NEW!

>>> **Welcome to Siemens – Highlights & Innovations in Transmission and Distribution**

International Workshop for

800kV High Voltage Direct Current (HVDC) Systems

at the 25th – 26th Feb, 2005 in New Delhi / India

hosted by POWERGRID, India and EPRI, USA

1. Plans for use of HVDC voltage higher than 600 kV

The growth and extension of power grids and consequently the introduction of high voltage levels have been driven by a big growth of power demand over decades. In the next 20 years, power consumption in developing and emerging countries is expected to increase for 220 %.

Priorities in future developments will be given to low costs at still adequate technical quality and reliability. The use of HVDC technology is the solution, especially for bulk power transmission from the remote generating stations over long distances to load centers (ref. Fig.1). In the future it will be necessary to transmit bulk power > 4000 MW over more than 2000 km. Therefore it is important to develop HVDC transmission technologies for voltage levels above ±600 kV.

In countries like Brazil, China, India, South Africa and Russia a number of large capacity hydro-electric projects are being developed with load centers located at distant locations.

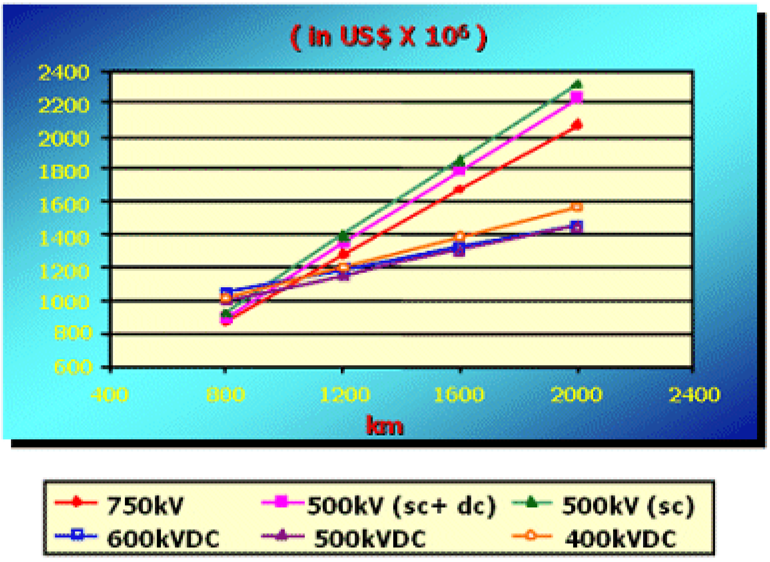

Fig.1: Costs of Transmission Systems AC in comparison with DC
Ref. to Furnas, Brazil:
"New HVDC Projects Under Study in Brazil and Some Experience in ± 800 kV HVDC"

China is planning to cover 26 % of their power demand by hydropower and 60 % by coal-fired power plays in 2020. Unfortunately the distribution of China's power energy resources and consumption center are extremely unbalanced. Now China will choose long distance and large capacity transmission from west to east as well as north to south as strategic plan. 2005 to 2010 is an important period for launching Ultra High Voltage (UHV) projects in China. For example for an ±800kV UHVDC for long distance with large transportation capacity (5400 -6200MW).

The Government of India has taken initiative for harnessing over 50,000 MW power potential in different river basins in the country. POWERGRID has been entrusted with the task of planning and implementing power transmission systems to link generation and load centers. The total power transfer capacity of about 12,000 MW would be required by the year 2016-17 and the length of the transmission lines involved would be in the order of 2000-2500 km. A proposed solution maybe an UHVDC with a bipole rating of 6000MW, ±800kV (2000 km) from the pooling station in NE region to Agra. The realization in two steps: First stage to build a 12-p 600kV valve group (VG) and in the second stage to add a 12-p 200kV VG in series is one realistic option.

In South Africa the WESTCOR JV Project (3500MW-4500MW over **?** km) is another example for planed UHVDCs at ±800kV. As well as the HVDC ±750kV Transmission Ekibastuz – Centre (6000MW, 2400 km) in Russia which was unfortunately stopped during the dissolution of the USSR. Even in Brazil several new UHVDC projects are under study.

2. 800 kV HVDC Converter configuration, Insulation coordination & Test voltage level & Conditions

All these study cases from countries like Brazil, Russia and South Africa show that HVDC transmission at 800kV is feasible and doable, but there are several challenges which have to be considered.
The 800kV HVDC transmission system includes the HVDC transmission line with different requirements for insulation, clearances and corona performance. There is evidence to suggest that several transmission line design companies have and can design an 800kV transmission line.
The converter station is also part of a HVDC. Its design and construction at 800kV is impacted by the following equipment and factors:

- converter transformers,
- external insulation,
- HVDC thyristor valves (valve hall refer to Fig.2)
- External Measuring Devices

Especially the external insulation causes a big challenge. Pollution (particularly urban, by automobiles and industrial as well as salted air, and to a lesser extent by agriculture) affects the steady state and switching surge withstands levels. Under DC voltage insulators electro-statically collect airborne particles so much so that often the flashover level outdoor insulation under DC is lower than under AC voltages.

Fig.2: HVDC Valve hall

External insulation performance

The performance of external insulation in HVDC converter stations is recognized to be the critical factor in determining the reliability of the transmission. Of all the different types of insulators used in a converter station wall bushings especially prone to flashover. Many of the flashovers on the wall bushings have occurred in conditions during which flashovers would not have been anticipated on the basis of contamination level or the degree of wetting that can cause a flashover.

Other insulators than wall bushings such as transformer bushings, reactor bushings, measuring devices housings and to a much lesser degree post insulators have been also experienced flashovers.
The answer maybe the reduction of the number of wall bushings and/or applying adequate surface material with hydrophobic properties. Another opportunity is the use of indoor DC switchyards and the insert of composite bushings and insulators. Higher creepage distances and longer insulators increase the performance of external insulation; therefore new machines for production may be required.
Not only in terms of pollution, but also the large size of insulators represent another challenge for internal stresses and long life especially for bushings. Further development work is needed on internal stresses and relationship between internal and external stresses.

Converter Transformer
One of the most critical components in an HVDC station is the converter transformer. Especially the insulation barrier around the oil end of the valve winding bushing is the critical area of the converter transformer. Its failure in general will mean DC power failure. The future UHVDC projects can not afford to have such failures. At 800kV DC proper design review of this area is recommended. Transport limits and converter configurations determine type and size. Investments in testing facilities are needed.

Testing
The report from EPRI and Cigré 14-32 recommend test levels for 800kV systems which have to be carefully reviewed and considered. The high test levels as well as the larger size of 800 kV equipments are a big challenge for the test availability of testing facilities.
A Siemens 397 MVA / 1 phase / 3 winding converter transformer is shown in Fig. 3.

Fig. 3: Siemens Testing Facility for Converter Transformers

3. Readiness for 800 kV HVDC equipment – Manufacturer's View & Conditions
From the Siemens point of view UHVDC system at 750-800kV is technically feasible. Almost all DC equipments like transformers, smoothing reactors, wall bushings, arresters, disconnectors refer to Siemens Power Transmission and Distribution "**UHVDC System and Equipment**" and are within Siemens product scope. Existing and proven technology can be fully utilized for design, manufacturing and testing of UHVDC equipment. R&D is only needed in the area of valve side bushings and in specific testing facilities. Some design verification shall be made to cover the requirements on creepage distance and mechanical strength of porcelain. Good experience from existing DC systems and modern MO-Arresters allow reasonably reduction of insulation levels from former suggestions.
A coordinating R&D program in few key areas will ensure that the availability of design of the UHVDC equipment for the first application is expected to be within 12 months.
The stage wise development of the UHVDC systems offer the benefits of the gradually increase of power demand, the adding of new power generations in steps and therefore an optimized time period of investments.

In the planning stage the reservation of space for expansion in the station layout as well as the final current, voltage rating and the OHL design have to be considered. The choice of a particular configuration will depend on:

- Economics,
- Reliability and availability,
- Size and weight of the converter transformers and restrictions for transport

A flexible control and protection concept is necessary.

Siemens is the pioneer in designing and delivering HVDC Equipment for the world's first HVDC system at voltage above 500kV (ref. Fig.4).

Fig. 4: Cahora Bassa, Mozambique - South Africa

Our presentation "**6000MW UHVDC System and Stage Implementation**" at the workshop in India shows an example for the stage wise development of the UHVDC system. Series converter groups, parallel converter groups and separate dipole schemes are feasible options for evacuation of large power over long distance. Final selection shall base on overall evaluation taking line length, power rating and time period between stages into account.

4. Concluding Session & Conditions

The development of the 800kV HVDC (UHVDC) does not represent an unreasonable risk. The UHVDC transmission line is the feasible and economical answer for bulk power transmission over long distances to cover the extremely increase of an energy demand in countries like India and China. Nevertheless challenges for external insulation, testing facilities and testing levels, the relationship between internal and external stresses at bushings and the size of the converter transformers have to be managed. For transformer, basic work is needed in understanding short term and long term effects of DC stress and use of appropriated insulation grading and barriers. A coordinating R&D program in few key areas will ensure that the availability of design of the UHVDC equipment for the first application is expected to be within the near future.