

An Integrated Approach of FACTS and HVDC in AC-DC to Improve Power System Efficiency and Reduce Power Losses

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Abstract

By Minimizing power loss in power systems, this study seeks to increase overall system efficiency, decrease energy waste, and maximize the utilization of network infrastructure. Resistive losses in transformers, transmission and distribution lines, and other components are the main cause of power losses in electrical systems. Reactive The effects of power compensation strategies on lowering resistive power losses and raising overall system efficiency are assessed. These strategies include synchronous condensers, SVCs, and shunt capacitors. The performance of the power system is assessed using a number of factors, including voltage profiles, power factor, power transfer capacity, transmission losses, and stability parameters.

Keywords: High-Voltage Direct Current (HVDC) ¹, Flexible AC Transmission Systems (FACTS)², Unified Power Flow Controllers (UPFCs)³ and StaticVar Compensators (SVCs)⁴.

1. Introduction

In recent years, technologies such as High-Voltage Direct Current (HVDC) and Flexible AC Transmission Systems (FACTS) have become indispensable for improving the flexibility, efficiency, and dependability of power transmission and distribution networks. This chapter examines the potential benefits that FACTS and HVDC technologies may offer, as well as the ways in which they affect the power system. The advanced control features of devices that employ the FACTS protocol allow for exact regulation of both voltage levels and power flow. FACTS devices preserve voltage stability, optimize power flow, and lessen congestion. They accomplish this by changing the line's impedance and adding or removing reactive power. As a result, there is an increase in the power's total efficiency. Static and other FACTS technologies are feasible. Unified Power Flow Controllers (UPFCs) and Static Var Compensators (SVCs), to optimize the utilization of the transmission network that is now operational. Through dynamically altering voltage and reactive power, FACTS devices may maximize the grid's transfer capacities while easing limits on transmission lines. Reactive power regulation is how this is accomplished. This reduces congestion, allows for more transmission capacity, and does away with the requirement for costly grid upgrades. The role that FACTS devices play in maintaining the grid's dependability in emergency situations is crucial. FACTS devices have the capability to promptly respond to faults or disturbances and regulate power flow, voltage, and reactive power in order to mitigate their impact. This aids in preventing voltage collapse, stabilizing the grid, and minimizing the duration and intensity of power outages. Furthermore, FACTS technologies improve the grid's ability to bounce back from disturbances, ensuring a steady supply of electricity. FACTS devices contribute to the improvement of power quality by controlling voltage levels, minimizing harmonics, and reducing voltage variations. Voltage dips, flicker, and other issues associated with power quality can be mitigated by FACTS technologies due to their active management of reactive power.

FACTS and HVDC Technologies

FACTS describe an extensive range of power electronic systems and equipment that make it feasible to adjust voltage and dynamically control and maximize the flow of AC power. These devices are introduced to the gearbox system to enhance power transmission capacities, boost voltage stability, and lessen system oscillations. Some of the most significant FACTS technologies are listed below: An SVC, or shunt-connected device, is in charge of supplying reactive power compensation to the system by either injecting or absorbing reactive power. Because an SVC can control the system voltage, it can lessen voltage fluctuations, preserve stable voltage profiles, and enhance power transmission capabilities.

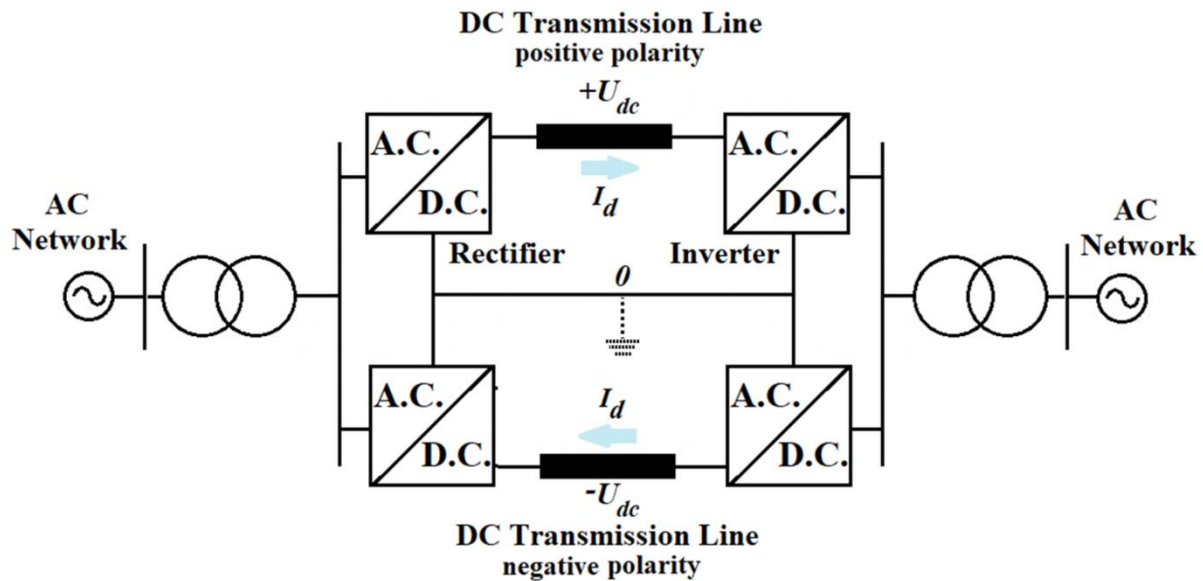


Figure 1. HVDC Transmission System

A series-connected device known as a TCSC can have its capacitive reactance changed in a range of values by using thyristor-controlled switching components. With the ability to control power flow and enhance system stability through oscillation damping and proper voltage maintenance, a TCSC can increase system stability. The reactance is changed to achieve this. Combining shunt and series FACTS devices, a UPFC performs both TCSC and SVC tasks. An alternative name for this type of equipment is a universal power factor corrector. It provides total control over voltage regulation, the stability of the power system, and the flows of both active and reactive power. The UPFC offers better dynamic performance and greater versatility than the individual FACTS devices.

2. Objectives

To reduce energy losses during power transmission by optimizing the routing and control mechanisms in the integrated AC-DC system using HVDC controllers. The combination of FACTS and HVDC interconnecting lines has emerged as a potential approach to manage unforeseen circumstances and severely loaded situations. By Integrating Renewable Energy Sources, HVDC systems are often used for long-distance transmission of renewable energy, and FACTS devices can help manage the variability and intermittency of these sources. To optimize the Power Flow Control and manage power flow between interconnected AC and DC networks. This involves using HVDC converters and FACTS devices strategically to minimize losses, improve voltage profiles, and maintain grid stability.

3. Methods

A thorough approach to examining how reducing power losses might increase power system efficiency. In order to identify the best switching practices for reducing power losses, the study starts by examining the current power system topology and load conditions. The study assesses how reactive power compensation strategies like synchr

onous condensers, SVCs, and shunt capacitors affect resistive power losses and raise overall system .A number of measures, such as voltage profiles, power factors, transmission losses, power transfer capacities, and stability parameters, are used to assess the power system's performance. In order to evaluate the effects of this combination on voltage regulation, power transfer efficiency, and system stability, researchers have combined Flexible AC Transmission System (FACTS) devices with High-Voltage Direct Current (HVDC) technology.

4. Results

Enhancing the overall effectiveness of the system, cutting down on energy waste, and making the best use of network infrastructure could all be achieved by reducing power loss, which is a key goal in the functioning of power systems. Resistive losses, which can happen in transformers, transmission and distribution lines, and other parts of the power system, are primarily responsible for power losses. This chapter looks at several approaches that are used to reduce the amount of power lost inside power systems. The process of reconfiguring a network necessitates changing the open/closed status of switches and chapteralizing devices, resulting in a modified distribution network topology. Because they facilitate effective power flow control, increase system stability, and facilitate the integration of renewable energy.

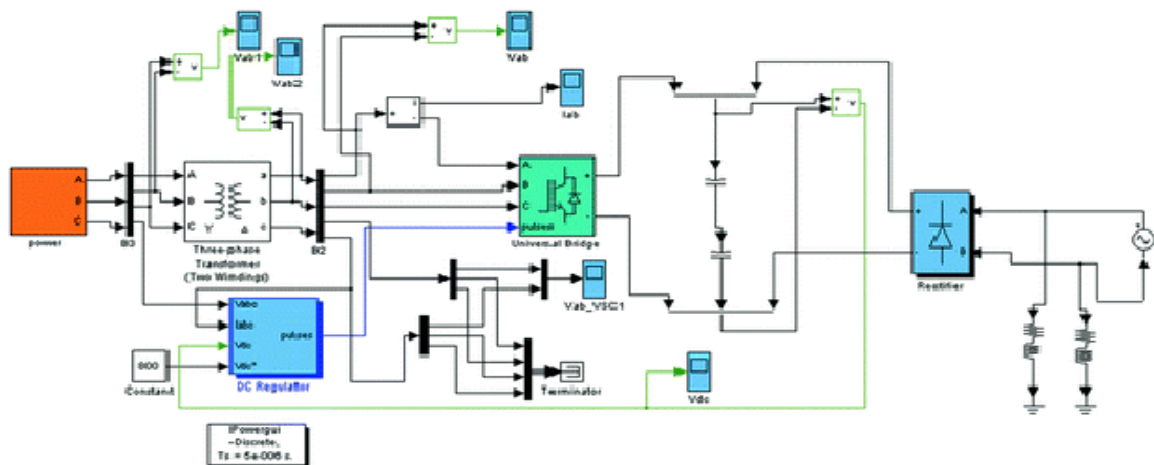


Fig:2. Simulink Diagram Of HVDC Control Strategy

Hence, these technologies are critical to the power sector's development. One can reroute power flows through network reconfiguration, which contributes to less energy being wasted. The following techniques are frequently used: By initially examining the network's architecture and the load conditions, it is feasible to determine which switching operations to employ in order to reduce power losses. In order to reduce resistive losses and boost the distribution network's capacity, this requires figuring out the best switch design, which may involve closing off unused channels and introducing unnecessary branches.

With proper voltage control, the quantity of power lost to resistance can be reduced to a manageable level. Methods for the mitigation of power losses and the optimization of system efficiency are significantly influenced by compensating reactive power. Even though reactive power increases line losses, it is required to maintain the voltage levels in the power system. The reactive power compensation process employs the following tactics: A power system is connected in parallel to banks of shunt capacitors to supply reactive power in a specific area. Voltage levels can be raised by providing reactive power close to the load centers, which reduces the amount of power.

Performance with FACTS and HVDC

Such characteristics must be evaluated in order to examine system performance. Conversely, systems using high-voltage direct current (HVDC). Maintain the same voltage levels over long distances. A number of factors are taken into account when studying voltage profiles, such as the voltage's magnitude, stability, and deviation from reference values. Accurate control of reactive power is feasible with devices that employ FACTS

technology, leading to more precise voltage management. Reactive power exchange and control are further options. HVDC lines make it easier. When examining the exchange of reactive energy, the main topics of inquiry are the power factor, the power factor control range, and reactive power losses.



Fig: 3. Conventional AC Transmission System

HVDC lines have the capacity to move large amounts of electricity with the least amount of loss. A number of factors, such as power transfer efficiency, transmission losses, and capacity, must be assessed in order to do an analysis of active power transfer. It is feasible to deploy FACTS devices in conjunction with HVDC lines to increase the system's active power transfer capability. Furthermore, the integration of FACTS and HVDC technologies significantly impacts the dependability of the power infrastructure. The system's damping properties are strengthened by FACTS devices and HVDC connections, which lead to improved transient stability. These and other stability parameters are evaluated as part of the system performance analysis.

The main goal of a contingency analysis is to assess a system's ability to withstand and recover from a range of unanticipated occurrences, which is a crucial part of a system performance analysis. FACTS and HVDC technologies work together to improve the system's capacity to withstand unanticipated occurrences and to make it more resilient overall. Important elements of a sensitivity analysis include the following: Capacity for fault ride-through: The system's ability to ride through faults is aided by the fast reactive power supply and voltage management that both FACTS devices and HVDC connections offer. A system's ability to "ride through" a defect is assessed using a variety of metrics, such as "fault clearance time," "voltage recovery time," and "fault current mitigation."

5. Discussion

This essay has examined numerous tactics and technological advancements meant to raise overall system effectiveness, cut down on energy waste, and maximize the reduction of power loss in power systems by the utilization of network infrastructure. The study concentrated on using reactive power compensation methods to lower resistive power losses and improve system efficiency, such as synchronous condensers, SVCs, and shunt capacitors. Power system metrics like voltage profiles, power factor, transmission losses, power transfer capacity, and stability parameters were used to assess the power system's performance.

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