HVDC Transmission an Outlook and Significance for Pakistani Power Sector

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Abstract: Recently a paradigm shift in the power sector is observed, i.e., countries across the globe have deviated their attention to distributed generation rather than conventional centralized bulk generation. Owing to the above narrative, distributed energy resources e.g., wind and PV have gained the adequate attention of governments and researchers courtesy to their eco-friendly nature. On the contrary, the increased infiltration of distributed generation to the power system has introduced many technical and economical glitches such as long-distance transmission, transmission lines efficiency, control capability and cost etc. To mitigate these complications, the utility of high voltage direct current (HVDC) transmission has emerged as a possible solution. In this context, this paper includes a brief discussion on the fundamentals HVDC and its significance in Pakistani power sector. Furthermore, the potential of distributed energy resources for Pakistan is also the subject matter of this paper, so that significance of HVDC transmission can effectively be deliberated.

1. Introduction
To mitigate the destructive repercussions of carbon-containing fuel [1], eco-friendly distributed energy resources (DERs) have gained adequate importance these days. DERs can be regarded as more flexible power resources, albeit with limited capacity as compared to centralized power units. One of the biggest challenge to exploit the potential of DERs is the long distance bulk power transmission. Because the availability of these resources is far away from the load centres. Be contingent on the terminal voltage and current waveforms at DC side of HVDC, the HVDC topologies can be classified into two major categories; current source converters (CSC-HVDC) or Line-commutated converters (LCC) and voltage source converter (VSC-HVDC). Analytical models of 2-level VSC-HVDC, with fundamental circuit configuration, can be found in [2] and [8]. Comparative analysis of both VSC and CSC configurations is explicated in [3-4]. Recently developed modular multilevel converters (MMC) built with a cascaded structure of sub-modules, and in comparison with conventional two or three level MMC own several superior characteristics, e.g., low harmonics, high power quality and reduced AC-filter requirements, full details are outlined in [6]. Some applications of HVDC in different countries are argued in [6-8], whereas different projects of HVDC in China utilizing CSC and VSC configurations are listed in Table 1. Furthermore, in this paper; the current scenario of Pakistani power sector in the light of statistics, the potential of distributed renewable energy resources in Pakistan and recommendations to overcome the power shortage are the subject matters of this paper.

| Project                  | Year | Converter Type | Voltage Level | Capacity | Terminals |
|--------------------------|------|----------------|---------------|----------|-----------|
| Gezhouba-Shanghai HVDC   | 1986 | LCC            | ±500kV        | 1200MW   | 2         |
| Sanxia-Changzhou HVDC    | 2003 | LCC            | ±500kV        | 3000MW   | 2         |
| Nanhui                   | 2011 | VSC            | ±30kV         | 20MW     | 2         |
| Nan’ao                   | 2013 | VSC            | ±160kV        | 200MW    | 3         |
| Zhousan                  | 2014 | VSC            | ±200kV        | 1000MW   | 5         |
| Xiamen                   | 2015 | VSC            | ±320kV        | 1000MW   | 2         |

2. Pakistani Power Sector: An Outlook

Pakistan is one of the countries on the globe which have been suffering due to consistent power shortage since the beginning of 21st century. Power shortage in Pakistan has badly dented the economy and day to day affairs of common public. Subsequent governments have failed to address this critical issue. One biggest dilemma is that, although, the county is rich in renewable energy resources, because of the topographical location, yet the governments have failed to effectively utilize these resources to counter the power shortage. As it is an evident veracity that, the availability of DERs, i.e., wind and PV reside far away from the load centres. Thus, the radical changes in the power system transmission are required, so that power generated by DERs can efficiently be transmitted to the load centres or nearby grids for the purpose of utility.

2.1. Power Demand and Supply Statistical Analysis
This section of the paper briefly enlightens the statistical information of power demand and supply for last few years. Be reliant on these numbers, power supply and demand is forecasted till 2020 by the national power regulatory agency in Pakistan, which is called National Electric Power Regularity Authority (NEPRA). The facts reported in this section are extracted from State of Energy Report by NEPRA [9].

From Figure 1, it can be observed that in recent years the maximum power deficit observed was approximately 6600 MW. If the supplementary generation of around 6000 MW is injected into the power system, the shortfall can approach to zero. Moreover, it should also be noted that in Figure 1 the data of K-Electric (private company) is not included, which is responsible for generation and distribution of power for the city of Karachi (capital of Sind province).

### 2.2. Potential of PV and Wind

| Region          | Solar Radiation Intensity | Wind Energy Assessment |
|-----------------|---------------------------|------------------------|
|                 | Minimum Intensity (W/m²)  | Highest Intensity (W/m²) | Land Area (km²) | Windy Area % of Total Land | Installable Capacity (MW) |
| Province Baluchistan | 135.73                    | 329.05                  | 11709           | 15.71                             | 58545                  |
| Province Sindh   | 145.29                    | 331.27                  | 29229           | 8.41                                | 146145                 |

Pakistan is one of the courtiers enriched in solar (PV) energy, the annual solar radiations for the different region of the country were calculated and explained comprehensively in the [10] and [12]. Be reliant on the important stats of solar radiation intensity discussed in [10], it can be concluded that...
solar radiation intensity remains suitable in different parts of the country from March to October. Similarly, Pakistan also enjoys the abundance of wind energy in the different parts of the county. The comprehensive analysis of wind potential in the different parts of the country is elaborated in [11]. Besides, recent developments in wind energy sector are elucidated in [13].

2.3. PV and Wind Generation Current Scenario

During FY-2016 solar power of 300 MW was added to the system. Therefore, the total power produced by solar energy has reached to 400 MW. Likewise, 50 MW of wind energy was added to the system, which makes the total of 306 MW. Finally, 63 MW from another renewable energy source i.e., bagasse was also added to the system and makes the total of 146 MW. Thus, the combined generation of all renewable energy resources at the end of the start FY-2017 was 852 MW [9].

3. VSC-HVDC: The Solution for Pakistani Power Sector

In order to connect the different regions of the country, to fully utilize the available energy resources long-distance power transmission power transmission is essentially required. In this regard HVDC projects in joint collaboration with the Chinese government is in progress. The project will utilize the potential of coal available in Thar (southeast part of the country), and then will be connected to the load centres situated in the eastern part of the country. Existing power transmission network of NTDC and route of the ongoing project are elucidated in Figure 2 and Figure 3.

Likewise, the northern regions of Pakistan are rich in hydroelectric potential, but far away from the load center. In addition, the southeast part of the country (e.g., Thatta in Sindh) is rich in wind energy, Whereas the substantial demand of load exists in the province of Punjab, which is the eastern part of the country and in the south part of the country (i.e., Karachi), which undeniably is the economic hub for Pakistan. So, to connect different parts of country economic and efficient network of the long-distance power transmission lines are becoming a necessity. Moreover, in future Government is planning to import electricity from the neighbouring counties e.g., Iran, China, India and Tajikistan, HVDC transmission can also be utilized for such purposes. Since, Pakistan’s pioneer HVDC project is under development, in this regard Pakistan can seek guidance from the experience of other countries [3-4], where HVDC is being practised for a long time for different purposes. Depending upon the capacity of DC transmission circuit, Pakistan can adopt the VSC-HVDC or LCC-HVDC based topologies for long transmission. The details of ongoing HVDC project in Pakistan are elucidated in Table 3. Pakistan can seek guidance from the countries where HVDC is practised for a long time, and for the particular project mentioned in Table 3, LCC-HVDC can be a most pertinent option, due to the fact that, for higher capacity LCC-HVDC is practiced widely, and it can also be observed from the Chinese HVDC projects enlisted in Table 1.
Table 3. Minor Details of Ongoing HVDC Transmission Line Project in Pakistan [15]

| Project                      | Voltage   | Capacity | Distance | Company | Status    |
|------------------------------|-----------|----------|----------|---------|-----------|
| Matiari to Lahore HVDC       | ±660kV    | 4000MW   | 878 km   | SGCC    | Under Progress |

As motioned earlier, in Pakistan renewable energy resource i.e., wind and PV reside far away from the load centres, and to completely utilize these resources long-distance power transmission lines are becoming an indispensable necessity. For that purpose, HVDC transmission has emerged as possible solution, and own several benefits over conventional AC transmission. The comprehensive analysis comprises of economic and technical comparison between HVAC and HVDC is debated in [16] and it was determined that for long distance power transmission HVDC is more suitable than HVAC.

4. Conclusion

A superficial view of Pakistani power sector was presented in this paper, which suggested that power shortage during peak hours was around 6600 MW. Moreover, it was observed that at the beginning of FY-2017 total generation by renewable energy resources was 852 MW, which surely is very less than the potential that Pakistan owns. Besides, the total transmission and distribution losses recorded by NTDC were approximately 18%. Thus, it can be concluded that the reduction of losses and increased utilization of renewable energy resources can unquestionably shrink the power shortage. To achieve these objectives, HVDC power transmission can prove pivotal for the power sector in Pakistan.

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