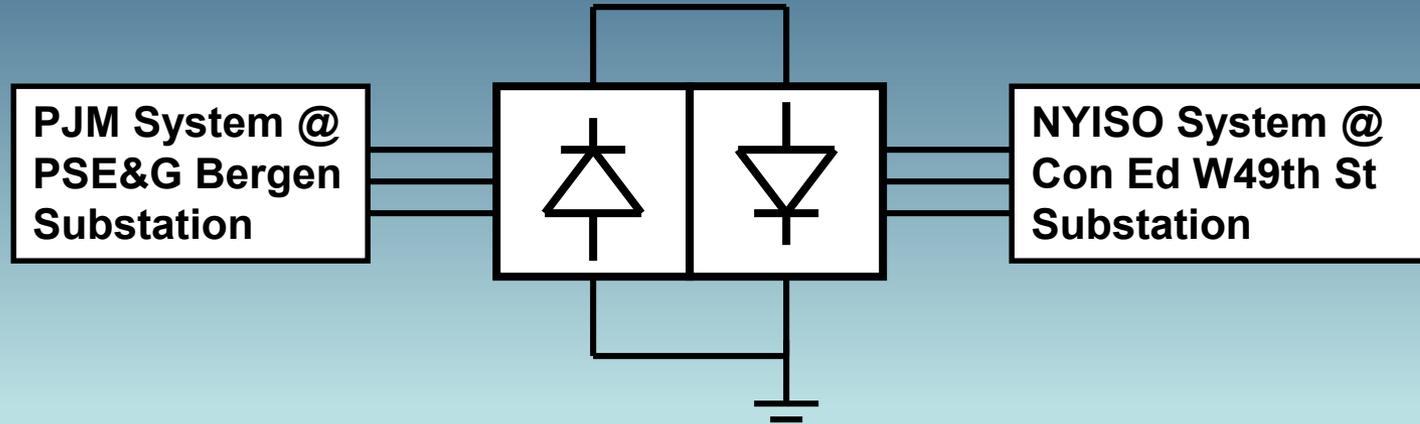
The logo for HUDSON, featuring the word "HUDSON" in a bold, blue, sans-serif font. Below the text is a stylized graphic of a suspension bridge with two towers and cables.

Comprising the Neptune Project Team – project management, permitting, financing success

The logo for SIEMENS, featuring the word "SIEMENS" in a bold, teal, sans-serif font.The logo for PRYSMIAN CABLES & SYSTEMS, featuring a stylized graphic of three parallel lines in pink and black, followed by the word "PRYSMIAN" in a bold, black, sans-serif font, and "CABLES & SYSTEMS" in a smaller, pink, sans-serif font below it.

Principal Contractors for Neptune – top global companies in HVDC and cable technology

The logo for the New York Power Authority, featuring a blue circular icon with a white stylized 'E' shape inside, followed by the words "New York Power Authority" in a blue, sans-serif font.



Advantages of HVDC Transmission

- **Controlled Power Exchange**
- **Limitation of Short Circuit Currents**
- **Transmission at variable voltages**
- **No fault cascading**



HVDC Development Stages

* = inc. cooperation with
Interconnecting Utilities and ISOs

- Pre-Engineering Studies
- Interconnection Studies*
- Interconnection Agreement (IA) Technical Specification Development*
- Post IA Detailed Design*
- Component Manufacture
- Installation
- Commission Testing*



Pre-Engineering Studies

- Terminal Location(s)
 - Network area(s) that could benefit from new transmission and HVDC
 - Close to robust interconnection points (minimize AC pathway)
 - Sufficient Converter Space (8+Acres for LCC; 5+/-Acres for VSC)
 - Attainable Interconnection Pathway (Existing ROWs; R/R; Water; or Public Roads)
- Project Development to support IR(s) and Permitting
 - Terminal Layouts and One-Line Diagram(s)
 - ROW acquisition
 - Installation Methods
 - Environmental Impacts



- Preliminary Electrical Characteristics
 - Voltage performance: Reactive allowances and limitations
 - Power Quality at interconnecting points
 - Harmonic Impedances (long-term measurements)
- Interconnection Optimization
 - Substation Access
 - Breaker position(s)
- PSS/E Modeling (Best Estimate definitions)
- Feasibility/SRIS Studies
- Technical Specification Development



IA Technical Specification Development

**PJM Interconnection, LLC
and
Public Service Electric and Gas Company**

TECHNICAL PERFORMANCE SPECIFICATION

For the

**Bergen (Hudson Transmission Project) 230 kV
HVDC PROJECT
Ridgefield, NJ**

May 9, 2009



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PJM Interconnection, LLC and Public Service Electric & Gas Company Technical Performance Specification

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Post IA Detailed Design

Design Reports

- 1. Project Main Circuit Design:** Verify technical parameters of IAs and EPC contract
- 2. Reactive Power Flow Exchange:** Verify allowable levels versus filter design
- 3. AC Protection and Metering:** Coordinate interconnecting design with utilities
- 4. Dynamic Performance:** Verify HVDC system behavior vs. system transients
- 5. PLC Filter Design:** Ensure HTP avoids interference with local PLC communication systems
- 6. Circuit Breaker Coordination:** Determine station breaker ratings and coordinate with interconnecting utilities.
- 7. SSTI Studies:** Evaluate interaction of HVDC Station with local generators and other FACTS
- 8. AC System Harmonic Performance:** Verify harmonics do not exceed technical requirements
- 9. Insulation Coordination Studies:** Establish insulation and arrester levels of the main equipment for converter station and interconnecting stations
- 10. Control Implementation:** Define SCADA system parameters and interconnecting utility data points
- 11. Load Flow and Stability Models (PSS/E):** Final models to ISOs & Interconnecting Utilities



Component Manufacture

- DC Valves
- Converter Transformers
- AC Switchyard Devices
 - Reactive Banks (for LCC; VSC may be NR)
- Protection and Control
 - Individual Panels, inc. FST
 - All-inclusive system, inc. DST (* for witnessing)



Component Manufacture

- Installation
- Commission Testing*
 - Voltage and reactive power control tests
 - AC Harmonic Filter performance tests
 - Power-Line Carrier Filter performance tests
 - Radio Interference performance tests
 - Television Interference performance tests
 - Nameplate Power Transfer
 - Load Losses





THANK YOU!

For more information please visit www.powerbridge.us