



School of Information Technology and
Engineering at the ADA University



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at the George Washington University

AN ANALYSIS OF HVDC IMPLEMENTATION STRATEGIES FOR ENHANCING
POWER TRANSMISSION IN AZERBAIJAN

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Sabina Aliyeva

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THESIS ACCEPTANCE

This Thesis by: Sabina Aliyeva

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Approved:

Orkhan Karimzada

(Adviser)

(Date)

Ramiz Gancaliyev

(Co-Adviser)

(Date)

Wisam Al-Dayyeni

(Program Director)

(Date)

Abzatdin Adamov

(Dean)

(Date)

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Aliyeva Sabina
(Full Name)

(Signature)

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ABSTRACT

This research endeavors to evaluate and compare High Voltage Direct Current (HVDC) implementation strategies for augmenting power transmission within Azerbaijan. The study delves into the efficacy of HVDC technology by conducting a comparative analysis between traditional Alternating Current (AC) transmission and innovative HVDC lines. Utilizing 'Dig Silent Power Factor' software, the research investigates the transmission of 500MW of electrical energy across a 500km stretch, addressing voltage disparities between border systems. The comparative analysis reveals compelling insights into the efficiency of HVDC systems. The AC model, employing multiple transmission lines and autotransformers, displayed notable losses, whereas the HVDC model exhibited remarkably minimized losses, highlighting its superior efficiency in transmitting power over extensive distances. [1]

Moreover, the study contextualizes Azerbaijan's commitment to sustainability and emission reduction within the global framework, recognizing the pivotal role of innovative energy infrastructure. It emphasizes the potential of HVDC technology in unlocking the nation's renewable energy resources, reducing reliance on fossil fuels, and fostering a cleaner, more sustainable energy grid. This research underscores the significance of HVDC implementation strategies in Azerbaijan's quest for sustainable energy transmission. It advocates for the adoption of HVDC technology as a transformative step toward a greener future, positioning Azerbaijan as a progressive hub in energy innovation and global sustainability efforts.

This study contributes substantively to Azerbaijan's ambitious energy plans, shedding light on the pragmatic advantages of HVDC systems in optimizing power transmission efficiency.

As Azerbaijan navigates its evolution from a traditional energy powerhouse to a burgeoning green energy exporter, this research underscores the pivotal role of innovative transmission technologies in realizing sustainable energy aspirations while consolidating Azerbaijan's position as a reliable global energy player.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
AC	Alternating Current
AG	Amplifying gate
AVR	Automatic voltage regulation
BC	Busbar connection
CC	Current control; Constant current
CCC	Capacitor commutated converter
DC	Direct Current
f	Fundamental frequency (50 Hz)
HVDC	High Voltage Direct Current
HVAC	High Voltage Alternative Current
LCC	Line commutated (current source) converter
PSS	Power System Stabilizer
VSC	Voltage source converter
RAM	Reliability, availability, and maintainability

CHAPTER ONE

Introduction

1.1. Introduction

As we know High-Voltage Direct Current (HVDC) transmission systems, pivotal in modern energy networks, originated in the 1930s through the pioneering use of mercury arc rectifiers. By 1941, the first commercial HVDC transmission project aimed to supply 60 MW to Berlin through a 115 km subterranean cable, marking a groundbreaking endeavor in power distribution. The commissioning of an HVDC system, a 10 MW transmission in Gotland, finally materialized in 1954. Subsequently, from the 1960s, HVDC technology flourished into a mature system, significantly impacting long-distance transmission and interconnecting power networks. In the dynamic realm of electrical power transmission, the emergence of High-Voltage Direct Current technology has revolutionized energy distribution across vast distances and terrains. Unlike traditional alternating current (AC) systems, HVDC functions by transmitting electrical power through a unidirectional flow of current, showcasing unparalleled efficiency and adaptability in modern power networks. The prowess of HVDC lies in its ability to traverse extensive distances with minimal losses compared to conventional AC transmission. This efficiency is rooted in direct current's properties, mitigating challenges encountered in AC systems, such as impedance and reactive power losses over long transmission lines. At the heart of HVDC's capabilities are sophisticated power converters, enabling seamless interface and conversion between AC and DC grids. These converters, utilizing advanced electronic switches, facilitate the efficient transmission of bulk power, offering a versatile solution to meet the escalating energy demands of our interconnected world.

The advantages of HVDC extend across technical, economic, and environmental domains. From overcoming distance limitations in AC transmission to interconnecting disparate power grids without synchronous operations, HVDC stands as a symbol of efficiency and reliability in power transmission. This section of the thesis aims to explore the intricate workings, foundational principles, and multifaceted advantages of HVDC technology. By unraveling its complexities and highlighting its potential, this thesis seeks to provide a comprehensive understanding of HVDC systems, emphasizing their pivotal role in shaping the global energy distribution landscape. The utility of HVDC spans various domains, including bulk energy transmission, connecting AC systems, enhancing network stability, addressing frequency disparities, integrating multiterminal DC links, linking remote renewable energy sources, and leveraging Voltage-Source Converter based HVDC technology tailored for grid-connected wind power.

1.2. Motivation

My primary motivation for undertaking this project lies in revolutionizing our country's energy landscape. Azerbaijan holds immense potential in producing electrical energy, not only through conventional power stations but also leveraging renewable sources. I am driven by the vision of not just meeting our domestic energy needs but also exporting surplus energy to neighboring countries. My thesis, titled 'AN ANALYSIS OF HVDC IMPLEMENTATION STRATEGIES FOR ENHANCING POWER TRANSMISSION IN AZERBAIJAN,' is the culmination of my passion for advancing our nation's power infrastructure. The absence of High Voltage Direct Current (HVDC) technology in Azerbaijan presents a compelling opportunity to explore and implement innovative strategies. By focusing on HVDC lines, I aim to contribute to the realization of efficient power transmission methods. This project isn't just academic; it's a practical endeavor to lay the foundation for a sustainable energy future in Azerbaijan. I envision our country becoming a

hub for electricity generation, incorporating renewables and advanced technologies. This not only boosts our energy independence but also positions us as a key player in regional energy trade. Ultimately, my aspiration is to catalyze the adoption of HVDC technology in Azerbaijan, enabling us to harness and distribute electricity efficiently, sustainably, and profitably—driving us closer to a greener, more interconnected future.

1.3. Objectives

This research is dedicated to investigating strategies for optimizing power transmission within Azerbaijan, focusing on the thorough examination of High-Voltage Direct Current (HVDC) implementation. The primary objectives encompass:

1. Comparative Analysis between HVDC and AC Transmission:

Conducting comprehensive comparative analyses between traditional Alternating Current (AC) transmission and innovative HVDC lines. Utilizing 'Dig Silent Power Factor' software to evaluate the efficacy of HVDC systems in transmitting 1000MW of electrical energy across a 500km distance and bridging voltage disparities between border systems.

2. Assessment of Transmission Efficiency:

Investigating the efficiency of both AC and HVDC models in transmission.

Highlighting the comparative losses encountered in AC transmission (3x115 MVA at each autotransformer side) versus the notably minimized losses in HVDC transmission (mere 10 MVA for the same distance), emphasizing the superior efficiency of HVDC systems.

3. Positioning HVDC for Sustainability and Emission Reduction:

Aligning Azerbaijan's commitment to emission reduction with the pioneering adoption of HVDC technology. Exploring how integrating HVDC aligns with the nation's strategies to curb carbon emissions and foster sustainability, especially through leveraging renewable energy sources like solar and wind power.

4. Global Participation and Economic Advantages: