HVDC Underground Cables

The Empire Connection

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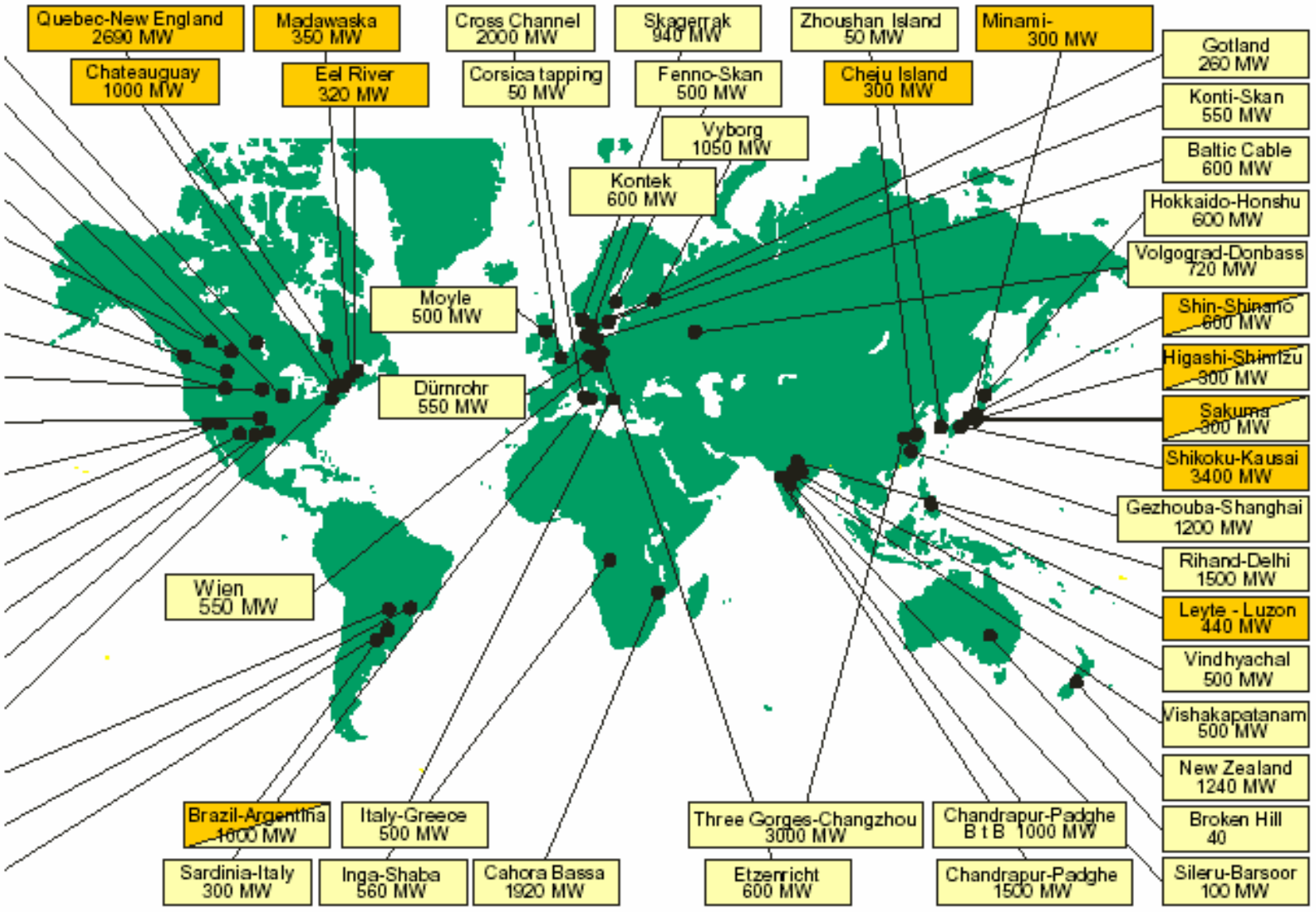
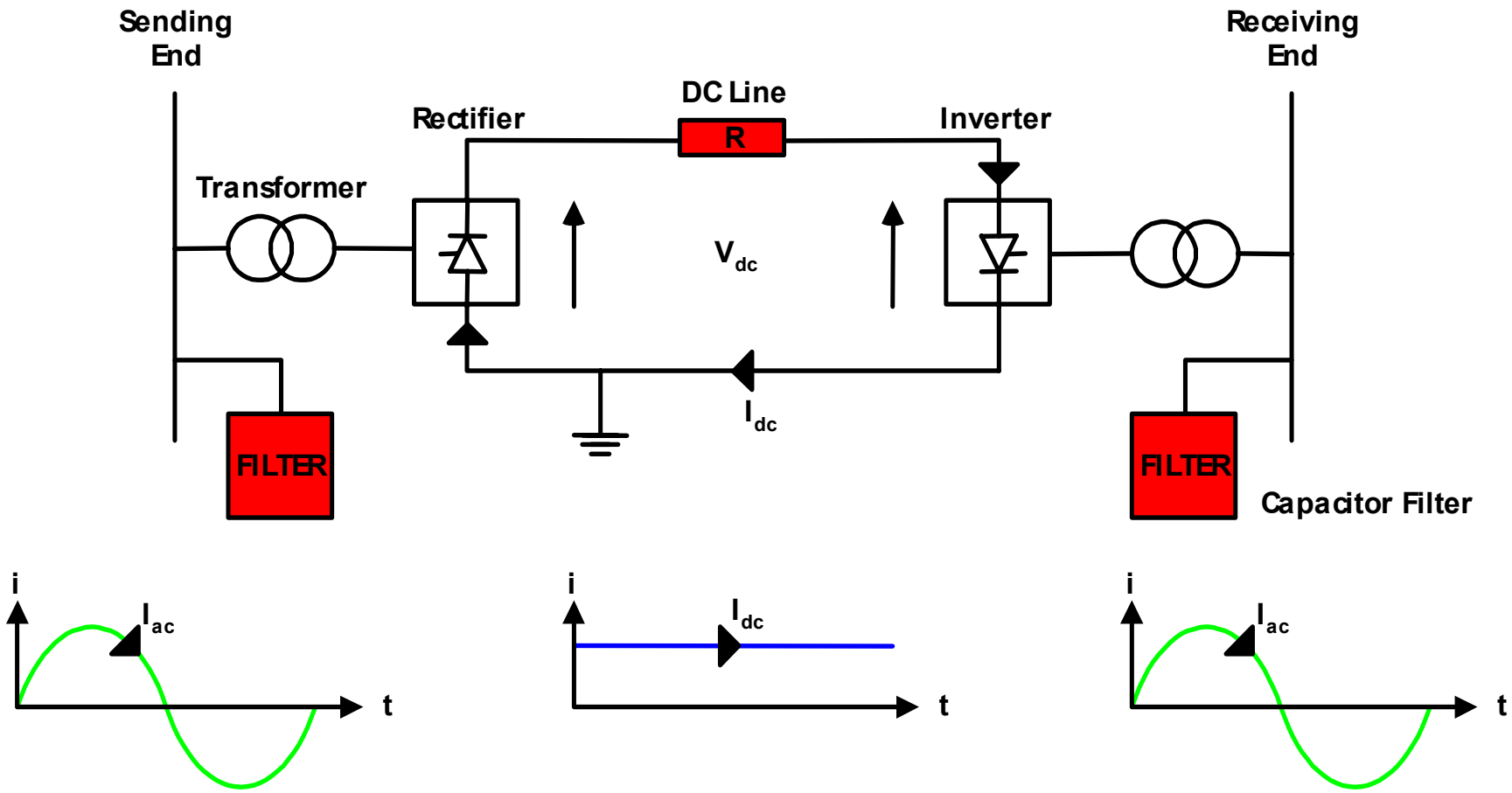
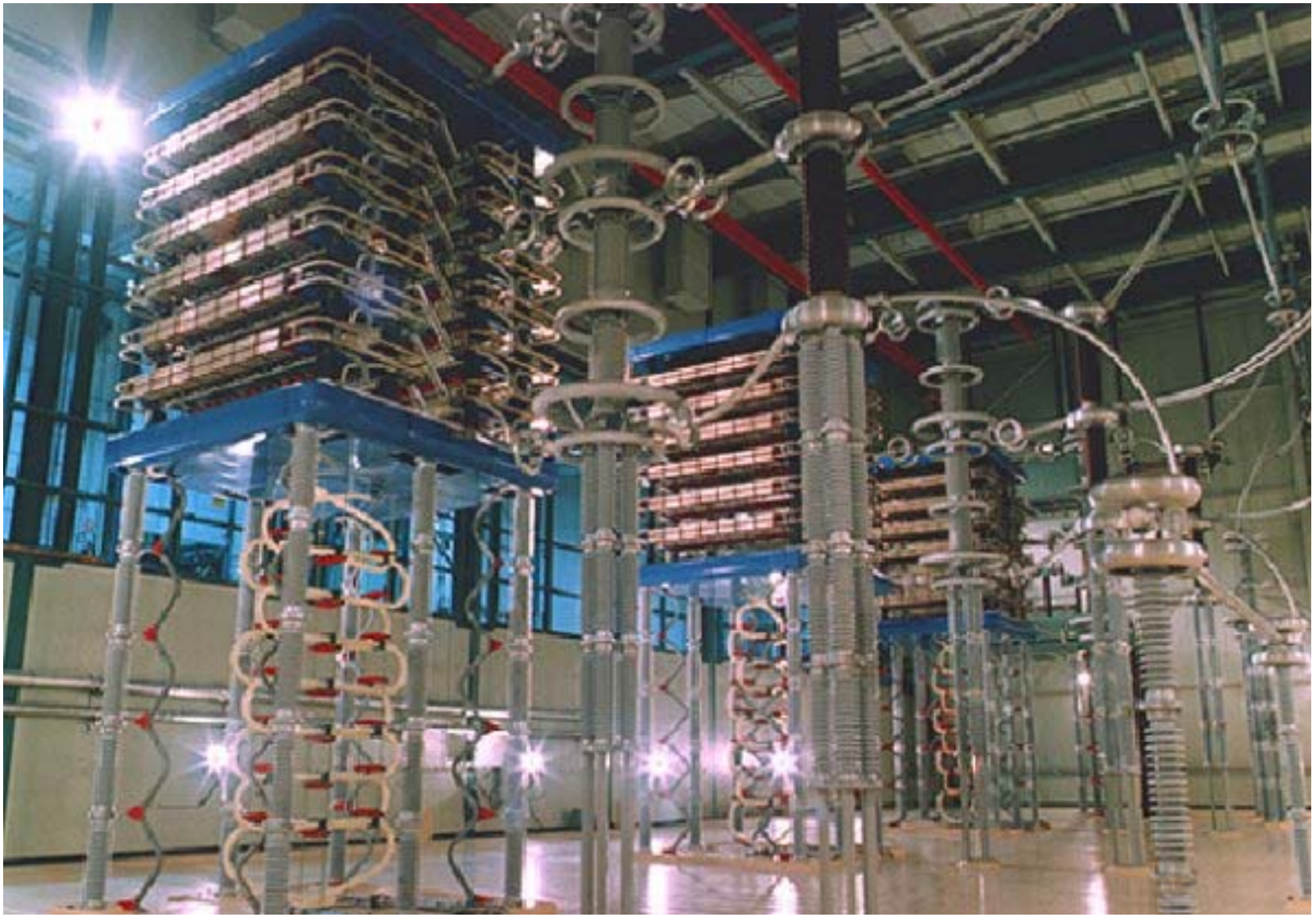
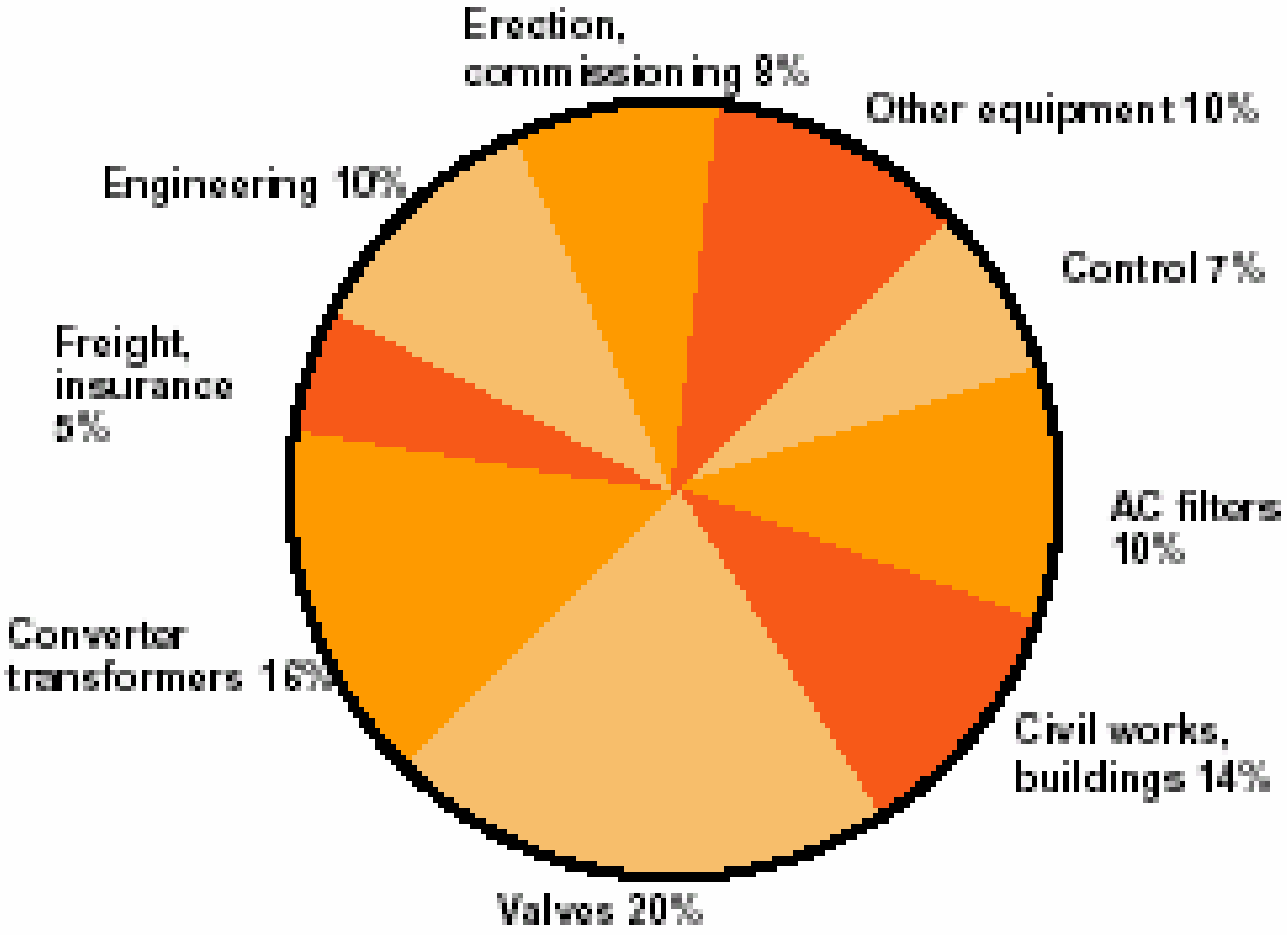
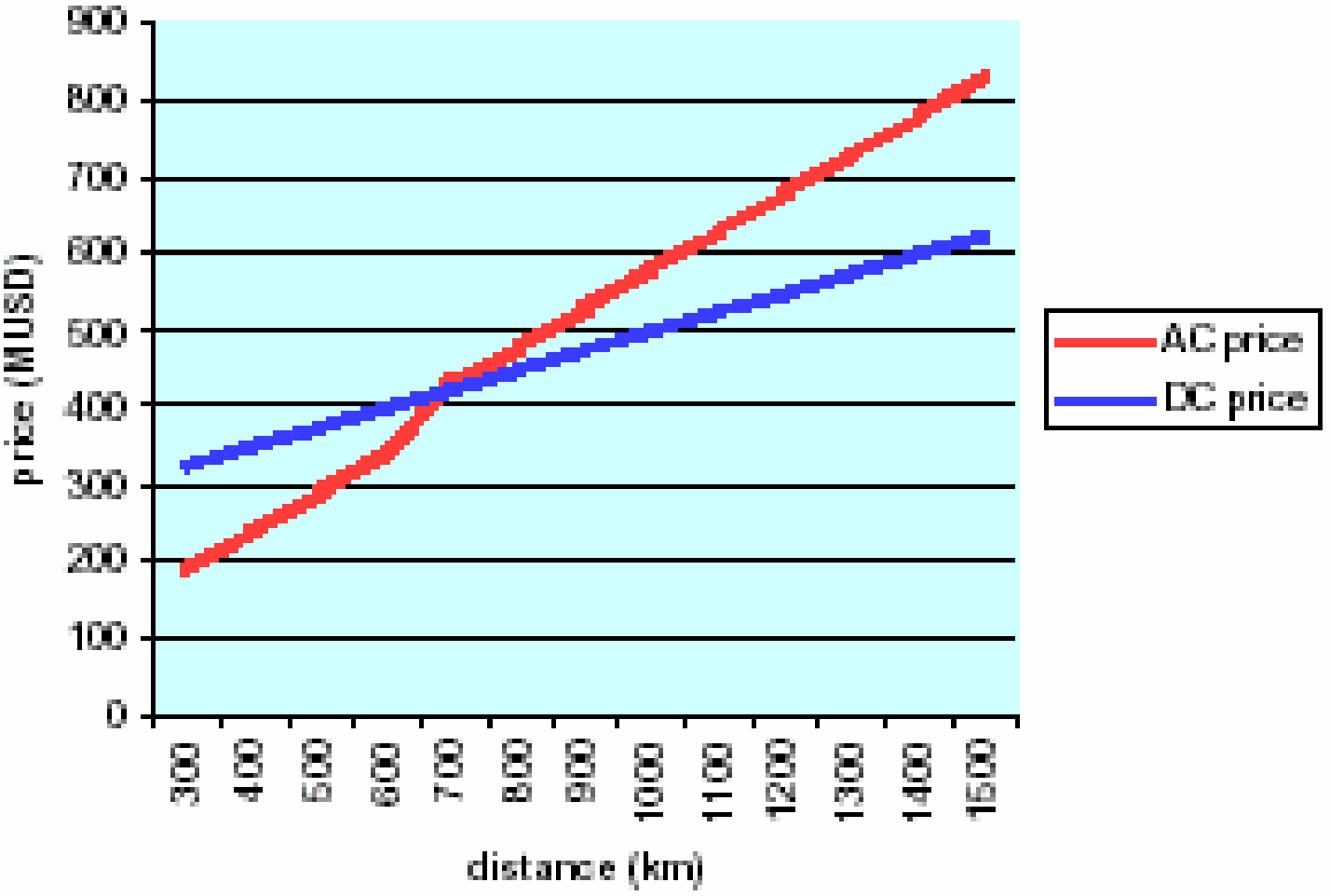

Quebec-New England
2690 MW
Madawaska
350 MW
Cross Channel
2000 MW
Skagerrak
940 MW
Zhoushan Island
50 MW
Minami-
300 MW
Chateauguay
1000 MW
Eel River
320 MW
Corsica tapping
50 MW
Fenno-Skan
500 MW
Cheju Island
300 MW
Gotland
260 MW
Konti-Skan
550 MW
Vyborg
1050 MW
Baltic Cable
600 MW
Kontek
600 MW
Hokkaido-Honshu
600 MW
Volgograd-Donbass
720 MW
Moyle
500 MW
Shin-Shinano
600 MW
Higashi-Shimizu
300 MW
Dürnrohr
550 MW
Sakuma
300 MW
Shikoku-Kausai
3400 MW
Gezhouba-Shanghai
1200 MW
Wien
550 MW
Rihand-Delhi
1500 MW
Leyte - Luzon
440 MW
Vindhyachal
500 MW
Vishakapatanam
500 MW
New Zealand
1240 MW
Brazil-Argentina
1000 MW
Italy-Greece
500 MW
Three Gorges-Changzhou
3000 MW
Chandrapur-Padghe
B t B 1000 MW
Broken Hill
40
Sardinia-Italy
300 MW
Inga-Shaba
560 MW
Cahora Bassa
1920 MW
Etzenricht
600 MW
Chandrapur-Padghe
1500 MW
Sileru-Barsoor
100 MW


Sending End
Receiving End
DC Line
R
Rectifier
Inverter
Transformer
V_{dc}
I_{dc}
FILTER
FILTER
Capacitor Filter
i
I_{ac}
t
i
I_{dc}
t
i
I_{ac}
t




Erection, commissioning 8%
Other equipment 10%
Engineering 10%
Control 7%
Freight, insurance 5%
AC filters 10%
Converter transformers 16%
Civil works, buildings 14%
Valves 20%


price (MUSD)
900
800
700
600
500
400
300
200
100
0
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
distance (km)
AC price
DC price

Box 1: Important Milestones in the Development of HVDC technology

- Hewitt's mercury-vapour rectifier, which appeared in 1901.
- Experiments with thyratrons in America and mercury arc valves in Europe before 1940.
- First commercial HVDC transmission, Gotland I in Sweden in 1954.
- First solid state semiconductor valves in 1970.
- First microcomputer based control equipment for HVDC in 1979.
- Highest DC transmission voltage (+/- 600 kV) in Itaipú, Brazil, 1984.
- First active DC filters for outstanding filtering performance in 1994.
- First Capacitor Commutated Converter (CCC) in Argentina-Brazil interconnection, 1998
- First Voltage Source Converter for transmission in Gotland, Sweden ,1999

- In Itaipu, Brazil, HVDC was chosen to supply 50Hz power into a 60 Hz system; and to economically transmit large amount of hydro power (6300 MW) over large distances (800 km)
- In Leyte-Luzon Project in Philippines, HVDC was chosen to enable supply of bulk geothermal power across an island interconnection, and to improve stability to the Manila AC network
- In Rihand-Delhi Project in India, HVDC was chosen to transmit bulk (thermal) power (1500 MW) to Delhi, to ensure: minimum losses, least amount right-of-way, and better stability and control.
- In Garabi, an independent transmission project (ITP) transferring power from Argentina to Brazil, HVDC back-to-back system was chosen to ensure supply of 50 Hz bulk (1000MW) power to a 60 Hz system under a 20-year power supply contract.
- In Gotland, Sweden, HVDC was chosen to connect a newly developed wind power site to the main city of Visby, in consideration of the environmental sensitivity of the project area (an archaeological and tourist area) and improve power quality.
- In Queensland, Australia, HVDC was chosen in an ITP to interconnect two independent grids (of New South Wales and Queensland) to: enable electricity trading between the two systems (including change of direction of power flow); ensure very low environmental impact and reduce construction time.

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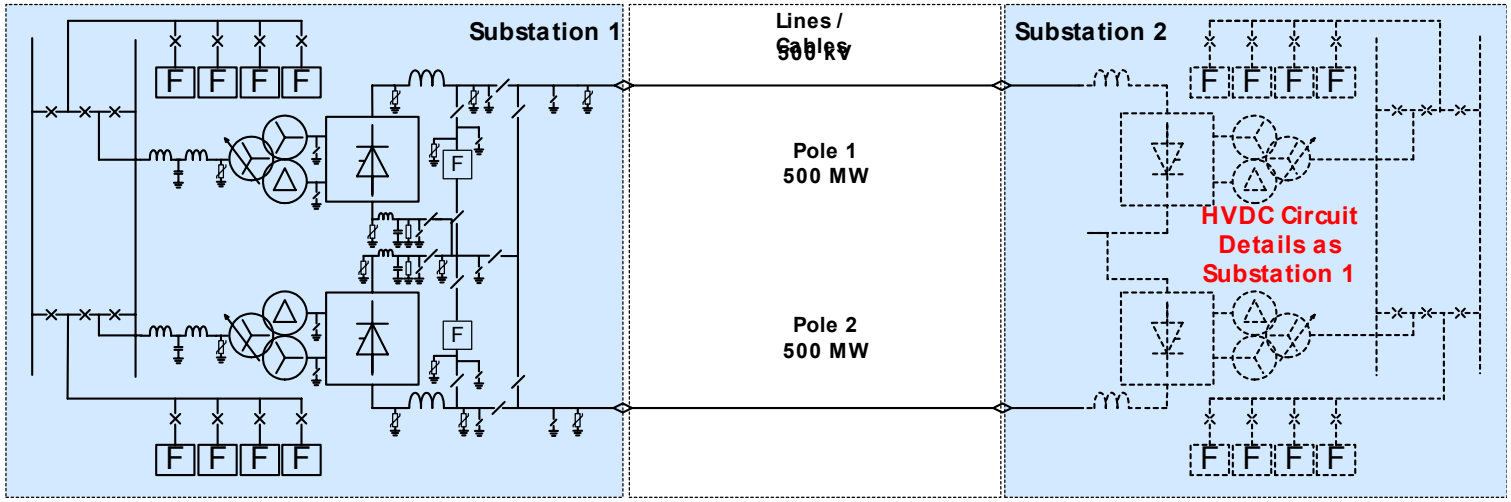
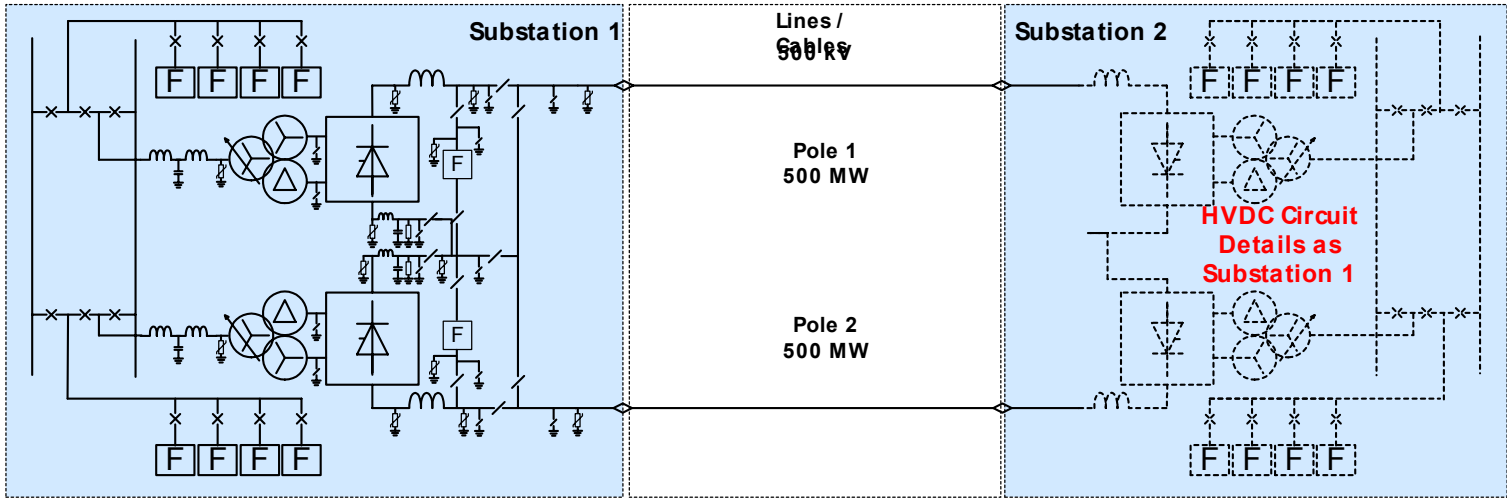
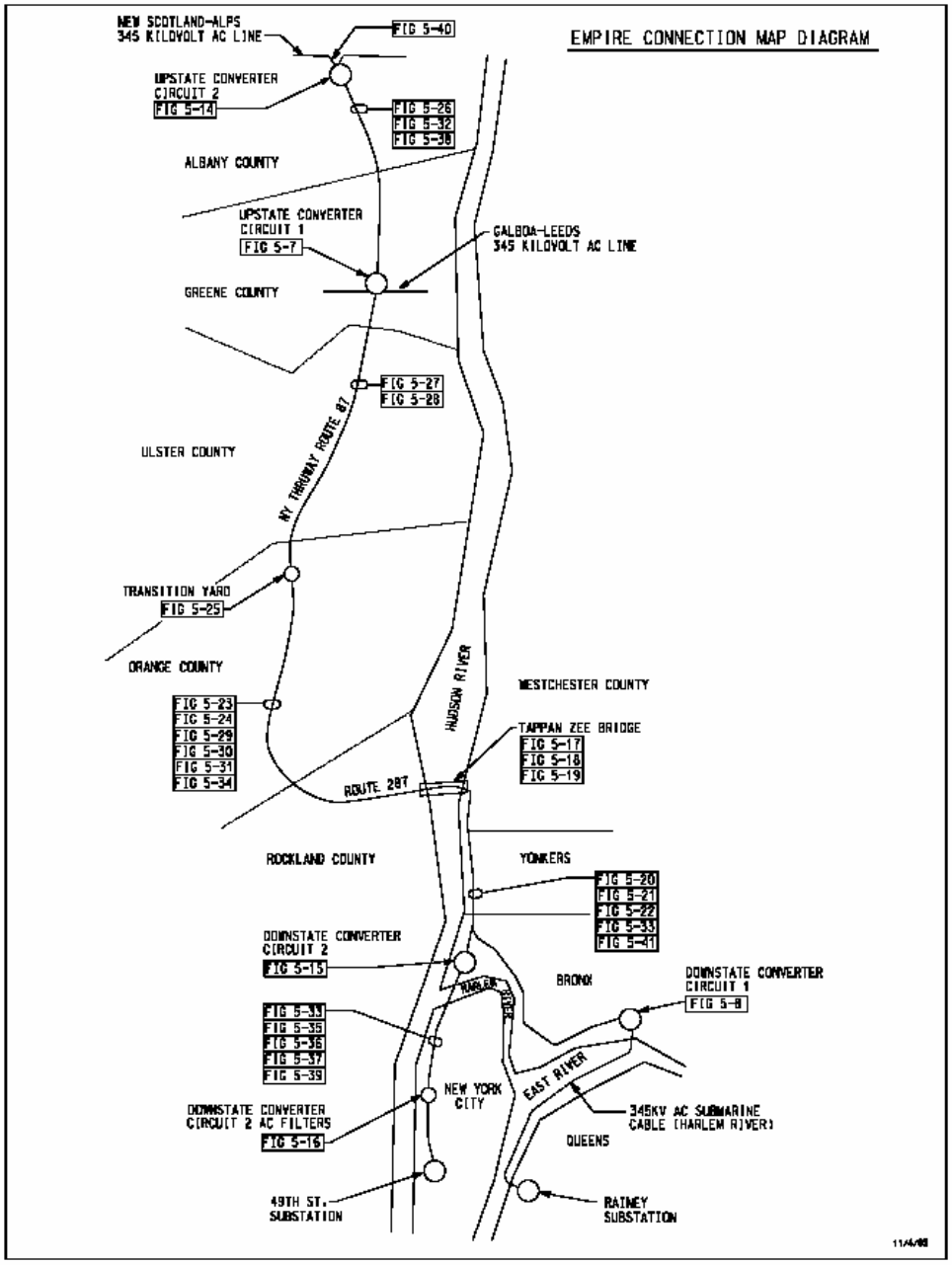
Total Capacity
2000 MW DC

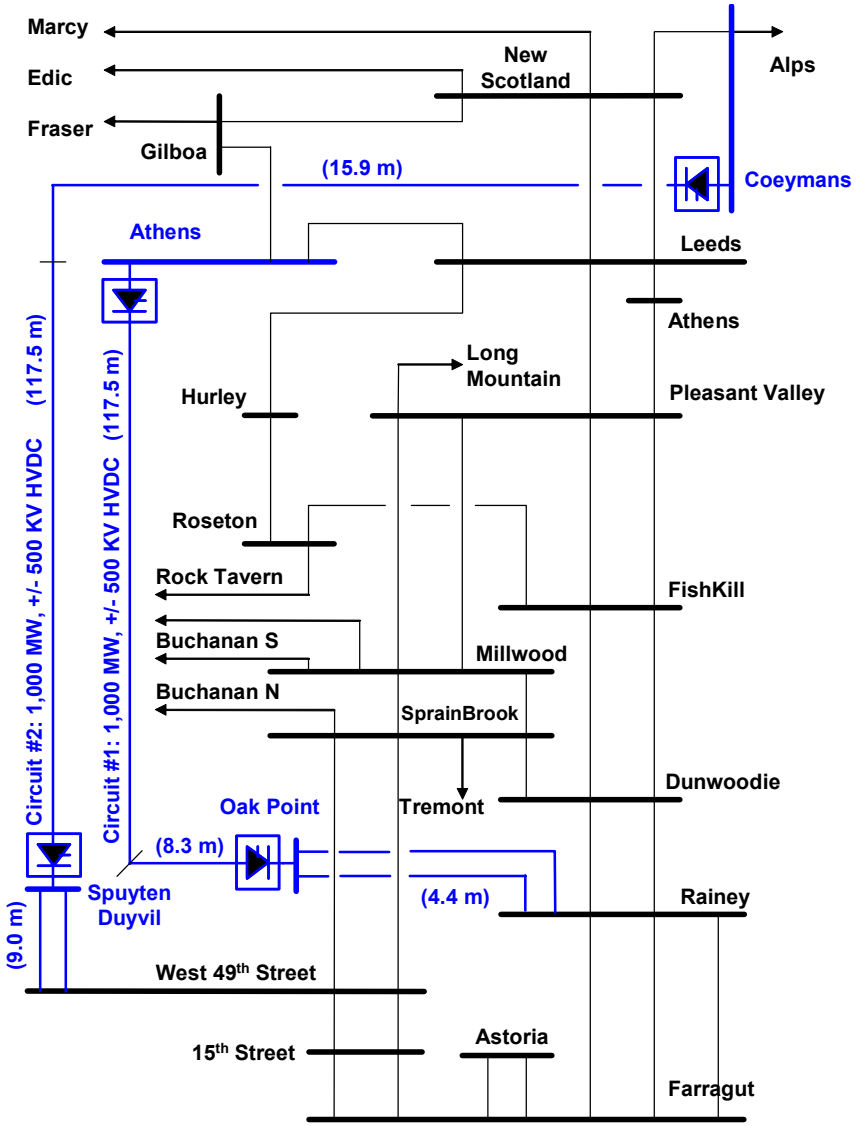
Bipole 1 - 1000 MW



Bipole 2 - 1000 MW







Empire Connection
& UPNY/SENY 345 KV Transmission Grid

November 5, 2003

Benefits

- Decreases pollution from power plants in and near New York City.
- Lessens the demand for new power plants in and near New York City.
- Helps budget-stretched Metropolitan Transportation Authority, New York State Thruway Authority and Amtrak by paying significant annual fees.
- Creates large number of union jobs during installation.
- Pays substantial taxes.
- Encourages the development of clean and renewable power upstate.
- Sets a precedent for underground invisible transmission.

Cost

- $ 750 M ($ 400 M “banked”)
- To Be Commissioned by Summer 2006

Return

- Loan Payment (4%, 40 yrs, 750 M$) = 35 M$/yr
- Labor, Overhead, Maintenance = 5 M$/yr
- Tariff = 0.5 ¢/kWh
- Capacity = 2000 MW
- Profit @ 50% Capacity = 4 M$/yr
- Profit @ Full Capacity = 48 M$/yr