



Next Generation of UHVDC System

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SUMMARY

Energy reliability and availability is of high demand in today's world. This in conjunction with an electric energy market forecast average growth rate of 9% [1] imposes an average increase of the installed power of 11% on the Transmission System Operators and Power Delivery/Generation Companies. Unfortunately in the majority of the cases worldwide, the energy resources capable to cope with the future electricity demand are not nearby the load center. The need of interconnecting the forecast power plants encourages the need and development of new generation UHVDC transmission systems. The need for higher voltage systems capable to cope with the high energy demand, reduce the transmission losses and lower right of way is inherent. The following article summarizes the challenges overcome on the development of new generation of Ultra High Voltage DC Systems with a maximum voltage rating of 1100 kVDC

KEYWORDS

Ultra High Voltage Direct Current (UHVDC), Transmission systems, Bulk Energy Transmission Corridors

Introduction

Today society had a strong dependence on the electric power network. Consumers are expecting a reliable, high quality and clean electricity supply. In this regards, electric energy market had a forecast average growth rate of 9% [1]. In order to cope the forecast power supply companies would require to had an average increase of their installed power of 11%

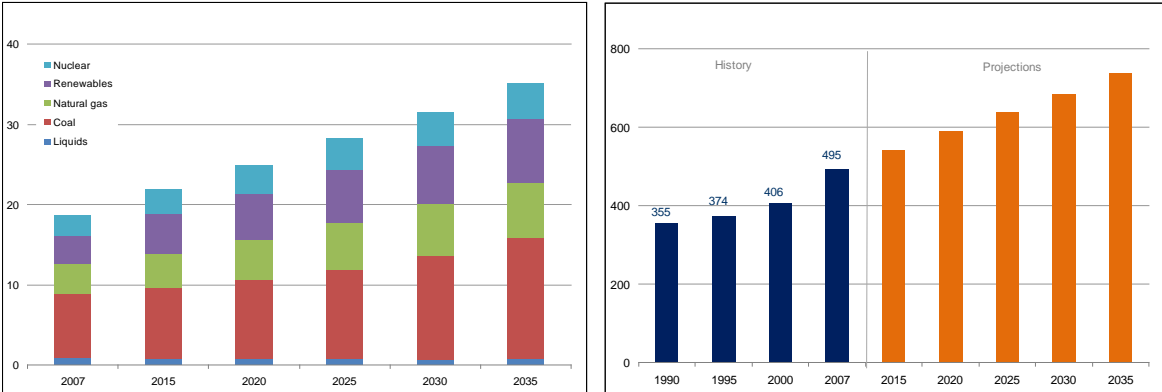


Figure 1: (a) World electricity generation by fuel (2007-2035) in trillion kilowatthours; (b) World marketed energy consumption (1990-2035) in quadrillion Btu

Unfortunately, the bulk energy resources are not located nearby the load center. For example, in China large resources of untapped hydro power generation is available, up to 500 GW. The location of generation is in western China in Sichuan, Xizang, and Yunnan provinces. In addition some coal fired generation in Xinjiang province is planned. The distance from all these generation sources to the heavy industrialized regions along the coast in eastern (Beijing, Shanghai) and southern (Guangzhou) part of China is 1000-3000 km. This problem has become more complex with strong public resistance, narrow transmission corridor, limited availability of Right Of Way, minimum transmission line route through forest and protection of flora and fauna for large blocks of power and long length of the transmission corridor. Primarily because of the difficulties to build overhead lines, the government of China is investigating the possibility to use a voltage rating of 1100 kV for power transmission of 10.000-13.000 MW per transmission in order to achieve as much power per line as possible for distances over 1000 km. For those transmission system bellow 1000 km the Chinese government had been considering increasing the rating current of 800 kVDC systems. Despite the maturity of HVDC technology , this new ratings, voltage or current, represent a major technological step that will be taken in a very short time.

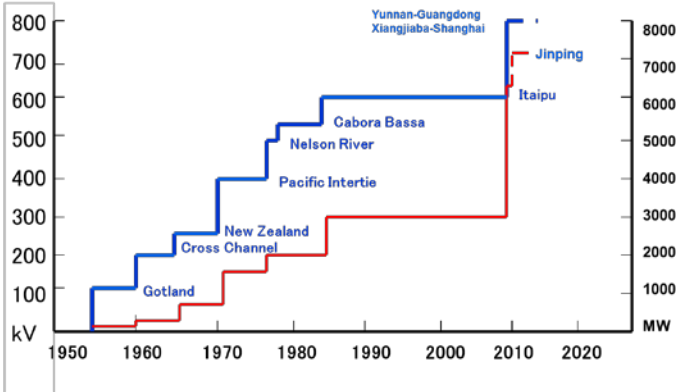


Figure2: HVDC systems evolution. Blue Line: Voltage Rating. Red Line: Power Rating.

Technical Economical Solution

A cost effective transmission system capable of handle bulk energy of 10.000 MW or more is necessary. In the recent years, 800 kVDC transmission systems had been in operation, capable to transmit over 0.7 GW over 1400 km. However, when the transmitted power is increased (> 10GW), 800 kV system become not economical feasible because it is not possible to transmit this energy by a single UHVDC link, instead two transmission link will need to be built.

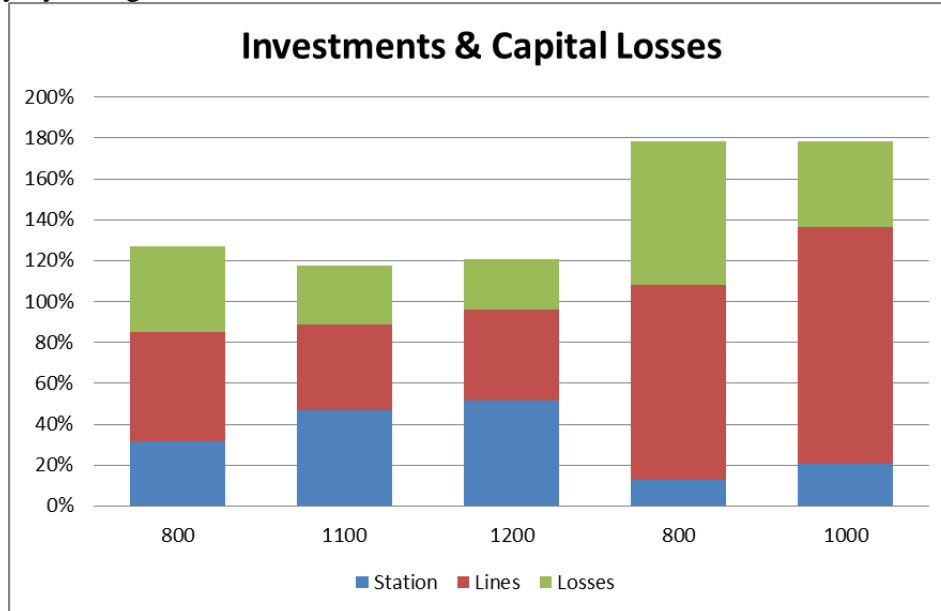


Figure3: Cost comparison for 800 kVDC – 1200 kVDC and 800 kVAC – 1000 kVAC

This estimate are based on the following assumption based on today's technology

- 1 HVDC lines, 10.000 MW, 800 kV
- 1 HVDC lines, 10.000 MW, 1000 kV
- 1 HVDC lines, 10.000 MW, 1200 kV
- 3 HVAC lines, 3167 MW, 800 kV
- 3 HVAC lines, 3167 MW, 1000 kV

The UHVDC system need to cope with an effective energy cost. There is no question that when increasing the voltage, the losses are reduced and the target energy cost could be achieved. However, to be able to cope with a target energy cost while increasing the current rating for 800 kVDC systems will need a development of different system components, especially thyristor valves.

Challenges

Availability and reliability

UHVDC systems design to transmit over 10.000 MW needs to cope with higher requirements on availability and reliability. One single pole trip will disconnect energy equivalent to half of the installed capacity of the largest hydro power plant today in the world, e.g., Itaipu installed capacity: 12.000 MW. This will also impose high requirement and strength on the AC systems at both ends of the UHVDC transmission. Thorough investigations are necessary to minimize an escalation of a single event at regions where multiple UHVDC systems will be

feeding the transmitted energy. That means that the reliability of the transmission is a very important issue and has to be a major design parameter.

Electromechanical Design and Equipment transport

Difficulties had been encountered in the design of outdoor insulators. It is difficult to fulfill, both the insulation and the mechanical requirement. This is because that, a higher voltage together with high pollution level requires longer insulators. To fulfill the mechanical strength for such a long insulator, the diameter of the insulator needs to be increased. However, an increase in diameter will result in a decrease in the pollution perform of this insulator. To compensate such effect, further increase of the insulator length may be required. Following this loop, the risk was a “run-away” situation [2].

Furthermore, high voltage equipment subjected to new rated voltage will also increase in size. As example, converter transformers need to be assembly, tested and shipped to site. Due to the new voltage requirements this might not be possible in the existing facilities and therefore, site manufacturing had been assessed as an alternative for the new rating voltages. Electrode size, corona shielding, terminal forces, etc. need to be properly design to guarantee a cost effective solution with the reliability that this new generation of UHVDC systems required.

Indoor vs. Outdoor DC Yard

Today, both outdoor and indoor DC yards have been adopted by different 800 kV UHVDC projects. However, the operational experience at this voltage level is still limited [2]. Other reason for selecting indoor solution is to obtain a more compact design, minimizing the footprint of the converter station. For equipment within this weather protected building, the creepage distance needed and the mechanical strength required can be reduced. Switching impulse voltage will be the dimensioning parameters. Smooth electrodes with a larger diameter can therefore be adopted to reduce the required air clearance [2].

In comparison to outdoor solution, the cost of indoor solution is higher because the cost of the building. Depending on the requirement for the ambient conditions inside the hall, auxiliary equipment such as humidity controller may need to be installed [2]. However, the building costs will partly be compensated by the reduced cost of apparatus. A reduced risk of failure is the major benefit of the indoor solution. A long term outage will due to risk associated with outdoor design will cover the cost difference associated with the indoor solutions.

Application for the new UHVDC systems

China economy had an average growing rate of around 12% continuously for the last thirty years. The improvement on people's wellbeing and economy growth is closely related with increase requirements of energy. To cope with the electricity demands, China had pioneer in implementing new high voltage systems, at AC and DC level. These are the most effective practices to accomplish a reasonable target energy cost. Being the first country to commission and have in full operation of 800 kVDC transmission systems, more than 21.000 GW of transmission capacity is solely installed at this rating voltage. Economy growth is further expected in the coming years and therefore need for new transmission systems are expected. After year 2020, it is planned to develop another seven hydro power projects in Xizang totally rated 110.000 MW for transmission to the east and south provinces of China. To enable the bulk transmission of the require electricity imposes the seek for next generations of UHVDC

systems, at new rated voltages, i.e., 1100 kVDC or at existing voltage rating with higher current capabilities. Presently there is not market interest for the new UHVDC transmissions systems elsewhere in the world beside China. However, when utilizing far away located hydro and solar generation in Africa, India, USA and South America, applications may arise for these new generations of UHVDC transmissions systems.

ABB Technology development

Since 2011 ABB started R&D activities necessary for the technology development of the key components for next generation of UHVDC transmission systems, i.e., those exposed to the new rating voltage (1100 kVDC). By means of advance electromagnetic simulations, transient studies and high voltage testing ABB had developed prototypes for converter valve, valve hall design, converter transformer, by-pass switch, radio interference capacitors, surge arresters, transformer bushing and wall bushing.

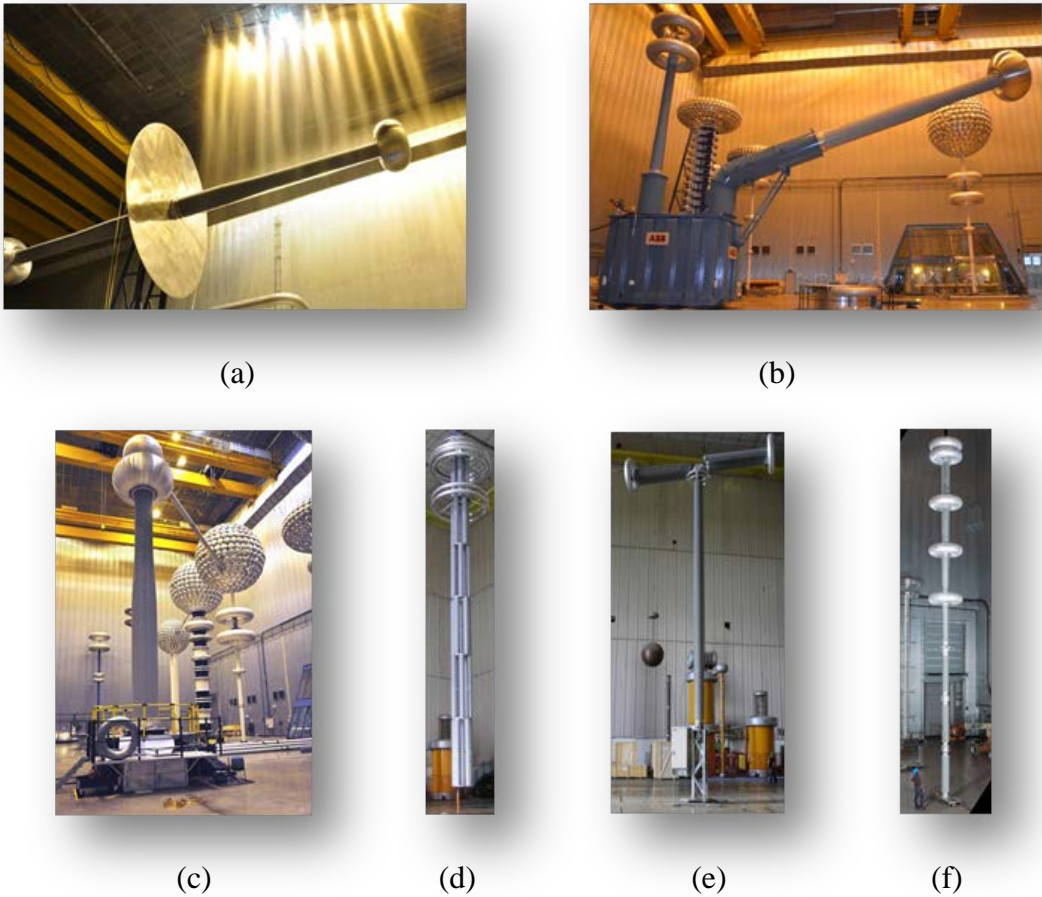


Figure 4: 1100 kV Prototypes: (a) Wall bushing, (b) Converter transformer mock-up, (c) Transformer bushing, (d) Pole arrester, (e) By-pass switch, (f) Radio Interference Capacitor (RIC).

Also, conceptual design for stations layout and indoor DC yard had been developed.

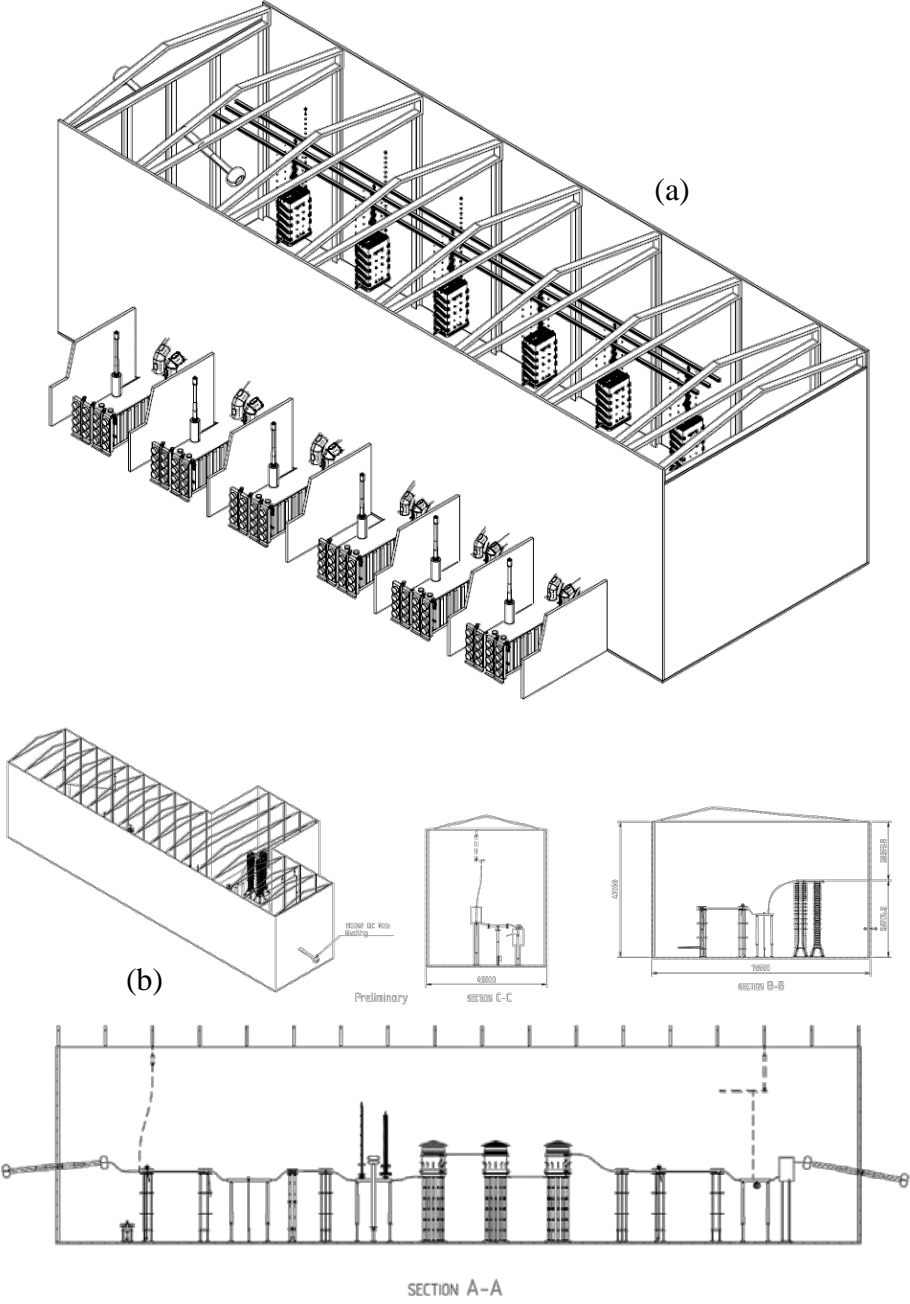


Figure 5: Conceptual design: (a) Valve Hall, (b) Indoor DC Yard.

Final remarks

Unfortunately in the majority of the cases worldwide, the energy resources capable to cope with the future electricity demand are not nearby the load center. The need of interconnecting the forecast power plants encouragement the need and development of new generation UHVDC transmission systems. The need for higher voltage systems capable to cope with the high energy demand, reduce the transmission losses and lower right of way is inherent.

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