Paper presented at the IET ACDC 2012 conference
in Birmingham, UK, December 4 - 5, 2012

Comparison of HVDC Light (VSC) and HVDC Classic (LCC) Site Aspects, for a 500MW 400kV HVDC Transmission Scheme

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Keywords: VSC, LCC, Site Layouts, Building Footprint

Abstract

This paper compares the site aspects of a Voltage-Sourced Converter (VSC-HVDC) project and a Line-Commutated Converter (LCC-HVDC) project of similar rating. Initially a brief description of the two technologies is presented. Then the project information for the EWIC (Shotton) and Grita (Galatina) sites is provided. Next, a comparison of the overall sites and converter buildings is given. This considers footprint, as well as building height and volume. Finally a comparison is made using the latest cascaded two-level (CTL) technology, against both the two-level technology used at EWIC and the LCC-HVDC technology used at Galatina.

1 Introduction

HVDC Schemes using Voltage-Sourced Converter (VSC) technology (such as ABB's HVDC Light®) are becoming increasingly prevalent, especially at power ratings up to 1000MW. This paper aims to consider the physical site impact of the choice between LCC-HVDC and VSC-HVDC, with all other factors assumed to be equal. Generation 3 and Generation 4 of the ABB's HVDC Light® technology are considered in this comparison.

A comparison is made of two ABB projects. The East-West Interconnector (EWIC) between Ireland and Wales, which uses Voltage-Sourced Converter (VSC) technology, is compared with the Greece-Italy (Grita) project, which uses Line-Commutated Converter (LCC) technology. Each of these projects has a nominal power rating of 500MW, and the DC voltage rating across the converter is 400kV.

To date, the EWIC project is the world's most powerful Voltage-Sourced Converter scheme, although it is scheduled to be overtaken in 2013 by the German offshore wind projects such as DolWin 1 [1], currently under construction by ABB. The EWIC project is significant as it is the first commercial VSC-HVDC project connected to the United Kingdom.

2 HVDC Technology

2.1 Common System Topologies

A schematic diagram of some common system topologies is shown in Figure 1. These are briefly described below [2]:

Symmetric Monopole: A single converter with mid-point ground between positive and negative voltage polarities.

Asymmetric Monopole: A single converter with grounded neutral. This could be with either ground or metallic return.

Bipole: A converter comprised of two monopoles. This could be with either ground or metallic neutral.

Series Bridge Scheme: A converter comprised of monopoles in series. This could be with either ground or metallic return.

Multi-Terminal: Multiple converters (more than two) connected to a DC network.

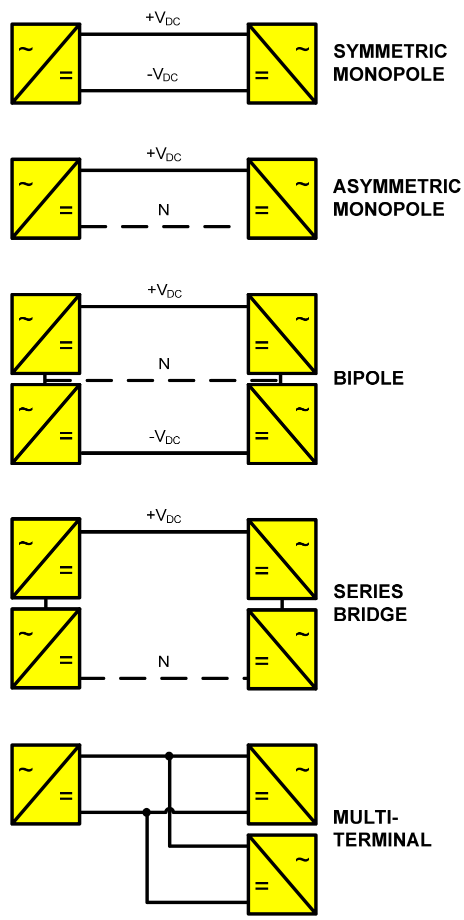

Figure 1 – Common System Topologies

2.2 Comparison of VSC and LCC Technologies

A brief summary of the differences between VSC and LCC technology is presented in Table 1 [1, 2, 3]:

Technology	HVDC Classic (LCC)	HVDC Light® (VSC)
Semiconductor (control)	Thyristor (turn on only)	IGBT (turn on / off)
Power Control	Active only	Active / reactive
AC Filters	Yes	No
Minimum Short-Circuit Ratio	> 2	0
Black Start Capability	No	Yes

Table 1 – Comparison of VSC and LCC

3 EWIC and Grita Projects

The Grita project is arranged as an asymmetrical monopole, while the EWIC project is arranged as a symmetrical monopole. The Grita sites include provision for a future additional asymmetrical monopole to constitute a bipole. For the purposes of this comparison, the area used by the existing pole only will be considered.

The headlines for the EWIC and Grita projects are as shown in Table 2, where it can be seen that both projects are rated nominally at 500MW, with 400kV DC across the converter valves. The AC system voltages are 400kV at both ends of both projects, and each schemes uses single-phase transformers.

3.1 Grita Project

For the Grita project, HVDC was chosen due to the total cable length. At commissioning the Grita HVDC cable was the world's deepest submarine cable (1000m), although this has subsequently been overtaken [4, 5].

There is an overhead line portion connected to the Arachthos station in Greece, meaning there is a DC filter at Arachthos. Therefore the Galatina site, which does not have a DC filter, will be used for the comparison. The Grita scheme is slightly undercompensated considering reactive power support. For an equivalent comparison, it is necessary to add one AC filter bank to the layout. A site plan for Galatina is shown in Figure 2.

3.2 EWIC Project

VSC-HVDC was chosen for the EWIC project after a full evaluation process by EirGrid of available technologies. Apart from the cable length issue, VSC-HVDC also allows controllability, black-start and active / reactive power support.

The two sites for the EWIC project are largely identical, meaning either site could be used. For this comparison, the Shotton station in Wales will be used. A site plan for Shotton is shown in Figure 3.

4 Site Layout and Buildings Comparison

For the as-installed site layouts at Galatina and Shotton, please refer to Figure 2 and Figure 3 respectively. The requirement for comparison purposes of an additional AC filter at Galatina is described in Section 3.1 above – the additional filter required for effective comparison purposes is shown in Figure 2.

This considers overall site footprint (civil works, land usage, planning), converter building height (civil works, planning, work at height), converter building footprint (civil works, planning) and converter building volume (civil works, ventilation system).

Scheme	Grita	EWIC
Technology	LCC	2-Level VSC
Commissioned	2001	2012
Customer	Enel	EirGrid
Power Rating	500MW	500MW
No. of Poles	1	1
System Voltages: AC (both ends) DC	 400kV 400kV	 400kV ±200kV
DC Conductors: Submarine cable Underground cable Overhead line	 160km 43km 110km	 186km 75km -
TOTAL	313km	261km
Converter Station Locations	Galatina (Italy) Arachthos (Greece)	Shotton (Wales) Woodland (Ireland)
HVDC Topology	Asymmetrical monopole	Symmetrical monopole
Transformer Arrangement	1-phase 3-winding	1-phase 2-winding
Indoor / Outdoor AC Switchyard AC Filters Transformers Valve Hall Reactor Hall DC Yard	 Outdoor Outdoor Outdoor Indoor - Outdoor	 Outdoor In & out Outdoor Indoor Indoor Indoor

Table 2 – System Parameters for EWIC and Grita Projects

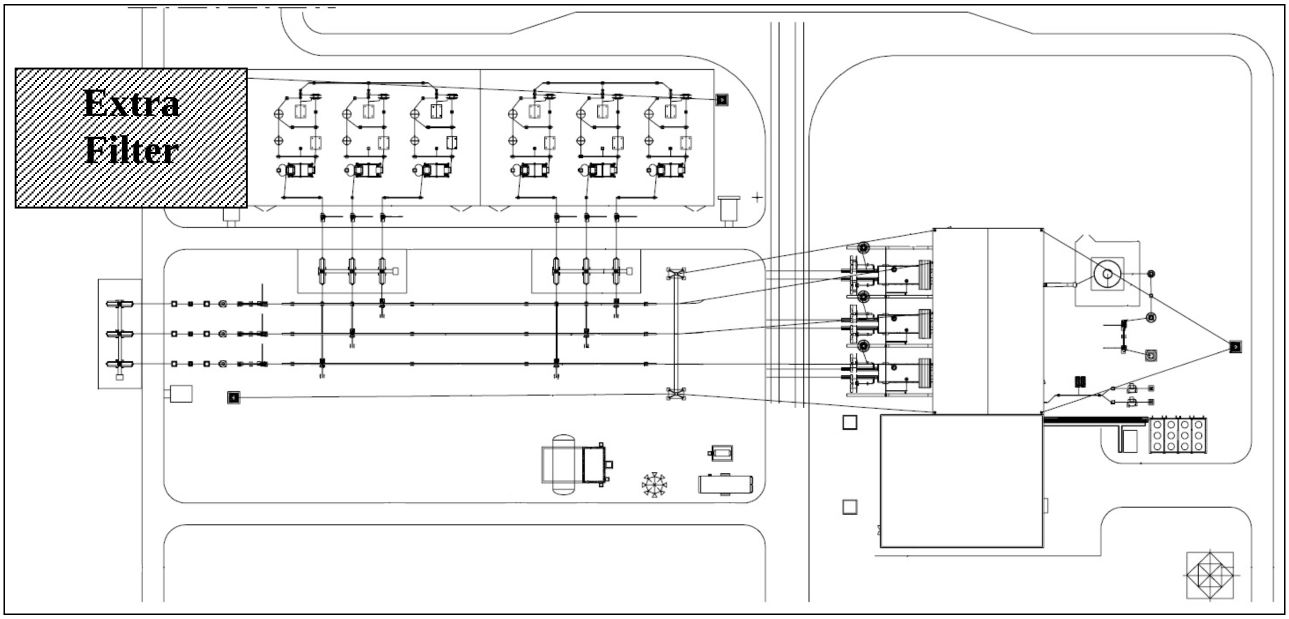

Figure 2 – Site Plan View for Galatina (Grita)

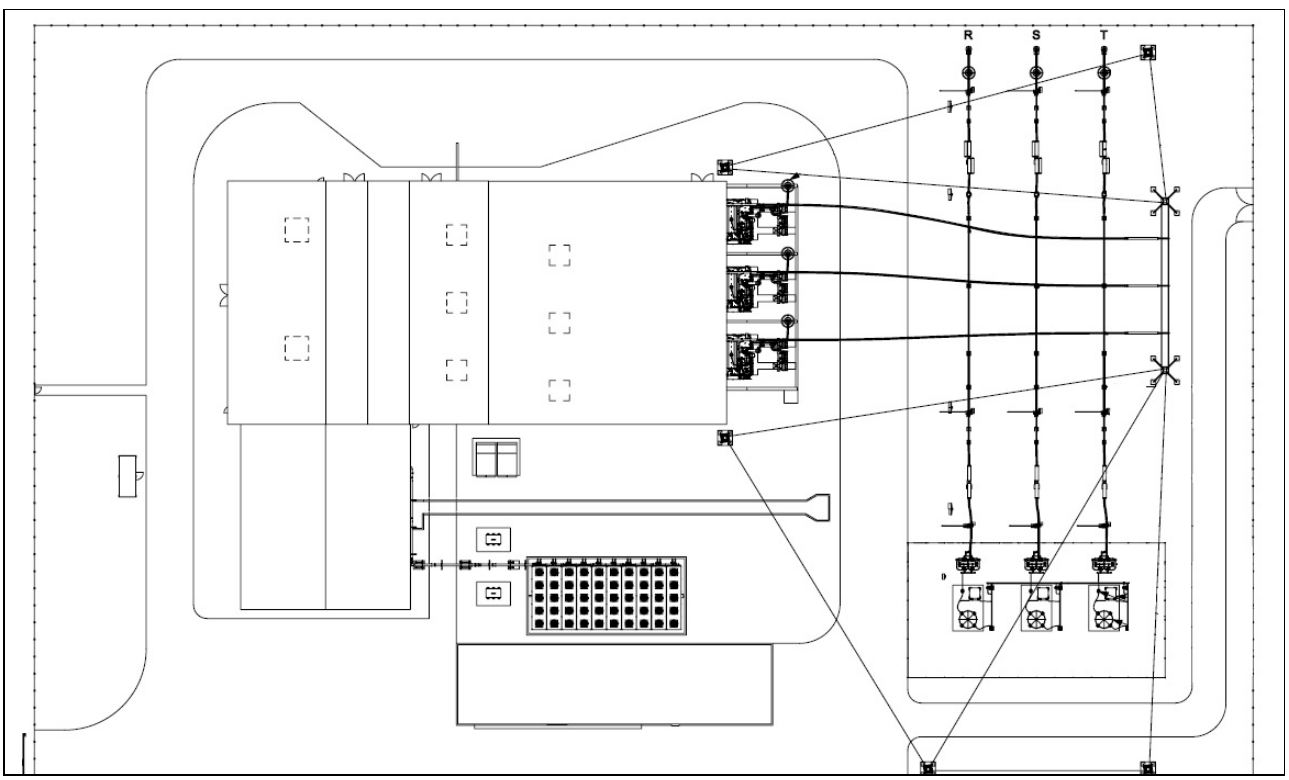

Figure 3 – Site Plan View for Shotton (EWIC)

A summary of the site footprint, building heights and building volumes for the two sites is presented in Table 3, using the Galatina site as the 100% reference for comparison with Shotton. From Table 3, the following are apparent:

- The overall site area required for 2-Level VSC-HVDC is only 77% of that required for LCC-HVDC. This is largely due to no reactive power compensation requirements on the 2-Level VSC-HVDC technology.
- The overall converter building height for 2-Level VSC-HVDC is 120% of that for LCC-HVDC.
- The overall converter building footprint for 2-Level VSC-HVDC is 190% of that for LCC-HVDC.
- The overall converter building volume required for 2-Level VSC-HVDC is 179% of that for LCC-HVDC.

Project / Site	**Grita Galatina**	**EWIC Shotton**
HVDC Site Footprint	225m x 120m	180m x 115m
HVDC Site Area (Percentage*)	27 000m^2 (100%)	20 700m^2 (77%)
Max. Building height (Percentage*)	20m (100%)	24m (120%)
Converter Building Footprint	35m x 20m	38m x 35m
Converter Building Area (Percentage*)	700m^2 (100%)	1 330m^2 (190%)
Converter Building Volume (Percentage*)	14 000m^3 (100%)	25 000m^3 (179%)

Table 3 – Comparison of Site and Building Areas

* *Galatina Site (Grita) = 100% reference*

5 Continuous Development of Technology

The VSC-HVDC technology is under continual development and improvement, and has been updated to a more modern design subsequent to the EWIC project.

For the VSC-HVDC scheme at EWIC, the technology uses HVDC Light® Generation 3, which is a 2-level converter. The 2-level converter topology is shown schematically in Figure 4, with switching pattern as shown in Figure 5.

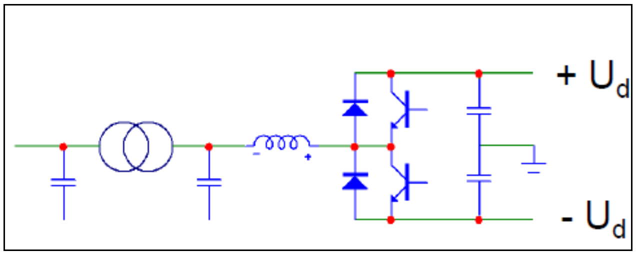

Figure 4 – 2-Level Circuit Topology

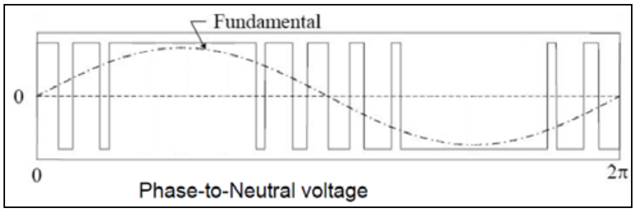

Figure 5 – 2-Level Switching

By contrast, the latest version of the technology (Generation 4) uses a cascaded two-level (CTL) design. The CTL converter topology is shown schematically in Figure 6, with switching pattern as shown in Figure 7.

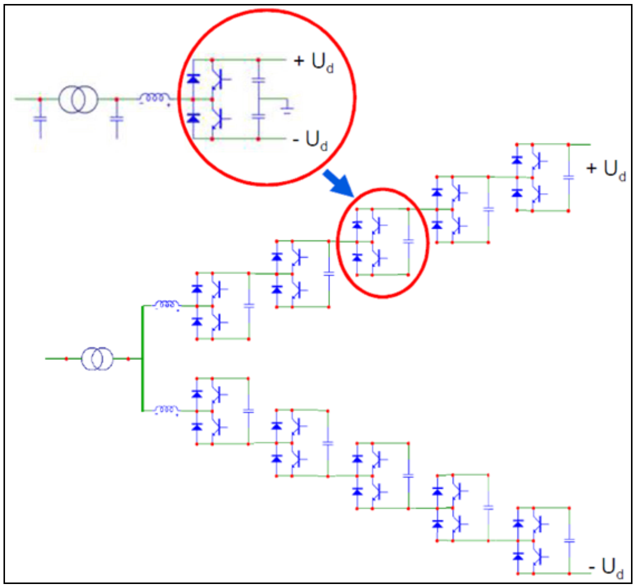

Figure 6 – CTL Circuit Topology

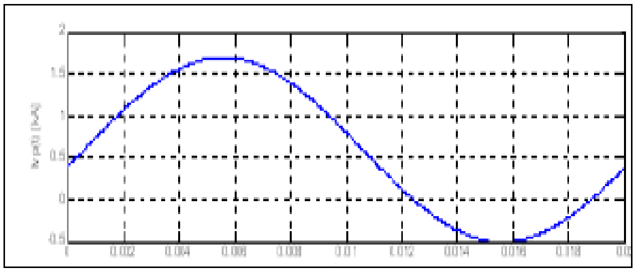

Figure 7 – CTL Switching

6 Equivalent Cascaded Two-Level VSC-HVDC Layout for Shotton

As a comparison point, a typical site layout using the CTL technology of equivalent rating to the 2-level arrangement at Shotton is shown in Figure 8.

Within the site layout there is an element of available spare space, which would allow for any project-specific additional requirements (e.g. Standby diesel generators, additional cooling, storage buildings, etc.).

The comparison is shown in Table 4 between the two generations of VSC-HVDC technology, considering the EWIC project and the latest generation of the technology. For consistency of comparison with Table 3, the Galatina site is used as a 100% reference for comparison.

As can be seen in Table 4, the overall site footprint is significantly smaller for the CTL equivalent when compared with Shotton.

Project / Site	Shotton 2-Level	CTL Equivalent
HVDC Site Footprint	180m x 115m	165m x 95m
HVDC Site Area (Percentage*)	20 700m^2 (77%)	15 675m^2 (58%)
Max. Building Height (Percentage*)	24m (120%)	15m (75%)
Converter Building Footprint	38m x 35m	70m x 45m
Converter Building Area (Percentage*)	1 330m^2 (190%)	2 730m^2 (390%)
Converter Indoor Volume (Percentage*)	25 000m^3 (179%)	29 500m^3 (211%)

Table 4 – Comparison of Site and Building Areas

* *Galatina Site (Grita) = 100% reference*

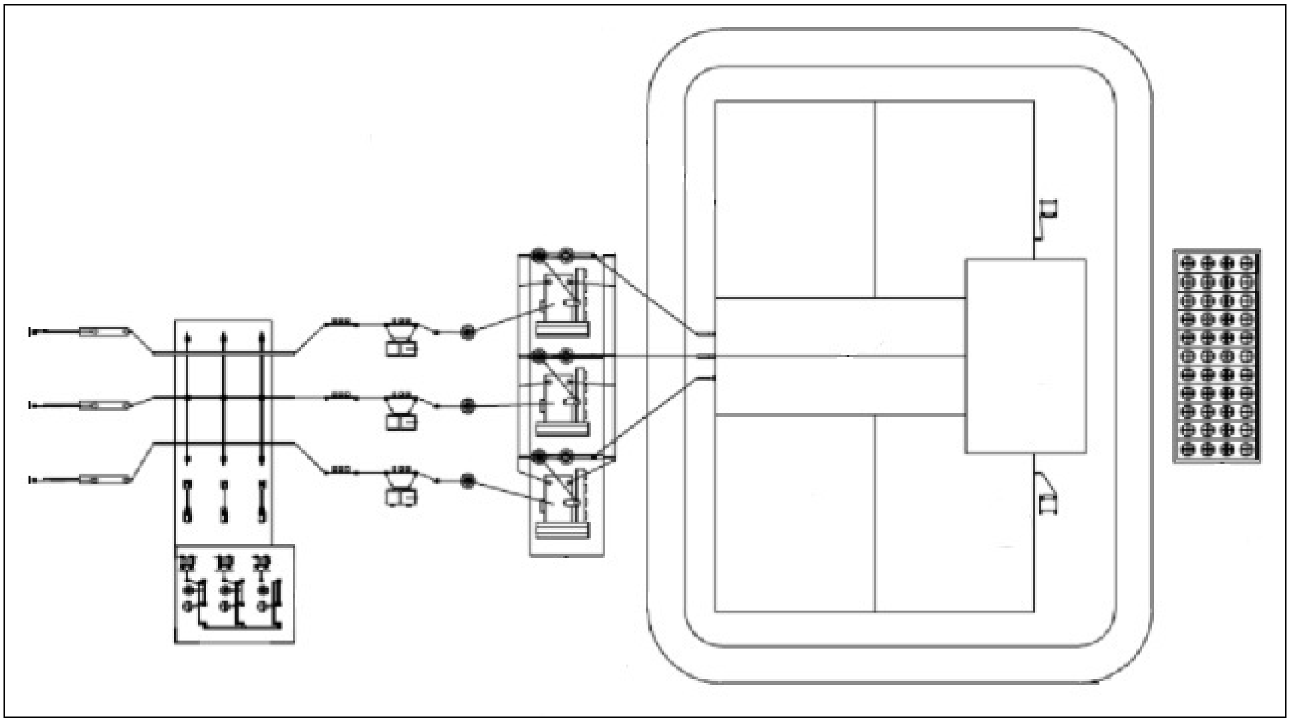

Figure 8 – Site Plan View for G4 Equivalent Layout

From Table 4, the following are apparent:

- The overall site area required for CTL VSC-HVDC is only 76% of that required for 2-Level VSC-HVDC, and only 58% of that required for LCC-HVDC.

- The overall converter building height for CTL VSC-HVDC is only 63% of that required for 2-Level VSC-HVDC, and only 75% of that required for LCC-HVDC.

- The overall converter building footprint required for CTL VSC-HVDC is 205% of that required for 2-Level VSC-HVDC, and 390% of that required for LCC-HVDC.

- The overall converter building volume required for CTL VSC-HVDC is 118% of that required for 2-Level VSC-HVDC, and 211% of that required for LCC-HVDC.

The lower buildings for the CTL technology are related to a reduced internal suspension height of the HVDC converter valves. This is desirable when considering the risks associated with working at height.

The reduction in overall site area required for the latest VSC-HVDC technology is a significant benefit, especially in areas where available site area is restricted or prohibitively expensive.

Typical converter station losses for CTL technology are below 1%, compared to approximately 1.7% for the 2-level technology used at EWIC.

7 Conclusions

The East-West Interconnector, which uses ABB's 2-Level HVDC Light® Generation 3 VSC technology, is the first commercial VSC-HVDC project connected to the United Kingdom, and to date it is the world's most powerful VSC project.

The 2-level VSC-HVDC technology uses a significantly smaller site area than an equivalent-rated LCC-HVDC project. This is at the expense of increased converter building size and higher losses.

The use of a cascaded two-level VSC-HVDC converter presents significant benefits over an equivalently rated 2-level VSC-HVDC converter or a LCC-HVDC scheme. The CTL arrangement offers a smaller overall site footprint and a lower building height than both the 2-level and LCC-HVDC alternatives. However, this is at the expense of increased converter building size.

The losses for the latest generation of CTL VSC-HVDC technology are now comparable with those of the LCC-HVDC technology.

Acknowledgements

The authors wish to thank EirGrid and Terna for permission to include the projects discussed in this paper.

The authors also wish to thank ABB colleagues in Stone and Ludvika for their support in writing this paper, especially: Sofia Håkansson and Chris Barber for assistance with the diagrams, Piotr Login for a useful discussion over the content, and Svante Svensson for proof-reading.

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