Future Power Networks & Smart Grids Centre for Doctoral Training

Embedded MVDC and Conventional Distance Protection

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MVDC?

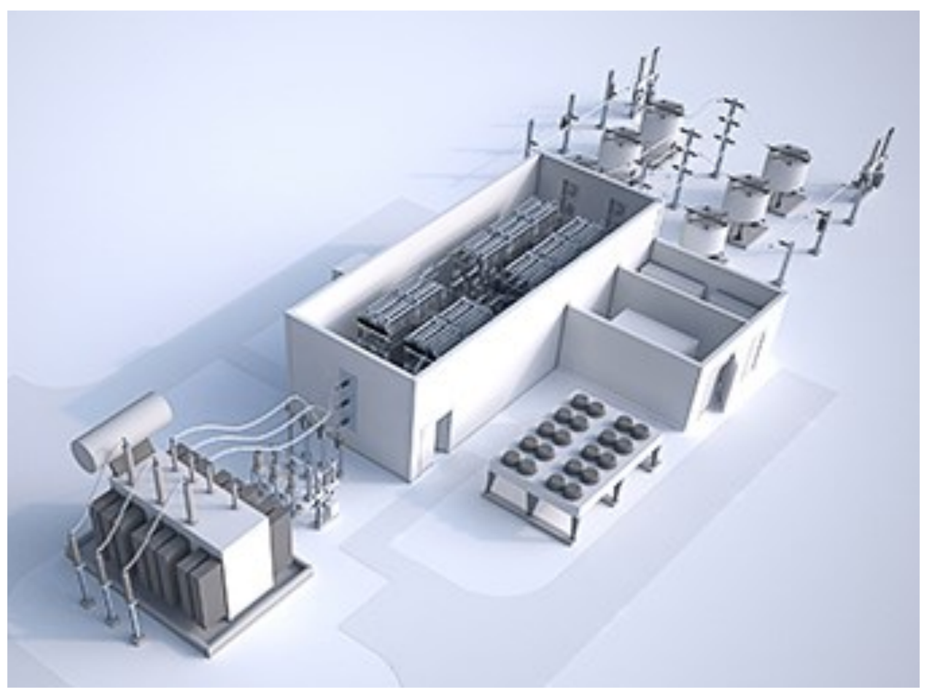

Fig. 1— MVDC converter station by Siemens

Embedded medium voltage direct current (MVDC) links could give the future DSO the ability to load network sectors more dynamically to allow significant increases in power flows whilst not exceeding the firm capacity of grid supply point transformers.

While load flow studies prove promising for MVDC, a review of system protection is required.

How do we protect dc?

The protection required to safeguard controlled links from a dc side fault needs to be fast to avoid damaging power electronic devices. This philosophy is somewhat contrary to traditional ac protection where trip signals may actually be delayed to allow more local circuit breakers to open first.

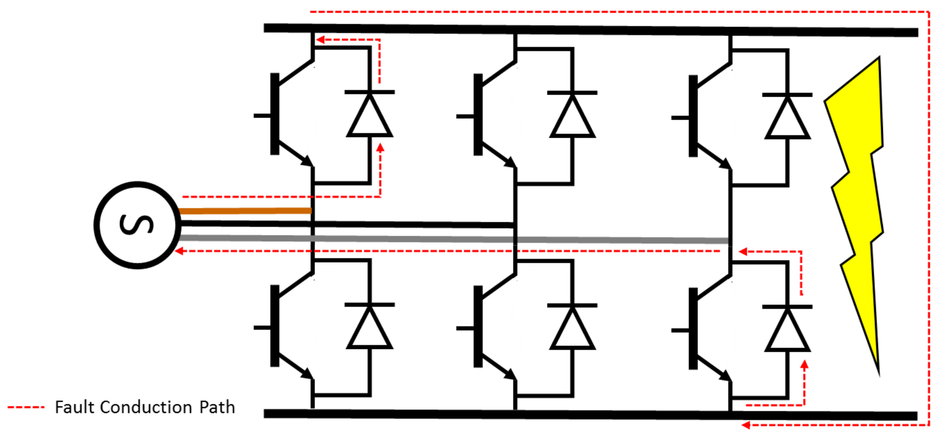

Fig. 2 —Fault path during DC side fault

During a dc side fault of simple VSC converter topologies the link appears as an uncontrolled rectifier (once the dc side storage energy has been dissipated) with current only being limited by the converter transformer, arm and series filter impendence (Fig. 2)

Converter ac circuit breakers should trip first…, but what if either of them fail? It is unlikely that remote overcurrent devices would trip due to the large impedance limiting current flow to the fault.

Distance Protection 101

The tripping time of a distance protection relay is a function of the electrical distance between the relay measurement point and the fault location. Distance protection relies upon measurement of both voltage and current from which the fault impedance is derived using ohms law. This principle allows operational zones, typically three (Fig. 3).

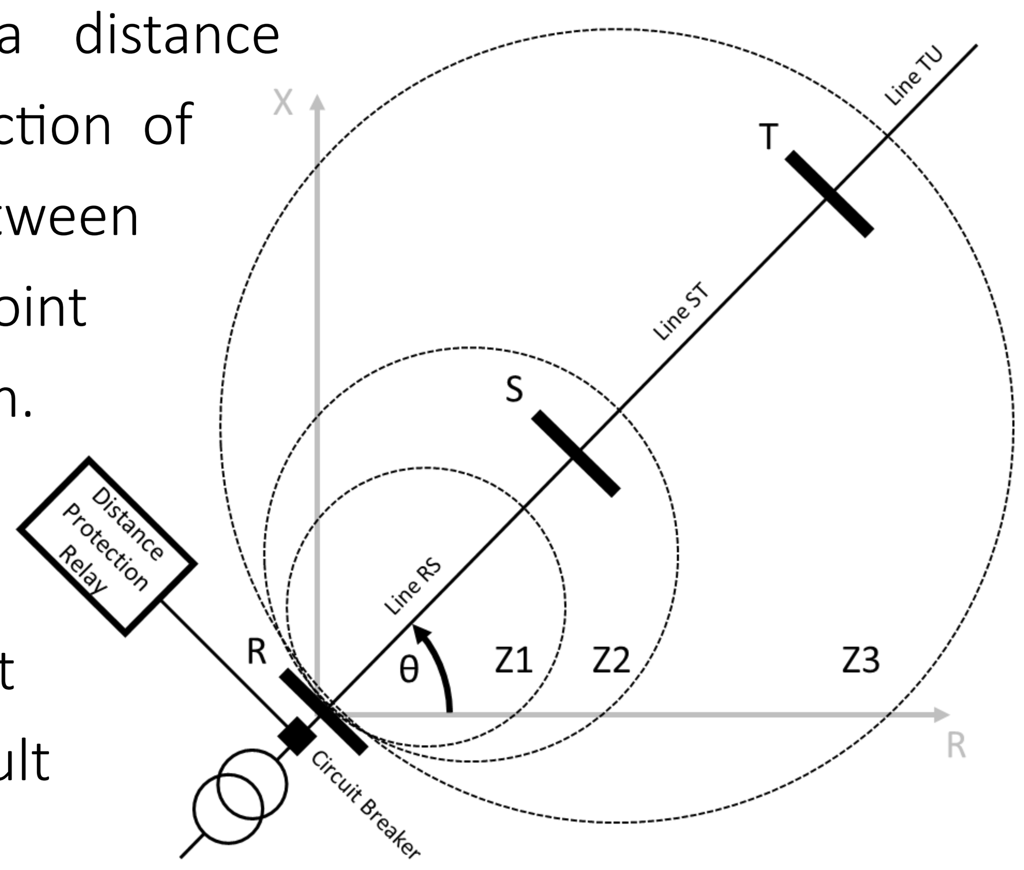

Fig. 3 — Distance Relay MHO Characteristic

"Can distance relays be used to act as a fast acting backup protection for embedded MVDC?"

Test Network

The 33 kV network used for these studies is outlined in Fig. 4. The network is based upon an existing Scottish distribution network. A MVDC link connects to a remote grid via a 10 km ± 27 kV link.

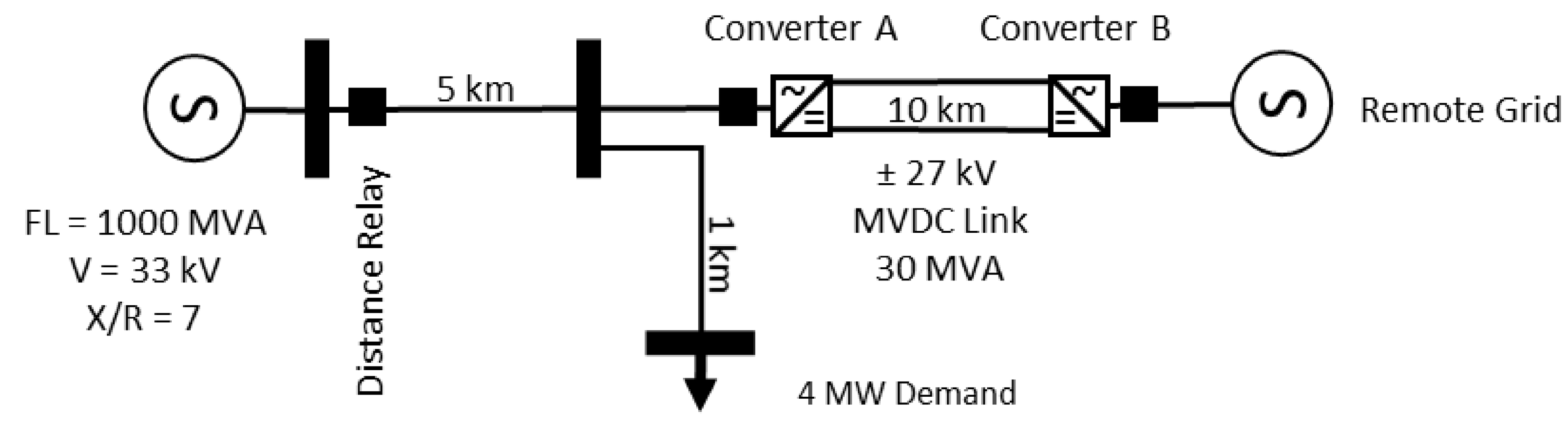

Fig. 4 — Test Network with embedded MVDC link

A pole to pole fault is thrown upon the dc link. Converter B is disconnected within 40 ms of fault detection. The ac breaker local to Converter A fails to isolate the fault. The impedance seen by the distance relay during the fault is presented in Fig. 5.

A distinct impedance settling point is observed at 1.5 + j17.5 Ω.

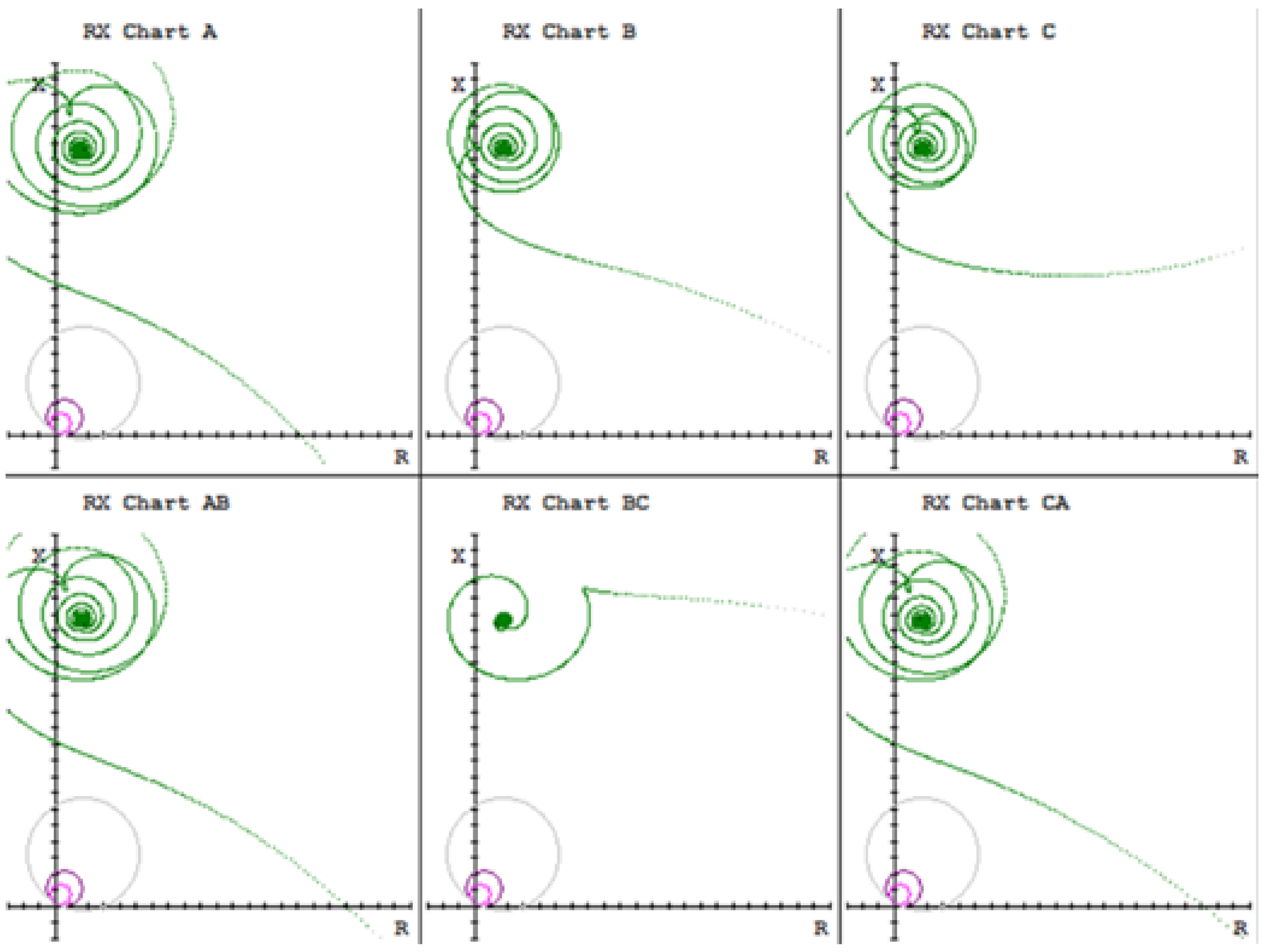

Fig. 5 — R-X Diagram showing fault trajectory for DC pole to pole fault

Potential protection strategy

Although the fault lies outside the normal setting parameters of Z1, Z2 & Z3, it is hypothesised that an accelerated quadrilateral Z4 characteristic (Fig. 6) could be deployed to provide backup protection.

Time grading studies between local and backup protection need to be investigated to ensure correct discrimination.

These theories are currently under-going further investigation which includes RTDS hardware in loop verification.

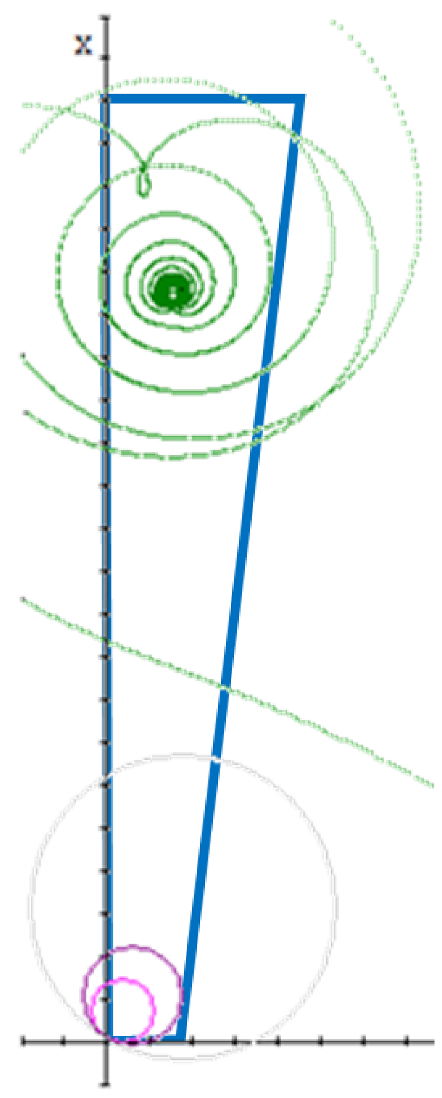

Fig. 6—MHO characteristic with Quadrilateral characteristic overlaid

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