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Upgrading transmission line capability by AC–DC conversion☆

Raju Manickam[a,*], Subramaniam Nettiampalayam Palaniappan[b]

[a] Department of EEE, Research Scholar, Sathyabama Institute of Science and Technology, Chennai 600119, India
[b] Department of EEE, Pondicherry Engineering College, Puducherry 605014, India

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A B S T R A C T

In recent times, it has been very difficult to build corridors for new overhead lines in industrialized countries like India due to various constraints. To avoid such complicated implementation, building of new infrastructure, new methods are required to upgrade conventional overhead lines. The conversion from AC to DC lines is an alternative way to upgrade the capability of power transmission in order to avoid Rights Of Way (ROW) issues. Hence, in this paper, a methodology is adapted to convert the High Voltage AC (HVAC) line and High Voltage DC (HVDC) for improved power transmission. Electric Field Intensity and Magnetic Field Intensity are evaluated and a real-time data over 400 kV transmission network is analysed to test its performance. The identified network is also analysed under steady and dynamic state with ETAP/PSS/E tool to measure the performance of power transmitted. Further, load flow analysis, short circuit and transient stability are also studied to check the efficacy of the methods adopted to convert HVAC to HVDC lines.

1. Introduction

Recently, the requirements of power in India have been increasing steadily. With the expected growth in GDP, many more power plants are likely to be built. The increasing capacity of power generation requires the transmission network to be strengthened, as the load centres are located at some distance from the generating stations. Hence, proper planning on an overhead transmission line must be considered to meet the demand over next 10–15 years. Since the demand for power increases each year, the installation of devices to meet the power demand also should grow and the energy has to be transmitted effectively via these transmission devices. However, saturation in transmission line occurs virtually once it reaches the threshold levels of sag and ampacity. Also, when the temperature of the transmission line conductor increases, there is a substantial increase in sag and this reduces the ground clearance. The construction of new lines becomes a difficult task and time-consuming.

In case of voltage up big changes are involved in operating voltage. Single conductor transmission lines have a difficulty in achieving satisfactory economical outcomes with reconnect or without bundled conductor installation on large conductors. Certainly, parameters like weight wind, and ice loads due to new bundled conductor needs upgradation or overloaded mechanical structures. If a 132 kV transmission line conductor with diameter 25 mm and horizontal spacing 3750 mm possess a 12 kV/cm surface voltage gradient and this can be utilised for uprating at 220 kV. Here, a possible solution involves installation of supplementary sub-conductors and this attains the phase spacing and realistic voltage gradient. These sub-

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* Corresponding author.
E-mail addresses: mraju.mrps@gmail.com (R. Manickam), npsubbu@pec.edu (S.N. Palaniappan).

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conductors leads to mechanical structure overloading and this makes the voltage increase an unviable one. There are many cases where transmission line designs have been developed so that in near future the line can be reconfigured to cater the voltage rating increase.

The Right-Of-Way (ROW) requirement is a crucial one, when a new transmission line has been constructed. The reduction in ROW and land requirement constraints for building the corridors of the transmission line is brought about by the use of Ultra High Voltage (UHV) AC transmission lines for 765 kV and High Voltage DC (HVDC) lines for 800 kV. AC Transmission line capacity is determined by stability and security constraints, as outlined in St. Clair's curve. Hence, to maintain a sufficient margin for transient stability, these lines are under-utilized. To better utilize the existing transmission lines, there are many alternatives that are intended to enhance the power transfer capability to meet the rising demand, thereby avoiding ROW constraints. As a result, the alternative way for constructing the transmission lines must be taken into effect to improve the capacity of transmission across the overhead lines [1]. Hence, the installation of flexible AC transmission system (FACTS) devices at suitable locations and HVAC to HVDC conversion of existing lines is the two alternatives other than high-temperature conductors and super conduction cables.

1.1. Common reasons of conversion from AC to DC

The three-phase AC is used in major transmission lines for power transmission. The main reason for choosing HVDC rather than HVAC for power transmission is often complex and numerous. In the exact sense, each conventional transmission project has its own reasons that specifically justify the choice. So, a comparison is needed to be presented and that shows the generic characteristics of transmission and the increased power transmission capacity, which is acquired when AC line transmit DC power and then the AC and DC lines are measured using proper analysis. Here, the difference between the AC and DC system are given below, out of which the reasons specified favours mostly the HVDC for flexible transmission of power.

- Power Loss: The loss in HVDC transmission system is lesser than AC system for the power transmitted. By considering the losses in sub and converter stations, the level of initial losses in HVDC system is high, but the losses in HVAC increases as the transmission distance increase.
- Cost: The overhead transmission line of HVDC system cost lesser than HVAC system, and acquisition of land in nearby regions of sub and converter station and ROW is not as high as AC system. Hence, the HVDC visual impact is less and this leads to increased power transmission capacity for ROW. In HVDC, the maintenance cost and operation cost is lower than HVAC system. However, the terminal stations of the HVDC system costs higher than HVAC, since it has to perform the conversion from HVAC to HVDC and vice versa. Furthermore, cost of converter station in HVDC system is falling, while the cost of substations in the HVAC is rising, but the initial costs in AC is dropping.
- Long distance Transmission: The HVDC does not have any limitations in transmitting the power to a long distance transmission cable. However, this problem exists in AC transmission lines, as there exist large cable capacitance which leads to increase in reactive power flow. Hence, HVDC is the only alternative for long distance power transmission.
- Asynchronous transmission: Certainly, in HVAC system, the connections cannot be made between two lines, due to instability and hence the possibility of power exchange between the networks fails. However, this problem is absent in case of HVDC and it further allows transmission of power between different nominal frequency network.
- Link Controllability: The HVDC system offers better power controllability in the links than the HVAC.
- The transmission line of HVDC does not allow short-circuit current to flow between the interconnected AC systems.
- Environmental issues: There are certain environmental factors like visual impact, audible noise, ground use or sea path in case of monopolar operation and electromagnetic compatibility. However, such factors do not affect much the HVDC system and its possibility of improved power transmission with better utilization of power plants.

The conversion from AC to DC lines has upgraded the power transmission to 3.5 times or more [14]. Upgrading HVAC lines to HVDC can utilize the entire current capacity to attain higher power transfer using the installed conductors [15].The action plan required for upgrading the HVAC to HVDC line is promoted due to following advantages.

- It helps to overcome the congestion during transmission and avoid bottlenecks in huge interconnected networks.
- It recycles the conventional assets to improve the power transfer efficiency and promotes the power transfer bi-directionally under varying system conditions.
- It promotes electrically separate and controlled power islands within huge interconnected networks.
- It enhances the controllability and stability of the power system with HVDC control via real-time services [15].

Hence, the conversion from HVAC to HVDC provides improved transmission capacity [13] and economically, a feasible one. This is regarded as a cost-effective solution to attain high current rated power using this conversion. The method also attains higher power transfers using the similar power lines and conductors installed across its respective cross-sectional area. This action of recycling is attempted to promote the limitation in power availability over new power lines [15]. There are many deciding factors involved in deciding the conversion possibilities. One of the prominent requirement is to evaluate parameters like surface voltage gradient, corona effect, electrical and magnetic field after conversion. The Table 1 shows an increasing effect in conductor spacing, total conductors in a bundle, spacing of sub-conductors, ground clearance level etc. are the main parameters that influence mainly the magnetic and electric field, audible noise and radio interference.

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