



HVAC AND HVDC

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Abstract –This case study explores the use of both HVAC (High Voltage Alternating Current) and HVDC (High Voltage Direct Current) transmission methods in the Nordic region's power grid. The region has a unique energy mix with a significant portion of their electricity generated from renewable sources such as hydropower, wind power, and solar power, and a high demand for electricity due to their cold climate. The power grid in the Nordic region is interconnected and operates as a synchronous grid, with an extensive network of HVAC transmission lines that connect various power plants and population centers. However, HVDC transmission is also used for longer distances, as it is more efficient than HVAC and incurs lower transmission losses. The successful use of a mix of renewable energy sources, an interconnected grid, and efficient transmission methods has allowed for a reliable and sustainable energy supply in the Nordic region.

Keywords: which is reliable system HVAC or HVDC

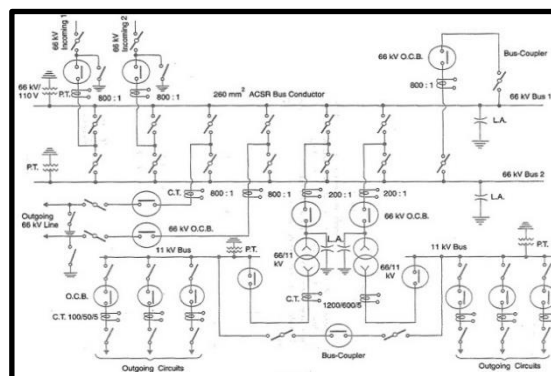
I. INTRODUCTION

One notable case study involving the use of both HVAC and HVDC is the Nordic region's power grid. The region, consisting of Norway, Sweden, Finland, and Denmark, has a unique energy mix with a significant portion of their electricity generated from renewable sources such as hydropower, wind power, and solar power. The Nordic region also has a high demand for electricity due to their cold climate, which requires extensive heating. The power grid in the Nordic region is interconnected and operates as a synchronous grid, meaning that the power plants in the region operate in unison to produce and distribute electricity. However, the region also uses both HVAC and HVDC transmission to efficiently distribute electricity across long distances. HVAC (High Voltage Alternating Current) transmission is used for short to medium distances, where the transmission distance is less than 400 kilometers. It is the most commonly used method of power transmission and is more economical than HVDC for shorter distances. The Nordic region has an extensive network of HVAC transmission lines that connect various power plants and population centers.

On the other hand, HVDC (High Voltage Direct Current) transmission is used for longer distances, where the transmission distance is more than 400 kilometers. HVDC is preferred for longer distances because it is more efficient than HVAC and incurs lower transmission losses. The Nordic region has several HVDC transmission lines that allow electricity to be transmitted across long distances, such as between Norway and Denmark. In conclusion, the Nordic region's power grid is a successful case study of using both HVAC and HVDC transmission methods to efficiently distribute electricity across long distances. The region's use of a mix of renewable energy sources, combined with an interconnected grid and efficient transmission methods, has allowed for a reliable and sustainable energy supply.

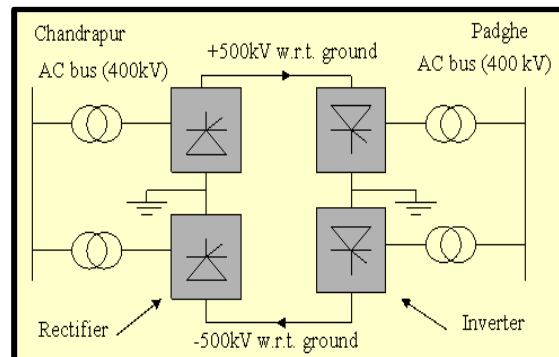
II. OVERVIEW

Diagram of research :





- This is the single line diagram of HVAC Substation
- There are circuit breakers, transformer, isolator, LA,CT,PT ,bays etc.



- This is the single line diagram of HVDC Substation.
- There are circuit breakers, Thyristors , Reactive power filters ,transformer, isolator, LA,CT,PT ,bays etc.

III. LOSSES IN HVAC

Copper losses: Copper losses occur due to the resistance of the copper conductors used in the substation. As the current flows through the conductors, some of the electrical energy is converted into heat, which is dissipated into the environment. Copper losses can be minimized by using high-quality copper conductors and reducing the length of the conductors.

Iron losses: Iron losses occur due to the magnetic properties of the transformers used in the substation. When the transformer is energized, some of the electrical energy is lost due to the magnetization and demagnetization of the transformer core. Iron losses can be reduced by using high-quality transformer cores and reducing the magnetization current.

Capacitive losses: Capacitive losses occur due to the capacitance between the conductors and the ground in the substation. As the voltage changes in the conductors, some of the electrical energy is stored in the capacitance and then discharged back into the conductors. Capacitive losses can be minimized by reducing the spacing between the conductors and the ground.

Inductive losses: Inductive losses occur due to the inductance of the transformers and other inductive components used in the substation. When the current flows through the inductive component, some of the electrical energy is stored in the magnetic field and then released back into the electrical system. Inductive losses can be reduced by using high-quality inductive components and reducing the length of the conductors.

Harmonic losses: Harmonic losses occur due to the presence of harmonics in the electrical system. Harmonics are caused by non-linear loads, such as computers and electronic equipment, which can introduce additional electrical energy into the system. Harmonic losses can be minimized by using harmonic filters and reducing the amount of non-linear loads in the system.

Losses in HVDC:

Electrical losses: Electrical losses in HVDC are similar to those in HVAC systems and are caused by the resistance and capacitance of the conductors and insulators used in the transmission line. As the current flows through the conductors, some electrical energy is dissipated in the form of heat. Similarly, the capacitance between the conductors and the ground can lead to capacitive losses. Electrical losses in HVDC can be minimized by using high-quality conductors with low resistance and insulators with high dielectric strength.

Conversion losses: Conversion losses are incurred when AC power is converted to DC power at the sending end of the transmission line and when DC power is converted back to AC power at the receiving end. The conversion process is not 100% efficient, and some energy is lost in the form of heat. The amount of conversion losses depends on the type of converter used, the power level, and the operating conditions. In general, voltage source converters (VSC) used in modern HVDC systems have lower conversion losses than earlier thyristor-based converters.



IV. INITIAL COST OF HVAC & HVDC SUBSTATION DEPENDS

The initial cost of an HVAC (High Voltage Alternating Current) substation and an HVDC (High Voltage Direct Current) transmission system can vary depending on several factors such as the type of equipment used, the voltage level, the distance to be covered, the complexity of the installation, and other site-specific factors. However, in general, the initial cost of an HVDC system is typically higher than that of an HVAC substation due to the additional equipment required for the conversion of AC to DC and vice versa.

The cost of an HVAC substation can vary depending on its capacity, voltage level, and the number of transformers and switchgear required. For example, a typical 230 kV substation with two transformers and switchgear can cost around \$5 million to \$10 million. However, the cost can increase significantly for higher voltage levels or larger capacity substations.

In comparison, the initial cost of an HVDC system is generally higher due to the need for specialized equipment such as the converter station, DC transmission line, and grounding equipment. The converter station is the heart of the HVDC system and includes transformers, AC and DC switchgear, and the converter valves. The cost of the converter station depends on its capacity, voltage level, and the type of converter used. For example, a typical 500 MW, 500 kV bipolar HVDC converter station can cost around \$500 million to \$1 billion.

Overall, the initial cost of an HVDC system is higher than that of an HVAC substation due to the additional equipment required for the conversion of AC to DC and vice versa. However, HVDC systems may have lower operating costs over the long term, as they can transmit power over longer distances with lower transmission losses, and can also provide better power quality and control.

V. HVAC ADVANTAGES:

Established technology: HVAC substations have been in use for many years, and the technology is well-established. This means that there is a large amount of knowledge and expertise available, which can be used to design, build, and operate the substation.

Lower equipment cost: The equipment used in HVAC substations, such as transformers, switchgear, and circuit breakers, is generally less expensive than the equipment used in HVDC (High Voltage Direct Current) substations. This is because the technology used in HVAC is more mature, and the manufacturing process is well-established.

Better fault tolerance: HVAC substations have a high level of fault tolerance, meaning that they can continue to operate even if there is a fault or failure in one part of the substation. This is because the electrical system can be reconfigured to bypass the faulty component, and power can be rerouted through alternative paths.

Availability of reactive power: Reactive power is required to maintain voltage stability in the electrical system, and HVAC substations can provide this reactive power by using shunt reactors or capacitors. This allows the electrical system to maintain stable voltage levels, even under varying load conditions.

Flexibility: HVAC substations can be designed to operate at different voltage levels, which provides flexibility in the design and operation of the electrical system. This allows the system to be adapted to different types of loads and to be integrated with different types of renewable energy sources.

HVAC DISADVANTAGE:

High losses: As mentioned earlier, HVAC substations can incur significant losses due to the resistance of the conductors, capacitance, and inductance of the system. These losses can reduce the efficiency of the transmission system and result in higher energy costs.

High maintenance: HVAC substations have complex systems with numerous components, such as transformers, breakers, and switchgear. These components require regular maintenance to ensure that they are operating properly, which can be time-consuming and expensive.

Environmental concerns: HVAC substations can have an impact on the environment due to the electromagnetic fields (EMF) generated by the high voltage power lines. These fields can have potential health effects on humans and animals



living near the substations. Also, HVAC substations can take up a significant amount of space and may disrupt natural habitats.

Voltage limitations: HVAC substations have voltage limitations due to the physical properties of the transmission lines and the electrical components used in the system. These voltage limitations can limit the distance over which power can be transmitted, which can be a significant disadvantage in large power transmission networks.

Susceptibility to lightning strikes: Since HVAC substations are exposed to the environment, they can be susceptible to lightning strikes. Lightning strikes can damage the electrical components of the substation, resulting in outages and costly repairs.

VI. HVDC ADVANTAGES

Lower transmission losses: HVDC systems have lower transmission losses compared to HVAC systems due to the absence of reactive power and lower resistance losses. This results in a more efficient and cost-effective transmission system.

Longer transmission distances: HVDC systems are capable of transmitting power over longer distances with lower losses compared to HVAC systems. This makes HVDC systems more suitable for interconnecting remote power generation sources with load centers.

Improved power quality: HVDC systems provide better power quality and stability compared to HVAC systems. The absence of harmonics and lower voltage drops result in a more stable and reliable transmission system.

Increased controllability: HVDC systems provide greater controllability over power flow compared to HVAC systems. The power flow can be easily controlled and adjusted by changing the voltage and polarity of the DC transmission line.

Reduced environmental impact: HVDC systems have a lower environmental impact compared to HVAC systems due to the reduced transmission losses and the ability to interconnect renewable energy sources with load centres, reducing the need for fossil fuel-based power generation.

HVDC DISADVANTAGE:

Higher initial cost: HVDC substations require more complex equipment and control systems than HVAC substations, which leads to higher initial costs.

Complex control systems: HVDC substations require sophisticated control systems to regulate the flow of power and maintain system stability. These systems are more complex than those used in HVAC substations and require highly skilled engineers and technicians to operate and maintain.

More expensive maintenance: HVDC substations require specialized maintenance and diagnostic equipment, which can be more expensive than the equipment used in HVAC substations.

Limited availability of equipment: HVDC equipment, such as converters and transformers, are not as widely available as their HVAC counterparts. This can lead to longer lead times for equipment procurement and replacement.

Environmental impact: The construction and operation of HVDC substations can have environmental impacts, such as habitat destruction and air and water pollution.

CONCLUSION

Both types of substations incur losses that affect the efficiency and reliability of the electrical system. Copper losses, iron losses, capacitive losses, inductive losses, and harmonic losses are some of the losses that occur in HVAC substations. Meanwhile, electrical losses and conversion losses are the primary losses that occur in HVDC substations. Efforts should be made to minimize these losses to improve the efficiency and reliability of the electrical system.

This can be achieved by using high-quality materials, reducing the length of conductors, using harmonic filters, reducing non-linear loads, and using high-quality converters. Overall, improving the efficiency and reliability of the electrical transmission system ultimately benefits both utilities and consumers by reducing costs and improving the quality of service.

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