

CONCEPT PAPER ON DEVELOPMENT OF UHVAC SYSTEM IN INDIA.

H. Huang*, D. Kumar**, V. Ramaswami*, D. Retzmann*

* Siemens AG, Power Transmission and Distribution, Erlangen, Germany

** Transgridsolutions Inc., Winnipeg, Canada

1. Back Ground

Indian economy is consistently growing at 8-9% GDP growth rate for last few years. In order to sustain the GDP growth, investments in power sector need to match the growing demand of energy across the country. With this view, the Govt. of India has taken initiative for harnessing over 50,000 MW power potential in different river basins in the country. There is large hydro potential in certain regions which is being developed in a phased manner. POWERGRID Corporation of India Ltd. (POWERGRID), the Central Transmission Utility of the country, has been entrusted with the task of planning and implementing power transmission systems to link generation and load centers. The length of the transmission lines involved would be of the order of 2500-3000 KM. So far Transmission voltage in the country has been mainly 400 kV AC with few lines of 800 kV AC also being commissioned recently. Future plans also include construction of a ring of 765 kV transmission lines interconnecting eastern, western and northern regional grids by the year 2010. For Long Distance, Bulk point to point Bulk power transmission, 500 kV DC has been implemented and three HVDC schemes at ± 500 kV are already in operation in the country. In order to meet the requirement of transmitting power from remote generating stations to load centers, it is now felt that there is need to increase the AC transmission voltage beyond 800 kV and explore the possibility of increasing the transmission voltage upto 1200 kV. There are only few countries, which have the power transmission system of 750 kV or more than 750 kV(such as Former Soviet Union, Japanese, US, Canada, Brazil, Venezuela, South Africa) As to 1000 kV electricity system, only former Soviet Union and Japanese have achieved these voltages. The AC voltage above 800 kV has been implemented in:

- 900 kV UHV AC transmission system was constructed in Russia in the year 1985.
- Japanese started building UHV AC system of 1200 kV in the year 1980.

At present China has also started exploring the feasibility of implementing UHV AC transmission system of 1000 kV AC. The UHV system , for which a voltage level upto 1200 kV is foreseen, will be:

- economical transmission of large amounts of power;
- Stabilisation of the power system to withstand large generation and transmission outages;
- Limitation of the number of transmission lines in order to reduce environmental impact and land use.

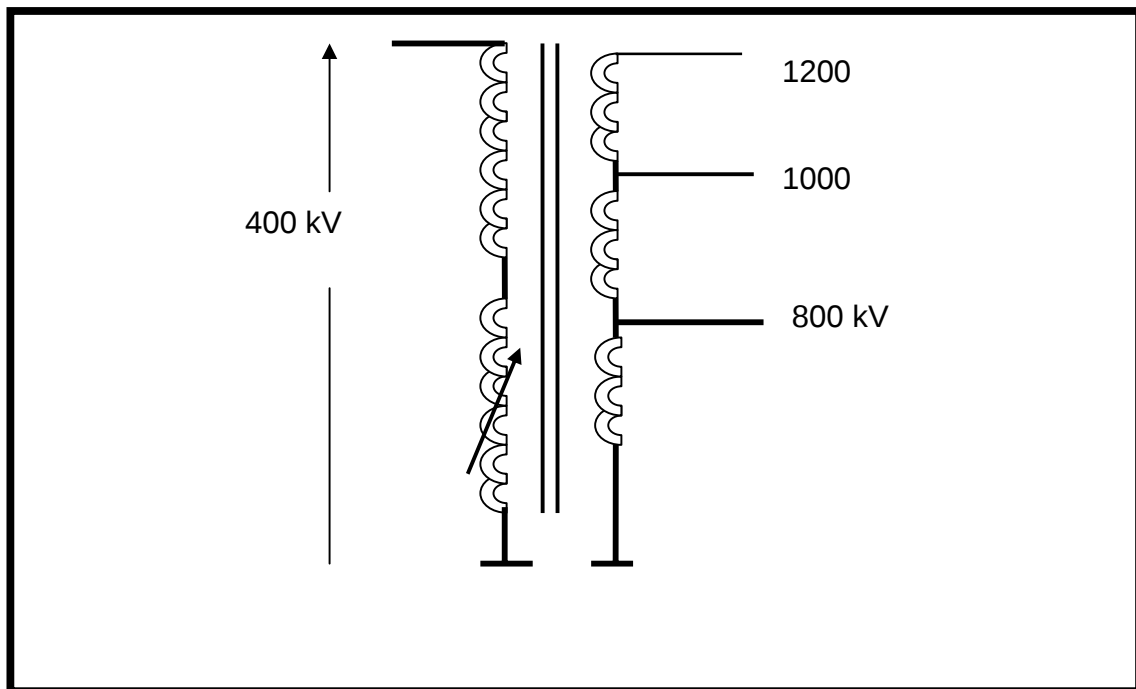
When going to a higher system voltage, the increased transfer capacity of line should justify its increased cost: Estimates by CIGRE indicate that the power transfer capability of a 1500 kV line is 4.2 times larger than that of 765 kV line whereas its cost increases roughly by a factor of 3.5.

The UHV AC power transmission has technically matured even although there is lot of research and development scope to properly optimize the external and internal insulation characteristics of UHVAC transmission and substation equipment. The most important aspect of developing EHV system is that it should not only be technical feasible but also it should be viable and adaptable for commercial operation. If an EHV system meets this requirement of commercial viability then good social benefits shall be obtained by restricting if not lowering the soaring energy prices world wide. In view of the above there is a need to put efforts for developing UHV AC system for achieving commercial viability.

2. Technical issues of UHVAC Transmission System

a) Reactive power management of UHVAC system

The UHVAC transmission line would be generating large capacitive charging MVAR and therefore to limit over voltages under lightly loaded condition and limit switching over voltages, large switch able shunt reactors would be required. A 75-100 percent shunt compensation is foreseen for UHVAC project. Further, as the development of generating stages would be taking place in time staggered manner, it is expected that during initial years of operation, the UHVAC transmission line would remain lightly loaded for considerable period. This would make task of reactive power management more onerous. One of the possible arrangement proposed to manage reactive power could be by making variable tap transformer with switching between taps as shown below:



Under lightly loaded condition, taps at 800 kV could be used and we can have switching arrangement to select higher taps at 1000 kV and 1200 kV as the loading of the transmission line increases. The Switching arrangement could be based on anti-parallel connected thyristor valves or fast speed Circuit breakers depending upon the requirement of the system.

b) Insulation of Transmission line.

Overhead line insulation is guaranteed by the air clearance and the insulation withstand capability of the insulator strings. These two types of insulation have to withstand various over voltage in the system operation such as power-frequency over voltage, switching – impulse over voltage and lightning –impulse over voltage. Further, because the line is in atmosphere, it will be influenced by natural phenomenon such as the wind, the rain, the snow and pollution . The insulation characteristics of UHV line under different voltage in practical natural situation is extremely important for electrical design and safety in operation of the system. When the voltage is very high, such as 1000 kV, we cannot solve the insulation problem by extrapolating the design for lower voltages because the relationship between long gap and disruptive discharge voltage is non-linear relationship

and these are related to the arrangement of the electrode configuration. It is necessary to study long gap external insulation characteristics in high altitude according to practical sample arrangement. The influence of pollution, altitude, insulator profile needs a detailed evaluation and testing for UHVAC system. Proper choice of equipment design and tower configuration could reduce substantially the construction investments of UHVAC project.

c) Over voltage & Insulation levels

Based on studies summarized by CIGRE WG , expected overvoltage levels for nominal operating voltage of 1000-1200 kV are:

- maximum temporary overvoltage : 1.3 -1.4 pu
- statistical switching overvoltage : 1.72 pu
- SIL(Power Transformer, Shunt reactors) :2100 kV
- LIWL(Power Transformer, Shunt reactors : 2250 kV
- LIWL (Switchgear, CTs, insulators,CVT) : 2900 kV

d) UHV line Design: transmission Capacity, land occupation, Corona and lightning performance.

The Design parameters of UHV lines shall be in the range of

- thermal capacity 10,000 MVA
- Surge impedance loading 4500 MVA
- Expected audible noise values at 15 m from the outer conductor – 56-58 dbA for wet conductors.
- The radio interference(RI) level at 15 m from the outer conductor -80 percent value of the overall statistical distribution – 60 dB
- Maximum electric field at ground, with a 15 m height of the conductors above ground, shall be between 11 and 15 kV/m
- Lightning caused outage rate < 0.1% per 100 km year.

3. Economic comparison between EHV and UHV AC transmission system

In the past great emphasis was given in comparing between EHV AC and HVDC technique. But AC and DC transmissions can not be directly compared only on the basis of cost. The transmission system shall be compared first on technical basis by taking

into account adaptability and most modern and extremely fast control features e.g. modulation control, swing control, frequency control, active and independent active and reactive power control, power direction control etc. UHV ac and 400 kV or 765 kv ac transmission systems can be directly compared because both the system are utilizing same philosophy for bulk energy transfer. Studies of cost comparison carried out by State Grid of China indicate if a power of say 10000 MW is to be transferred over a distance of say 1200 kms, considering the investment, operating cost and losses, following cost can be put:

- Cost of UHV AC (1200 kV) transmission is 2.6 billion Yuan (1 US\$ = 8 Yuan)
- Cost of EHV transmission system having three to four circuits running parallel is 3.1 Billion Yuan

Apart from that most important consideration is lack of right of way even if one is ready to pay higher land cost. Pit head generation of power shall be cheaper than the power being generated at load centers. However it depends upon many factors like cost of the coal, cost of coal transportation, quality of coal with respect to its ash contents and on the other hand the power evacuation network which has been chosen to feed to load centers. This means whether it is AC or DC transmission, quantum of power to be transferred and transmission voltage etc. Coal transportation cost of generation near load centre becomes more significant when coal has high ash contents. Normally difference between pit head generation and load centre generation is typically 250 to 350 Yuan/ton. Cost of power transfer at 1200 kV AC for a distance of about 1100 kms is 0.06 yuan/kwh.

Other important aspect to be considered is as follows:

- The day by day more and more generating units are added up in the power system and in order to match with it more transmissions lines shall be added at EHV level. This shall progressively increase fault level of the various EHV buses and at one stage situation shall definitively come when fault level at various buses shall exceed their fault current rating and it shall require replacement of all circuit breakers with higher fault current rating. In case UHV transmission system is adopted , the fault rating of the EHV system shall be more or less same and

additional power generation may be catered by UHV system and there by no additional cost on EHV system shall be incurred.

- By generating power at coal heads and transporting the energy by EHV transmission system to load centers, the pollution of land , air and water in and around load centers may be contained. Disposal of ash and Pollution of water, air etc near big cities has become a major problem which is difficult to be solved.
- By pit head generation, the load on railways is also reduced, environment is protected, uncertainty coupled with coal transportation is also reduced.

4. Demonstration of financial viability

On the field EHV technology was field tested to check technical feasibility. However, elaborate field testing shall make its way clear for commercial operations in future.

In China for UHV demonstration project, three substations and two lines are used. Southeast Shanxi and Jinmen substations each having a transformation capacity of 3000 MVA, Nanyang substation is the switching station, the south east shanxi-Nanyang-Jinmen line is 645 km long. The total system cost excluding dynamic compensation cost is reported as 5890 million Yuan and cost of dynamic compensation is 6070 million yuan. It is expected that transmission capacity of this project shall become 3200 million kwhr and by the year 2010, the total energy handled is expected to be 10000 million kwhr and ultimately it shall touch 15000 million kwhr mark.

The initial cost per unit energy transfer is 0.006 Yuan/kwhr for experimental project is higher than EHV transmission because of the following Reasons:

- Energy being transferred over the experimental project is low that means there is low utilization of the project.
- Secondly being first UHV project, the entire R&D cost has been booked to this experimental UHV project.

Due to these reasons it can be definitively concluded that the energy transfer cost of mature technology shall be much lower than the cost of energy of the demonstration project. This will opens further application possibilities in other part of the world.