BASIC PRINCIPLES OF INTERSTATE ELECTRICAL POWER LINKS ORGANIZATION IN NORTHEAST ASIA REGION.

Lev A. Koshcheev

1. The main reasons for the interstate electrical power transmission lines creation in NEA region.
2. Russia interests in interstate electrical ties organization.
3. The peculiarities of electrical links in NEA region.
4. Grounds of giving preference for HVDC transmission systems.
5. Electrical ties in NEA examples.
6. The main technical and economical characteristics of HVDC transmission systems.
7. Conclusion.

1. THE MAIN REASONS FOR THE INTERSTATE ELECTRICAL POWER TRANSMISSION LINES CREATION IN NEA REGION.

- Electrical power purveyance from countries, which have surpluses of energy supplies, to countries having electrical power shortage.

- Economical effect from combining of essentially different daily and annual load diagrams in various countries.

- Mutual assistance in emergencies and generation reserves decreasing possibility.

- Ecologically harmful ejections decreasing due to the involving into region's energy balance hydro power plants (HPP) and tidal power plants (TiPP).

2. RUSSIA INTERESTS IN INTERSTATE ELECTRICAL TIES ORGANIZATION.

- Large untapped possibilities for HPP erection on East Siberia rivers
- Presence of convenient power sites for high-capacity tidal power plants erection.
- Major fields of power station coals, gas and mineral oil.
- Concernment of Russia in electric power exporting.
- Concernment of Russia in foreign investment for power installations erection.

3. THE PECULIARITIES OF ELECTRICAL LINKS IN NEA REGION.

- Large distances (this is, first of all, concerned with the links between Russia power system and power systems of other countries).
- The water barriers presence (Japan, Alaska).
- Technical problems of large power systems integration with small transfer capacity AC power links.
- Differences in the frequency standards (Alaska, Southern part of Japan).
- Various power and frequency regulating conditions in different countries power systems, and also differences in control organization, language barriers etc.

4. GROUNDS OF GIVING PREFERENCE FOR HVDC TRANSMISSION SYSTEMS.

- Length of interstate transmission lines in NEA as usual exceeds the "critical length" (600 –1000 km).

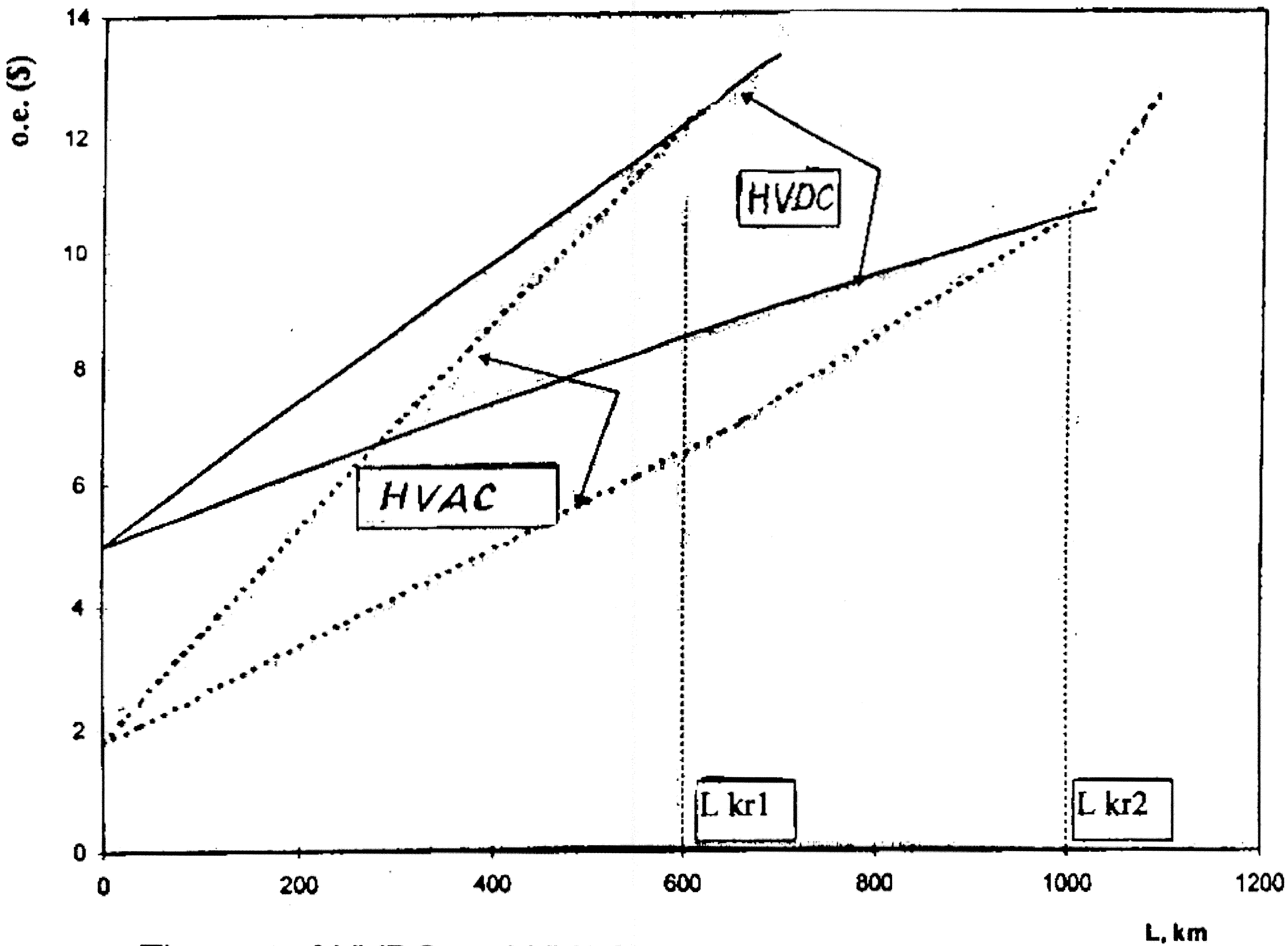
- Cable lines, used for laying underwater, preferably are to be constructed using direct current at line length exceeding 40 – 80 km.

- HVDC power tie can be arbitrarily low transfer capacity, and HVAC have to be not lower then specified value.

- Using HVDC transmission systems the hardships concerned with operational control, which exists at different countries power systems synchronous integration, are eliminated.

- Using HVDC transmission systems the emergency processes' spreading on other's countries power systems is excepted.

- Distant HPPs and TiPPs can operate with variable rotation speed through HVDC transmission system, which lets to obtain the economical effect during HPPs storage reservoir fill up and at drastic variable pressure on TiPPs.



Thecost of HVDC and HVAC transmission lines of the same capacity depending on line's length.

5. INTERSTATE POWER TRANSMISSION LINES EXAMPLES.

5.1 Power transmission Russia – Japan was considered in two variants:

- Sakhalin – Japan from specialized combined-cycle TPP on Sakhalin island, capacity 4GW;
- HPP in South Yakutia – Sakhalin – Japan transfer capacity 5 or 10 GW.

5.2 Russia – China through Mongolia territory.

5.3 So-called “HVDC bus” Siberia – Russia Far East

5.4 Russia – USA.

MAIN REASONS FOR THE RUSSIA-JAPAN ELECTRIC TIE.

For Japan:

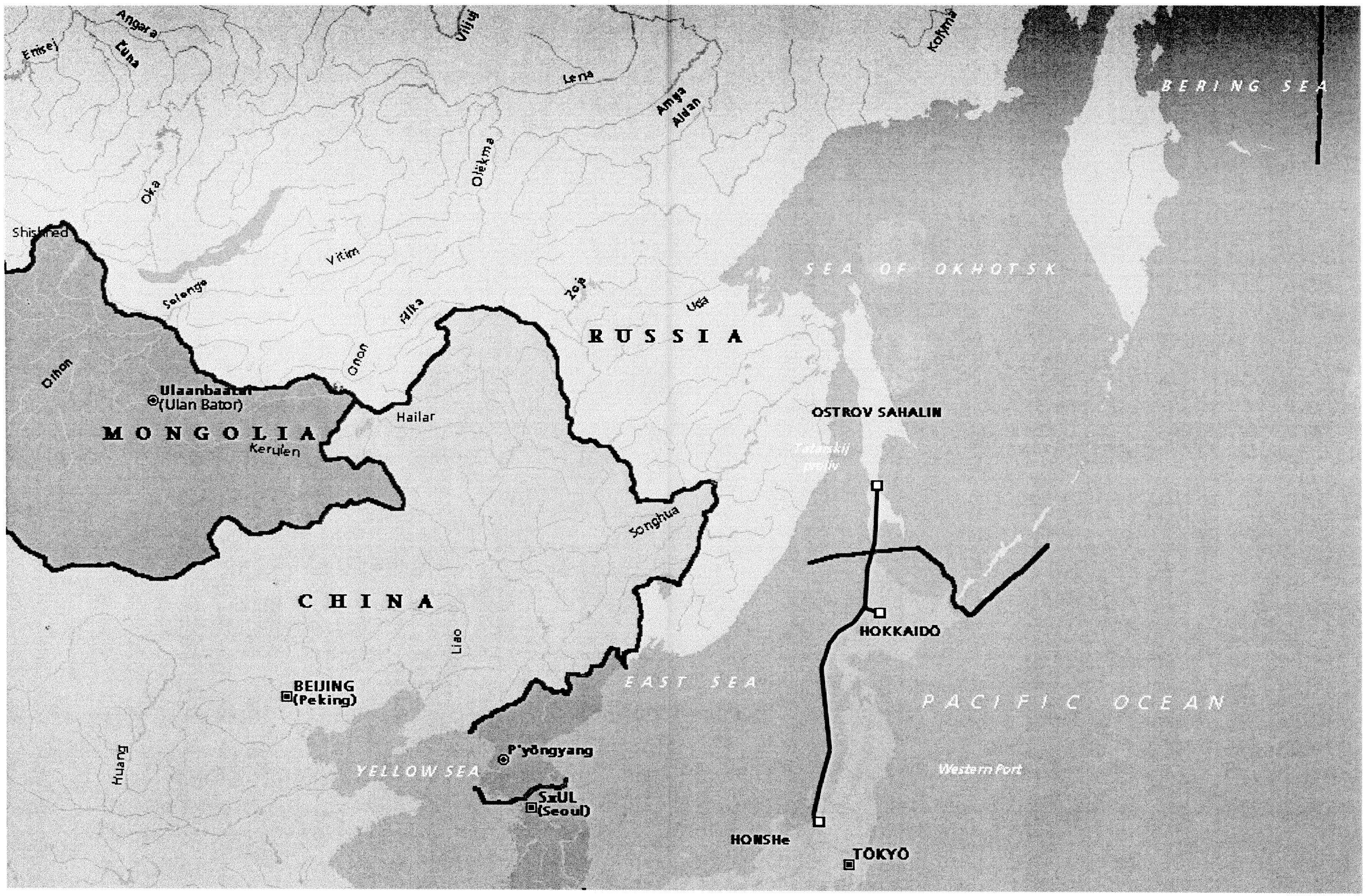
- Forecasts of a growing demand for electric power.
- Diversifications of energy supply sources.
- Reduction of carbon dioxide emission.

For the Russian Federation:

- Development of the economy and infrastructure of the Region, including creation of new jobs.
- Steady flow of hard currency incomes to the federal and regional budgets.
- Enhanced reliability of electric power supply to consumers.

For both countries:

- Mutual assistance in emergencies and other system effects.


BERING SEA
SEA OF OKHOTSK
RUSSIA
OSTROV SAHALIN
HOKKAIDŌ
PACIFIC OCEAN
Western Port
EAST SEA
HONSHe
TŌKYŌ
MONGOLIA
Ulaanbaatar
(Ulan Bator)
Kerulen
CHINA
BEIJING
(Peking)
P'yŏngyang
SxUL
(Seoul)
YELLOW SEA
Hailar
Songhua
Liao
Huang
Enisej
Angara
Oka
Selenge
Vitim
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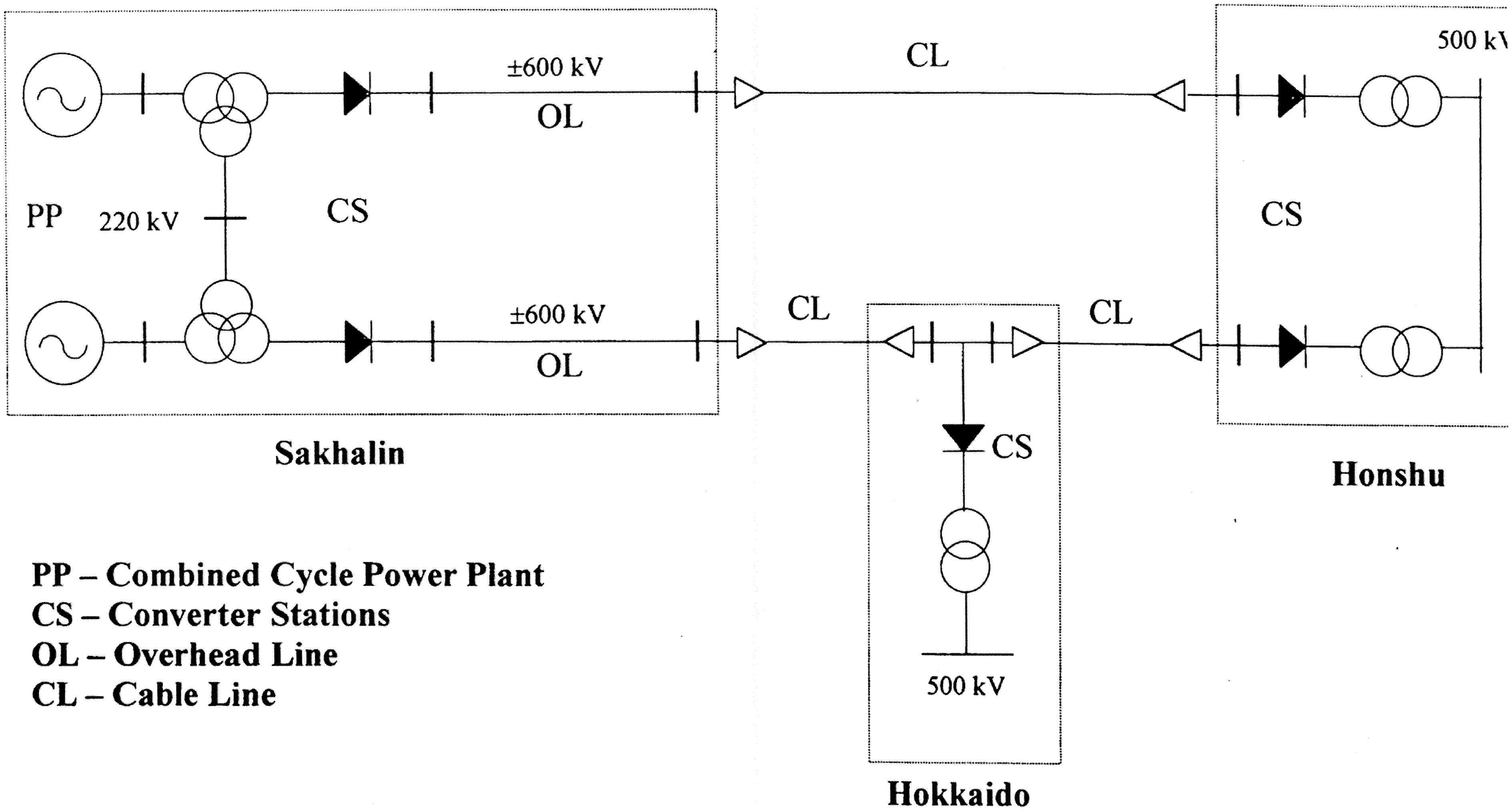
2. The fundamental scheme and the major objects of Sakhalin-Japan Power Bridge



PP – Combined Cycle Power Plant
CS – Converter Stations
OL – Overhead Line
CL – Cable Line

OUTLINE OF THE SAKHALIN – JAPAN POWER TRANSMISSION SYSTEM

Type of system: 1,800 km long multiterminal HVDC transmission system with two bipolar overhead lines, four submarine cable lines and three converter stations.

Voltage: ±600 kV.

Capacity ratings: 2,000 MW per bipolar line, 1,000 MW per one cable.

CONVERTER STATIONS

Common scheme: twelve-phase conversion by converter units for pole voltage of ±600 kV. The most up-to-date regulation and control facilities for multiterminal HVDC transmission system.

Capacity:

Sakhalin Island: 4,000 MW (four 1,000 MW units);

Hokkaido Island: 1,000 MW (two 500 MW units);

Honshu Island: 3,000 MW (two 500 MW units and two 1.000 MW units)

DC OVERHEAD LINE

Voltage: ±600 kV

Length: 400 km

Bundle conductor: 4 x ACSR 800/105

Insulators: 300 kN long-rod units Scheme: two bipolar lines

Towers: guyed single-post towers, there is possibility to install them by helicopter.

SUBMARINE CABLE SECTION

Cable section length: 1400 km

Route: from the southern extremity of Sakhalin to the Kashiwazaki area (Honshu island) with an extra exit to the shore near from Sapparo (Hokkaido island).

Maximum depth of cable laying: 1,000 m.

Transfer capacity: 1000 MW for each of four submarine cables.

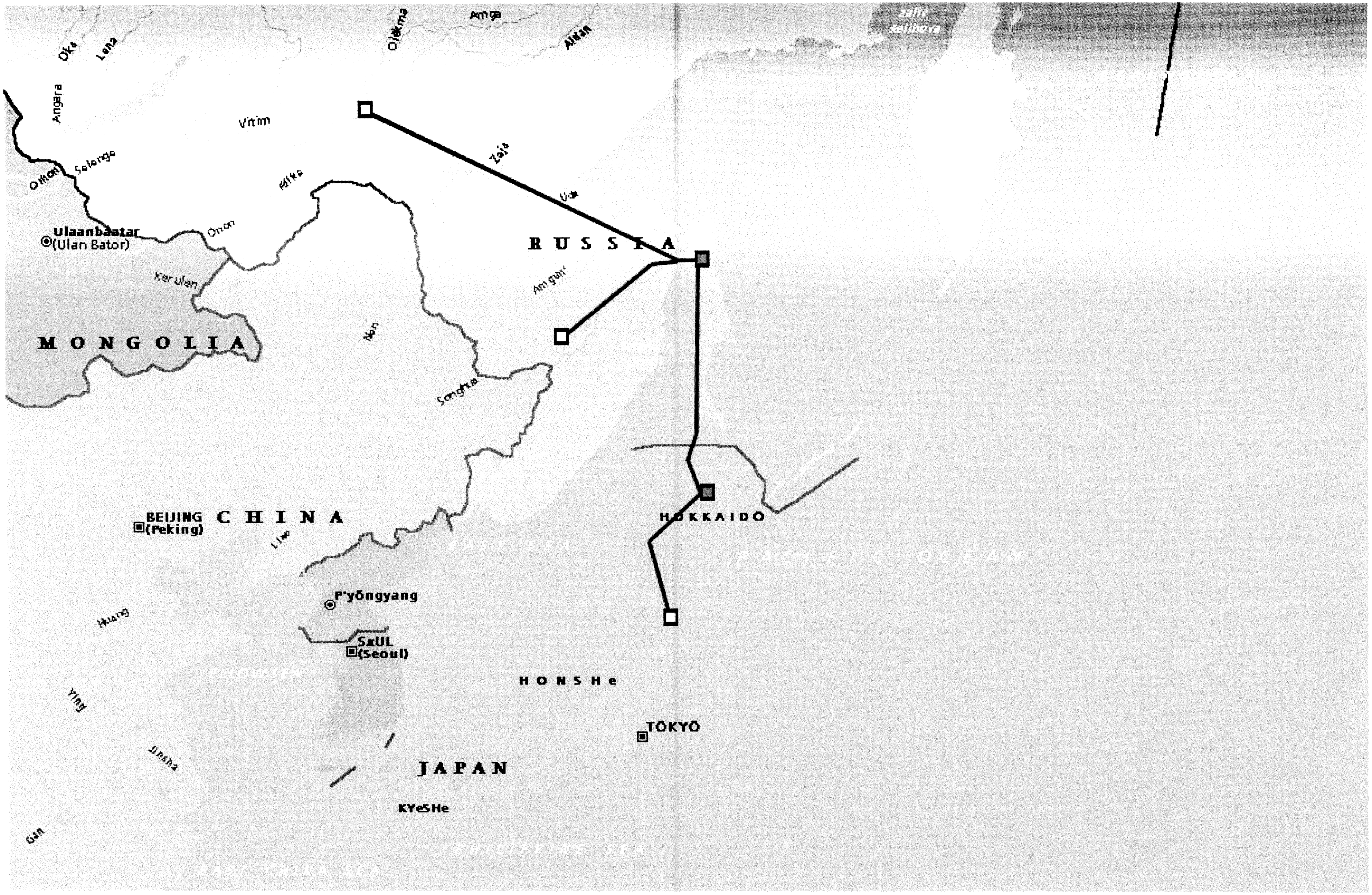
Voltage: 600 kV

OUTLINE OF THE SOUTH YAKUTIA – SAKHALIN – JAPAN POWER TRANSMISSION SYSTEM

Type of system: 2,800 km long multiterminal HVDC transmission system with two bipolar overhead lines, four submarine cable lines and five converter stations.

Voltage: ±750 kV.

Capacity ratings: 5,000 MW per bipolar line, 1,000 MW per one cable.


RUSSIA
MONGOLIA
CHINA
JAPAN
HOKKAIDO
HONSHe
KYeSHe
Ulaanbaatar
(Ulan Bator)
BEIJING
(Peking)
P'yŏngyang
SxUL
(Seoul)
TŌKYŌ
EAST SEA
PACIFIC OCEAN
YELLOW SEA
PHILIPPINE SEA
EAST CHINA SEA
zaliv
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Oka
Lena
Angara
Olekma
Amga
Aldan
Vitim
Zeja
Uda
Selenge
Orhon
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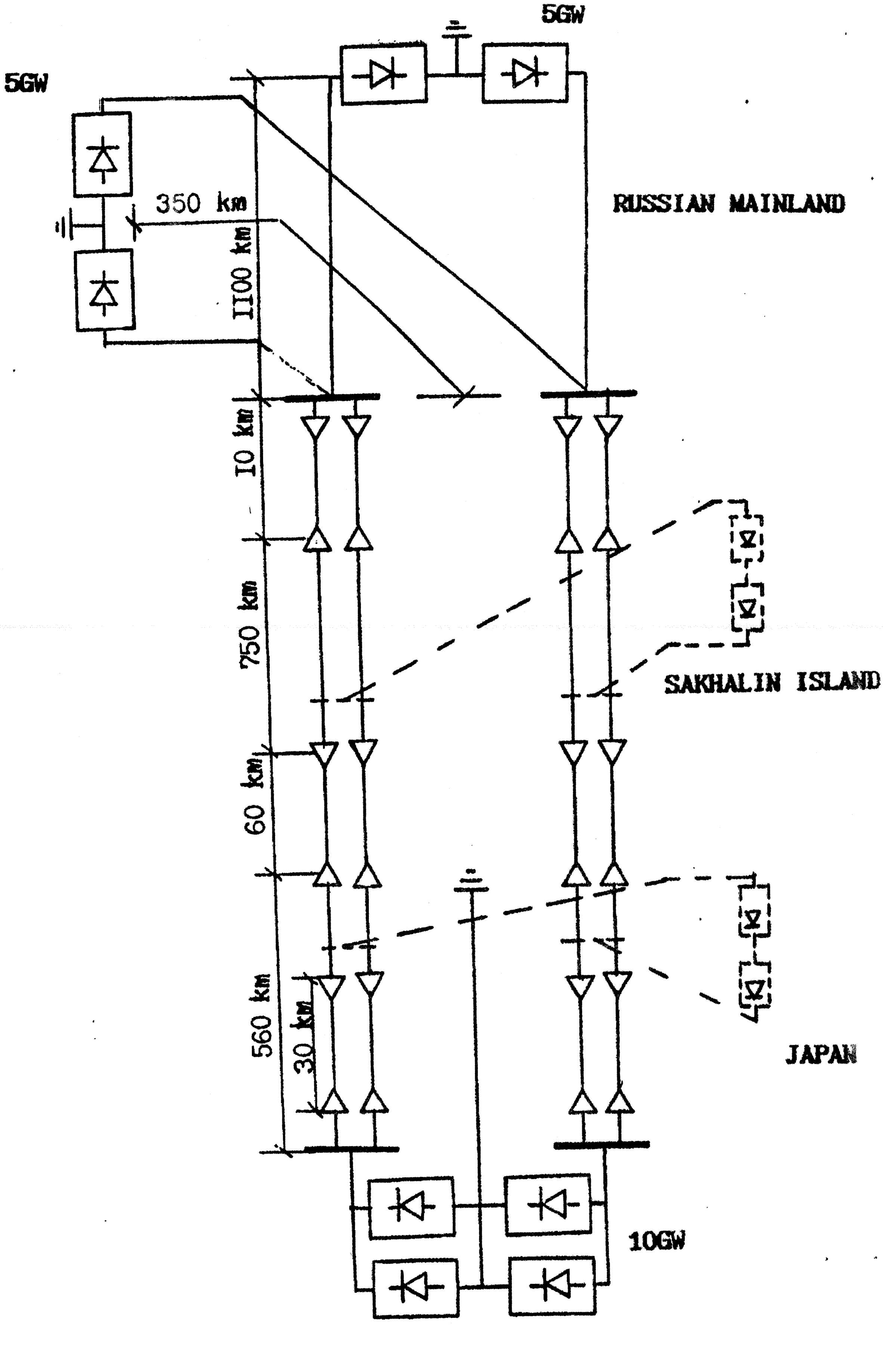
RUSSIA-JAPAN MTDC TRANSMISSION IN MAXIMUM SIZE 10GW

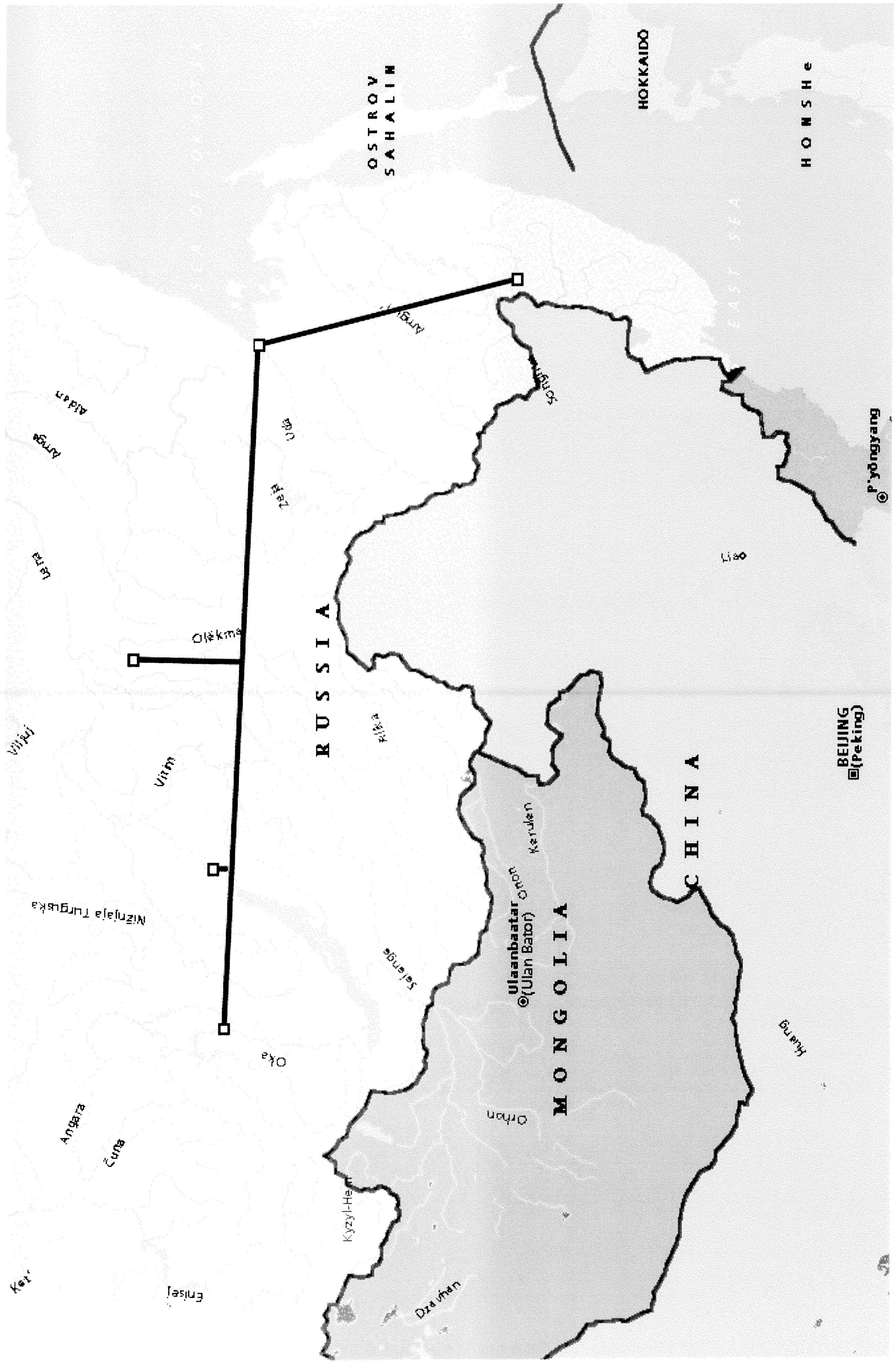


5.2 INTERSTATE POWER TRANSMISSION RUSSSIA – CHINA

- Overhead transmission line length is about 2500 km from Bratskaya HPP on river Angara to Beijing region.
- Transfer capacity 3000 MW.
- Transmission line voltage level ± 600 kV.

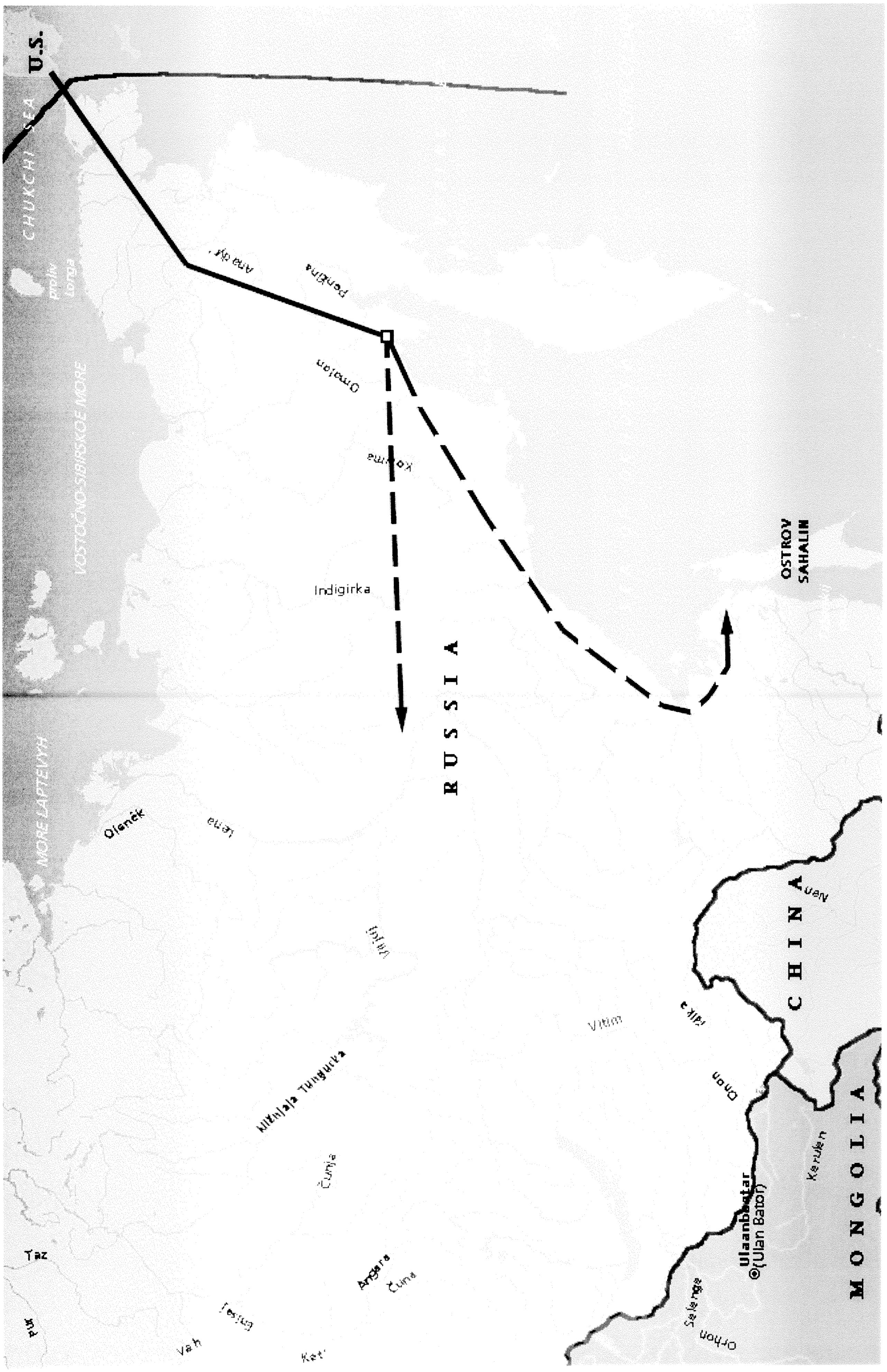
5.3 "HVDC BUS" SIBERIA – RUSSIA FAR EAST.

- "Bus" is executed as two bipolar HVDC transmission lines ±750 kV.
- On the "Bus" power capacity of 15-20 GW is gathered from Tugurskaya TiPP and several HPPs.
- This power can be used for consumers supply in Russia and for exporting to NEA countries.
- Providing the alignment of TiPP power output diagram.
- TiPP and some HPPs can operate at variable turbine's rotating speed, as all power from these HPPs and TiPP is outputting to HVDC transmission system.


OSTROV SAHALIN
HOKKAIDO
HONSHU
RUSSIA
CHINA
MONGOLIA
Ulaanbaatar (Ulan Bator)
BEIJING (Peking)
P'yŏngyang
EAST SEA
SEA OF OKHOTSK
Aldan
Amga
Lena
Viljuj
Vitim
Olëkma
Zeja
Uda
Amgun
Songhua
Liao
Nižnjaja Tunguska
Angara
Čuna
Oka
Ket'
Enisej
Selenge
Onon
Kerulen
Orhon
Kyzyl-Hem
Dzavhan
Huang

5.4 INTERSTATE ELECTRICAL TIE RUSSIA – USA (CANADA).

- Was considered according to the initiative of Global Energy Network Institute (GENI).
- On Russia side the variants of connecting to Siberia power system and (or) to Russia Far East power system were proposed.
- Connection of Pengenskaya TiPP to this link was proposed.
- The length and transfer capacity of this link were varied in wide range.
- Cable through Bering Strait can be laid on the sea floor or in the railway tunnel.


U.S.
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VOSTOČNO-SIBIRSKOE MORE
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Indigirka
RUSSIA
OSTROV SAHALIN
Olenëk
Lena
Viljuj
Vitim
Onon
CHINA
MONGOLIA
Kerulen
Ulaanbaatar (Ulan Bator)
Selenge
Orhon
Nižnjaja Tunguska
Čunja
Angara
Čuna
Taz
Pur
Vah
Ket'

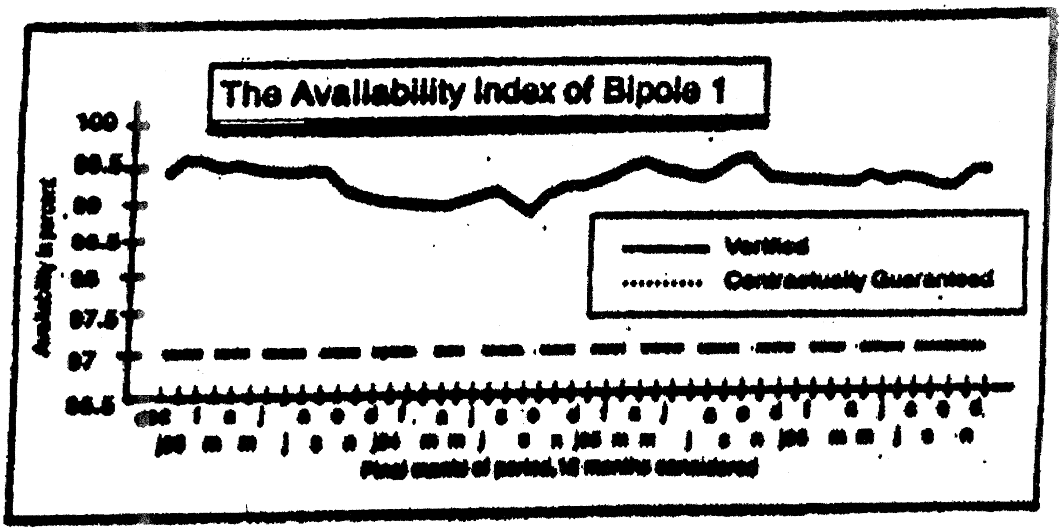
6. Technical and economical characteristics of HVDC transmission system.

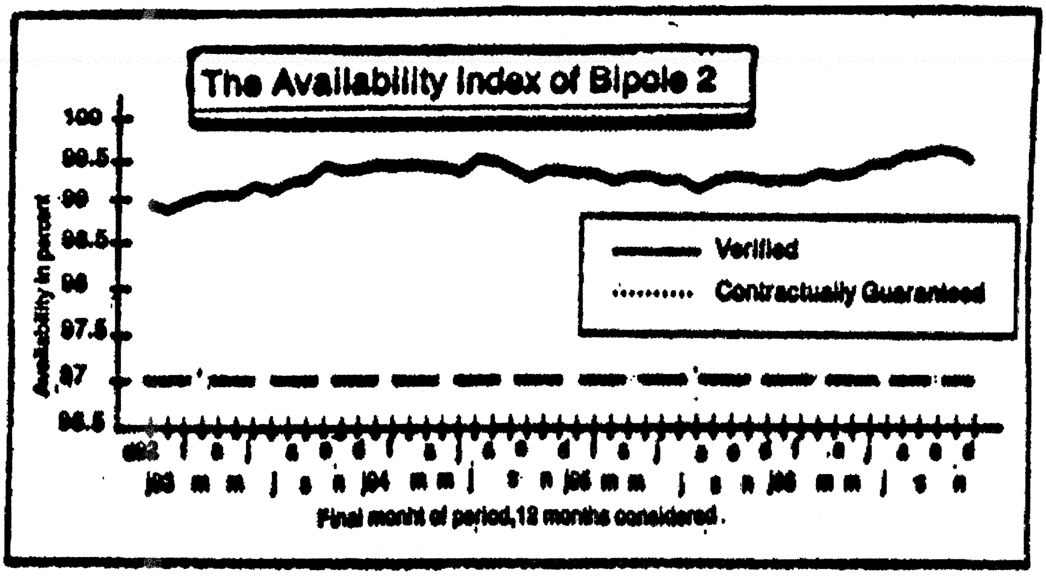
6.1 Technical characteristics of HVDC transmission system.

- Up-to-date HVDC transmission systems do not concede HVAC transmission lines in the reliability.

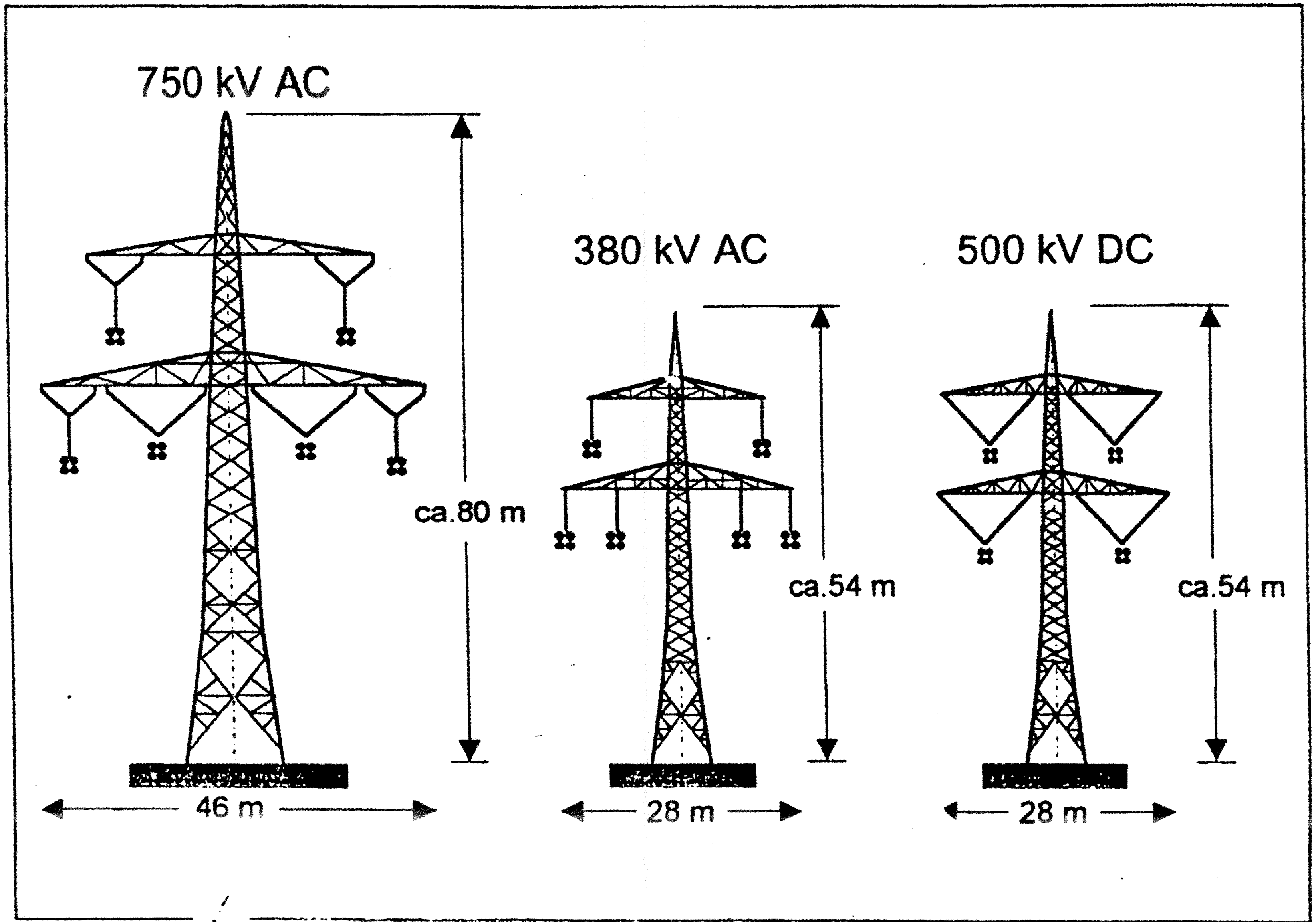
- HVDC transmission systems has several ecological advantages, which appears finally in 1.5 times lower territory taking aside for 1 MW transmitting power in comparison with HVAC transmission lines.

- HVDC transmission systems have better controllability in normal operating mode and emergencies, which permits to increase stability, reliability and survivability Integrated power system as a whole.





Itaipu HVDC Transmission: Availability and Reliability Guarantees



Comparison of 750kV, 380kV and ±500kv towers for 4GW transmission line

6.2 ECONOMICAL CHARACTERISTICS OF HVDC TRANSMISSION SYSTEMS.

- Per unit cost of 1 km of HVDC transmission line in 20 – 30 % lower tan HVAC transmission line per unit cost of equal transfer capacity.

- Per unit cost of HVDC converter substations depends on installed capacity (transfer capacity) of HVDC transmission system.

- Direct costs of transmitting of 1kWh with HVDC transmission system for overhead line is:

  $P=[0.3+(0.2\div0.6)\cdot L_{o.l}]$ cents/kWh

  for cable line is:

  $P=[0.3+(1.5\div2)\cdot L_{c.l}]$ cents/kWh,

  where $L_{o.l}$,$L_{c.l}$ — length of overhead and cable transmission lines in thousands km.

These costs can be justified only with differences in electrical energy costs between sending and receiving power systems.

- At F.S. developing system effects have to be taken into consideration.

- In spite of the appreciable cost of power transmission, it in many cases has advantages over the gas transporting.

UNIT PRICE ASSUMPTIONS FOR THE ±750KV 5GW AND 10GW HVDC TRANSMISSIONS.

1. Converter Terminals

5 GW converter terminal package	$98-102/kW
including:	
Uncontrolled filtering and var compensation	$10/kW
Controlled filtering and var compensation	$20/kW
var compensation system	
Grounding system	$20 min
10 GW converter terminal package	$90/kW

2. Overhead Line

5 GW single-circuit line	$650 M/km
10 GW double-circuit line	$1040M/km
Two single-circuit	$1300 M/km

3. Cable Line

5 GW cable line	$7.5 MM/km
10 GW cable	$15MM/km

UNIT PRICES FOR THE ±500KV 3GW HVDC TRANSMISSIONS.

1. Converter Terminals

Two converter terminal packages	$110–150/kW
including:	
Converter valves system	21.7%
Converter transformers	22.0%
DC switchyard	6.0%
AC switchyard	9.3%
Control, protection & communication	7.7%
Civil works	13.7%
Auxiliary power	2.3%
Project admin.	17.3%

2. Overhead Line $ Mill. 0.22–0.45/km

3. Cable Line $ Mill. 3/km

UNIT PRICE ASSUMPTIONS FOR THE ±750KV 5GW AND 10GW HVDC TRANSMISSIONS.

1. Converter Terminals

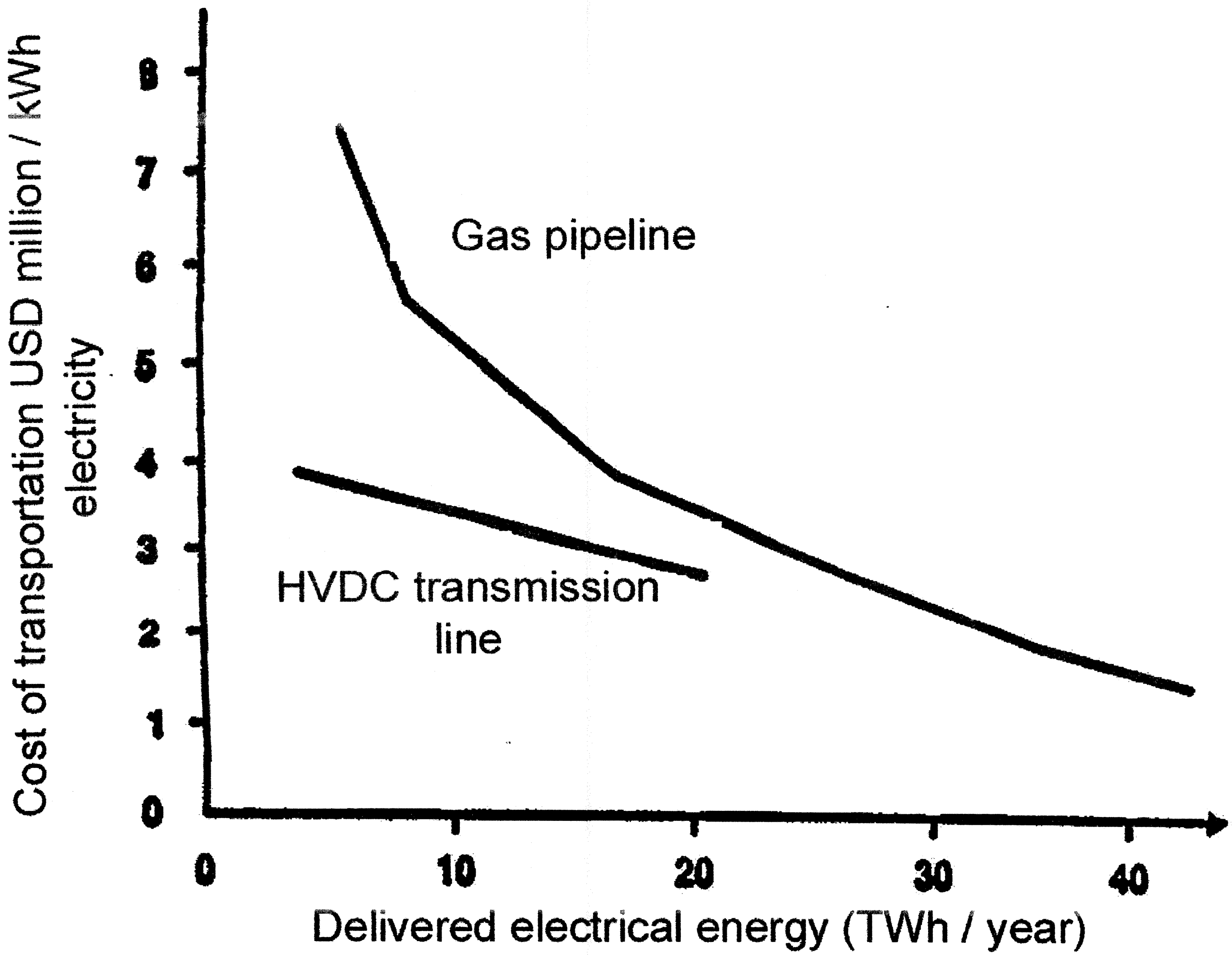
5 GW two converter terminal packages	$98-102/kW
including:	
Uncontrolled filtering and var compensation	$10/kW
Controlled filtering and var compensation	$20/kW
var compensation system	
Grounding system	$20 mill
10 GW two converter terminal packages	$90/kW

2. Overhead Line

5 GW single-circuit line	$ Mill. 0.65/km
10 GW double-circuit line	$ Mill. 1.04/km
Two single-circuit	$ Mill. 1.3/km

3. Cable Line

5 GW cable line	$ Mill. 7.5/km
10 GW cable line	$ Mill. 15/km



Gas pipeline vs HVDC transmission line. Transportation cost of equivalent delivered energy vs energy quantity

7. CONCLUSION

- There are essential grounds for interstate electrical ties organization in Northeast Asia region.

- Taking into consideration a number of unbiased peculiarities of interstate electrical links the preference are to be given to HVDC power transmission systems.

- Interstate electrical ties organization is connected with great investments (hundreds of millions USD). For substantiation of each of such tie it is necessary to perform preliminary feasibility study (F.S.)