Study Committee B4

DC Systems and Power Electronics

Paper ID_10212

Clearance of Temporary Faults in MMC-HVDC Overhead Line Transmission

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GE Grid Solutions

Introduction

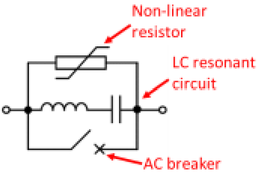
Most voltage sourced converters (VSC) in service today use submarine or underground cable, however, overhead transmission line for bulk onshore transmission offers economical benefits.

Submarine and underground cable faults are permanent and do not self restore, whereas overhead lines are subject to temporary faults.

The *aim* of this research is to show that by adding neutral bus switches into the DC side and incorporating additional control, a DC overhead line fault can be cleared, and the scheme restored to its pre-fault operating condition. This work also aims to display that during fault recovery, the power can be redistributed between poles.

Neutral Bus Switch (NBS) Operation

An NBS can be used to improve the clearing time for a DC side fault, and they are incorporated into the neutral pole(s) of an asymmetrical or bipole topology. The construction comprises of three conduction branches.



NBS Operating sequence following a DC fault occurring:

- DC current decays below threshold value after the AC side AC breakers have opened.
- AC Breaker component in the NBS opens.
- A growing current oscillation is initiated between the arc of the opening circuit breaker contacts and the resonant branch.
- This results in creating a current zero crossing in the arcing AC breaker, allowing the conduction path through the AC breaker to extinguish.
- Load current is commutated into the non-linear resistor and increases the dissipation of the trapped fault energy.

Objects of Investigation

There are two main objects investigated in this work:

1) Investigate the advantage of incorporating NBSs into a bipole scheme for DC fault clearance.

2) Investigate how to distribute the available power between the two poles and how to regulate power between the HVDC system and the AC transmission system.

OverHead Line Fault Clearence and Recovery Sequences

Fault clearence

DC side fault clearence relies on fault detection, protection scheme operation, and trapped fault energy dissipation.

	Fault clearance
i	Fault occurs on an OHL conductor and the DC and AC currents start to increase
ii	Protection functions detect over current and initiate converter block and AC breaker open commands
iii	Converters are blocked
iv	AC circuit breakers CB_A and CB_B open. This action is slower than the block process due to the mechanical operation of the circuit breakers
v	Intrinsic energy within the converter and OHL dissipates through the resistance of the scheme
vi	Once the current has decayed below the AC circuit breaker NBS component, the NBS opens.
vii	Fault current decays to zero and the air de-ionises

Scheme recovery

Before power transfer can resume, the effected converter stations must be re-energized and synced with the offshore system.

	Scheme recovery
i	Re-close NBSs (if present in the circuit)
ii	Re-close receiving end AC breaker CB_A
iii	Deblock converter stations
iv	DC voltage is built back up to nominal
v	Synchronise converter station VSC B output AC voltage magnitude and phase with AC system B
vi	Close sending end AC breaker CB_B
vii	Adjust converter station VSC B internal phase angle to enable power exchange

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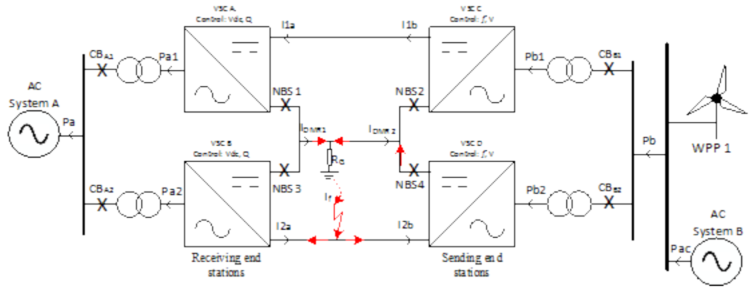
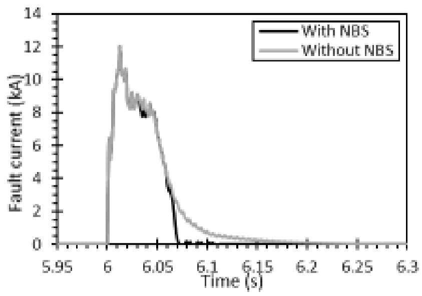
Bipole Configuration Test System with NBSs

A 2 GW rated bipole configuration has been implemented in PSCAD to undertake the investigations. Both poles are operating at 500 MW providing 50% headroom. A DC fault is applied to pole 2 at its receiving end.



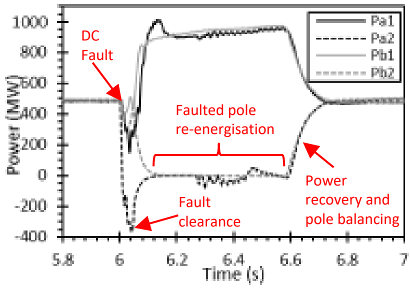
Comparison of Incorporating NBSs

The use of an NBS is seen to improve the fault current decay time and subsequent clearance. This would enable a faster re-energization attempt.



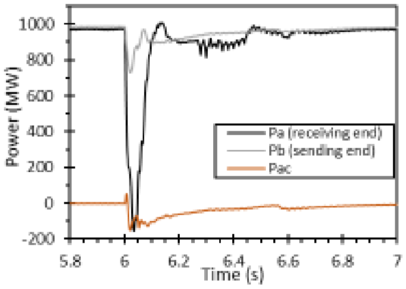
Bipole Power Redistribution

Receiving end power transfer of the bipole scheme is disturbed and reduced when the DC fault occurs @6s. The Fault is cleared by a combination of AC breakers and NBSs. The faulted pole power is conducted into the healthy pole, limiting the loss of power transferred. After fault clearance, the faulted pole is then re-energized and power sharing between the two poles resumes. This whole process occurs in under 800 ms.



Power Regulation between the HVDC and the AC transmission

The plot below shows the total power transferred by the sending and receiving end stations. It also shows the power transferred to the AC system (*AC System B*), that operates in parallel to wind power plant (*WPP 1*). During the DC fault, the rejected power from the HVDC system is absorbed by *AC System B,* but once the faulted pole has been re-energised, the power is regulated so that the HVDC system absorbs all the power from *WPP 1.* This is achieved using a common mode phase offset for both poles.



Conclusion

This research has shown that:

- Using NBSs, DC fault clearance on HVDC overhead line transmission schemes can be accelerated. They can also reduce the loss of power transferred by disconnecting the faulted pole.
- Using additional control, power distribution between the two poles in a bipole scheme can be balanced and power sharing between the HVDC and the AC transmission can be regulated.