Evolution of Protection Testing in Low-Strength and Converter-rich areas within the GB Grid.

The National HVDC Centre

BACKGROUND

Protection schemes form part of the most fundamental components of any power system. They ensure that when faults occur on networks, the effect of the fault is seen only briefly by the wider system and its connections, isolating the faulted infrastructure or generator from the network, hence allowing the healthy elements to continue to operate. By doing so, risks to personnel and risks of damage to the infrastructure of the AC power system are reduced. This article explains how declining system strength presents challenges to confidence over future protection relay operation - and **highlights how the HVDC Centre is helping to address these challenges**.

KEY PRINCIPLES

Protection systems on the network comprise protection relays, which are devices which trigger based on a given indicator of an event; thereby informing the operation of AC circuit breakers. Several approaches are used to achieve correct protection operation; however, the common theme is that all need to measure the behaviour of the power system through a fault (how voltage, current and the voltage angle change), and then use algorithms and settings to determine how the protection relay should act. It is critical that a power systems' protection operates reliably and rapidly.

PROTECTION TESTING APPROCAHES

Traditionally, demonstration of protection relay algorithm and settings are verified by physically testing the provided relay. Modelling of the relay is not normally undertaken as part of a procurement process given the ability to rely on a physical test ahead of installation. This means that whilst models of relays do exist in most power system software, these are hypothetical and bear limited resemblance to the devices installed in practice. Protection testing is based on injecting various levels of currents and voltage into the relays. The levels injected are based on theoretical relay setting calculations that assume a given short circuit current, and short circuit current variation at the protected zone. The conventional relay algorithm is also based on assuming the behaviour of the rotating machine, that have very high inertia limiting voltage angle movement across a fault period and contribute very high and predictable fault currents during the first few milliseconds of the fault. So, in the traditional world of protection testing the fault current that a relay needed to respond to have a predictable waveform. These expected waveforms could easily be reproduced in a test environment and injected using convention relay testing kits that are widely in use across the industry, to check that the protection relay would respond as expected.

CHANGE IN GENERATION MIX

Today, the generation mix in GB is changing. Several thermal generators are being decommissioned, or less available across the year, combined with the growth of renewable generation connected via power electronic converters. The fault performance of power converters is very different to the traditional fault behaviours of a synchronous generator. The controllers of power electronic converters highly influence both the magnitude and the shape of the fault current waveform during fault inception, dynamically changing the angles of injected current as a fault evolves, and across the clearance of fault. This means a protection relay is no longer seeing what was expected when it was designed, and settings were implemented. It also means it is no longer a straightforward process to inject a fault current signal into a relay with confidence that this would reflect what is observed by that protection relay in a real fault.

PRACTICAL IMPLICATIONS

Figure 1 shows illustrative polar impedance plots of a test network, with power converters and synchronous generators - where the plot (a) in the left is a well-defined fault impedance behaviour where the protection relays provides precise decision.

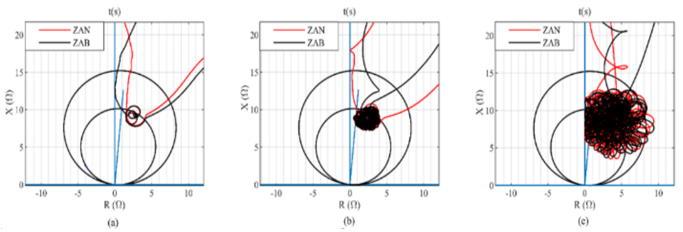

Figure 1: Illustrative Polar impedance plot from ongoing research project as system strength declines from results (a) to (c).

On the other hand, moving towards the right plots in Figure 1 (b) and (c), these represent more complex impedance behaviour due to the lower short-circuit and high converter penetration for which the conventional protection relays may struggle to respond reliably and rapidly.

DE-RISKING SOLUTIONS

The National HVDC Centre has been in forefront of detailed diagnosis and analysis of current and future protection challenges and innovation projects in GB. Using real-time simulators, power amplifiers and hardware relays, the Centre has been supporting Transmission Operators (TO's) to de-risk the integration of the renewable generation, HVDC interconnectors, and FACTS. The transition to the detailed protection testing is an area recognised internationally as a critical area. The Centre infrastructure enables detailed protection testing, while ensuring confidentiality of network data and manufacturers' IP. This transition would ensure that the critical network protection devices in the GB grid perform as intended.

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