BASIC PRINCIPLES 0F INTERSTATE ELECTRICAL POWER LINKS ORGANIZATION IN NORTH-EAST ASIA.

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There are technical and economical reasons for the creation of interstate electrical ties in the North-East Asian region. The ties have some peculiarities which cause the grounds for giving preference to HVDC transmission systems. Preliminary investigations of several interstate electrical ties were executed last year, and the main data of the ties are submitted in the paper.
Key words: INTERSTATE ELECTRICAL TIE, HVDC TRANSMISSION SYSTEM.

1. BACKGROUND

In the North-East Asian (NEA) region there are countries with different economies and power engineering development levels, as well as with different conditions of provision with energy resources. The main technical and economic reasons for the creation of interstate electrical power transmission lines between the countries are:

- Electrical power purveyance from countries which have surpluses of energy supplies to countries having electrical power shortages.
- Economic effects from the combining of essentially different daily and annual load diagrams in various countries.
- Generation reserves decreasing possibility.
- Mutual assistance in emergencies.
- Ecologically harmful ejections decreasing due to the involvement in the region's energy balance of hydro power plants (HPP) and tidal power plants (TiPP).

In particular, Russia's interests in interstate electrical ties with the other NEA countries consist of the following:

- There are large untapped possibilities for HPP erection on rivers in the Russian Far-East and East Siberia.
- There are at least two convenient power sites in the region for the erection of high-capacity TiPPs.
- In the region there are major fields of coal, gas, and mineral oil.
- Russia is interested in exporting electric power from the Far East and East Siberia.
- There is concern in Russia over foreign investment for power installations erection.

2. THE PECULIARITIES OF INTERSTATE ELECTRICAL TIES IN NEA REGION.

The peculiarities are first of all concerned with the electrical ties between Russian power system and the power systems of other countries, although a considerable part of these peculiarities can be attributed to other ties.

- In this region most interstate overhead transmission lines will be very long. In some cases the length exceeds one or even two thousand km.
- A power transmission line for such a large distance can be warranted for the large transmitting capacity (one and more GW) only.
- Japan is separated from other countries by the water barriers, and the same is true of Alaska. For getting over the barriers submarine cables must be used. Of course, this complicates and increases the cost of the ties.
- There are technical problems of large power systems integration with comparatively small transfer capacity AC power links. It is so called the «weak ties» problem.

Small stochastic changes of consumption in big power systems leads to large changes of power flow in the weak tie between the power systems. For guaranteed stability the AC line must sometimes have transfer capability, which can many times exceed the economically expedient transfer capability of the interstate tie.

Transfer capability of an AC tie is chosen according to special rules. For example, in terms of USA rule the transfer capability of an AC intersystem tie must not be less than 10% of the installed power of the lesser power system. By the way, that is the reason for the installation of many back-to-backs in the North American united power system.

- Various power and frequency regulating conditions in different countries' power systems, and also differences in operational control, emergency control system, language barriers, etc., cause additional difficulties for connecting the power systems of different countries.
- Differences in the frequency standards (50 and 60 Hz) exclude an opportunity to use AC lines between certain power systems.

3. GROUNDS FOR GIVING PREFERENCE TO HVDC TRANSMISSION SYSTEMS.

According to the above peculiarities of the interstate ties, High Voltage Direct Current (HVDC) transmission lines should be preferred as the basic solution for realization of the ties. This conclusion results from some special features of HVDC transmission systems.

3.1. It is known that HVDC overhead line is cheaper than HVAC line of the same transfer capacity, and reactive power compensation of DC lines is not required. But DC substations are more expensive than AC substations. Thus there is a length of line corresponding to equal costs of DC and AC transmission systems. This so called «critical length» corresponds to 600 – 1000 km (see Figure 1). The more difficult the route the less the critical length. Additional reduction of the critical length can occur in case of very high price for earth. The length of interstate transmission lines in NEA usually exceeds the critical length.

In case of using submarine cable line the critical length of a transmission system doesn't exceed 80 km.

It is necessary to mention that many specialists believe the more widespread utilization of cable lines and especially HVDC lines to be more perspective in the XXI century due to ecological reasons. Using HVDC cables, as usual, is more preferable for their laying on the sea ground [1]. Thereby the area of HVDC utilization is enlarging and simultaneously the stimulus appears for the development of the cable industry and for the perfection of high capacity HV cable technology. In the last several years impressive results in this area were obtained—as demonstrated by many of the operating sea cable lines and the much more grandiose projects in the planning or construction phase, for example the Bakun project in the South-East Asia.

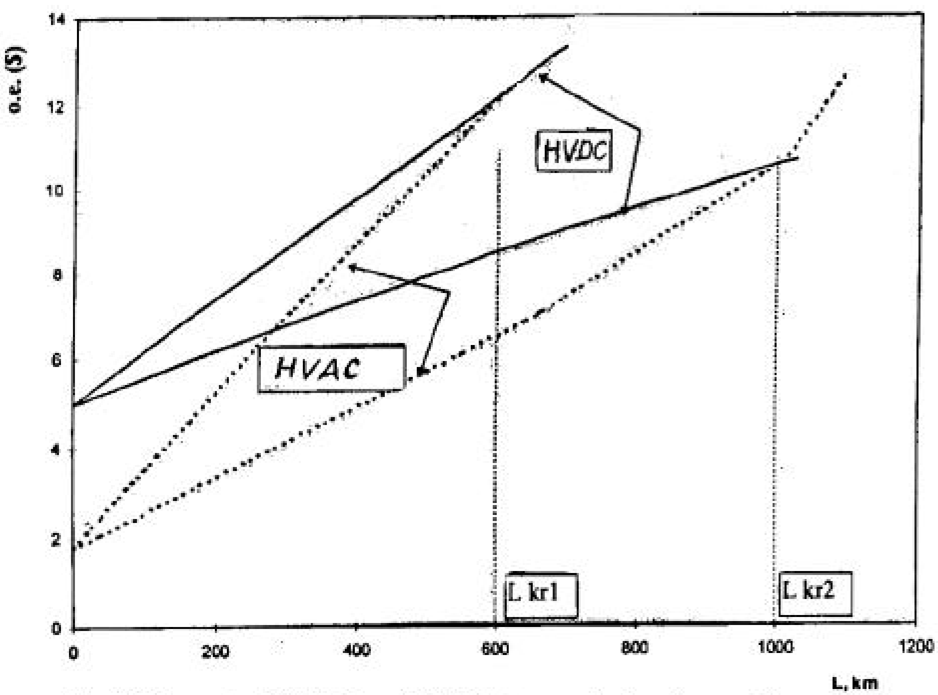

Fig.1. Thecost of HVDC and HVAC transmission lines of the same capacity depending on line's length.

3.2. HVDC transmission lines have a high reliability level. Figure 2 illustrates the very favorable characteristics of availability of the biggest HVDC transmission lines from HPP Itaipu to Saint-Paulo in Brazil [2].

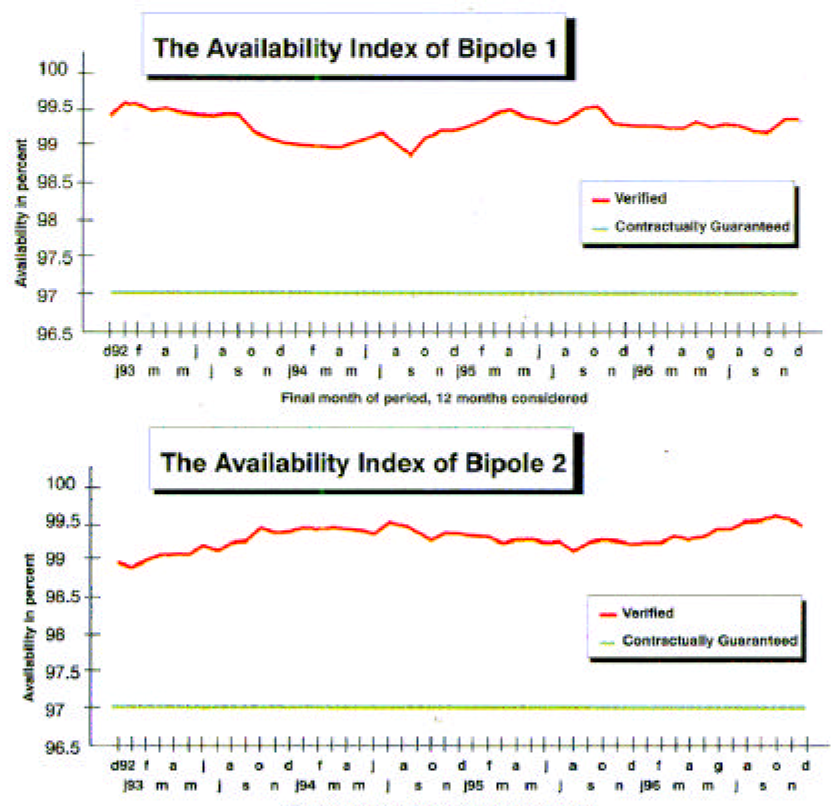

Fig. 2. Itaipu HVDC transmission: Availability and Reliability Guarantees.

The design disturbance in bipolar HVDC transmission lines is the shutdown of one pole in an emergency. Consequently, the accident rate of bipolar HVDC transmission lines corresponds to the accident rate of HVAC double-lines. After shutdown of one pole, spontaneous overloading of another pole does not occur. On the contrary, loading the pole in post-contingence can be arranged at the maximum allowable level by emergency control acting.

3.3. Power flow on an HVDC transmission line is set with the control systems of the converter substations, and the flow doesn't depend on the operating mode of united power systems. Thus, as distinct from HVAC ties, HVDC intersystem ties can be of arbitrarily low transfer capacity. By this means the weak tie problem can be excluded from consideration, and in each case parameters of the line can be adopted reasoning from the minimal required transfer capability to bring about projected power flows.

Thanks to the same circumstance the hardships of concordance of the different operational control systems, which exist at different power systems, are eliminated.

Emergency control systems may be simplified in large measure as well. Moreover, the fast acting control systems of HVDC transmission lines can be used to increase the stability and reliability of the power system as a whole. The result is achieved thanks to the possibility of the fast changing power flow of the HVDC line by emergency control systems. Besides, power flow regulation can be used for damping oscillations in power systems or in parallel HVAC lines.

The emergency processes' spreading on the power systems of other countries is eliminated in the case of using HVDC transmission systems. It is very important because the need for coordination of the different emergency control systems is excluded. Each emergency control system can act within the scope of its power system only.

The exclusion of the weak tie problem and the prevention of emergency developments on nearby power systems are the main essential stimuli for separating large power systems into several non-synchronous parts. As an example, such power systems' structure can serve the power systems of North America, China, and India. In particular, the quickly growing Indian power system is being constructed according to the major plan in the way of several regional power systems interconnected with HVDC transmission lines and back-to-backs with centralized control of these HVDC elements [3].

It is known that HVDC can be joined to power systems without increasing the short circuit current level at the point of connection. Hence, the commutation apparatus need not be changed.

3.4. HVDC transmission systems have several ecological advantages, which finally appear in an average 1.5 times lower territory taking in comparison with the territory required for HVAC transmission lines.

This is evident from Figure 3, which is borrowed from the feasibility study of an HVDC transmission system for Russia-Belorussia-Poland-Germany.

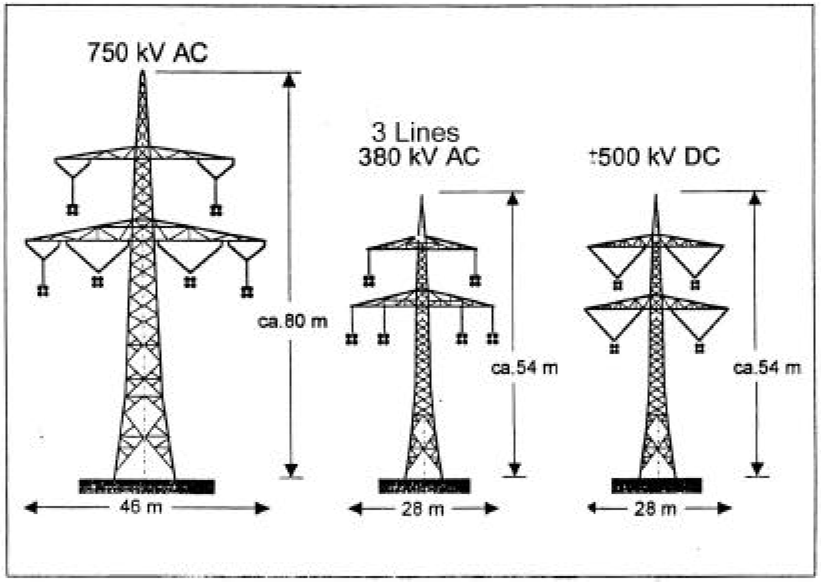

Fig. 3. Comparison of 750kV, 380kV and ±500kv towers for 4GW transmission line

3.5. Modern HVDC transmission lines can be realized with several terminals. These are called multiterminal HVDC transmission systems. So far only several multiterminal systems function. This is an active area of research. For instance, ABB Corp. achieved much success in the area on the basis of a new technology called «Light technology» [4,5]. Now Light technology is applied to rather small HVDC transmission systems, but there is good reason to believe that this or other technologies permit improvement of the technical and economic characteristics of multiterminal HVDC systems. Such systems may be in some cases used in the NEA region for connecting several power systems, for example, the power systems of Russia, North Korea, and South Korea.

3.6. At last, specific features of DC power transmission system can be used in some special cases. For example, distant HPPs and TiPPs can operate with variable rotation speeds through HVDC transmission system. This allows these systems to obtain an economic effect. In particular, HPPs and TiPPs are used more effectively during storage reservoir fill up and at drastic variable pressure on TiPPs. Working wheels of HPP water-turbines do not need to be changed as long as the storage reservoir is filled up, and simpler and cheaper TiPP turbines can be used.

This is one more beneficial property of a DC system, which can be used in the NEA region, because there are several remote power sets for HPPs and TiPPs in the Russian Far-East and East Siberia. These power sets are located far from consumption centers, and energy from the future power plants can be used completely for distant transportation, in particular to abroad.

3.7. Together with HVDC advantages, in comparison with HVAC transmission systems, some essential disadvantages exist, which we have to consider when we choose the way for power transmission. To the disadvantages of modern HVDC transmission systems the following can be attributed:

– Converter substations are more complex than HVAC substations. And the question is not only in additional converting equipment but also in more complicated control and regulating systems. The necessity of further complication of automatic control systems appears in the case of multiterminal HVDC transmission system construction, because, in this case, based on the modern principles of such systems' construction, we have to provide the coordinative controlling of operating conditions of all multiterminal HVDC converting substations. Such controlling is concerned with not only algorithms' complication but also makes a demand for telecommunication systems.

– Nowadays HVDC transmission systems are used successfully only with fulfillment of several demands in the ways AC systems join to HVDC systems. In particular, the stable HVDC transmission system operation is guaranteed only when the ratio between short circuit power on the AC buses of inverter substations and this substation's capacity (so called short circuit ratio, SCR) is not lower than 3. If this ratio is between 2 and 3, it is necessary to pay special attention to the regulating system. If the ratio is lower then 2, then it is practically impossible to provide for stable operation of the HVDC system.

– A modern converter substation generates current and voltage harmonics. Besides, the conversion process is accompanied by reactive power consumption. Usually it is assumed that for harmonics filtering and reactive power compensation it is necessary to install filter-compensation units and reactive power compensation units consuming 0.5 – 0.6 of total converter substation capacity. Moreover, in some cases such units have to be regulating compensators (SVC or SC) and filtering units with automatic resonance circuit adjustment.

– During short circuits in the AC power systems close to the HVDC substations, power faults in the HVDC transmission system take place for the duration of the short circuit. Most sensitive to the voltage decrease and distortion on the AC buses are the inverter substations. During short circuits of the inverters' AC buses a full HVDC transmission system power fault can be caused by forward sequence voltage decreasing by 50% and sometimes more than 50%. The power fault due to short circuits of the rectifier's AC buses is usually proportional to the forward sequence voltage decrease.

There is another limitation concerned with short circuits in the AC system. This limitation can be essential during multiterminal HVDC (MTDC) transmission system construction. The question is in the limitation of minimal capacity of MTDC substations. The minimal capacity according to the thermal stability at short circuits must not be lower than 10 – 15% of the sum of all the substations' capacities. This means that the number of substations of a modern multiterminal HVDC transmission system has to be no larger than 6 – 8, and large differences in their capacities is not allowed. The larger the number of substations, the smaller the differences in their capacities.

Taking into account all these considerations one can conclude that based on modern techniques it is practically impossible to construct an HVDC transmission system with more than 5 substations.

– The high frequency constituents in direct current can cause radio noise in communications lines which are situated near the HVDC transmission line. To prevent this it is necessary to install on HVDC transmission lines rather expensive special filters. In the last years these so-called active filters were developed. Use of such filters allows one to decrease the installed capacity of filter devices and correspondingly the cost of filter units as a whole.

– Among HVDC transmission system disadvantages one usually includes current return via the ground, in the case of monopole HVDC transmission systems, or non-symmetrical operating conditions in the case of bipolar HVDC transmission lines (for example, during an emergency outage of one pole). The operating grounding of HVDC transmission constitutes a rather complex and expensive installation, providing a reliable and permanent contact for current going from the grounding device to the earth and eliminating the possible appearance of the dangerous «step voltage». The continuous current passing through the earth can cause the electrocorrosion of underground metal installations, mainly pipelines. This impact depends on the grounding device construction, the current value and the carrying term of this current, and the distance from the pipeline or other corrosive installation to the grounding device.

Some of the disadvantages can be eliminated with the use of new technologies.

In particular, disadvantages such as the impossibility of operating with low SCR, complete power fault of the HVDC transmission system during short circuits in the AC power system, and reactive power consumption can be eliminated completely or mostly with the utilization of turn-off thyristors. There are still no grounds for the assertion that all the technical questions of converters based on such thyristors for high capacity HVDC transmission construction have been solved.

However, in several research centers work in the direction of the perfection of high-capacity turn-off thyristors and also in the direction of new types of converter devices for high capacity HVDC transmission is being carried out successfully.

There is ground for the hope that utilization of turn-off thyristors and new circuit design will cause the elimination of limitations on the number of substations in the MTDC transmission system.

There are several new techniques for the perfection of grounding devices, providing for decreased electrocorrosion impacts and formation of so-called «metal return,» which excludes the working current from flowing through the ground.

The development of other techniques for HVDC technology perfection is being carried out.

One can recall that the first HVDC transmissions (Kashira-Moscow in USSR and to Gotland Island in Sweden) appeared only after the Second World War. During these years HVDC technology has developed a lot: the utilization of mercury-arc valves was completely rejected, converting blocks are used on the full voltage of the HVDC transmission line, the possibility of MTDC transmission systems was demonstrated, and so on. Undoubtedly, this technique follows developing perspectives.

However, even with modern techniques, the advantages of HVDC transmission over HVAC transmission for the solution of many tasks are undoubted. HVDC transmission systems have to be proffered for the construction of a major part of the proposed interstate power links in NEA region.

4. ECONOMIC CHARACTERISTICS OF HVDC TRANSMISSION SYSTEMS.

4.1. Investments in overhead lines depend on different conditions of the line route. For example, per unit cost of 1 km of bipolar HVDC line (±400-600) kV, 3 GW is conventionally estimated at $0.22-0.45 million/km. The unit cost for HVDC transmission line is 20-30% lower than the unit cost for HVAC transmission line of equal transfer capacity.

The price can significantly increase if the routs runs across a heavily populated area or preserved area. In such cases the HVDC overheard line has additional advantage as compared with HVAC overheard line. Moreover, cable line may be competitive with overhead line in terms of capital costs, and HVDC line has received further advantages in these cases. In parallel with the increase in cost, difficulty in obtaining the authorities' solution for the allotment of physical space also increase. This is an additional reason for using HVDC overhead line or cable line.

Capital costs of HVDC cable line is dictated by many circumstances, including voltage and capacity of the cable line, route conditions, etc. The per unit cost of 1 km of HVDC submarine cable can be very roughly estimated at $1 million/GW.

4.2. The per unit cost of 1 kW of HVDC converter substation depends on the installed capacity (transfer capacity) of the HVDC transmission system and, to a lesser degree, the location of the substation.

Dr. Hingorani (EPRI, USA) submitted in [6] a relationship between the cost of two converter substations and the transfer capacity of HVDC transmission line (Figure 4). His evaluation is close to the evaluations of other authors.

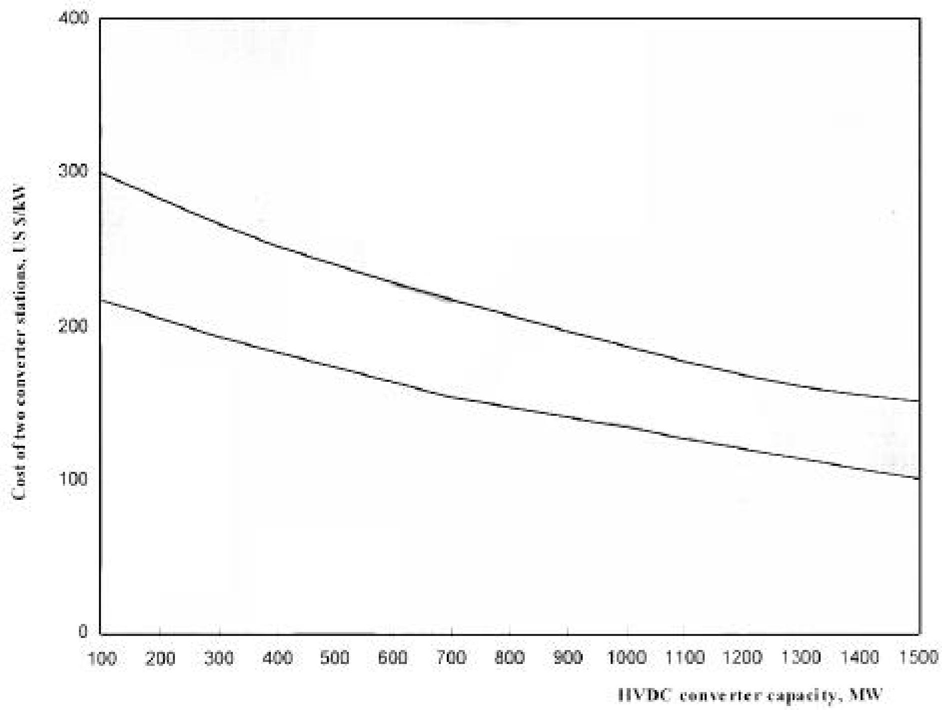

Fig. 4. Per unit cost of two converter substations depending on HVDC transmission capacity, by N. Hingorani

In the following table are given the substation unit costs and components of the cost by Denis Woodford [7].

Table 1 Unit cost and components of cost for the ± 500 kV, 3 GW. 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 administration	17.3%

It should be remarked that no account has been taken in this table of the means for reactive power compensation at the substations. The cost of these means depends in very large measure on the local conditions and an average makes no sense. In some cases cost of the means of reactive power compensation can amount to 15 - 20% of the total cost of a substation.

4.3. So far we were dealing with capital costs. But the cost of transmitting energy is very important for economic estimation of the expediency of a transmission system or an intersystem tie. Very roughly, the direct cost of transmitting 1 kWh with an overhead line HVDC transmission system is

$P = [0.3 + (0.2 \div 0.6)\cdot L_{o.\,l}]$ cents/kWh;

And for a cable line is

$P = [0.3 + (1.5 \div 2)\cdot L_{c.\,l}]$ cents/kWh

Where $L_{o.\,l}$ and $L_{c.\,l}$ are the lengths of the overhead and cable transmission lines, respectively, in thousands of km.

For example, if we have a 1000 km HVDC transmission line, cost of transmitting 1 kWh is from 0.5 to 0.9 cents for an overhead line and from 1.8 to 2.3 cents in case of a cable line. These costs can be justified only with differences in electrical energy costs in sending and receiving power systems.

This is very rough estimate in which are represented only direct investment and maintenance expenditures including losses and depreciation (8% per year). The estimate can be used only in the first stage of the feasibility study. But the estimate does provide a rough idea of the advisability of the tie.

4.4. All of the preceding is concerned with transportation facilities of the transmission line.

However, system effects have to be taken into consideration along with the electric power transportation in the feasibility study of each intersystem electrical tie.

Part of the effects can be economically estimated directly, for instance combination of the consumption curve and reduction of the reserves in the united power systems. But mutual assistance in emergencies, increasing stability and reliability, reduction of carbon dioxide emission, etc, are difficult to value. At the same time real benefits from these effects may be no less than from the previous.

Feasibility study of an international tie involves additional difficulties, because account must be taken of different rules and standards, political relations, and perspective of the development. At the same time, interstate electrical ties may be a factor in developing the economic and political relations of the countries.

4.5. Final Short Remark.

In spite of generally accepted opinion, electric power transmission in several cases has economic advantages over gas transporting.

Figure 5 from [8] demonstrates the relationship between prices (or transmitting costs) and transmitting power for a gas pipeline and an HVDC power transmission line. By this is meant gas or electrical power transport for 600 km.

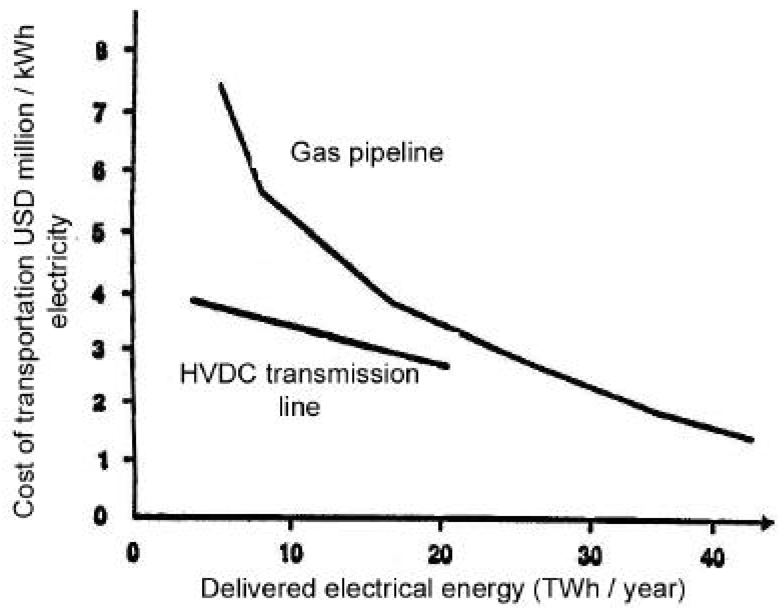

Fig.5. Gas pipeline vs HVDC transmission line. Transportation cost of equivalent delivered energy vs energy quantity

It follows from these diagrams that within the scope of real capacity for electrical power transmission line an HVDC line has economic advantages over a gas pipeline. Of course, if a pipeline is not used exclusively for power plants but for combined functions (for chemical industry, transport, and so on), a pipeline has advantages over an electrical line.

5. INTERSTATE POWER TRANSMISSION LINES EXAMPLES.

The following examples of possible interstate ties are considered:

- Power transmission from Russia to Japan in two variants (from specialized combined-cycle thermal power plant (TPP) on Sakhalin island; and from HPPs in South Yakutia through Sakhalin).
- From Russia to China through Mongolian territory.
- So-called «HVDC bus» from Siberia to the Russian Far East.
- From Russia to the USA.

These examples are submitted because the author of the paper participated in studying the projects. It must be noted that the projects were done at the stage of pre-feasibility study and that no decisions concerning further elaboration of the projects have been made. The interstate tie between Russia and China was more elaborated than the others. But no decision for further work on this project has been made either.

5.1. Russia - Japan Power Transmission Systems.

What are the main reasons for the Russia — Japan electric tie?

<u>For Japan</u>:

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

<u>For the Russian Federation</u>:

- Development of the economy and infrastructure of the region, including creation of new jobs.
- Steady inflow of hard currency to the federal and regional budgets.
- Enhanced reliability of electric power supply to consumers on Sakhalin island.
- Improvement of Russia's export structure.

<u>For both countries</u>:

- Mutual assistance in emergencies and achievement of other system effects.
- Development and application of the achievements of science and new technology to production of new equipment and long-distance electrical transmission systems.

<u>The first version of the Russia-Japan interstate tie</u> represents a transmission system from the/a specialized combined-cycle thermal power plant (TPP) on Sakhalin Island to power systems on Honshu and Hokkaido (Figure 6).

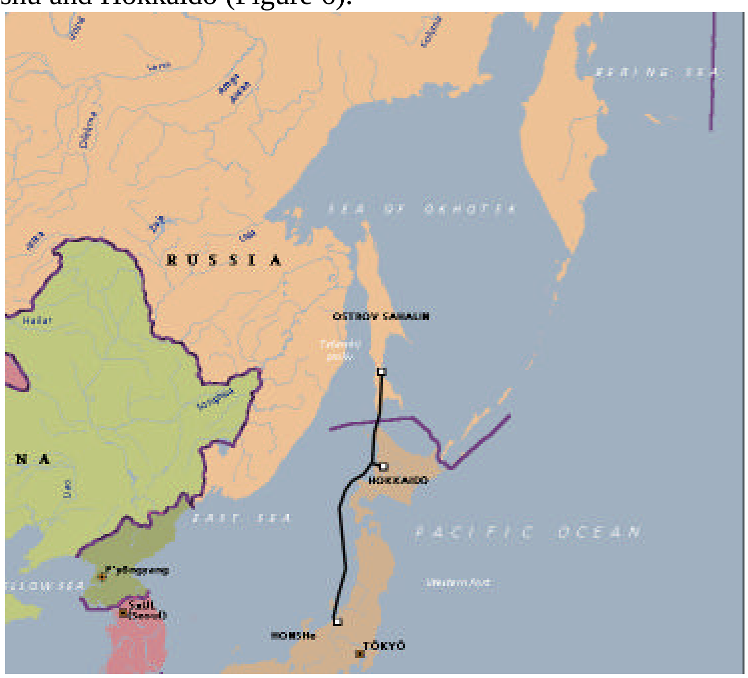

Figure 6. Transmission System from Sakhalin to Hokkaido and Honshu

<u>Type of system</u>: 1,800 km multiterminal HVDC transmission with two bipolar overhead lines, four submarine cables (two bipolar lines), and three converter stations.
Fundamental scheme of the system is shown in Figure 7.

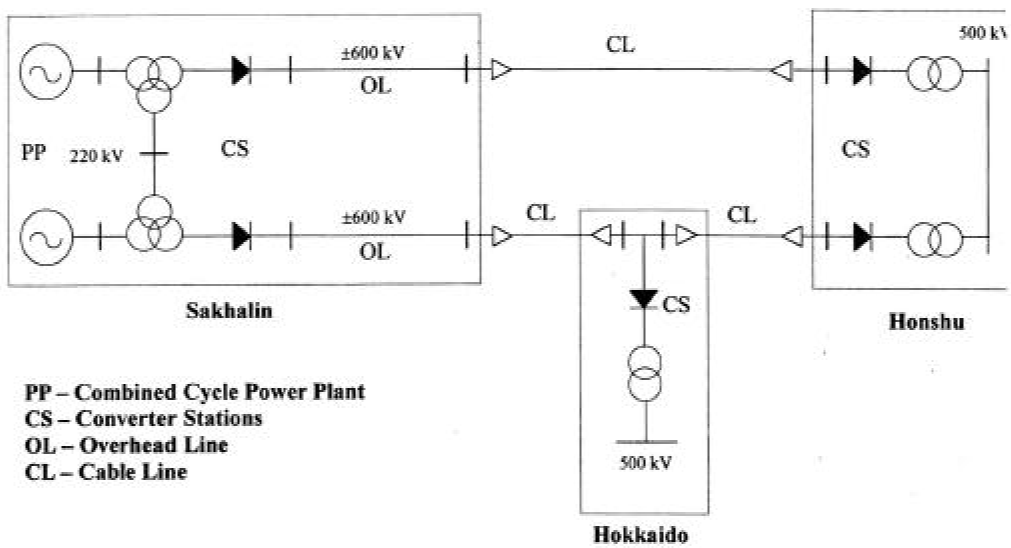

Fig. 7. The fundamental scheme and the major objects of Sakhalin-Japan Power Bridge

Some details of the main components of the system are cited below.

<u>Converter stations</u> are formed on the basis of twelve-phase conversion by converter units for pole voltage of 600 kV, with the most up-to-date regulation and control facilities for multiterminal HVDC transmission systems.

The Sakhalin Island station's capacity is 4,000 MW (four 1,000 MW units); the Hokkaido station's capacity is 1,000 MW (two 500 MW units); and the Honshu station's capacity is 3,000 MW (two 500 MW units and two 1.000 MW units).

<u>DC overhead line</u> is used on Sakhalin Island only.

Two bipolar lines run from the middle part of Sakhalin Island, where the place for TPP was fixed, to the southern extremity of Sakhalin Island.

Voltage of the line is ±600 kV, length 400 km, capacity 2,000 MW per bipolar line.

Bundle conductor: 4 x ACSR 800/105; insulators: 300 kN long-rod units.

Towers: guyed single-post intermediate towers. There is the possibility to install them by helicopter. The last is important, because the line runs on a mountain chain.

<u>Submarine cable section</u> has a length of 1400 km.

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

Maximum depth of cable laying is 1,000 m.

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

<u>The second version of the Russia-Japan interstate tie</u> represents an HVDC multiterminal transmission system from several HPPs on the tributaries of the Lena river in Southern Jakutia to Japan through Sakhalin Island, with an intermediate connection to the Khabarovsk power system (Figure 8). On the first stage the system will have a transfer capacity of 5,000 MW, and on the second stage 10,000 MW. Besides three basic substations, one or two additional terminals can be created on Sakhalin Island.

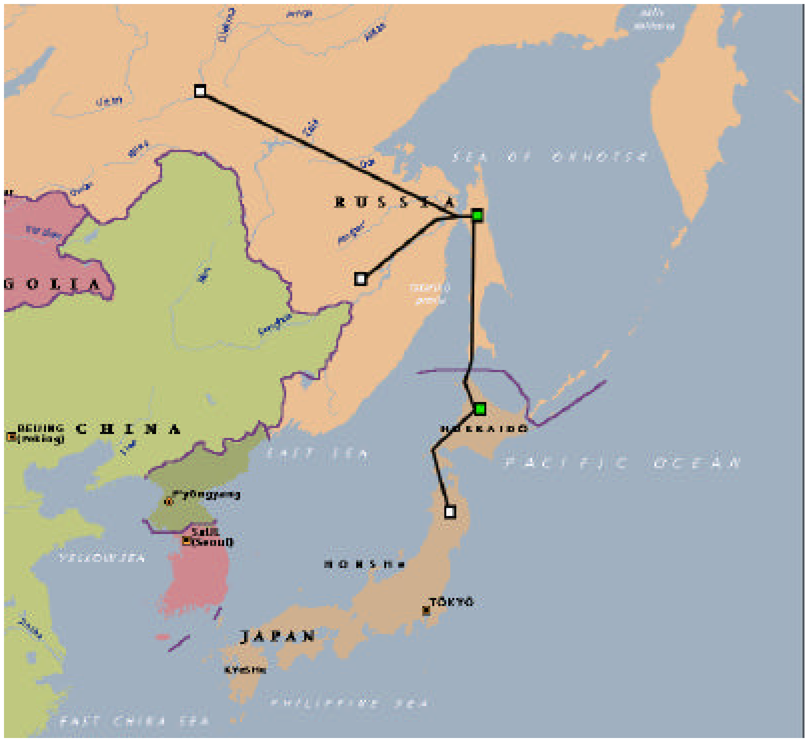

Figure 8. Transmission system from HPPs in Southern Jakutia to Japan

The voltage of the system is ±750 kV (this class of voltage was elaborated for the HVDC transmission line from Kazakhstan to the Center of Russia). Two bipolar overhead lines will have a length of 2,800 km and a capacity of 5,000 MW each.

As distinct from previous versions, cable line is used in this system for the crossing of straits only.

Capacity of basic substations: 5,000 MW in Jakutia and Khabarovsk areas, 10,000 MW in Japan.

If the previous version of the Russia to Japan interstate electrical tie is considered as a line for transportation of electrical energy from a special power plant to Japan only, the second version of the Russia - Japan interstate tie is intended for receipt of system effects too; in particular, for mutual smoothing out of power plants' load curves.

5.2. Russia - China Power Transmission Line.

This interstate tie represents an HVDC power transmission line from the Angara River area through Mongolia to China, near Beijing (Figure 9).

Figure 9. Transmission line from the Angara River area to Beijing

In this part of Russia there are several big HPPs (Bratskaja, Yst-Ilimskaja, Krasnojarskaja, and Boguchanskaja (under construction)).

Power transmission can provide Northeastern China with relatively cheap electrical energy, and receipt of system effects can be provided too.

Transfer capacity of the HVDC transmission line is 3000 MW at a voltage level of ±600 kV.

5.3. «HVDC Bus» Siberia to the Russian Far East.

«HVDC Bus» is a new or rather well forgotten term. 50 years ago the famous Russian academician Professor Naiman spoke up for the HVDC Bus from the Atlantic Ocean to the Pacific Ocean. At that time it was an absolutely fantastic idea. Now the idea is still fantastic, but not absolutely. And the rather short «Bus» is real idea.

Figure 10. HVDC Bus from Siberia to the Russian Far East

The Bus is intended for gathering and distributing electrical power.

On the Bus, power capacity of 15 - 20 GW is gathered from the Tugurskaya TiPP and several existing and projected HPPs. This power can be used to supply consumers in this part of Russia and for export to other NEA countries.

The Bus can be executed as two bipolar HVDC transmission lines of ±750 kV and a length of about 2500 km.

The Tugurskaya TiPP and some HPPs can operate at variable turbine rotating speeds, as all power from these HPPs and TiPP is output to the HVDC transmission system. The alignment of the TiPP power output diagram is provided.

5.4. Interstate Electrical Tie from Russia to the USA.

This interesting idea was considered according to the initiative of the Global Energy Network Institute (GENI) several years ago.

Figure 11. Interstate Electrical Ties from Russia to the US

On the Russian side several variants of power transmission were proposed; in particular, extension of the tie to the Siberia power system and (or) to the Russia Far East power system was considered. Connection of a prospective Pengenskaya TiPP to this power link is proposed.

Of course, the interstate tie can be created on the basis of an HVDC power transmission system because there are different frequency standards in Russian and North American power systems, as well as the Bering Sea strait, which must be crossed with a cable line.

The length and transfer capacity of the power transmission system were varied in wide range. The system may be connected with other lines from the Russian Far East to other NEA countries.

Cable through the Bering Strait can be laid on the sea floor or in a railway tunnel. The idea of the railway tunnel was spoken of in the early twentieth century. Moreover, a joint-stock company was created at that time. But the world war and the revolution in Russia prevented the idea, unfortunately.

It goes without saying that the creation of the interstate tie bebngs to the remote future.

6. CONCLUSIONS.

- There are essential grounds for the creation of interstate electrical ties in the Northeast Asian region.
- Taking into consideration a number of objective peculiarities of interstate electrical ties, the preference is to be given to HVDC power transmission systems.
- Creation of interstate electrical ties is connected with great investments (hundreds of millions of USD). For prior substantiation of each of such tie it is necessary to perform a preliminary feasibility study.
- Carrying out full-scale feasibility studies of such installations needs large financial expenditures and time which can turn out to be unjustified without preliminary investigations and crude economic guesses.
- Economic evaluation of intersystem ties must be executed taking into account both the transport function and the system effects of the ties, although the system effects do not have direct economic evaluations in some cases.
- Interstate electrical ties between Russia and other NEA countries are intended, first of all, to distribute Russia's energy surplus. There are many investigated power sets for HPPs and TiPPs, as well gas, oil, and coal fields in this part of Russia.
- The energy potential in this part of Russia can be significantly increased with new HPPs, TiPPs, and TPP creation. Power transmission lines from the power plants are, as a rule, very long, and they require big capital investments.

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