

Project Aquila Information and References

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Purpose of Document

This document serves as a resource base for information, dissemination activities, and publications delivered by The National HVDC Centre for Project Aquila and SSEN Transmission. It comprises the research and innovation work undertaken by the Centre over several years on the Aquila Interoperability Package, which has led to world first multi-vendor multi-terminal interoperability demonstrations, conference and journal publications, along with three accepted patents covering the multi-terminal control intellectual property developed by the Centre and SSEN Transmission. This document provides those new to Project Aquila with necessary information to get up to speed with its methodologies and approach to future multi-vendor DC grids.

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Information, Dissemination, and Press Releases

	Title	Media Type	Description	Link/Access
[1] 2023	Introduction to Project Aquila	Video	Short introduction to Project by SSEN Transmission	Project Aquila on Vimeo
[2]	Aquila webpage on HVDC Centre website	Webpage	Overview of the Aquila interoperability project	Aquila Interoperability Package – The National HVDC Centre
[3] 2024	Webinar: Introduction to project Aquila	Webinar	Public webinar delivered by HVDC Centre lead Engineer, Dong Chen, describing activities of the Aquila Interoperability Package	WEBINAR: Introduction to Aquila Interoperability – The National HVDC Centre
[3] 2025	Aquila project concept and mitigating stability risks in HVDC grids	Presentation slides	Slideshow describing Aquila concepts, presented at CIGRE UK SC-C4 Technical Liaison Meeting (January 2025)	Advancing Grid Stability, System Modelling and Risk Mitigation Techniques in Power Systems Insight from the National HVDC Centre
[5] 2025	First public demonstration of multi-vendor multi-terminal interoperability at IET ACDC Conference 2025	Press release	SSEN Transmission press release on the latest Aquila demonstrations	World-first technology to unlock full power of HVDC power systems - SSEN Transmission

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Publications List

	Title	Publication Type	Description	Link/Access
[1] 2023	“Towards HVDC interoperability - assessing existence of equilibrium with reference to converter terminal behaviour” [Aquila Patent 1]	Conference Paper (IET ACDC 2023)	Outlines first principles of multi-vendor interoperability and proposes a steady-state DC system monitoring index to quantify the domain of safe operation of DC voltages.	Towards HVDC interoperability - assessing existence of equilibrium with reference to converter terminal behaviour - University of Strathclyde
[2] 2024	“Towards HVDC interoperability—Vendor agnostic control architecture and quantifying domain of operating point”	Journal paper (IET GT&D)	Extension of (1), with further proof on vendor agnostic applicability of the index.	Towards HVDC interoperability—Vendor agnostic control architecture and quantifying domain of operating point - Chen - 2025 - IET Generation, Transmission & Distribution - Wiley Online Library
[3] 2023	“Modelling asymmetrical HVDC transfer network for multi-vendor-multi-terminal interoperability” [Aquila Patent 2]	Conference Paper (IET RPG 2023)	Describes the mathematical framework for characterising asymmetry in a bipolar MTDC network comprising of both rigid and DMR return paths.	Modelling asymmetrical HVDC transfer network for multi-vendor-multi-terminal interoperability IET Conference Proceedings
[4] 2024	“Towards HVDC Interoperability - Neutral Current Control for Multiple Terminals”	Preprint open access	Builds on asymmetric DC network modelling in (3), applying the principles to a neutral current control concept designed to quench earth current at rigid HVDC stations under unbalanced conditions.	Towards HVDC Interoperability - Neutral Current Control for Multiple Terminals
[5]	“Towards HVDC Interoperability - On Dominance of Nodal Impedance” [Aquila Patent 3]	Preprint open access	Details mathematical proofs and conceptual overview for vendor-agnostic small-signal stability and DC impedance envelope specification in multi-vendor multi-terminal DC grids. The paper describes a sufficient but not necessary condition to guarantee the closed-loop DC grid interactions will be positively damped.	Towards HVDC Interoperability - On Dominance of Nodal Impedance

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[6] 2025	“Practical delivery of multi-vendor, multi-terminal HVDC systems; the Project Aquila experience”	Conference Paper CIGRE 2025 International Symposium		
[7] 2025	“PLL-Based Control Strategy for Interconnecting Multiple VSCs under Islanded Control”	Preprint open access	Provides a reference to a control framework and one illustrative implementation of Phased-locked-loop (PLL) based Voltage Sourced Converter (VSC) for islanded operation in a 3-phase AC network	PLL-Based Control Strategy for Interconnecting Multiple VSCs under Islanded Control

Interoperability patents filed on the above (GB and international).

HVDC multi-vendor multi terminal - 2219373.4
Asymmetrical Bipolar HVDC Control Methods and Systems - 2307888.4
Stability and Multi Terminal HVDC Systems and Control Methods - 2315901.5

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Full Details of Publications

- [1] The HVDC Centre, "Towards HVDC interoperability – assessing existence of equilibrium with reference to converter terminal behaviour," Aquila Patent 1, in *Proc. IET ACDC Conf.*, 2023. [Towards HVDC interoperability - assessing existence of equilibrium with reference to converter terminal behaviour - University of Strathclyde](#)
- [2] Chen, D., Phurappa, P., Marshall, B., Scott, A., Henderson, C. "Towards HVDC interoperability—Vendor agnostic control architecture and quantifying domain of operating point." *IET Gener. Transm. Distrib.* 19, e13298 (2025). [Towards HVDC interoperability—Vendor agnostic control architecture and quantifying domain of operating point - Chen - 2025 - IET Generation, Transmission & Distribution - Wiley Online Library](#)
- [3] D. Chen, B. Marshall, "Modelling asymmetrical HVDC transfer network for multi-vendor-multi-terminal interoperability," *Renewable Power Generation and Future Power Systems Conference 2023*. [Modelling asymmetrical HVDC transfer network for multi-vendor-multi-terminal interoperability | IET Conference Proceedings](#)
- [4] Dong Chen, Pimonpan Phurappa, Benjamin Marshall, Mohammad Wasim Ahmad and Callum Henderson, "Towards HVDC Interoperability - Neutral Current Control for Multiple Terminals", *Easychair Preprint*, No. 13292, 2024. [Towards HVDC Interoperability - Neutral Current Control for Multiple Terminals](#)
- [5] Dong Chen, Benjamin Marshall, "Towards HVDC Interoperability - On Dominance of Nodal Impedance". *TechRxiv*. October 25, 2023. DOI 10.36227/techrxiv.244122. [Towards HVDC Interoperability - On Dominance of Nodal Impedance - TechRxiv](#)
- [6] B. Marshall, P. Hofbauer, D. Chen, C. Barker, K. Yamamoto, and J. Hernandez, "Practical delivery of multi-vendor, multi-terminal HVDC systems; the Project Aquila experience," presented at CIGRE 2025 International Symposium, Palais des Congrès de Montréal, Québec, Canada, Sept. 29–Oct. 3, 2025. Session: B4 DC Systems and Power Electronics, PS1 System Enhancement, Markets and Regulation.
- [7] Dong Chen . "PLL-Based Control Strategy for Interconnecting Multiple VSCs under Islanded Control". *TechRxiv* September 19, 2025. DOI: [10.36227/techrxiv.175424357.77713611/v2](#)