Analysis of Potentiality of HVDC in Future Power System in Bangladesh

Rupak Kanti Dhar[1], Md. Rifat Hazari[2]

[1, 2]Department of EEE, American International University-Bangladesh (AIUB),
Banani, Dhaka 1213, Bangladesh

Abstract: ***In order to satisfy the Power demand, Bangladesh need advance technologies to establish a promising Power sector. Some of literatures have described the effectiveness of High Voltage Direct current transmission (HVDC) over traditional transmission system. This article gives a background to HVDC transmission in general and demonstrates how HVDC Transmission can be implemented in Bangladesh Power network and could be used as backbones to establish strong and fully controllable transmission links and thereby strengthening and increasing the reliability and availability of the electrical transmission system. Again from the discussion of smart grid, cost and loss comparison in different types of transmission line it is suggested that HVDC transmission could be a new approach for the future power system of Bangladesh and would be more cost effective than the traditional power transmission system.***

Keywords: HVAC, HVDC, VSC converter, LCC converter, Interconnection links, Smart grid.

1. Introduction

AC voltage conversion is simple, and demand little maintenance. Further three-phase generator is superior to DC generator in many aspects. Those reasons causes that AC technology is today common in production, transmission and distribution of electrical energy. However alternative current transmission has also some drawback which can be compensate in DC links. No effect of capacitive and inductive elements, point to point transmission of different frequency, Low transmission loss, ability to rapidly control are the reasons why DC technology has been chosen instead AC [1]. Utilizing HVDC links for long-distance transmission and for interconnecting HVAC grids is proven technology that has been in use for many years [2]. The first commercial application of HVDC transmission was between the Swedish mainland and the Island of Gotland in 1954 and they used mercury-arc valve and provided a 20 MW underwater link of 90 KM. With the advantage of thyristor valve converters, HVDC transmission becomes even more attractive. The first HVDC system thyristor valve was the Eel River scheme commissioned in 1972, forming a 320 MW back-to-back dc interconnection between the power systems of the Canadian provinces of New Brunswick and Quebee. Thyrirstor valve have now become standard equipment for dc converter. Recent developments in conversion have reduced their size and cost and improve their reliability. In North America, the total links in 1987 was over 14,000 MW and more links are under construction [3]. Some advantages of HVDC over AC transmission are as follows:

- HVDC is more economic and lower losses than AC for transmitting large amounts of power point-to-point over long distances. Even though HVDC conversion equipment at the terminal stations is costly, overall savings in capital cost may arise because of significantly reduced transmission line costs over long distance routes. Depending on voltage level and construction details, HVDC transmission losses are quoted as about 3.5% per 1,000 km, which is less than typical losses in an AC transmission system.
- HVDC needs fewer conductors than an AC line, as there is no need to support three phases. Also, thinner conductors can be used since HVDC does not suffer from the skin effect. These factors can lead to large reductions in transmission line cost for a long distance HVDC scheme.
- HVDC schemes can transfer power between separate AC networks. HVDC power flow between separate AC systems can be automatically controlled to provide support for either network during transient conditions, but without the risk that a major power system collapse in one network will lead to a collapse in the second. The combined economic and technical benefits of HVDC transmission can make it a suitable choice for connecting energy sources that are located far away from the main load centers.

Bangladesh is a country of population, and always has a power generation and transmission problem with a high cost. It never could meet with the Public demand because of its various problems. In Bangladesh, total installed capacities in public Sector is 5,962 MW (58%) and in private sector 4251 MW (42%), so total 10213 MW [4]. But maximum power demand served 6675 MW. To overcome the power problem it was necessary to import electricity in Bangladesh. A revolutionary step has been taken that South Asia’s first-ever HVDC interconnection between India- Bangladesh a 500 megawatts (MW) HVDC substation at Bheramara, about 27 kilometers in 400 kilovolt transmission lines a key step forward in regional power sharing and cooperation. HVDC is the latest technology has been using in all over the world could be bless for Bangladesh power system. In Bangladesh HVDC links could be use as interconnector of two HVAC grids, as high voltage transmission link from district to district connections and as a smart grid links. HVDC could be the key technology with several new applications to transition of power grids based on sustainable generations like solar cell and wind turbine.

2. Components in HVDC Systems

The main components associated with the HVDC system as shown in Figure 1 and the description of the main components is as follows:

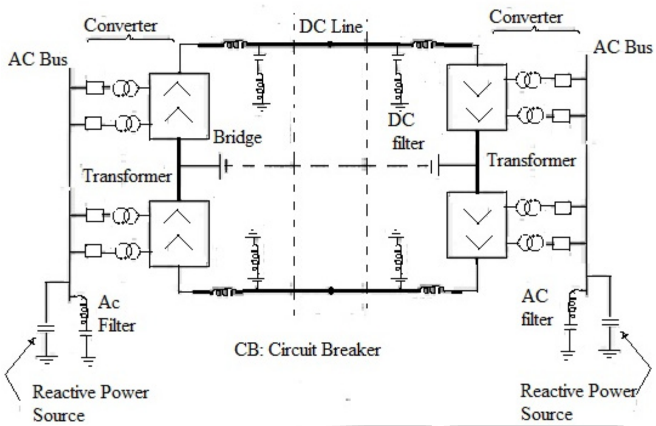

Figure 1: A schematic diagram of a bipolar HVDC System [3]

2.1 Line Commuted Converter (LCC) and Voltage Source converter (VSC)

Converter perform ac/dc or dc/ac operation. It consists of valve bridges and transformer with tap changers. The valve bridges consist of high voltage valves connected in a 6pulse of 12 pulse arrangement. Mainly two types of converter used in HVDC system. These are Line commuted converter (LCC) and Voltage source converter (VSC). The LCC HVDC technique, introduced in the early 1950s, employs line-commutated CSCs (Current Source Converter) with thyristor valves. Such converters require a relatively strong synchronous voltage source in order to operate. Figure 2 shows a classical HVDC converter station with Line commutated current source converters. The technology is well established for long for high power around. More than 100 projects in the world established based on LCC HVDC technique [5].

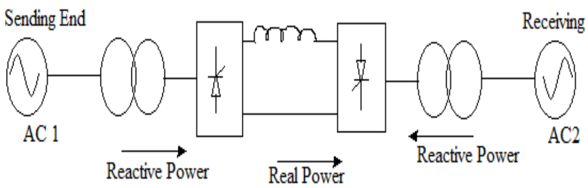

Figure 2: HVDC system based on LCC technology with thyristors [6].

VSC-HVDC is a transmission technology based on voltage source converters (VSC) and insulated gate bipolar transistors (IGBT). The converter operates with high frequency pulse width modulation (PWM) and thus has the capability to rapidly control both active and reactive power independently of each other to keep the voltage and frequency stable. The Maximum power of bipolar VSC HVDC is 1200 MW with cables and 2400 MW with overhead lines Figure 3 shows a HVDC Light® converter station [5].

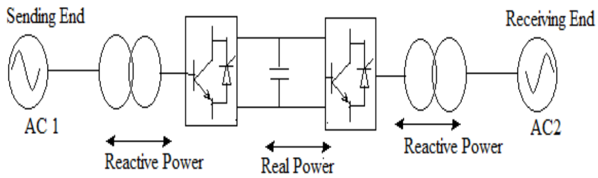

Figure 3: HVDC system based on VSC technology built with IGBTs [6].

LCC-HVDC and VSC-HVDC can both be used for the following typical applications:

- Long-distance bulk power transmission
- Underground and submarine cable transmission
- Interconnection of asynchronous networks

New converter designs have significantly extended the range of applications of HVDC transmission. In particular, Self-commutation, dynamic voltage control, and black-start capability allow compact VSC-HVDC transmission to serve isolated loads on islands or offshore production platforms over long-distance submarine cables. Table 1 summarizes the main characteristics of the LCC-HVDC and VSC-HVDC technologies.

Table 1: Comparison of VSC and LCC technology [7]

Technology	*HVDC Classic (LCC)*	*HVDC Light (VSC)*
Semiconductor(Control)	Thyristor (Turn on only)	IGBT (turn on/off)
Power Control	Active Only	Active/Reactive
AC Filters	Yes	No
Minimum Short Circuit Ratio	>2	0
Black Start Capability	No	Yes

For HVDC technology, whether LCC or VSC, there are no such technological limits, neither for the length of overhead lines or for submarine cables. Due to the capability of combining VSC technology and low-weight, extruded polymer insulated cables with their prefabricated joints; this technology is well suited for very long underground transmissions. Due to the somewhat different applications for the two different HVDC technologies, LCC is presently being used for transmissions using overhead lines and for submarine cables, while VSC is used for submarine cables, underground cables and to some extent for overhead lines. This does not reflect any limitations due to the respective technologies, but is instead a result of different market demands.

2.2 Smoothing Reactors and Reactive Power Supply

Smoothing reactors are in series with the converter [3]. They serve for decrease harmonic voltages and currents in the dc line, Prevent commutation failure in inverters, limit the crest current in the rectifier during short circuit on the dc line. Under steady state condition the converter absorbed reactive power, this is about 50% of the active power. Under transient condition the absorption is much higher. So, reactive power suppliers are provided near the converters [3]. On the other hand harmonic filters used both in dc and ac sides to eliminate the harmonic voltages and currents. The other components are DC lines, Ac circuit breaker, Electrodes etc.

3. Control and Stabilization of HVDC System

3.1 HVDC as System Controller

An HVDC system is highly controllable. Its effective use depends on appropriate utilization of this controllability to ensure desired performance of the power system. The following consideration influences the selection of control characteristics:

1. Prevention of large fluctuations in direct current due to variations in ac system voltage.
2. Maintaining direct voltage near rated value.
3. Maintaining power factors at the sending and receiving end that is as high as possible.

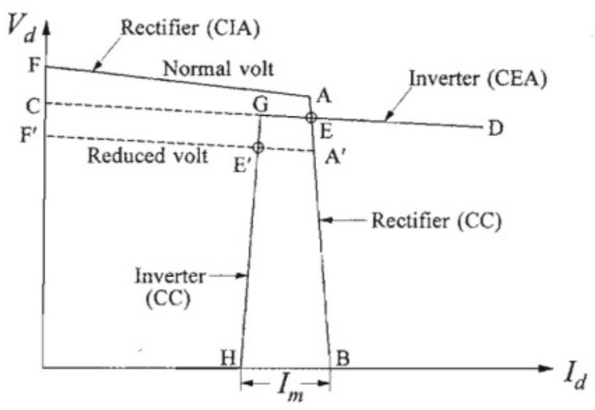

Figure 4: Actual converter control steady state characteristics [3]

The rectifier maintains constant current by changing delay angle (α). However, α cannot be less than its minimum value (αmin). Once αmin is reached, no further voltage increase is possible, and the rectifier will operate at constant ignition angle (CIA). Therefore, the rectifier characteristic has really two segments (AB and FA) as shown in Figure 4. The segment FA corresponds to minimum ignition angle and represents the CIA control mode, the segment AB represents the normal constant current (CC) control mode. The Constant extinction angle (CEA) characteristic of the inverter intersects the rectifier characteristic at E for normal voltage. However, the inverter CEA characteristic (CD) does not intersect the rectifier characteristic at a reduced voltage represented by F'A'B. Therefore a big reduction in rectifier voltage would cause the current and power to be reduced to zero after a short time depending on the dc reactors. The system would thus run down. Such a phenomenon corresponds with unstable system behavior. In order to avoid the above problem, the inverter is also provided with a current controller, which is set at a lower value than the current setting for the rectifier. The complete inverter characteristic is given by DGH, consisting of two segments: one of CEA and one of constant current. The difference between the rectifier current and the inverter current order is called the current margin, denoted by Im. Under normal operating conditions, the rectifier controls the direct current and the inverter controls the direct voltage. With a reduced rectifier voltage, the operating condition is represented by the intersection point E'. The inverter takes over current control and the rectifier establish the voltage. In this operating mode the role of the inverter and rectifier are reversed. The change from one mode to another is referred to as a mode shift. Therefore the above curve determines the power stability [3].

3.2 HVDC as System Stabilizer

HVDC allows power transmission between unsynchronized AC distribution systems. It can help increase system stability, by preventing cascading failures from propagating from one part of a wider power transmission grid to another. Changes in load that would cause portions of an AC network to become unsynchronized and to separate, would not similarly affect a DC link and the power flow through the DC link would tend to stabilize the AC network. The magnitude and direction of power flow through a DC link can be directly controlled, and changed as needed to support the AC networks at either end of the DC link. This has caused many power system operators to contemplate wider use of HVDC technology for its stability benefits alone.

4. Solution for Smart Grid with HVDC in Bangladesh

To deliver the promised benefits of the smart grid and satisfy the stability, seamless interconnectivity, real-time information for customers and grid operators the country's aging, isolated AC grids will have to be replaced by a robust new transmission network and that future dream looks like it will HVDC power lines, which are super-chilled to boost capacity and can carry Gigawatts of electricity. India, China and Brazil are well advanced in the development of remote hydroelectric power plants. Brazil is now considering ever longer transmission distances, with the planning of hydroelectric development in the Amazon region. In Africa we also see plans to develop large hydroelectric projects with very long transmission distances Using HVDC [8].

A remote wind power farm could be connected with either HVAC or HVDC. Depending on the size of the wind farm, along with grid conditions, the use of HVDC is applicable where the distance to the connecting AC grid exceeds 40-70 km. When connecting a wind park to the main grid by means of a VSC transmission system, the wind park can easily be electrically separated from the main grid. This results in several technical and economical benefits for transmission system operators (TSOs), wind park developers and wind turbine generator manufacturers. Perhaps most importantly for TSOs is that a VSC-connected wind park becomes comparable to a normal power plant (although a generation with intermittent operation); the main grid-side of the VSC converter can be directly connected to a control or power dispatch center [2].

In Bangladesh leading power stations are Ghorashal Power station (950 MW), Horipur Power plant (100 MW), Meghnaghat Power station (450 MW), Shiddirganj ST (210 MW), Horipur EGCB 360MW, Ashuganj Power Station (724 MW), Bheramara (150 MW), Summit Power (182 MW), Kaptai Hydro Power plant (230 MW) [4]. In Table 2 the percentage of generation according to power plant has been shown.

Table 2: The Total Installed Capacity In Bangladesh

Power plant type	*Capacity MW*	*Percentage*
Hydro	230 MW	(3.95 %)
Steam	2638 MW	(45.31 %)
Gas Turbine	1466 MW	(25.18 %)
Combined Cycle	1263MW	(21.69%)
Diesel	226 MW	(3.87 %)
Total	5823	(100.00%)

In Bangladesh generated electrical power from hydro, steam, gas turbine are transmitting through HVAC links, But from the earlier research it is seen that HVDC requires less cost and loss is minimized in this technology. So the generated power should be e transmitted through HVDC lines to the National Grid which would be more stable and Cost effective. All types of installed power plant in Table 2 are not sufficient to fill up the present power demand, So the government of Bangladesh is thinking of alternative power source like solar and wind power plant which are known as sustainable energy. Now adays smart grid is a modernized electrical grid that uses information and automatic technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity. To implement a Smart Grid network in Bangladesh it is essential to interconnect the entire sustainable energy source to National grid. Bangladesh Power Development Board (BPDB) has already implemented three solar projects in Juraichori Upazilla, Barkal Upazilla and Thanchi Upazilla of Rangamati District. Total of 173.81 kWp Solar PV Systems have been installed in Juraichori, Barkal and Thanchi upazilla of Rangamati District under the Hill Tracts Electrification Project. In 2012-2013 BPDB has implemented 27.2 kWp Solar Power System at Chandpur 150 MW Combined Cycle Power Plant. Many projects like 650 KWp (400 kW load) Solar Mini Grid Power Plant at remote Haor area of Sullah upazila in Sunamgonj district under Climate Change Trust Fund (CCTF) on turnkey basis in going on [4]. Around 200-250 kWp solar system has been installed in chitagong division and installations of about 407 kWp solar PV systems are under planning/implementing stages.

In Bangladesh the potential of wind energy is limited to coastal areas, off-shore islands, rivers sides and other inland open areas with strong wind regime. In order to generate electricity from Wind Energy, BPDB installed 4x225 KW = 900 KW capacity grid connected Wind Plant at Muhuri Dam area of Sonagazi in Feni. Another project of 1000 KW Wind Battery Hybrid Power Plant at Kutubdia Island was completed in 2008 which consists of 50 Wind Turbines of 20 kW capacities each. Steps have been taken to install 15 MW Wind Power Plant across the coastal regions Muhuri Dam Area of Feni, Mognamaghat of Cox'sbazar, Parky Beach of Anwara in Chittagong, Kepupara of Borguna and Kuakata of Patuakhali. Toatl 1900 KW wind power plant has been istalled in Feni and kutubdia and around 2000 kW wind plant is planning to establish in Chitagong region. The generated power from wind turbine can be directly connected to the power grid using VSC converter. One of the superior features of HVDC is the easy control strategy and it deliver a great performance for combine power plants. So the generated sustainable power from Solar and Wind power plant in South Zone could be cascaded using HVDC link and the dreams of set up a smart grid will come true in Bangladesh.

5. Interconnection Link through HVDC

Although interconnecting different frequency AC networks is one of HVDC applications. Ongoing projects are coming soon to connect a 60 Hz network to different 50 Hz networks. Transmission of energy between two asynchronous alternating current (AC) networks like Turnkey Project Alstom Grid Back-to-Back system gives their own system more flexibility and can prevent them from having to build a new generation network. The power flow is fast and accurate and prevents widespread blackouts from occurring [9].

Again VSC based HVDC transmission is investigated for interconnection of two very weak ac systems. By using the recently proposed power-synchronization control, the short-circuit capacities of the ac systems are no longer the limiting factors, but rather the load angles. As an example, it is shown that the proposed control structure enables a power transmission of 0.86 p.u. from a system with the short-circuit ratio (SCR) of 1.2 to a system with an SCR of 1.0. This should be compared to previous results for VSC based HVDC using vector current control. In this case, only 0.4 p.u. power transmission can be achieved for dc link where only one of the ac systems has an SCR of 1.0 [10].

In recent years, with deregulation and the addition of more and more renewable energy sources, the number of built and planned HVDC interconnections has risen significantly. The increased installation of wind power, requiring back-up regulating power, also increases the demand for HVDC interconnections. For example, the NorNed link between the Netherlands and Norway [2]. China maintaining several synchronous areas, interconnected by HVDC. At present long HVDC interconnections are used to transmit power from regions with ample hydroelectric capacity, with back to back connections being proposed for future trade purposes. China seems to have settled for three synchronous super-grid structures, North Power Grid, Central Power Grid and South Power Grid.

A traditional use of HVDC is the interconnection of systems in different countries and regions. This has been widely used to connect regions with different frequencies or when regions have the same frequency but they are not synchronized. It is also widely used when submarine cabling is required. A grid interconnection between Bheramara in Bangladesh and Baharampur in India was completed at the end of August, to deliver 500 MW of power from India to Bangladesh [4]

In Bangladesh total transmission lines set up is 3020 ckt.KM (230 kv) and 6302 ckt.K.m (132 kv). Again total distribution lines are 34,827 K.M (33 kv and below). Power Grid Company of Bangladesh Ltd. (PGCB) is responsible for operation, maintenance and development of transmission system all over the country. Presently power generated in various power plants in Bangladesh is transmitted to the national grid through 230 kV and 132 kV transmission lines [14]. The High voltage transmitted overhead lines for long distance are given below in Table 3.

Table 3: The High Voltage Transmitted Overhead Lines For Long Distance.

Name of Lines	*Length in Route kilometers*	*Length in Ckt. kilometers*	*No. of Ckt.*
Ghorasal-Ishurdi (1st EWI)	178	356	Double
Ashuganj - Comilla North	79	158	Double
Comilla North - Hathazari	150	300	Double
Comilla North - Meghnaghat	58	116	Double
Ashuganj - Sirajganj (2nd EWI)	143	286	Double
Khulna - Ishurdi	185	370	Double
Bogra-Barapukuria	106	212	Double
Sirajganj-Bogra	72	144	Double
Bibiyana-Comilla(N)	153.55	307.10	Double
Siddhirganj – Shahjibazar (132 Kv)	138	276	Double
Shahjibazar - Chatak	150	300	Double
Siddhirganj - Kaptai	273	546	Double
Ashuganj - Jamalpur	166	332	Double
Goalpara - Ishurdi	169	338	Double

Some upcoming project are Aminbazar-Maowa-Mongla 400 kV & Mongla- Khulna (S) 230kV Transmission line (NG3) (2011-12 to 2014-15); Anowara – Meghnaghat 400 kV Transmission line (NG4) (2011-12 to 2014-15); Ruppur-Bheramara-Zajira 400kV Transmission line (2014-15 to 2016-17); Electricity interconnection between Tripura and Eastern Region of Bangladesh (2011-12 to 2012-13) [4]. The transmission line from Table 3 and upcoming transmission project are depending on HVAC technology which is most costly and transmission loss is huge. Although HVDC has less magnetic loss and higher power flow control, so the HVAC links may be replaced. It is a matter of concern that LCC and VSC converter requires millions of USD; again the replacement of cables meant so much cost. But for the future planning of power network it is necessary in Bangladesh to establish a HVDC base power system.

Majority of large city power grids in Bangladesh are characterized by high load densities, strict requirements for reliability and power quality, and excessive dependence on power import from outside sources. Increasing power delivery to large urban areas with ac expansion options is often limited by the risk of increased short circuit levels [5]. Figure 5 shows a version of proposed multi terminal VSC-HVDC network that may embedded in the existing city power grid. The proposed scheme suggested that, Power is fed from transmission grid radically from different sources and distributed through a dc-cable ring to the inverter stations located at different load pockets.

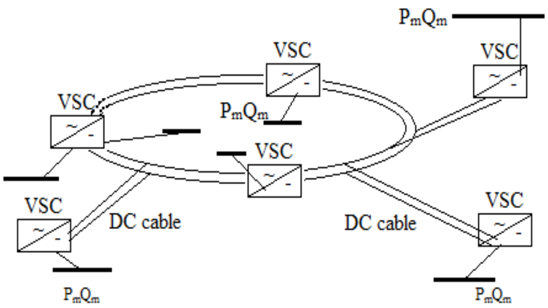

Figure 5: DC network embedded in existing city grid

In Syshet, Rongpur, Khulna Using back to back interconnected of small power plant with VSC HVDC, power stabilization and utilization could be increased. Large Power plants like Ashuganj and Ghorashal; Shiddhirganj and meghnaghut; Horipur and Ashuganj could be interconnected through HDVC transmission lines. Thus, two asynchronous power plants could be interconnected to improve the power Factor and power flow in Bangladesh.

6. Cost Comparison of HVDC with Traditional System

One of the latest HVDC LCC interconnections built, that also uses submarine cable transmission, in between Greece and Italy (2002). From the studies of Barberis Cost Equation for LCC HVDC as follows [11]: Cost=1.148P+156.1

Where Cost is the cost of the cable per km (including installation) in thousands of Euros and P is the power capacity of the cable in MW. According to the cost data, provided in a technical report by ABB about HVDC VSC cost equation is as follows [11]:
Cost =0.286 +0.00969P.

In the formula above P is the rated power of the cable in MW, and Cost is the cost only for purchasing the cable in MSEK. In HVAC transmission systems the list of components whose cost has to be defined is more extensive. To be more specific, costs of Transformers, Compensators, 132 kV, 220 kV and 400 kV three-core, XLPE, submarine cables, Cables installation cost, Switch gear have to be defined in HVAC system. Here we have only considered the cost of Ac transformer with the LCC and VSC HVDC system. The mathematical expression for the cost of as follows [11]:

$$Cost_{trans} = 0.03327 * P^{0.751}$$

Where, P the rated power of the transformer in MVA. Cost of HVAC transformers, LCC and VSC converter at rated power are shown in Table 4.

Table 4: Cost of Transformers and Converter at Rated Power

Rated Power MW / *Cost*	*130MW*	*250MW*	*300MW*	*350MW*	*500MW*
HVDC LCC Components cost(MUSD/Km)	0.4196	0.6090	0.687	0.7668	1.160
HVDC VSC Components cost(MUSD/Km)	0.410	0.4164	0.509	0.6120	0.8365
HVAC transformers cost(MUSD)	1.771	2.886	3.320	3.728	3.3400

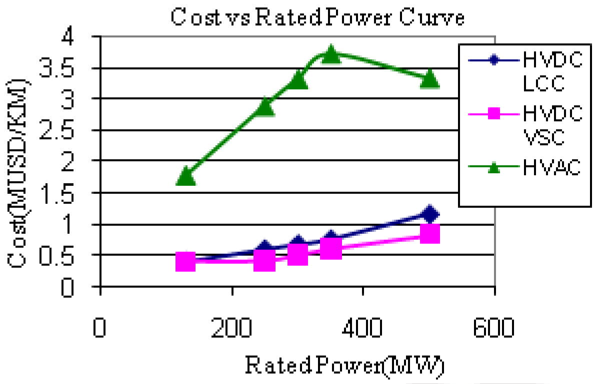

Figure 6: Cost of transformers and converter at rated power

Figure 6 shows Cost vs rated power for different transmission technology. HVAC transmission technology gives higher cost at any rated power. But HVDC transmission technology gives lower cost at any rated power compared with HVAC technology. Comparing with VSC-HVDC and LCC-HVDC, VSC-HVDC gives lower cost for a given rated power. With the help of some earlier project the Cost of HVDC, LCC HVDC and VSC HVDC has been calculated in terms of length [11]. The cost of transmission for 400 MW and 700 MW has been shown in Table 5 and Table 5.

Figure 7 and Figure 8 show that the energy transmission cost for HVDC systems presents a linear dependence to distance, with VSC systems having a higher initial value and gradient compared to LCC systems. Thus the energy transmission cost for VSC systems is always higher to the corresponding value for LCC systems for all transmission distances. The value of the energy transmission cost for HVAC systems appears to have a less uniform behavior, presenting a small increase versus distance for smaller transmission distances and a much higher one when the transmission distance exceeds 100 km in Figure 7 and 150 km in Figure 8.

Table 5: For 400 Mw Capacity Energy Transmission Cost Vs. Transmission Distance.

Trnas. Lengthkm system Cost(USd/KWh)	*50km*	*100km*	*150km*	*200km*	*250km*
HVAc	.0036	.0080	.0123	.0274	.0519
VSC HVDC	.0054	.0072	.0089	.0106	.0124
LCC HVDC	.0038	.0050	.0063	.0076	.0089

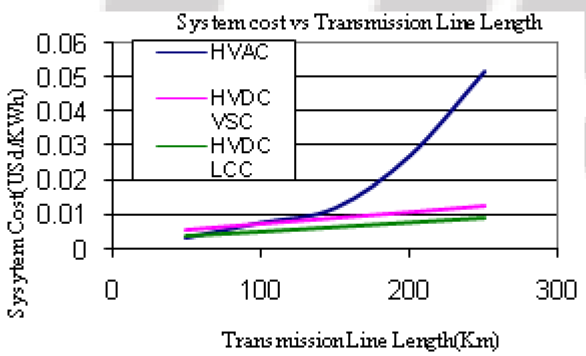

Figure 7: For 400 MW capacity Energy transmission cost vs. transmission distance

Table 6: For 700 Mw Capacity Energy Transmission Cost Vs. Transmission Distance

Transmission Length km system Cost(USd/KWh)	*50km*	*100km*	*150km*	*200km*	*250km*
HVAc	.0023	.0046	.0129	.0257	.0405
VSC HVDC	.0049	.0062	.0075	.0089	.0103
LCC HVDC	.0037	.0049	.0061	.0074	.0087

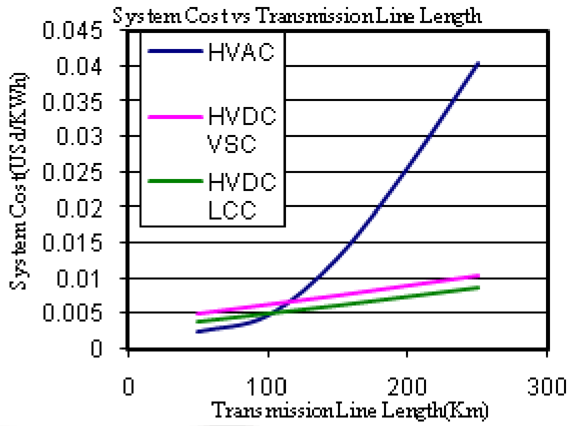

Figure 8: For 700 MW capacity Energy transmission cost vs. transmission distance

The Tables were referred for 400 MW and 700 MW capacities, because most of the power plant capacity in Bangladesh is within 1000 MW. So, it would be easier to compare the cost for Bangladesh prospect. From the above discussion it is clear that LCC HVDC technology can be implemented for short distance transmission and VSC HVDC can be implemented for long distance transmission in spite of conventional HVAC transmission line in Bangladesh.

7. Loss Comparison between HVDC and HVAC Transmission Systems

The Electric power transmission and distribution loss in Bangladesh was 865000000kWh in 2009, according to a World Bank report, published in 2010. The main losses are copper loss, dielectric loss, corona losses, radial and induction losses are the common phenomena which are possible to minimize using HDVC network.

The design of conductors for HVAC and HVDC lines are optimized with regard to the investments costs for the line and the operation costs for the losses. For HVAC lines, the resistive losses determine the conductor cross section. AC corona losses are important to the design of the conductor bundle. With only a few kW/km of loss in fair weather, the level may increase 10-100 times during conditions of rain or hoarfrost and may reach several hundred kW/km [13], [15]. The effect of altitude on corona loss is quite dramatic: at 1800 meters above sea level, the losses at any given weather condition are four times higher than at sea level. For HVDC lines, the selection of conductor cross section with regard to the resistive losses is done in the same way as with HVAC. DC corona losses are, however, of less concern to the design of the conductor bundles, since the increase during rain or hoarfrost is much smaller than with AC, only about 2-3 times. The effect of altitude on the DC corona loss is similar as with AC. When comparing HVDC and HVAC line with regard to power losses, the main difference is that corona losses of HVDC lines are much less sensitive to variations in weather conditions.

In Figure 9 the comparison of HVDC and HVAC has been shown and the percentage of losses of HVAC is always greater than HVDC. Also it is observed that with the increasing of length for high voltage line loss is minimized.

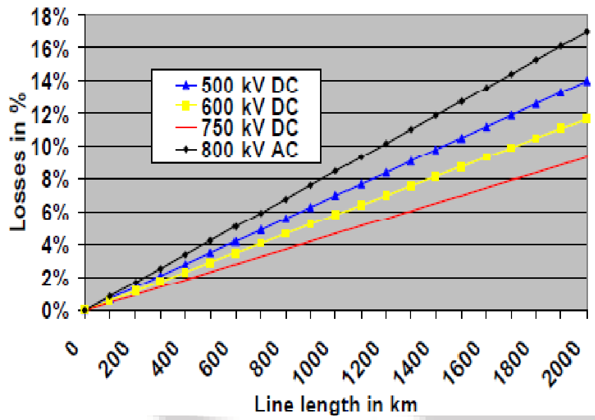

Figure 9: Loss Comparison between HVDC and HVAC Transmission Systems

8. Limitation and Future Scopes

The main limitation of HVDC is the initial cost for set up the converter stations. But, HVDC will be the backbone for future power system with it's limitless advantages and features. The future VSC and LCC converter could be designed using advanced thyristors and IGBT to make the system cost effective. Improvement of reliability, mobility and capacity might be considered in future HVDC transmission models.

9. Conclusions

Energy is the basic necessity of the modern world and the consumption is increasing everywhere. Efficient energy supply system is the backbone for smooth development of a country which requires interconnection between different areas and countries and transmission of power over long distances. HVDC is one of the systems which can provide power efficiently and have many advantages technically, economically and environmentally over the HVAC. The high transmission capacity of the HVDC lines, combined with lower requirements on conductor bundles and air clearances at the higher voltage levels, makes the HVDC lines very cost efficient compared to HVAC lines. The cost advantage is even more pronounced at the highest voltage levels.

This is why when it comes to interconnection and transmission over long distances, HVDC would be the first to discuss and study. Bangladesh Power development Board, Power Grid Company of Bangladesh and Government should think about HVDC base power network in order to minimize the losses and transmission cost and to establish a well control and stable power network.

References

[1] Tomasz Drobik,''High-voltage direct current transmission lines," IEEE Conference Publishing ul. Pulaskiego 32/13 46-100 Namyslow, Poland.
[2] Olaf Saksvik, ''HVDC Technology and Smart Grid,"- The 9th IET International Conference, Hong Kong November 2012. Advances in Power System Control, Operation and Management.
[3] Prabha Kundur,"Power system stability and control," Mcgraw-hill and Inc.
[4] http://www.bpdb.gov.bd/
[5] Jiuping Pan, Reynaldo Nuqui, Kailash Srivastava, Tomas Jonsson, Per Holmberg and Ying-Jiang Hafner, "AC Grid with Embedded VSC-HVDC for Secure and Efficient Power Delivery," IEEE Energy2030 Atlanta, GA USA, 17-18 November, 2008.
[6] Nikolas Flourentzou,Vassilios,G. Agelidis and Georgios D. Demetriades, "VSC-Based HVDC Power Transmission Systems: An Overview," IEEE Transactions On Power Electronics, Vol. 24, N0. 3, March 2009.
[7] Dr RL Sellick and M Akerberg, "Comparison of HVDC Light (VSC) and HVDC Classic (LCC) Site Aspects, for a 500MW 400kV HVDC Transmission Scheme," IEEE Transactions On Power Electronics, Vol. 20, N0. 3, March 2008.
[8] John Graham, Abhay Kumar, Geir Biledt, ''Role of HVDC FACTS and Emerging Technologies in Evolving Power Systems" CIGRE SC B4 Colloquium on 23-24 September 2005 at Bangalore.
[9] Al Murawwi, E. Mohsin, M. El Chaar, L.Lamont, ''Interconnection between two variant frequency systems using HVDC links,"- 2nd International Conference on Electric Power and Energy Conversion Systems (EPECS), 2011.
[10] Lidong Zhang, Harnefors, Lennart, Nee, H.-P, ''Interconnection of Two Very Weak AC Systems by VSC-HVDC Links Using Power-Synchronization Control,"- Power Systems, IEEE Transactions on (Volume: 26, Issue: 1).
[11] Lazaros P. Lazaridis, ''Economic Comparison of HVAC and HVDCSolutions for Large Offshore Wind Farms under Special Consideration of Reliability,"- Master's Thesis X-ETS/ESS-0505, Royal Institute of Technology Department of Electrical Engineering Stockholm 2005.R.
[12] Alessandro Clerici, Luigi Paris, Per Danfors, "HVDC conversion of HVAC lines to provide substantial power upgrading," IEEE Transactions on Power Delivery, Vol. 6,No.1 January 1991.
[13] Denis Lee Hau Aik , Göran Andersson,'' Voltage and Power Stability of HVDC Systems – Emerging Issues and New Analytical Methodologies Sarawak Electricity Supply Corporation,"Invited paper to VII SEPOPE, Curitiba, Brazil, 23 – 28 May 2000.
[14] https://www.desco.org.bd
[15] Abhijit T. Naghate, Gaurav G. Gulhane, ''Novel Algorithms of HVDC and FACTS in future Power Systems," International Journal of Scientific & Engineering Research, Volume 4, Issue 6, June-2013 101ISSN 2229-5518.
[16] Md. Meganur Rhaman,'' Hybrid Renewable Energy System for Sustainable Future of Bangladesh,"

International Journal of Renewable Energy Research, Vol. 3, No. 4, 2013

Authors Profile

Rupak Kanti Dhar was born in Sylhet, Bangladesh on March 7, 1991. He has received his B.S. degree in Electrical and Electronic Engineering from American International University-Bangladesh (AIUB) in August, 2013 and currently he is studying in Master of Science in Electrical and Electronic Engineering at American International University-Bangladesh (AIUB). His research interest includes Power System, Renewable Energy, Motor Drives and optoelectronic devices.

Md. Rifat Hazari was born in Naogaon, Bangladesh on December 25, 1991. He received his B.Sc degree in Electrical and Electronic Engineering from American International University-Bangladesh (AIUB) in August, 2013 and stood top 2% among the Engineering graduates in the class of 2013 (CGPA). Currently he is studying in Master of Science in Electrical and Electronic Engineering at American International University-Bangladesh. His research interest includes electric motor drive, power electronics, power system, renewable energy and communication network.