Wets'03 Workshop "World Energy Transmission Systems"

Discussion Topics

Contribution to Topic 2: Do studies on a world energy transmission system exist?

To this question I only can formulate thought from the point of view of possible energy transmission systems, available today and expected in the future.

The 50 year time span from 2000 to 2050 seems to be a very long time into the future and any kind of prediction may be unsharp or totally wrong. Taking the experiences made so far with the development of the electric power transmission systems world-wide, it seems clear that the next step will be the creation of a global electrical network.

Going back in history:

In the beginning of the electrification at the turn of the twentieth century in Central Europe and North America and Japan the first local electrical power supplying networks were built with voltages up to about 100 kV using overhead lines. This power transmission systems were usually connected to small and medium size power generation, often in or close to cities. Also first solid insulated cables were developed. Over the decades the sizes of the power generation units were increasing and the increase length of the transmission lines was also reached by the fact that higher voltage levels could be reached up to today's standard of 400 and 500 kV levels. Hand in hand with this development the electrical utilities grow bigger creating a more or less monopolistic situation in regions of Europe, North America and Japan, sometimes covering complete states. These utilities were generating as much energy as they were using in this region. In Germany, for example, RWE, PreussenElektra, Bayernwerk, in Italy ENEL, in France EDF, or if you look in North America New York Edison, Boston Edison, or Bonneville Power Association. The first goal of the utilities was to serve the customers in their regional area.

During the last decades the connections were made between the different regional networks, mainly by the use of overhead lines, which created in Europe the UCTE in the connected network, NORDEL in Northern Europe, CENTRAL in Eastern Europe, or MAGHREB in North Africa. Similar situations are found in North America and some places in Asia. These regional networks are based on strong local power generation, transmission and distribution related to a region. The next layer in the network are the strong national interconnections with its strong bindings at national levels, e. g. RWE, e-on power exchange. The final level on the top are the continental interconnections, e. g. Europe, to Asia or Africa.

In Figure 1 the five layers are listed. It can easily be predicted that all of these layers will continue its development into the future by increasing power ratings and lengths. This meets the requirement of higher electrical power demand at local regions, mainly in city centres and metropolitan areas. This will lead to a more complex interconnected transmission network on the regional level. Deregulation politics on the other hand is a driver in the field of energy trade over longer distances which will require now transmission capacity on layer 2 and 3. Also the use of new alternative energy sources, like windfarms, or hydropower stations will require new transmission capacity in level 2 and 3 but also on layer 4. Again with the deregulation of the electricity market pressure is given on national and international level so that new power flows will be the result and also new transmission capacity on layer 5 will be needed.

1. Layer:	Local	City (e. g. Frankfurt, Munich)
2. Layer:	Regional	Utility (e. g. RWE, Bayernwerk, PreussenElektra)
3. Layer:	National	State (e. g. Germany, EDF, ENEL)
4. Layer:	International	Interconnected Networks (e. g. UCTE, NORDEL, MAGHREB)
5. Layer:	Intercontinental	Intercontinental Networks (Europe, Africa, Asia, America)

Figure 1: Layers of network

In the past the transmission of electrical energy was mainly carried out by overhead lines, if long distances had to be covered. If overhead lines were not possible, solid insulated cables were used, mainly in dense populated areas, metropolitan areas, or in case of sea laying. With the high sensitivity in the public overhead lines are not seen to be the future solution of power transmission. New underground transmission systems were needed and are found in the technology of solid insulated cables (XLPE) and in gas-insulated transmission lines (GIL), using aluminium pipes for the conductor and Nitrogen/SF_6 gas mixture for the insulation. Both systems are available today and they will be applied in their proper way where they fit best the project needs. Beside the AC transmission systems for long distance power transmission also DC underground transmission systems can be expected in the future. Two effects will make it possible to build long lengths for such underground systems. First, the cost per km have been substantially reduced with the latest developments in this field. From price level of 25 - 30 times the price of an OHL, now the price level is about 5 - 10 of the price of the OHL. Second, the life cycle cost analysis combined with the need of very high rated current of 3000 - 4000 A are in favour of the underground transmission systems cable and GIL.

Contribution to Topic 3: Links characteristics of a world transmission system

The main characteristic for a future world transmission system is certainly the price to build and operate it. But prices can be seen from very different perspectives. Until those days the main indication for evaluating a price was the cost of investment. In the past the thinking was, that the profit made by the power generation and transmission losses were not in the main focus of the profit calculations. Decision were mainly made on investment costs. In Figure 2 the cost factor for the investment cost of transmission systems are shown. The overhead line shows the lowest investment cost, while the investment cost of GIL and cables are higher, depending on the transmission power. If life cycle costs are seen, which include transmission losses, maintenance cost, failure rating cost, and all aspects during lifetime, the calculation changes. The main influence into a life cycle cost study is coming from the transmission losses. In Figure 3 transmission losses of typical transmission systems are shown. The overhead line, the oil and XLPE cable, both grounded or cross bonded, and the GIL in two versions 2000 MVA and 3000 MVA transmission ratings. As the losses are the square of the current at high current ratings, the transmission losses are significant.

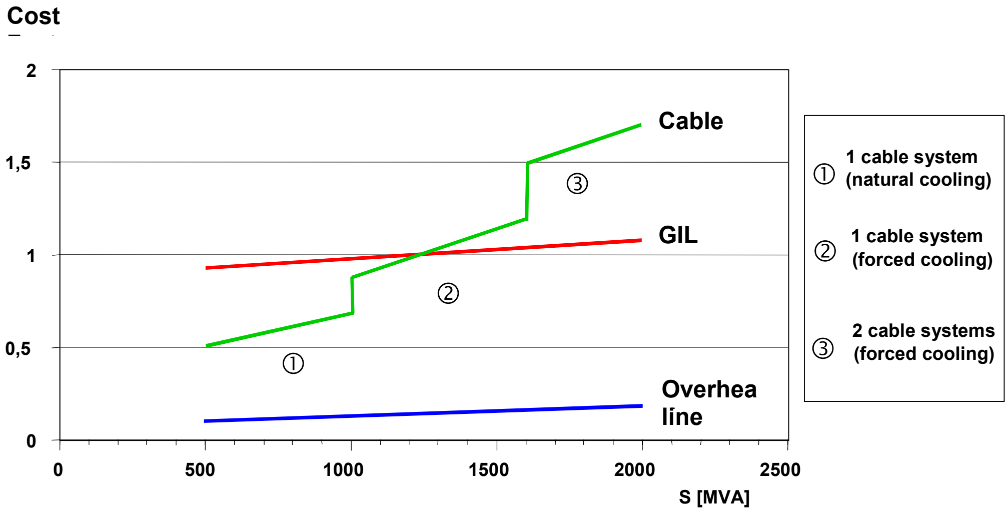

Figure 2: System cost of 420 kV cable, OHL and GIL installations

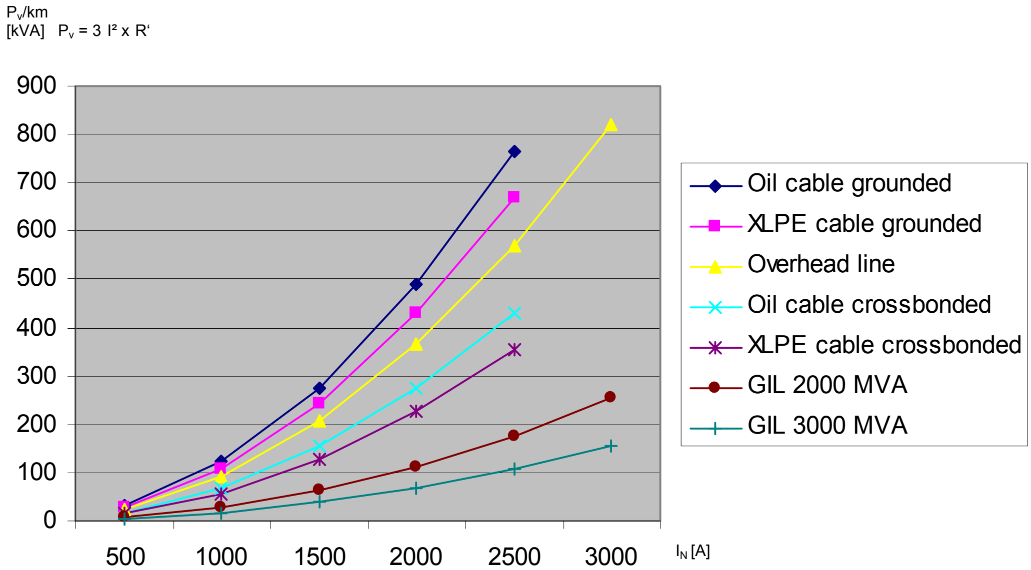

Figure 3: Transmission losses of different 420 kV systems

In Figure 4 the cost differences of transmission losses are calculated for the overhead line and GIL. The values are taken out from Table 3 for 2000 MVA transmission power which is equivalent to about 3000 A. The difference of losses between GIL and overhead line for 100 kilometre system length is 64 MW. To evaluate these losses with the energy price of 5 Euro Cent per kWh are taken. This sums to costs for yearly losses of 27'520.000 Euro, is about 10 % of the investment cost. This calculation only takes into account the ohmsch losses of transmission. Other aspects of low maintenance cost and high reliability are not counted. Also the possibility that the required permits to build a long distance transmission line are easier to get for an underground system.

		OHL	GIL
Transmission power	MW	2000	2000
Losses per system-meter	W/m	820	180
Losses of 100 system-km	MW	82	18
Difference between GIL and OHL	MW	△ 64	
Difference cost of losses per year:			
(Energy price 5 Ct/kWh x 8600 h x 64 000 kW)			€ 27‘520.000
to compare: Investment GIL, 100 km			€ 300‘000.000

Figure 4: Cost differences of transmission losses of OHL and GIL

In terms of a world energy transmission system the future needs can be formulated in high power, long distance, and underground.

Contribution to Topic 4: Advanced technologies, which could be envisaged for electrical links

Most of technologies which will be applied in the next 50 years are known today. Depending on the requirements, borne by the project, different solutions or combinations of solutions are visible. I would like to give two basic ideas:

Idea 1
In a remote area energy resources are available. They need to be transported to the customers over a far distance. Not much population or energy needs are along the way. This could be the case in North Europe, North America, Canada, or places in Asia. The landscape in this rural area today often is widely protected and permit for erecting new overhead lines are very unlikely to get on the total length or on major parts of it. In such a case a DC system using an underground DC gas-insulated line (GIL) can be the solution. The DC-GIL is consisting of 2 pipes and has the ability to transmit 3000 MVA of DC power at a DC voltage of ± 500 kV. Distances of 500 and 1000 km can be covered by such an underground system. The electrical power is then directly transmitted into the load centres, e. g. in Central Europe or the United States. Advantage of such underground systems would be that the enclosure can be fabricated with steel pipes, making this DC-GIL more economical.

Idea 2:
Between existing networks or inside existing networks new links are needed to overcome a continental connection under the sea, like in the Eurotunnel, or through mountains, like long railroad tunnels in the Alps or the Pyrenees, a combination of public tunnels for rail and street traffic are used to establish strong connections between existing interconnected transmission networks. Also in submarine applications high power gas-insulated transmission lines can be laid under sea like pipelines or like sea cables, allowing transmission ratings of 3000 MVA per system over long distances. The way and the procedures of how to lay such an under sea GIL are known, the technology is available in a two step program with a prototype and a pilot project. This technology could be available within 3 to 5 years of time.

The superconductor technology for long distance application still needs to have a material breakthrough to solve the cooling problems along a long distance application. When this is solved, this is unknown, microwave and lasers only can be used if they are encapsulated because in other cases no bird can fly anymore because of microwave or laser beams. Also in the aspect of high frequency transmission system pipe systems like the GIL basically could help to solve such a problem. The energy density is much higher than 50 Hz and the GIL has a very good high frequency transmission capability with low loss factors. So maybe the world fair in 2049 will introduce the first high microwave GIL.