Session 2b

Hingorani

High-Megawatt Converter Technology Workshop

DOE Office of Clean Power Systems,
U.S. Army Construction Engineering Research and Development Center (ERDC), and
National Institute of Standards and Technology (NIST)

January 24, 2007, 8:00 AM -5:00 PM

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High MW Power Electronics - Areas of Applications

Generation
Wind Farms
Fuel Cell
Variable Speed Hydro

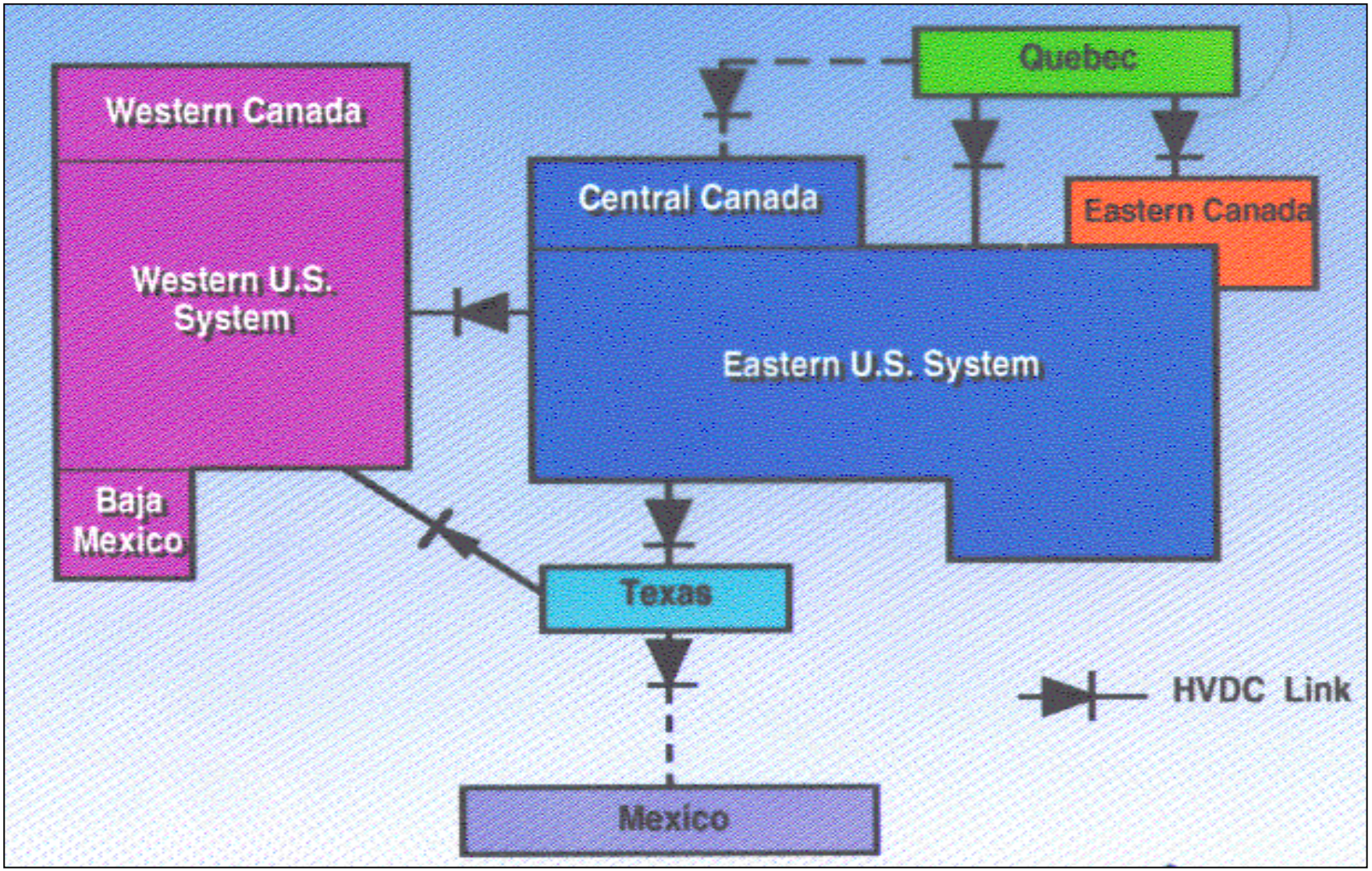
Transmission
HVDC Transmission
FACTS

Distribution
Custom Power

Storage
Battery
Flywheel
Super Capacitor
Superconducting-Magnet

Industrial
Variable Speed Drives
Rail Transportation
Ships

Military
Ship Propulsion
Aircraft Launch
Weapons
Bases



North America AC Power Systems and HVDC Interconnections

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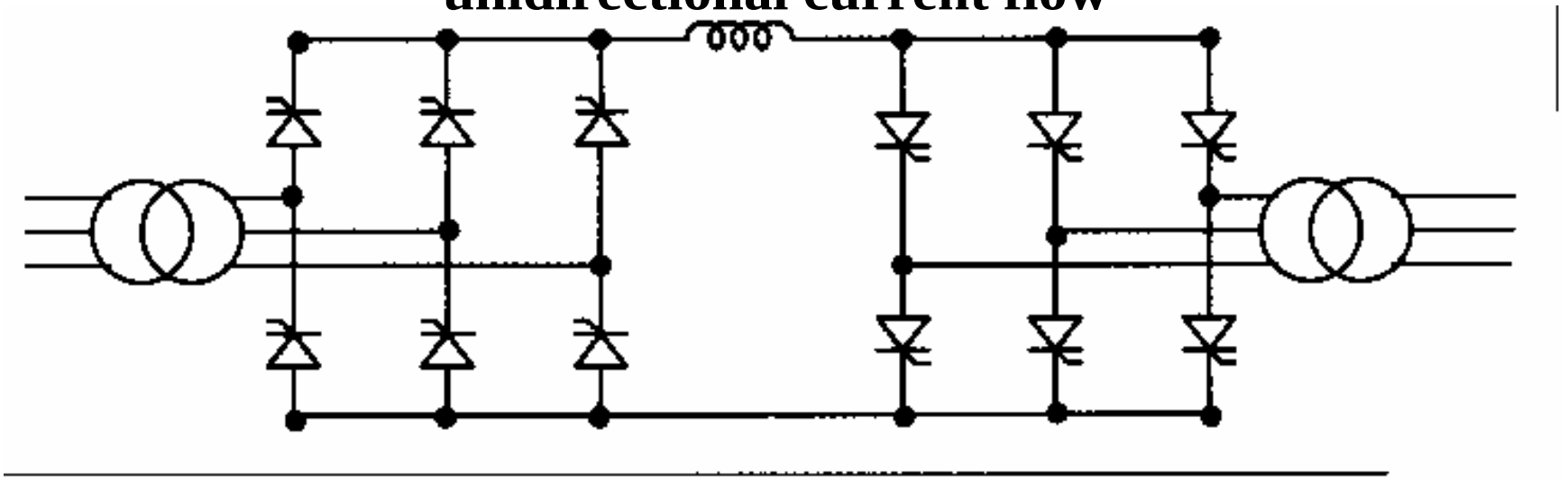
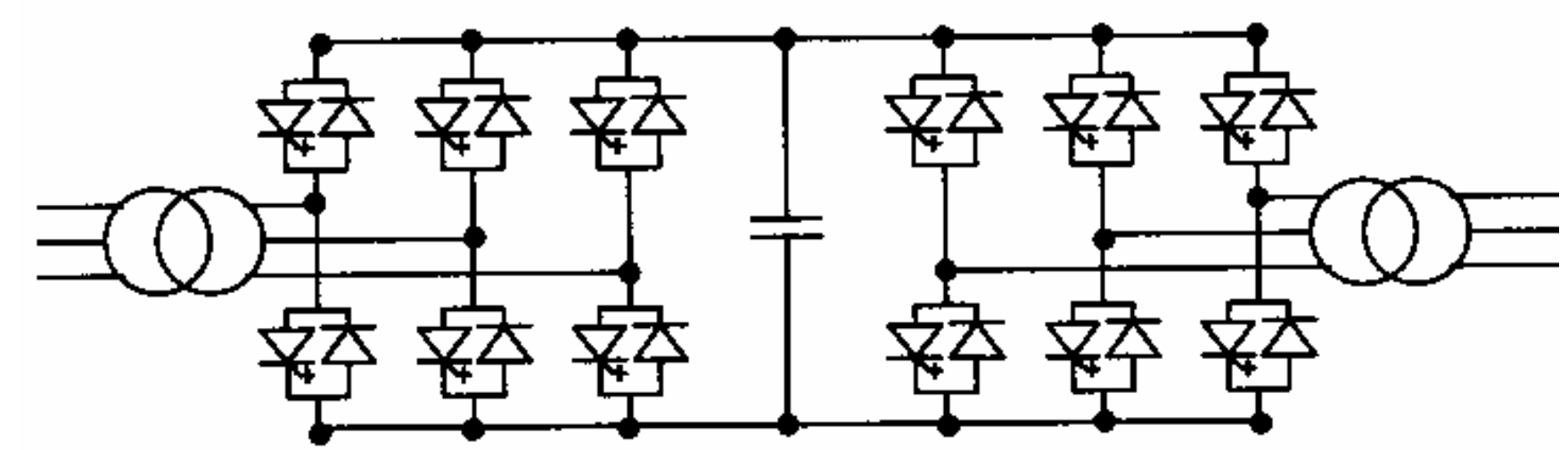
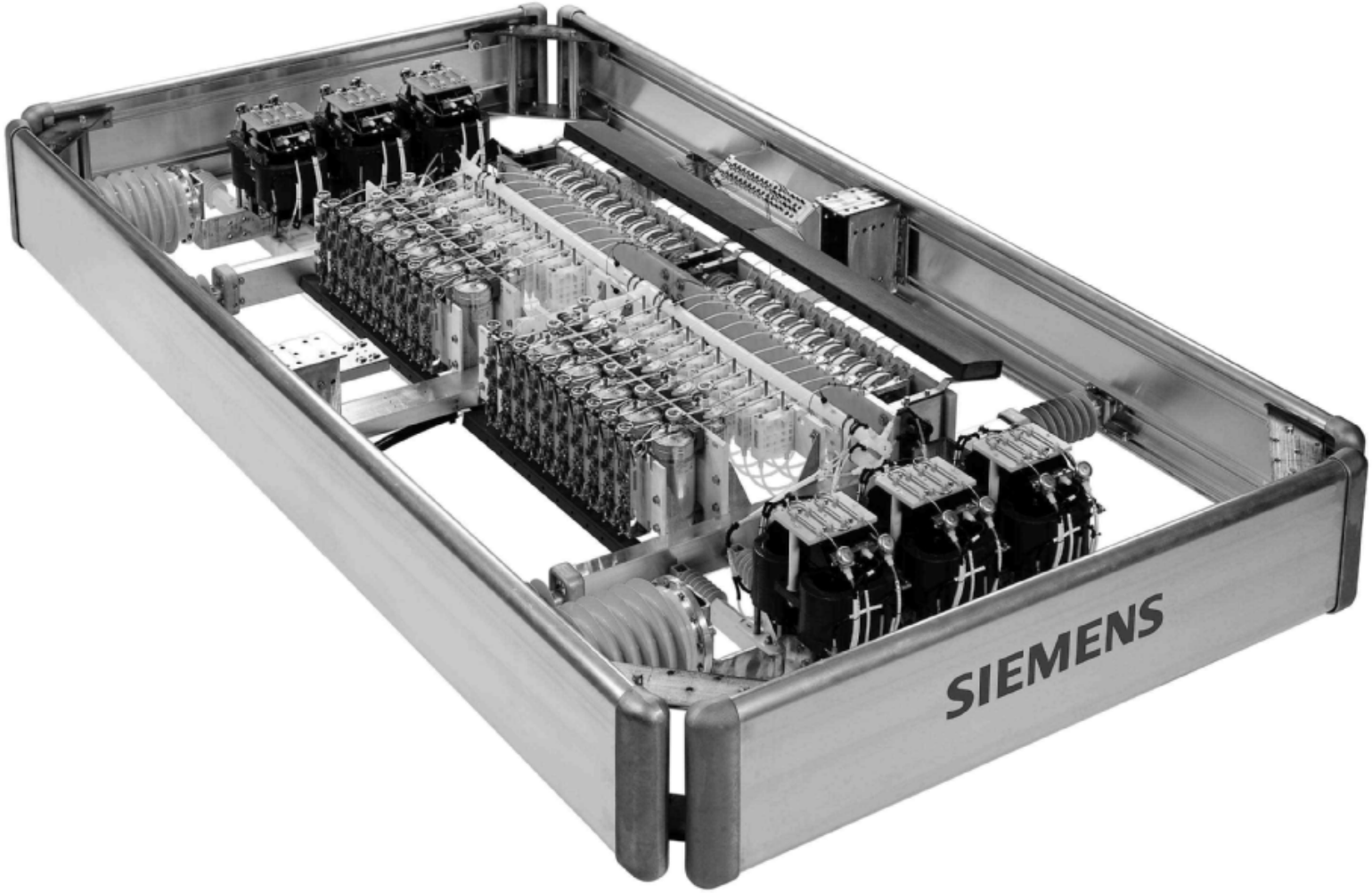
Current Sourced Converter System, which requires unidirectional current flow



Voltage Sourced Converter System which requires unidirectional dc voltage

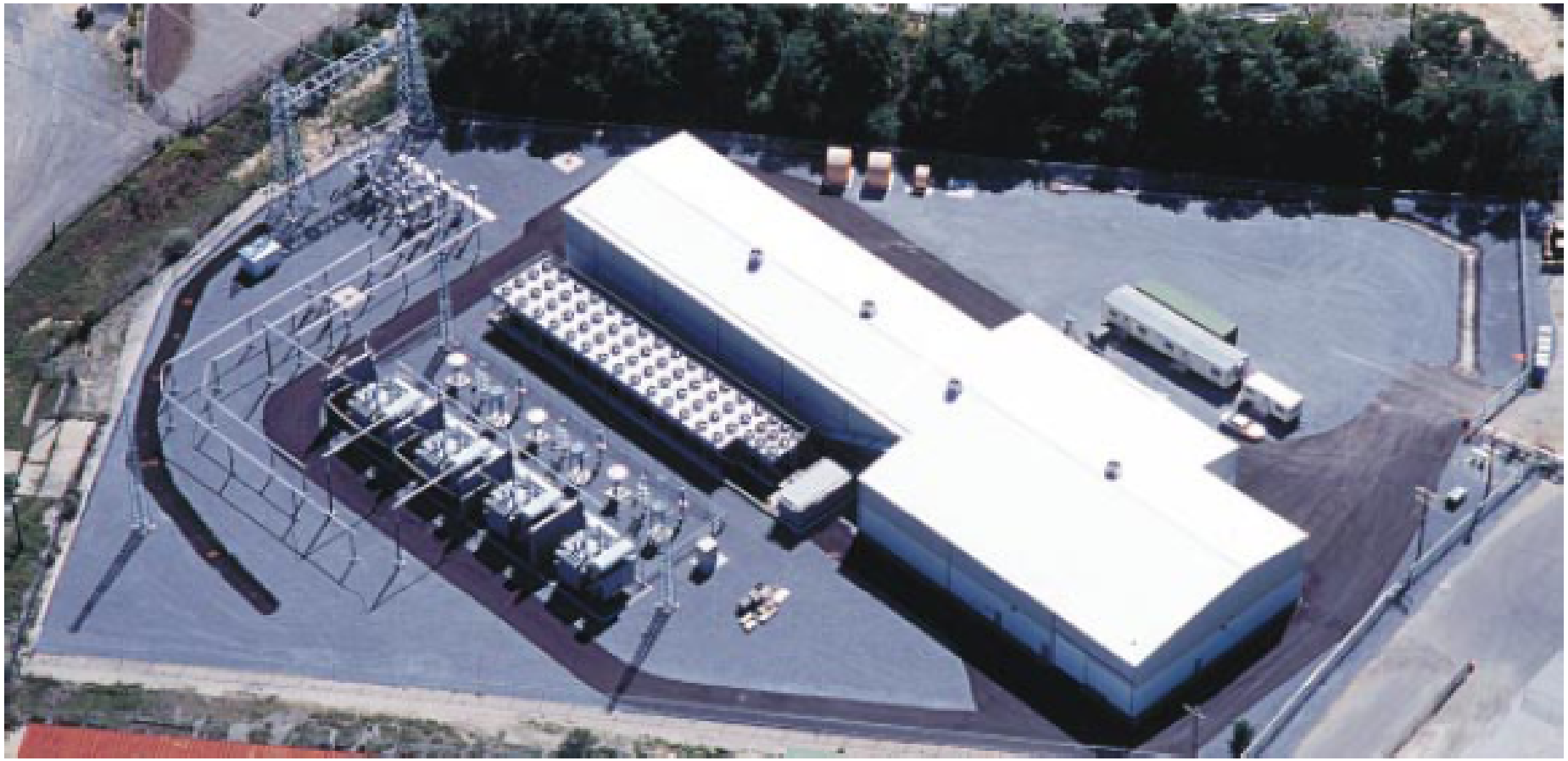


Suspended Thyristor Based Quadruple Valves making a 12-Pulse Converter rated 500kV (Pacific DC Intertie) (Siemens)

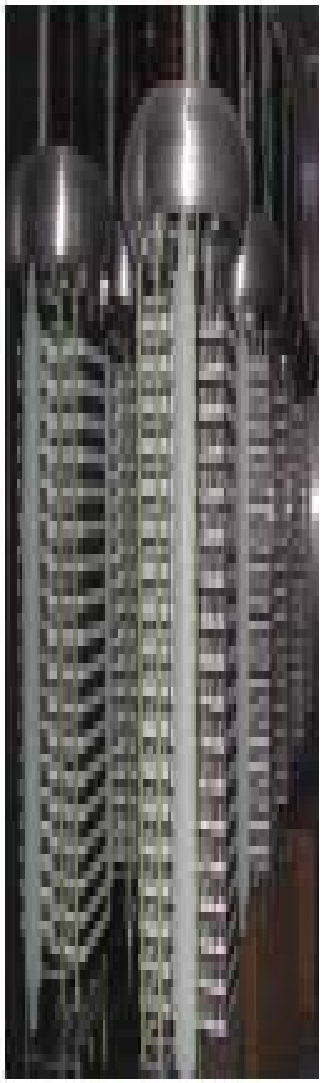


Building block for HVDC application including up-to thirty series Thyristor levels (Siemens).

Cross Sound Cable Interconnector
Connecticut and Long Island, USA



Converter Station at Shoreham. 330MW. + -150kV.
80m x 25m x 11m (ABB)



ABB

Constraints on Useable Transmission Capacity – FACTS

System Dynamics:

Transient and Dynamic Stability
Subsynchronous Oscillations
Dynamic Overvoltages and Undervoltages
Voltage Collapse
Frequency Collapse

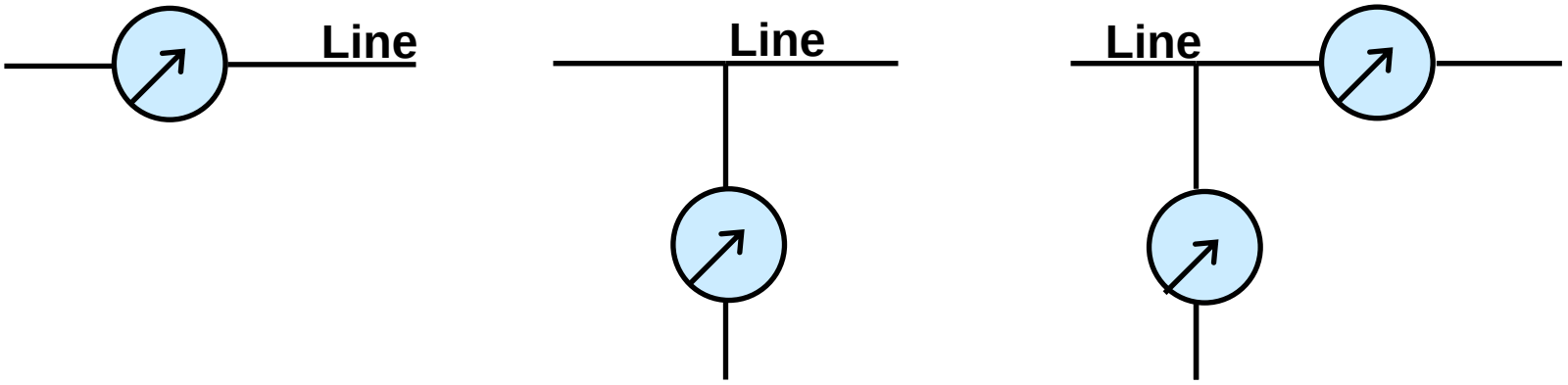
System Steady State:

Uneven Power Flow
Excess Reactive Power Flows

Natural Limits

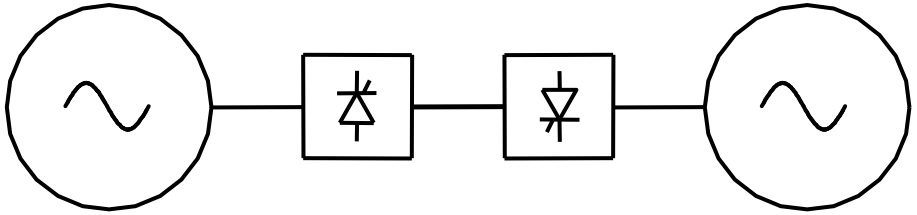
Insulation Voltage Capability
Conductor Thermal Capability

FACTS and Custom Power Concepts



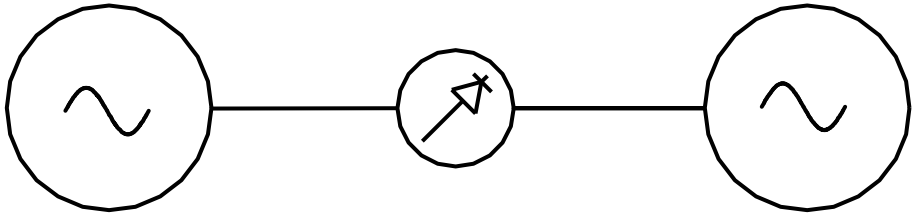
- **May be active static switch or impedance converter or a combination thereof.**
- **When in shunt, cause current injection into the line, and when in series, causes voltage injection in series with the line.**

HVDC and FACTS: Complementary Solutions



HVDC:

- **Power control, voltage control, stability control**
- **Independent frequency and control**

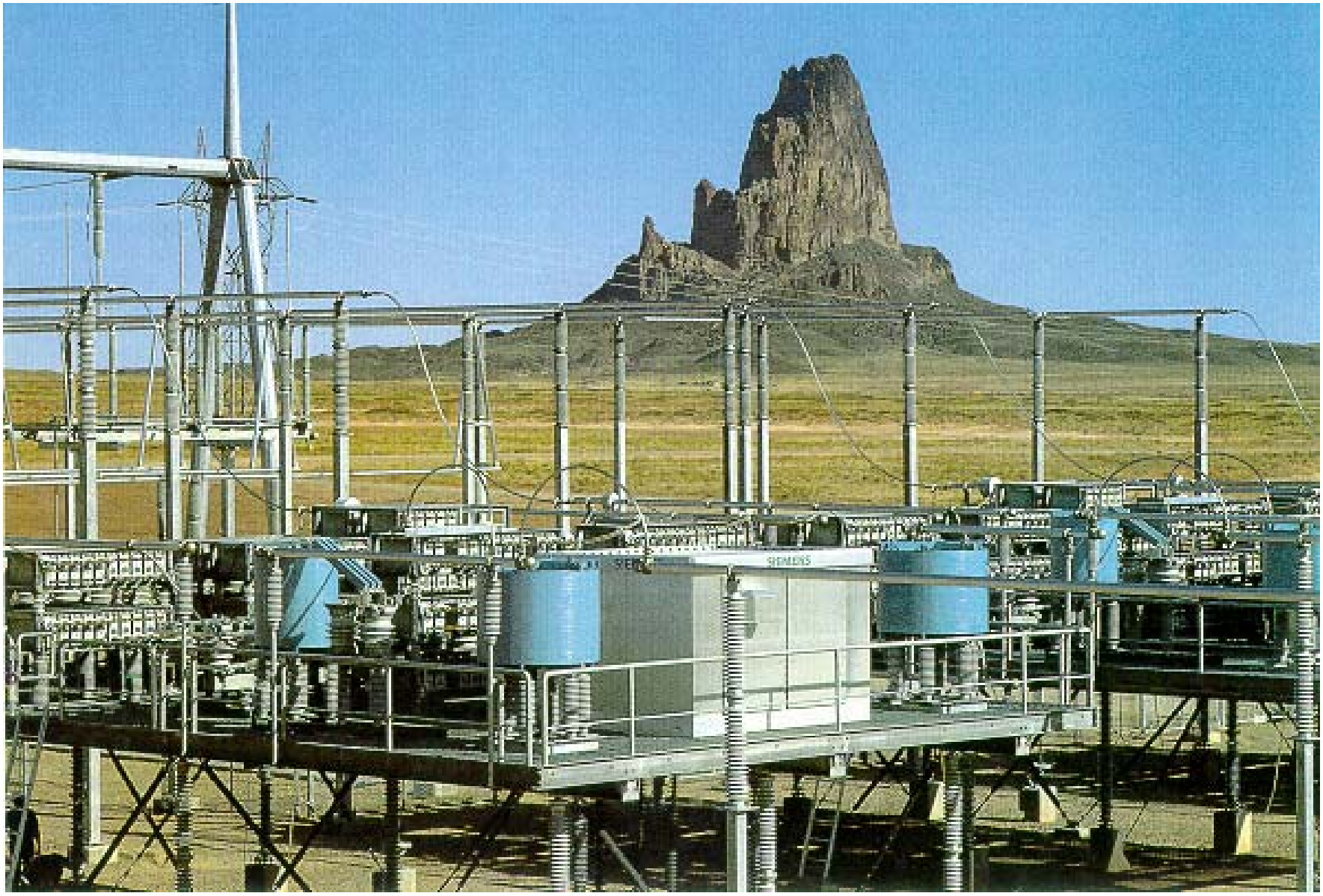


FACTS:

- **Power control, voltage control, stability control**

Installed Costs (million of dollars)

Throughput MW	HVDC 2 Terminals	FACTS
200 MW	$M 40-50	$M 5-10
500 MW	75-100	10-20
1000 MW	120-170	20-30
2000 MW	200-300	30-50



Kayenta TCSC

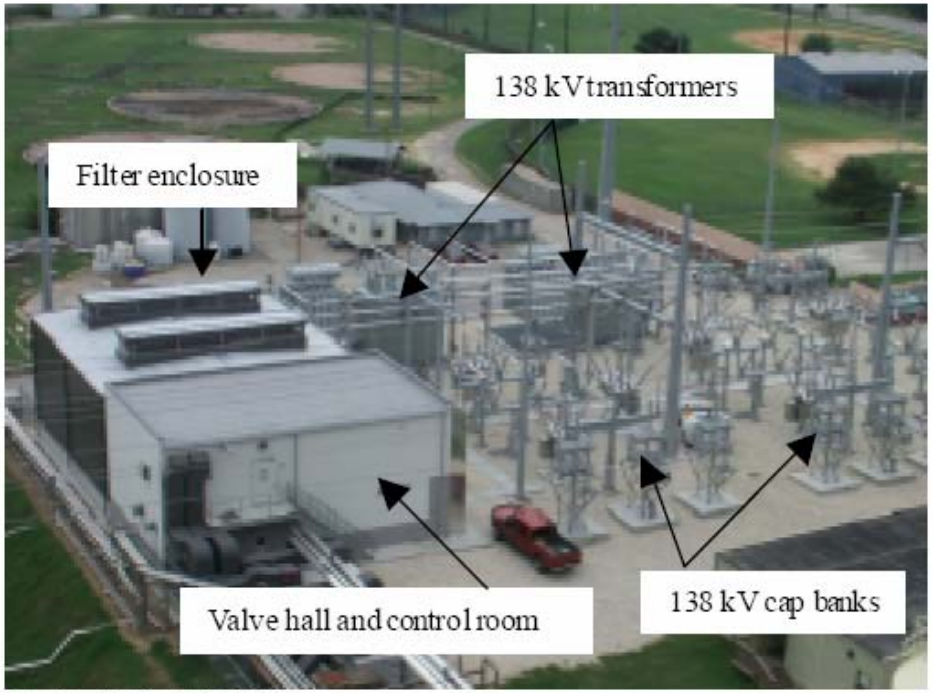


Fig. 3. Holly STATCOM

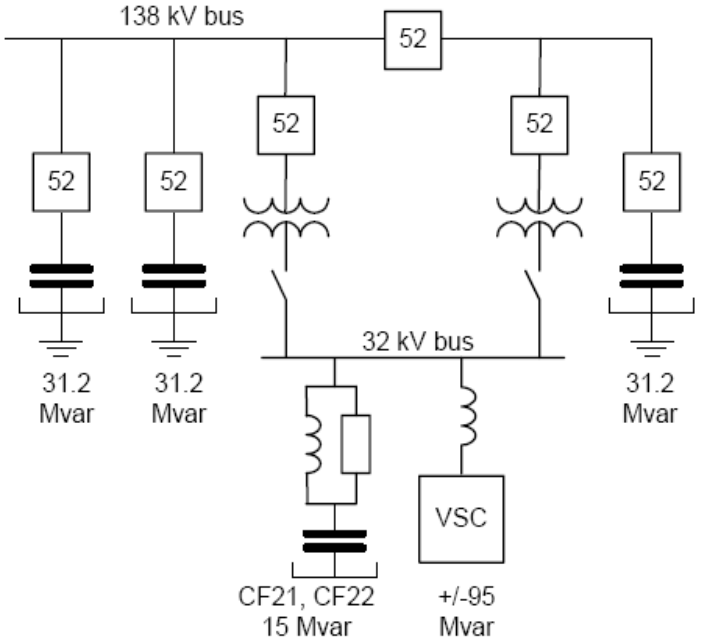


Fig. 1. Holly STATCOM single line diagram.

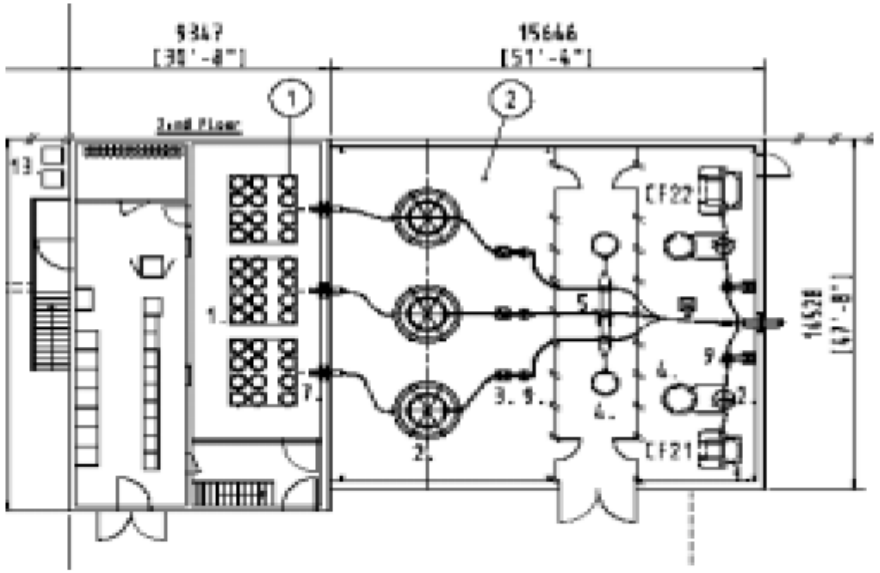
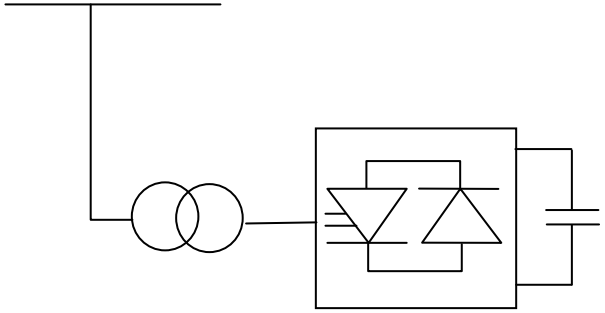
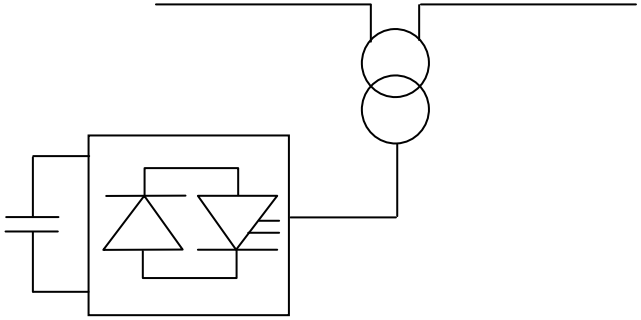


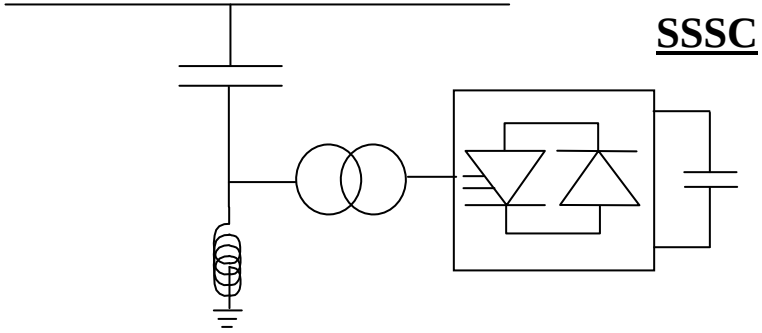
Fig. 2. Holly STATCOM layout
1) Valve hall
2) Enclosed 32 kV equipment



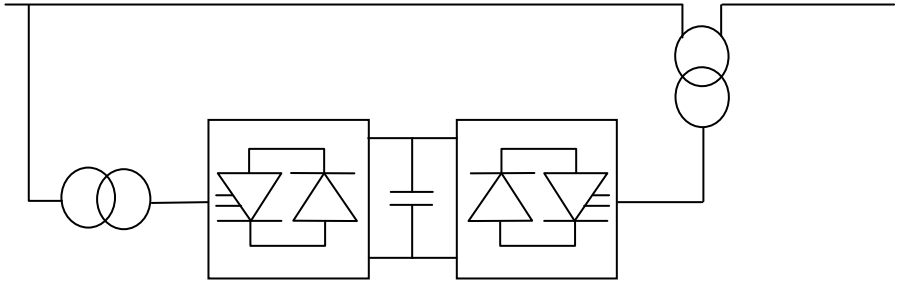
STATCOM



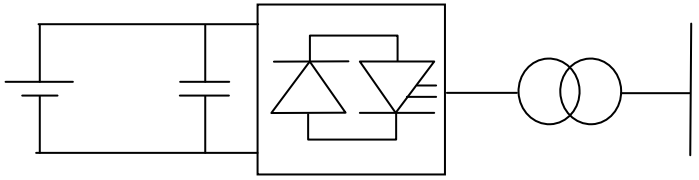
SSSC



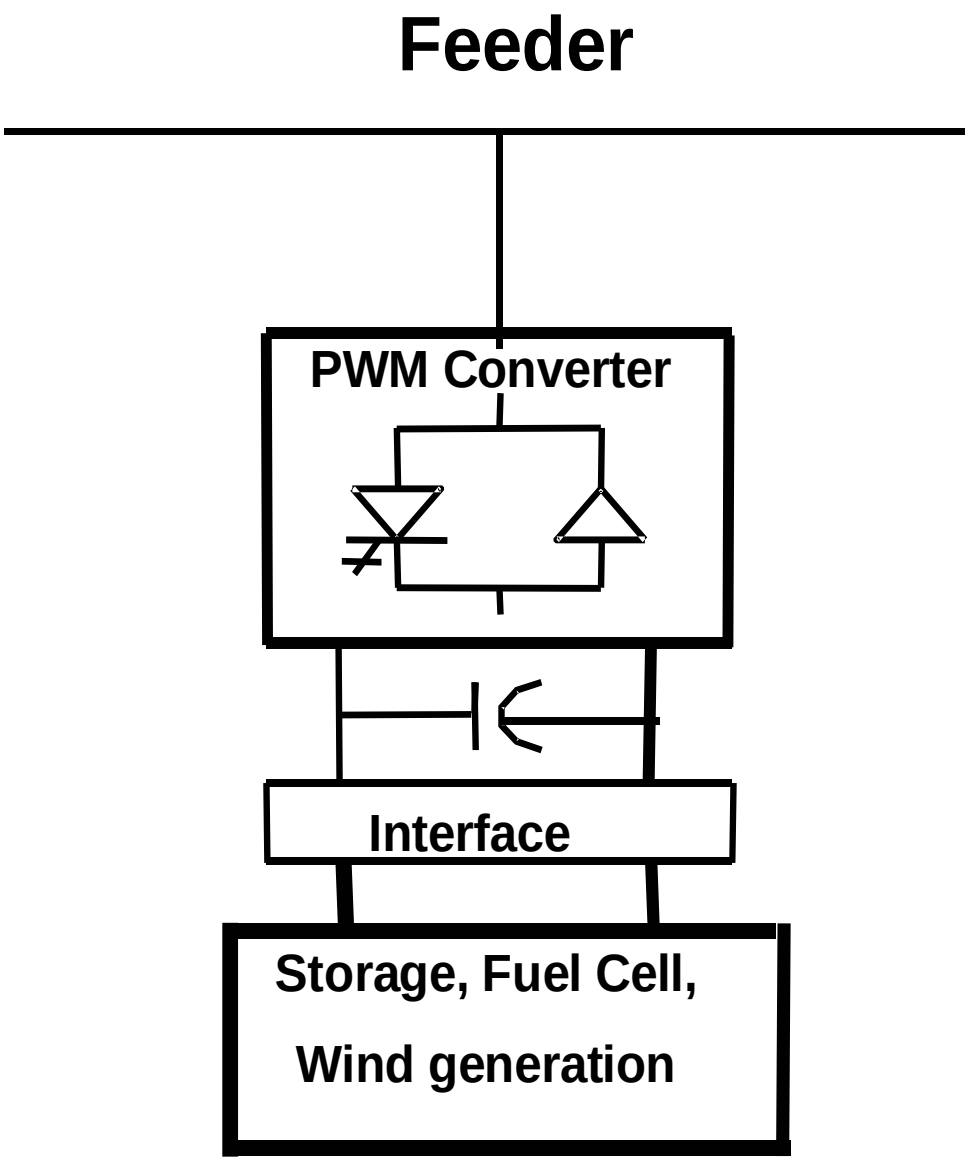
Active filter



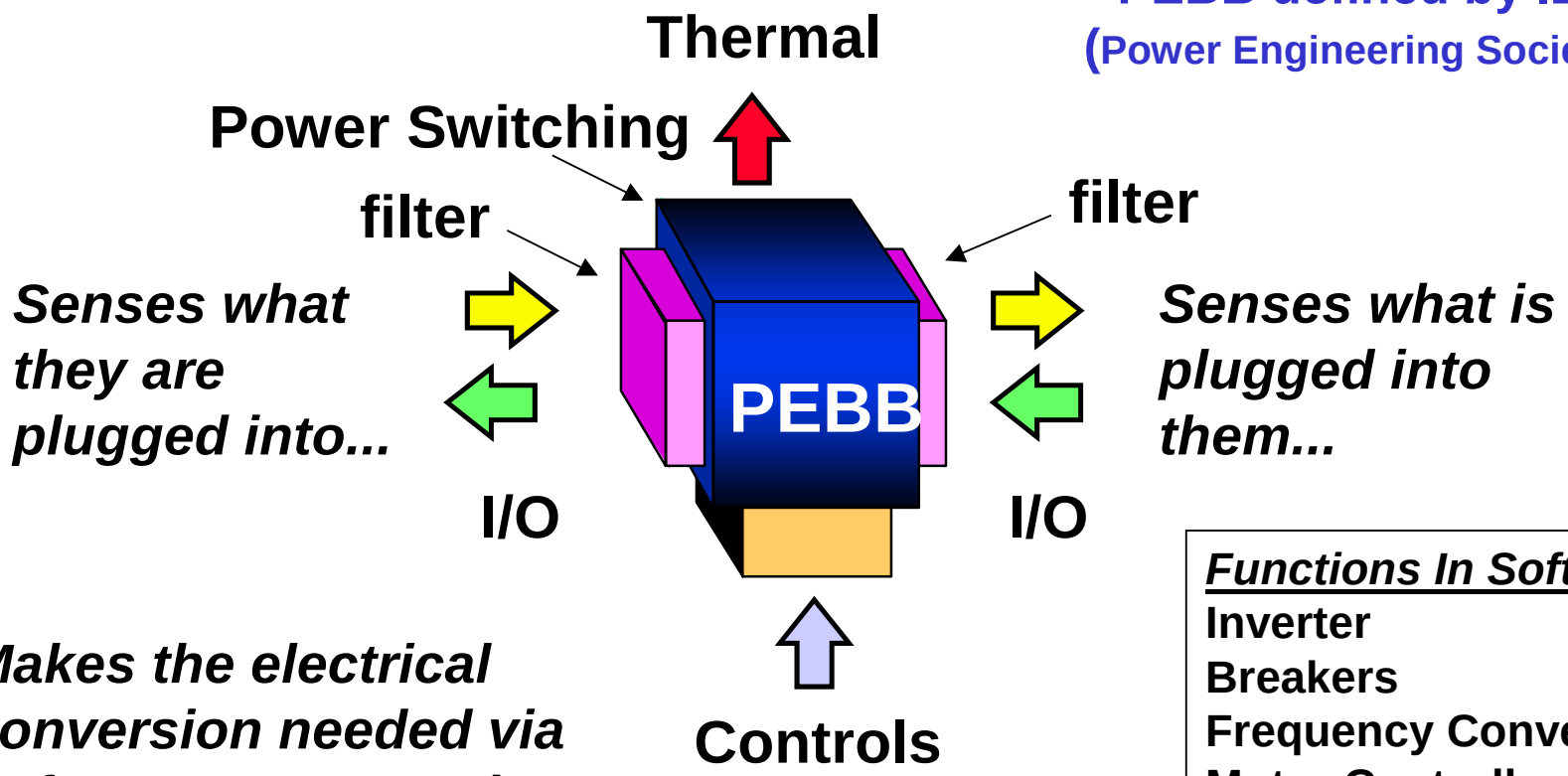
UPFC



Energy Storage


Feeder
PWM Converter
Interface
Storage, Fuel Cell,
Wind generation

* PEBB defined by IEEE
(Power Engineering Society)



Makes the electrical conversion needed via software programming

Functions In Software
Inverter
Breakers
Frequency Converter
Motor Controller
Power Supply
Actuator Controller

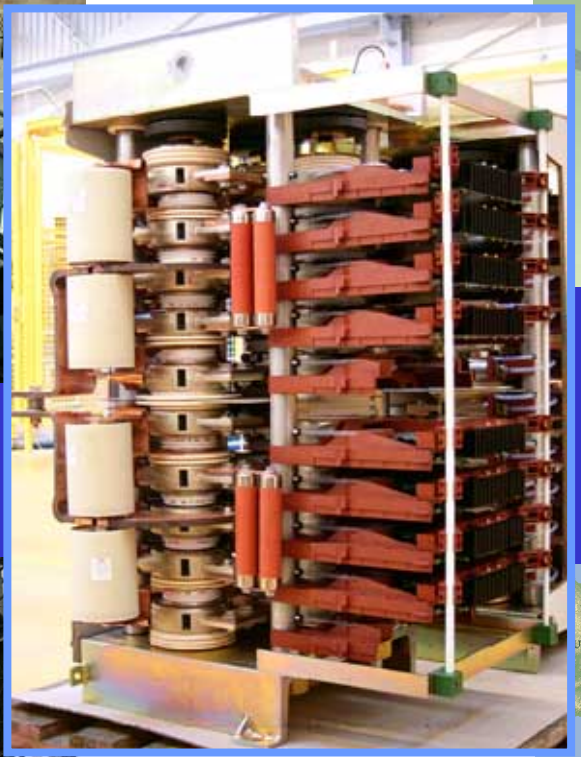
Like a child's set of blocks

Power Electronic Building Blocks PEBB

MV IGCT PEBB based Power Conditioning Systems

Chip Manufacturing Plant,
DVRs (Dynamic Voltage Restorer)
installed: 2 units, 22 MVA each

9MVA
IGCT PEBB



Regenerative Fuel Cell (RFC),
Power Quality for Columbus AFB
Mississippi Delivery 2002, 15MVA

Frequency Changers (FC)
DB Energie (Germany),11 units
installed to date, 18 MVA each

with a leading power density in MV applications

BESS - Golden Valley Electric,
World's Largest Battery Energy
Storage System (BESS) installed at
GVEA, Fairbanks, Alaska,
40MW / 60MVA

Future Power Electronics Needs

Significant Reduction in:

- **Cost**
- **Losses**
- **Size**
- **Weight**

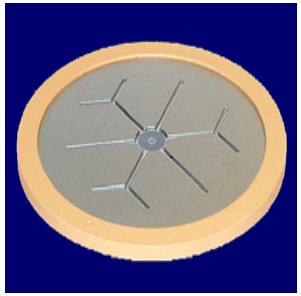
Significant Improvement in Switching Frequency

A Perfect Power Semiconductor Switch

- **Turn on and off instantaneously on command**
- **Zero switching losses**
- **Zero conduction losses**
- **Zero gate power requirements (accept digital signal for turn-on turn-off)**

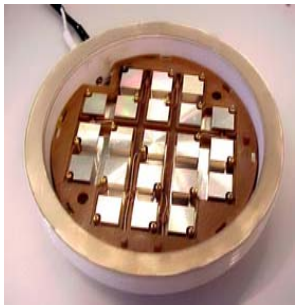
Need High-Voltage High-Power Building Blocks

- **Packaged Building Blocks with Functional Specifications**
- **Programmable to serve multiple applications**
- **Can be connected in series and parallel to achieve higher ratings**

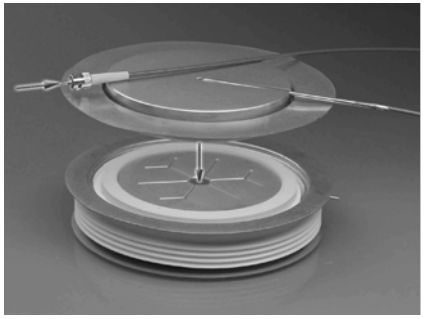


Conventional Thyristor

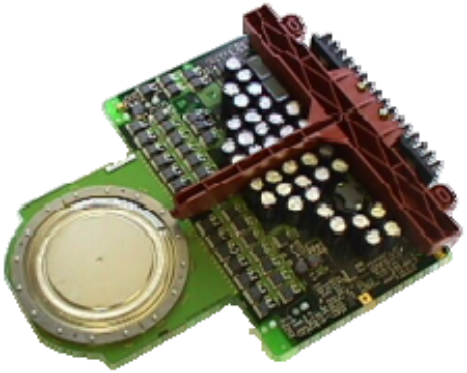
GTO



IGBT High Power Device



Direct Light Triggered Thyristor



Integrated Gate Commutated Thyristor

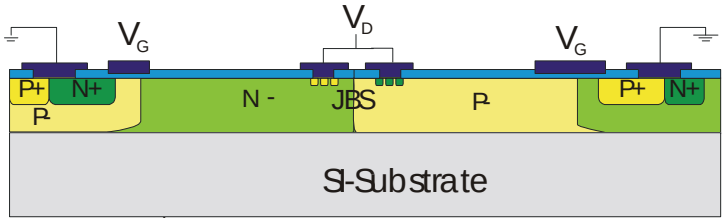
IGBT High Power Device

Press-Pack High Power Devices

Advanced Power Devices

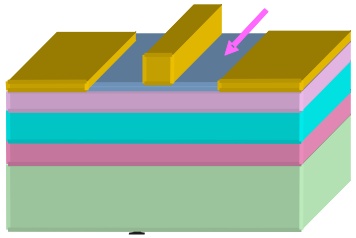
Reduce Losses and Raise Switching Frequency

- **Advanced Silicon Devices**



Low Losses; Fast Switching; Low Thermal Resistance; Bidirectional; Integration of Passives

- **Wide Band Gap Devices**

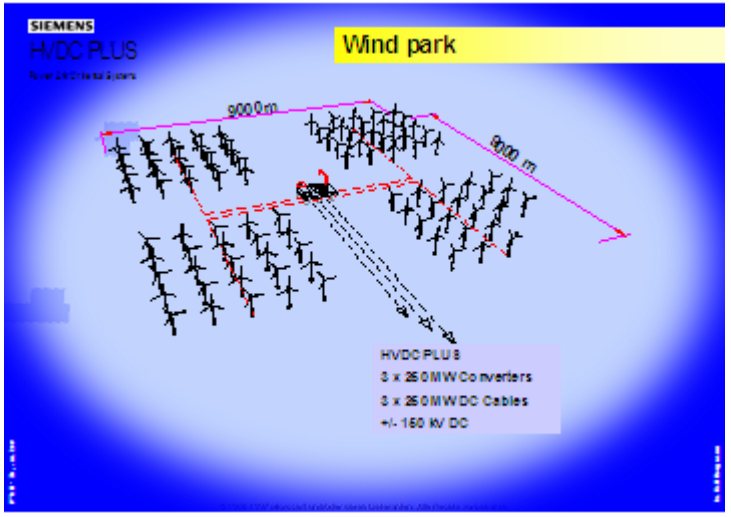


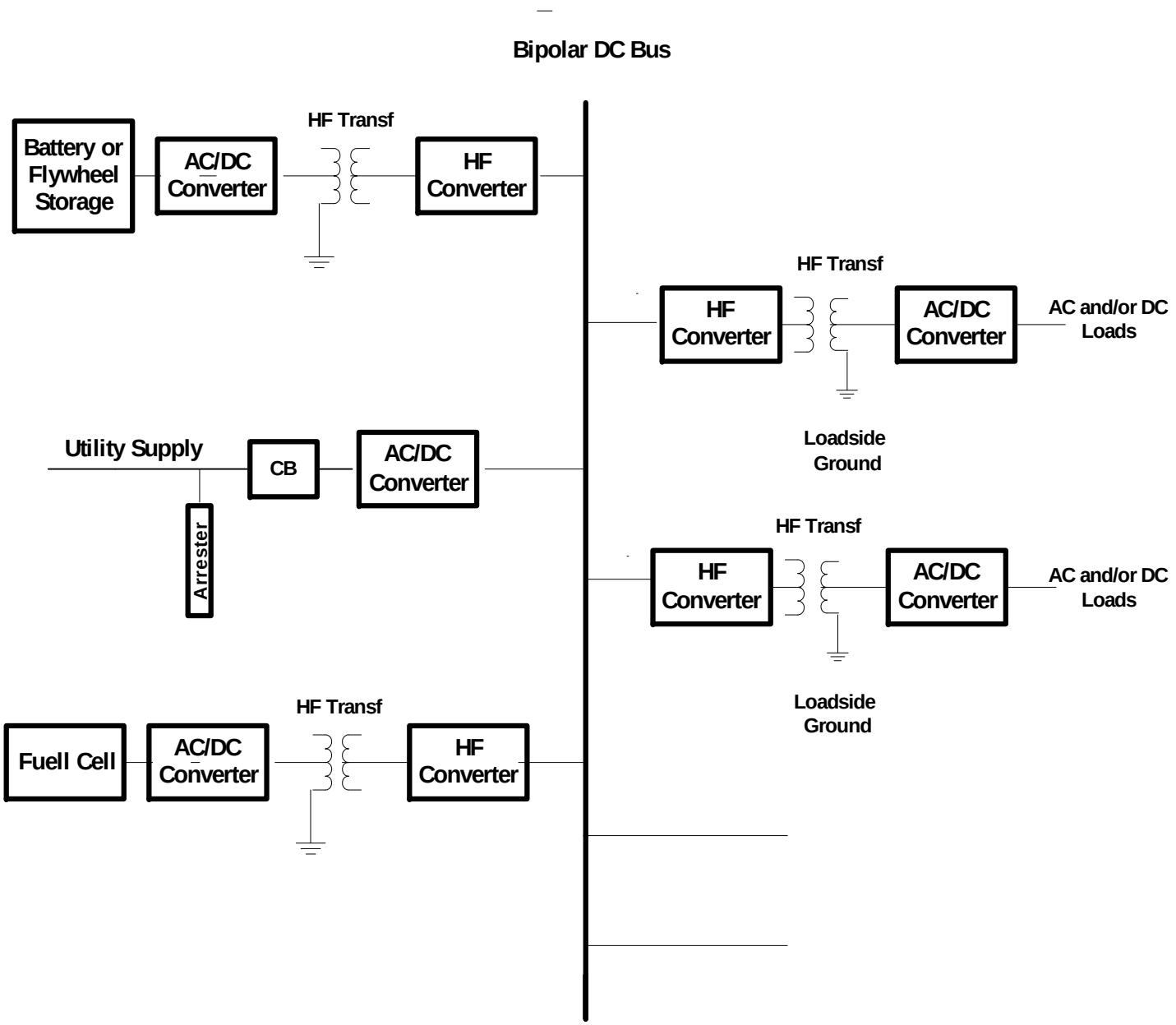
SiC

Silicon Carbide

HVDC Transmission for Integration of Wind Generation Farms in Transmission Grid

- **Obtaining Transmission ROW takes much longer than Building Wind Farms**
- **Underground DC Transmission with Voltage Sourced Converters could have**
  - **Lower Cost**
  - **Improved System Integration**
  - **Much smaller Permit and Construction time**





Proposed Conceptual Sub-transmission or Distribution System

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