# Module 7a: Point-to-Point HVDC Configurations

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| Prerequisite Competencies: | 1. Motivating needs for high-capacity electric transmission  2. HVDC converter types and operations as found in Modules 1a, 1b, 1c. |
| Module Objectives: | 1. Identify features of point-to-point HVDC transmission  2. Distinguish from multi-terminal HVDC systems.  3. Identify point-to-point applications and describe implementations of each |

## Abstract

In contrast to multi-terminal HVDC systems, point-to-point (P2P) HVDC transmission connects only two converter terminals via a direct current transmission path. They may connect two asynchronous AC systems, or they may provide a DC transmission path within a single AC system. P2P is the oldest HVDC design, having seen application since the early 1950s, and with over 200 implementations worldwide, it is by far the most common design. Many new P2P HVDC projects are being planned or built today.

The objective of this module is to characterize P2P HVDC designs. To do so, we begin in Section 7a.2 by summarizing point-to-point design basics in terms of types of components, e.g., converters, protection, filters, and conductors, and in terms of configuration (monopole, bipole, and tripole). Section 7a.3 describes four different P2P applications, including overhead, back to back, underground, and submarine, and provides descriptive examples of each. Section 7a.4 describes P2P applications for offshore wind. Section 7.4a.5 summarizes the main learning points of this module and concludes.

## Introduction

High voltage direct current (HVDC) transmission has seen applications since the early 1950s. The first such line for commercial purposes was installed in 1954 to interconnect the Swedish mainland 98 km (61 miles) to the island of Gotland in the Baltic Sea; a monopole design employing mercury-arc valves, its capacity was 20 MW at a voltage level of 100 kV [[[1]](#endnote-1)]. The Sweden-Gotland HVDC connection was unique in that it was a submarine cable; another HVDC submarine cable would not be built until 1965 when the HVDC Inter-Island line was energized in New Zealand and the Kontiskan 1 line was energized to connect Denmark to Sweden [1]. However, the Sweden-Gotland line was highly representative of almost all HVDC lines that came afterwards, at least until recently, because it was a point-to-point HVDC line.

Reference [[[2]](#endnote-2)] provides an extensive and up-to-date list of all HVDC projects around the world. Of the 233 projects listed, which include projects that are decommissioned, existing, or under construction, 226 of them are point-to-point HVDC configurations; only seven are multi-terminal. Of the seven multi-terminal projects, only five have been built after 2013; although the other two were built in 1991 and 1992, respectively, they used an older technology that limits their operational flexibility and are not considered state-of-the-art multi-terminal HVDC developments[[3]](#footnote-1). Furthermore, of the 30 planned HVDC projects listed at [2], all are point-to-point configurations. Therefore, although interest in multi-terminal HVDC systems is certainly growing, point-to-point configurations have and will continue to comprise the greatest percentage of HVDC projects.

## Point to point design basics

The most important motivating feature of a point-to-point HVDC design is that its protective elements can reside on the AC side of the converter station. This is possible because, for a point-to-point design, the AC sides of both converters (one at each end) are in series with all current-carrying components of the overall project. That is, as illustrated in Fig. 1, converter A, the line, and converter B, are in series, and so the line, generally the part of the design that is most exposed to the possibility of faults, can be equally well-protected with breakers on the AC side of the converter or on the DC side of the converter, as long as the breaker is in the terminating substation. Because DC breakers are much more expensive than AC breakers, it is always the case that AC breakers are preferred.

SAMPLE FIGURE

Figure 1: Components in a basic point-to-point HVDC design

## Point-to-point applications

### Overhead

### Back-to-back

### Underground

### Submarine

### Reach circuits

## Summary and conclusions

## Equations

Both inline and numbered equations are supported. Inline equations are written in a pair of $.

For example, `$this\_{is}^{inline}$` renders

Numbered equations need to be written in a pair of $$. For example,

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a + b = c

$$ (label-for-equation)

renders

(1)

The equation can be referred to later by inserting (label-for-equation) in the text.

One can choose to typeset equations in Word. That is fine too. Not all of them can be automatically converted, but we will manually fix them after proofreading:

Labeling and equation reference can be done manually; we will convert them later, too.

## Multi-Choice Quiz Questions

Quiz questions cannot be directly inserted in Word. You will work with the Quiz spreadsheet and then insert the quiz id in the Word file.

The `quiz\_template` file contains the template for providing the question, answers, feedback, etc. You can assign a unique identifier as the “name” of the quiz.

## Reference

1. [] M. Ardelean and P. Minnebo, “HVDC Submarine Power Cables in the World,” JRC Technical Reports, European Commission. Accessed 3/13/2024. Available: [www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiBtOa3pfKEAxU55ckDHd\_YDGEQFnoECBAQAw&url=https%3A%2F%2Fpublications.jrc.ec.europa.eu%2Frepository%2Fbitstream%2FJRC97720%2Fld-na-27527-en-n.pdf&usg=AOvVaw3NADemFd8YHWET2R-pn56Z&opi=89978449](http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&ved=2ahUKEwiBtOa3pfKEAxU55ckDHd_YDGEQFnoECBAQAw&url=https%3A%2F%2Fpublications.jrc.ec.europa.eu%2Frepository%2Fbitstream%2FJRC97720%2Fld-na-27527-en-n.pdf&usg=AOvVaw3NADemFd8YHWET2R-pn56Z&opi=89978449). [↑](#endnote-ref-1)
2. [] Wikipedia, “List of HVDC projects,” Accessed 3/13/2024. Available: <https://en.wikipedia.org/wiki/List_of_HVDC_projects>. [↑](#endnote-ref-2)
3. The 1990 and 1991 multi-terminal HVDC projects were both built using thyristor-based line-commutated converters (LCC), as opposed to IGBT-based voltage source converters (VSC). LCC-based multi-terminal designs requires power flow on all lines connected to a bus to be either into the bus or out of the bus. This is because LCCs must change the voltage polarity at a bus to reverse flow on a line. [↑](#footnote-ref-1)