Paper presented at UPEC 2013, August 02, Dublin, Ireland.

Overview of the 500MW EirGrid East-West Interconnector, considering System Design and Execution-Phase Issues

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***Abstract-* The EirGrid East-West Interconnector between Ireland and Wales, which uses ABB's HVDC Light® Voltage-Sourced Converter (VSC) technology, is to date the world's most powerful VSC scheme, it is the first commercial VSC project connected to Ireland, and it is the first HVDC Light® scheme to use ±200kV cables.**

Ireland has plans to expand wind power generation and the link will facilitate the addition of renewables and provide the possibility to export or import energy to / from the UK market. The new link also enhances security of supply in the Irish grid, allows both Ireland and the UK access to more competition and provides black-start capabilities.

This paper presents an overview of the EirGrid East-West Interconnector project, considering the Converter topology, System Design, Overview of the VSC technology used, and some of the significant execution-phase site works issues.

***Index Terms*-- HVDC Light, VSC, Cable Installation**

I. INTRODUCTION

Background

The 500 MW EirGrid East-West Interconnector HVDC Light® transmission system connects the grids of Ireland and Wales. This is the first HVDC Light project to use ±200 kV cables and the link is about 260 km long [1].

ABB was responsible for system engineering including design, supply and installation of the converter stations and the sea and land cables.

Ireland plans to expand wind power generation and the link facilitates development of renewable energy and allows for the export and import of energy between Ireland and the UK market. The link also enhances security of supply of the Irish grid and allows both Ireland and the UK access to more competition [2].

HVDC technology was selected due to the overall cable length. HVDC Light in particular was used due to the controllability offered.

Additional benefits provided by the HVDC Light technology are:

- "black start", a way of restoring power after a blackout without the aid of external energy sources
- active AC voltage support

Benefits

The EirGrid East-West Interconnector to the UK is vital for Ireland. It helps ensure that Ireland is able to access more energy into the future, as follows [2]:

Fig. 1. EWIC Project

Energy security for a growing population

Energy security means making sure there is enough high-quality power to cater for a growing population that requires more and more electricity.

Promotes competition in the electricity sector

By connecting to the UK grid, Ireland has access to power from right across Europe. This will create a more competitive market and help reduce the price of electricity for consumers.

Encourages the growth of renewable energy in Ireland

Ireland can increase its reliability on wind generated electricity. This is because additional supplies can be imported as a back-up for wind power, to be used during calm days in Ireland. Likewise, when Ireland has excess electricity (including wind generated electricity) it can be exported to the UK.

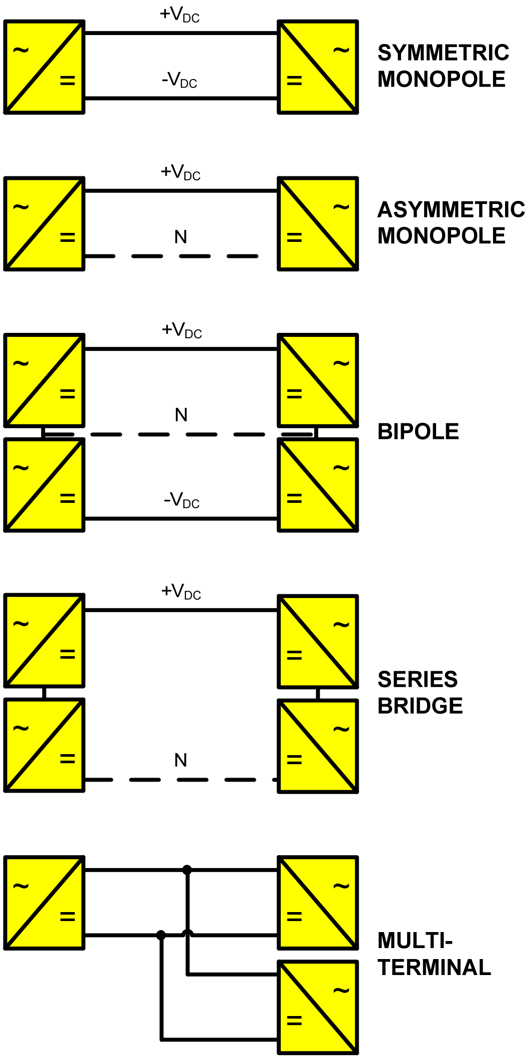

Fig. 2. Common System Topologies

Allows Irish companies to trade power with the UK

The interconnector is bidirectional, and it can import or export energy. This allows Irish energy companies to sell energy to the British market. Likewise energy can be purchased from the UK when it is cheaper or if there is insufficient generation in Ireland.

II. CONVERTER TOPOLOGY

Common System Topologies

A schematic diagram of some common system topologies is shown in Fig. 2. These are briefly described below [4]:

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.

The EirGrid East-West Interconnector is configured as a symmetric monopole. The main system design parameters are shown in Section III below.

Comparison of VSC and LCC Technologies

A brief summary of the differences between VSC and LCC technology is presented in Table 1 [3, 4, 5].

Table 1 – Comparison of VSC and LCC Technology

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 (SCR)	> 2	0
Black Start Capability	No	Yes

VSC-HVDC was chosen for the EirGrid East-West Interconnector after a full evaluation process by EirGrid of available technologies. VSC-HVDC allows controllability, black-start and active / reactive power support, in addition to resolving the cable capacitance issue if the system was designed using AC.

III. SYSTEM DESIGN

The main technical parameters of the scheme are as follows:

Connection point (Ireland) – Woodland
Sea cable landing: Rush North Beach, Co. Dublin

Connection point (Wales) – Deeside
Sea cable landing: Barkby Beach, North Wales

Operator: EirGrid, Ireland

Technology HVDC Light® by ABB

Transmission capacity: 500 MW

DC voltage: ± 200 kV

AC voltage: 400 kV (both ends)

AC frequency: 50Hz (both ends)

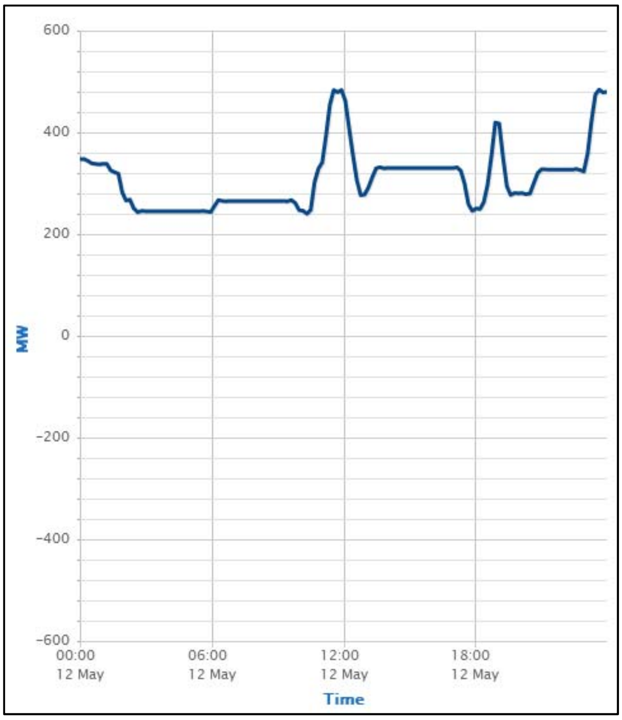

Fig. 3. Typical Flow Graph

DC Cable route length: 261.9 km parallel cables
Submarine: 187.7 km
Ireland: 44.3 km
Wales: 29.9 km

AC Cable route length: Ireland: 0.5 km
Wales: 2.8 km

The HVDC cable details are shown in Table 2.

Table 2 – Featured HVDC Cables

Featured Cable	Submarine	Land
Insulation	Extruded polymer	Extruded polymer
Conductor area	1650mm^2	2210mm^2
Conductor material	Copper	Aluminium
Armouring	Steel	-
Diameter	117mm	107mm
Mass	39 kg/m	12 kg/m

The oil-free HVDC Light® cables minimize the environmental impact on sea and on land.

A typical flow graph of the HVDC link is shown in Fig. 3.

IV. SITE WORKS AND CONSTRUCTION

Site Layout

A plan view of the Woodland Converter Station is shown in Fig. 4. The overall dimensions are approximately 110m x 190m with the main areas including the incoming AC connections and filter area, transformers and converter buildings.

The Shotton converter station portion is identical, but the incoming AC substation is located at Deeside, approximately 3km away.

Site Works Programme

The key dates in the execution phase were as follows:

- HVDC Cable Ducting commences 11/2009
- Construction Phase Confirmation 04/03/2010
- Converter Station Civil Works Start 03/2011
- Transformers In Position 12/2011
- Main Equipment Installation 05/2012
- Sea Cable Laying Complete 11/05/2012
- Sea Jointing Complete 30/05/2012
- HV Cable Test 06/2012

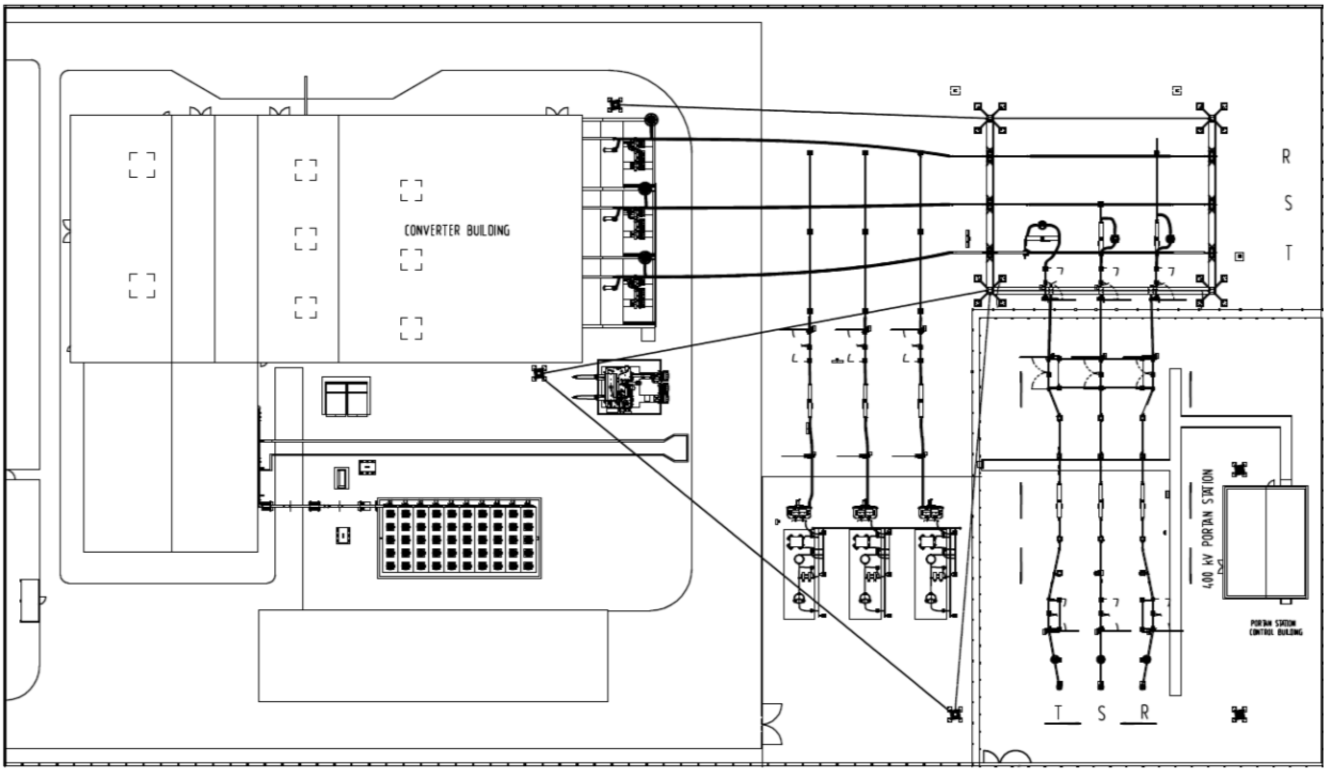

Fig. 4. Woodland Converter Station

Land Cable Installation Issues

For the cable installation there were some significant issues, notably the following:

- River Dee Horizontal Directional Drill (HDD)
- Railway Crossing HDD
- Transition Joint HDD – Barkby Beach
- Proximity to 400kV Deeside National Grid Substation

Seabed Conditions

The marine route presented an extremely challenging mix of seabed conditions that required various cable installation techniques.

- Irish shore end: A rock reef at the Irish shore required a 500m trench to be cut through it by heavy rock cutting equipment operated from jack-up barges. HDPE ducts were then installed in the trench before carefully backfilling the trench and winching the cables through the ducts from the land side.

- Shallower waters: A barge with a vertical injector tool successfully laid & buried the cables in the shallower sandy / cobbles / clay seabed at each side.

- Deep waters: New build cable laying vessel, the Lewek Connector, with the biggest cable capacity of any ship in existence, on its maiden cable laying project, laid the

Table 3 – Offshore Cable Challenges

Challenges:	Solutions:
Clear & challenging deadline	Multiple vessels operating simultaneously on different parts of the route. New build high capacity cable laying ship utilised. Works programmed early to allow for slippage .
Variable & very stiff seabed	Mix of burial techniques utilised. Trenching & Jetting equipment on same vessel allowing flexibility.
Permitting requirements	Permitting managed very proactively by Client and Contractor.
Manufacturing capacity	Cable manufacture and cable laying carefully co-ordinated.
Cable jointing	Dedicated jointing vessel utilised
Crossings of existing utilities	Early engagement with existing asset owners followed by careful execution of the works resulted in all five crossings taking place successfully.
Weather	Weather in 2011 was a particular issue. Robust vessel selection, careful planning and use of autumn / winter seasons as a contingency were all employed to maintain works on programme.

cables in the deepest section in one continual length. These cables were then buried using water jetting in sandier areas, and a mix of chain cutting and rock placement techniques in heavily compacted glacial clay, boulder and bedrock areas.

Marine Installation Programming Issues

In order to achieve an on time delivery for a most demanding work scope, challenges were carefully addressed in advance by both Client & Contractor working closely together. Refer to Table 3.

Civil Works Aspects

The basic electromechanical designs at Woodland and Shotton Converter Stations are identical due to the similar electrical rating at each converter. It was elected to use an integrated design and construction approach with a single Civil Designer, to ensure commonality in the solutions that were designed and consistency in the materials that were selected to house the HV equipment.

Ground conditions were different for each converter. The Woodland site had a challenging topography and some issues with groundwater, typical of a greenfield site in this part of Ireland, where ground bearing foundations were selected to support the building loads.

Shotton was a brownfield site, containing contaminated made ground associated with a former gas works, over the older reclaimed sands from the Dee estuary. These aspects, together with predominantly soft ground over the site, lead to the selection of driven piles that significantly reduced spoil generation. Materials that were excavated for the pile caps and other parts of the foundations were successfully retained in a corner of the site thus significantly reducing the amount of material taken to landfill and saving many vehicle movements on public roads.

V. VOLTAGE-SOURCED CONVERTER (VSC) TECHNOLOGY

Two-Level Converter Technology

For the VSC-HVDC scheme at the EirGrid East-West Interconnector project, the technology uses HVDC Light® Generation 3, which is a 2-level converter. The 2-level converter topology is shown schematically in Fig. 5, with switching pattern as shown in Fig. 6.

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 EirGrid East-West Interconnector project.

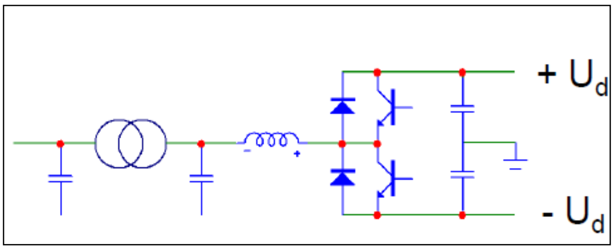

Fig. 5. 2-Level Circuit Topology

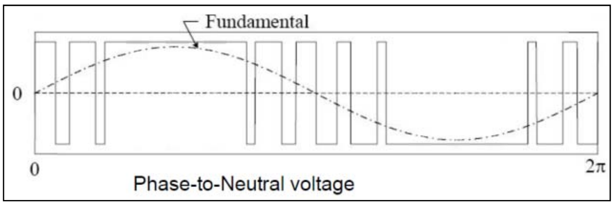

Fig. 6. 2-Level Switching

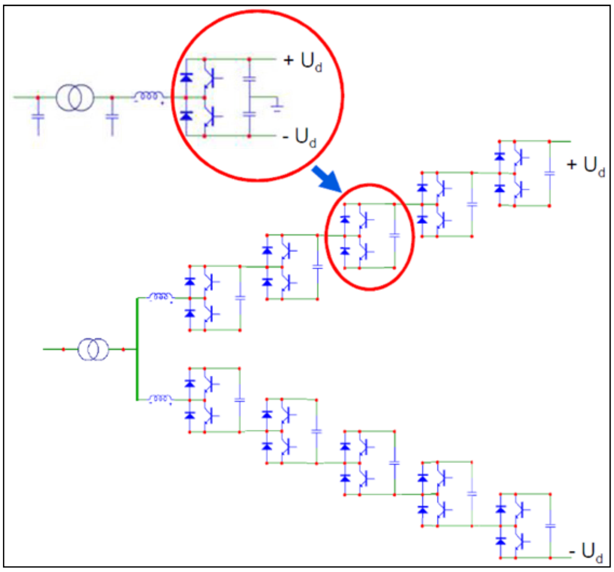

Fig. 7. CTL Circuit Topology

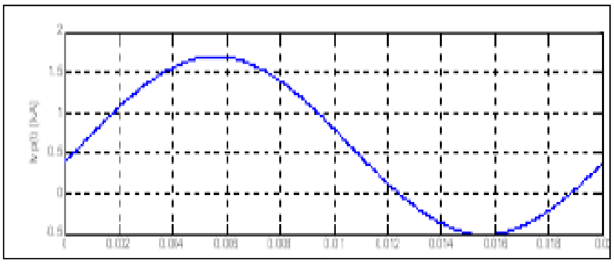

Fig. 8. CTL Switching

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 Fig. 7, with switching pattern as shown in Fig. 8.

VI. SUMMARY AND CONCLUSIONS

The EirGrid East-West Interconnector represents a significant milestone in the development of the VSC technology. It is the first project to use ±200kV cables, and has the world's longest HVDC cable section without a joint. At commissioning the 500MW rating made the EirGrid East-West Interconnector project the world's most powerful VSC converter.

The converter is also the first commercial VSC-HVDC project connected to both the United Kingdom and to Ireland.

VII. ACKNOWLEDGEMENTS

The authors wish to thank EirGrid for permission to present the project, and also ABB colleagues in Stone, UK and Ludvika, Sweden for their support in writing this paper, especially Chris Barber for assistance with the diagrams.

VIII. REFERENCES

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IX. AUTHOR PROFILES

John Egan joined EirGrid in 2009 and is currently the Senior lead project engineer for the 500MW EirGrid East-West Interconnector project. John has a degree in Electrical Engineering from University College Dublin and is an active member of the Cigre working group on HVDC commissioning. John was primarily responsible for all detailed engineering design reviews from initial design through to site works, system testing , acceptance and performance testing, Grid Code compliance in UK & Ireland for the EirGrid East-West Interconnector project.

Paul O'Rourke joined EirGrid in 2008 and was the Marine Project Manager for almost 5 years, before being appointed to the role of Project Director for the final months of the project. In his role as Marine Project Manager, he lead the project from route selection & permitting right through to procurement of EPC Contractor and supervision of the marine works. Paul has a Bachelor's Degree in Electrical Engineering from University College Dublin, a Master's Degree in Engineering from the Dublin Institute of Technology, and prior to working for EirGrid worked for Siemens Energy in the UK.

Dr Rob Sellick joined ABB in 2011 and is currently Engineering Design Manager for Grid Systems. Rob is a Chartered Engineer, has a PhD in Electrical Engineering from the University of Cape Town and is a Member of the Institution of Engineering and Technology. Rob joined ABB as Lead Plant Systems Engineer, bringing 15 years of experience in AC and HVDC substations. He is currently involved in the engineering design of UK transmission system reinforcements and HVDC interconnectors.

Bernard Johnson Bernard Johnson joined ABB in 2003, and has been working in the Power systems business for almost 20 years. His projects experience has been gained from working with prestigious clients including Jaguar Cars, cutting edge Pathology systems, EMU Traction systems for the Channel Tunnel Trains, as well as large coal and gas power station EPC contracts. More recently Bernard was the Planning Manager at the inception of the National Grid Electrical Alliance, and is now Planning Manager for ABB Grid Systems UK.

Pete Tomlinson has been with ABB since 2006 and is presently Civil Construction Manager for Grid Systems, and also has over 5 years' experience in the civil aspects of AC substation design and construction. Holding an MSc in Civil Engineering Design and Management, Peter has worked extensively in both Civil Design and Site Construction both in the UK and abroad over the last 14 years. His current focus includes informing stakeholders how to achieve well planned and innovative civil works for HVDC and Offshore Wind projects.

Svante Svensson started with ABB HVDC in 1974 directly after gaining a Masters degree in Electrical Power Engineering from the Royal Technical University. He has had many different positions within the ABB's HVDC unit, but mostly as a Project Manager for projects worldwide.