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A Review on Electrical Energy Losses in Different Transmission Lines

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ABSTRACT: The comparison of transmission losses for different electrical transmission lines is mentioned in this paper. Most efficient ways of electrical energy delivery from generation to distribution infrastructure leads to most efficient way of electrical energy consumption. For the large amount power transfer over long distances required improved transmission efficiency is an important target to ensure less electrical energy losses and costs. For a single bipolar system, application of conventional HVDC schemes at 500 kV dc is said to be economically substantial up to a power capacity of 3500 MW. For increased power levels requires increase; and therefore for a power transfer of 6400 MW over a transmission distance of 2500 km a ±800 kV UHVDC bipolar system is utilized. In this paper, the effectiveness of electrical energy losses and costs of UHVDC transmission lines are assessed in comparison with those of ±500 kV and ±600 kV double bipolar systems and single bipolar systems with parallel twelve-pulse converter valve circuits applications.

I. INTRODUCTION

Electric power transmission is the bulk transfer of electrical energy, from generating power plants to electrical substations located near load centers. This is different from the local wiring between high-voltage substations and customers, which is typically known as electric power distribution. A wide area synchronous grid, also known as an "interconnection" in North America, directly connects a large number of generators delivering AC power with the same relative frequency, to a large number of consumers. Most transmission lines are high-voltage three-phase alternating current (AC), also single phase AC is often used in railway electrification systems. High-voltage direct-current (HVDC) technology is used for more efficiency at very long distances (typically hundreds of miles (kilometers)), in submarine power cables (typically longer than 30 miles (50 km)), and in the interchange of power between grids that are not mutually synchronized. HVDC links are also used to stabilize and limit problems in large power distribution networks where sudden new loads or blackouts in one part of a network can otherwise result in synchronization problems and cascading failures.

Electricity is transmitted at high voltages (115 kV or above) to reduce the energy losses in long-distance transmission. Power is usually transmitted through overhead power lines. Underground power transmission has a significantly higher cost and greater operational limitations. But it is sometimes used in urban areas or sensitive locations. There is an increasing demand for high efficiency and high quality of power transmission in our world. In this time the modern High Voltage DC Transmission (HVDC) and Flexible AC Transmission Systems (FACTS) gets more importance and utilization in today's power transmission system. For the power conversion and power quality control, both HVDC and FACTS systems use power electronic converters. Therefore the performance and quality of converter systems depend much on the key component- high power thyristors. In recent years there are several large HVDC transmission schemes under planning in China, India and Brazil, which have a transmission distances between 1000 km and 2000 km. Ultra high dc voltage (UHVDC) in the range 800 kV is the preferred dc voltage level for these applications.

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II. THEORETICAL BACKGROUND

2.1 OVERHEAD TRANSMISSION

Fig.2.1: 3-phase high-voltage lines in Washington State

High-voltage overhead conductors are not covered by insulation. The conductor material is nearly always an aluminum alloy, made into several strands and possibly reinforced with steel strands. Copper is sometimes used for overhead transmission, but aluminium is lighter, yields only marginally reduced performance and costs are much less. Overhead conductors are a commodity supplied by several companies worldwide. Better conductor material and shapes were always used to allow increased capacity and modernize transmission circuits. Due to skin effect, thicker wires would lead to a relatively small increase in capacity,that causes most of the current to flow close to the surface of the wire. Because of this current limitation, multiple parallel cables (known as bundled conductors) are used when higher capacity is needed. Also at high voltages, bundle conductors are used to reduce energy loss caused by corona discharge.

2.2 UNDERGROUND TRANSMISSION

Instead of overhead lines, electric power can also be transmitted by underground power cables. On comparing with overhead lines, underground cables take up less right-of-way than others and have lower visibility, and are less affected by bad weather. So that the costs of insulated cable and excavation are much higher than overhead construction. Faults in buried transmission lines take longer to locate and repair. Underground lines were strictly controlled by their thermal capacity, which permits fewer overloads or re-rating than overhead lines. Long underground AC cables have greater capacitance, which may reduce their ability to provide useful power to loads beyond 50 miles. Long underground DC cables have no such issue and can use for thousands of miles.

2.3 SUBTRANSMISSION

Sub transmission is part of an electric power transmission system that runs at relatively lower voltages. It is impossible to connect all distribution substations to the high main transmission voltage, because the equipment is larger and costly. However, only larger substations connect with this high voltage. It is stepped down and sent to smaller substations in cities and neighbor hoods. Sub transmission circuits are usually arranged in loops so that a single line failure does not cut off service to a large number of customers for more than a short time. Loops can be "normally closed", where loss of one circuit should result in no interruption, or "normally open" where substations can switch to a backup supply. While sub transmission circuits are usually carried on overhead lines, in urban areas buried cable are used. The lower-voltage sub transmission lines use less right-of-way and simpler structures; it is much more feasible to put them underground where needed. Higher-voltage lines require more space and are usually above-ground since putting them underground is very expensive.

2.4 HVAC TRANSMISSION

Overhead transmission lines are a good balance from a cost perspective. For power transmission distances in the shorter to medium range, 500 kV HVAC overhead transmission lines with the use of FACTS technologies should remain the central option. The use of HVDC transmission should be considered for higher capacity and longer transmission distances. HVAC underground cable transmission is that it has potential application for short distances (less than 50 km). While overhead transmission cannot be accommodated such as in densely populated urban and commercial areas with limited right-of-way for overhead transmission.

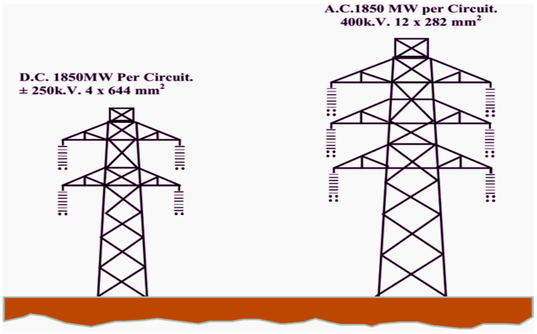

Fig: 2.4 HVAC transmission

The overall investment and operational costs will be less, if an HVDC solution is used for longer underground transmission distances. Historically, the transfer of electricity between regions of the United States has been over high voltage alternating current (AC) transmission lines, which means that both the voltage and the current on these lines move in a wave-like pattern along the lines and are continually changing direction. In North America, this change in direction occurs 60 times per second (defined as 60 hertz [Hz]). The electric power transmitted over AC transmission lines is exactly as same as the power we use every day from AC outlets, but at an increased voltage. Unlike an AC transmission line, the voltage and current on a direct current (DC) transmission line are time- invariant, meaning they do not change direction as energy is transmitted. For zero-frequency movement of electrons from an area of negative (-) charge to an area of positive (+) charge, DC electricity remains constant.

2.5 HVDC TRANSMISSION

A high-voltage direct current (HVDC) electric power transmission system (also known as a power super highway or an electrical super highway) uses direct current for the bulk transmission of electrical power, in contrast with the more common alternating current (AC) systems.

Fig:2.5: HVDC transmission lines

HVDC systems may be less expensive and suffer lower electrical losses, for long-distance transmission. HVDC avoids the heavy currents required to charge and discharge the cable capacitance in each cycle in the case of underwater power cables. For shorter distances, the higher cost of DC conversion equipment compared to an AC system may still be warranted, due to other benefits of direct current links. HVDC permits power transmission between unsynchronized AC transmission systems. Since the power flow through an HVDC link can be controlled, independently of the phase angle between source and load, and it can stabilize a network against disturbances due to rapid changes in power [4]. HVDC also allows power transfer between grid systems running at different frequencies, such as 50 Hz and 60 Hz. By allowing exchange of power between incompatible networks, the stability and economy of each grid will improve.

2.6 UHVDC SYSTEM

The development of ultrahigh-voltage direct current (UHVDC) technology has provided the biggest leap in capacity and efficiency leap in HVDC transmissions in 20 years. It transmits electricity at 800 kilovolts (kV), compared with 600 kV on the highest-voltage power line in the world today, built by ABB at Itaipu in Brazil in 1987.UHVDC is often suited to vast countries, where industrial and residential centers are far away from the sources of power. ABB is supplying ultrahigh-voltage technology for the world's longest power link, a 2,000-kilometer power line in China. At 6,400 megawatts, the transmission line's power rating is also more than double the most powerful rating in operation today, creating a power superhighway to support economic growth in China. Given UHVDC's very high ratings, it is essential that these valuable assets operate safely, reliably and efficiently. The first UHVDC system has just been commissioned in China. The main application of the UHVDC is that, where there is a requirement to transmit very large amounts of power (up to 6,400 MW) over very long distances. Because of this, UHVDC technology should used only in very large electrical systems. The use of Ultra High Voltage Direct Current (UHVDC), i.e. voltages above the highest in use, 600 kV, has been found to be economically attractive for power blocks up to 6400MW for distances above 1000 km.

III. CONCLUSION

The use of an UHVDC system has proven to be the most techno-economically attractive long distance bulk power transmission solution over the conventional HVDC systems, through the evaluation of energy losses and costs using appropriate configurations with proportionality in conductor type and conductor bundle size for a specified system. The annual energy loss cost savings of an UHVDC system was significantly large in relation to the annual energy loss costs that occurred in the conventional HVDC systems, 71.42% and 27.99% less the cost of conventional HVDC systems operating at dc voltage levels of 500 kV and 600 kV respectively. The UHVDC system achieved optimum power transfer to the receiving end at 92.08% efficiency as opposed to 72.39% and 88.84% efficiencies for the conventional HVDC systems operating at dc voltage levels of 500 kV and 600 kV respectively. Therefore, this will provide reliable and sustainable electrical energy supply, and thus will profitably benefit the power utility and end users for its surplus power transfer capability to the receiving end of the transmission line. However, for effective cost evaluation of lines the cost of selected conductors, and their annual interest and depreciation costs are of necessity and need to be considered. Furthermore, the cost assessment of the impact of variation in the operating voltage, system circuit and the overhead line configuration, that is the conductor selection and conductor bundle size for each system, on tower structures, ROW and overhead insulation requirements must be carried out.

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