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Power Systems Technical Performance

Paper ID 10823_2022

SEMI-PROBABILISTIC INSULATION COORDINATION FOR HVDC CONVERTER STATIONS

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Motivation

- The aim of this paper is to present semi-probabilistic approach for HVDC insulation coordination. Overvoltage distribution for each node of the station is obtained by performing failure simulations. The simulated failures can be phase-to-earth, phase-to-phase and can be inserted in different locations of the station. The calculations are semi-probabilistic as frequency of occurrence of failure is not evaluated, and most of the preconditions of the system are taken into account in a deterministic way.
- Insulation coordination results indicate that semi-probabilistic calculations can provide a hint of the risk taken by the station design, enabling a more effective design and a better understanding of the transient overvoltage behavior of HVDC stations background of study, describe problem and previous findings.

Model set-up

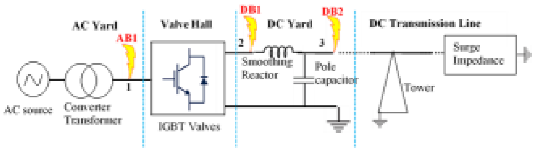

Table 2 Fault location details for lightning strike current injection in converter station

Fault Number	Description
AB1	Fault location at Converter valve AC bus at node 1
DB1	Fault location at Converter valve DC bus at node 2
DB2	Fault location at Converter valve DC bus at node 3

	Configuration	Fault Case
Switching impulse	PQ points, operating modes, with and without transmission system, grid strength, loading	Fault location Fault type – 3ph-gnd, 2ph-gnd, 1ph-gnd, pole-ground, and pole-pole
Lightning impulse	Polarity, tail time, tower footing resistance	Fault location Fault type-shielding failure, back flashover and direct strike in station

Simulation results and discussion

The probability distribution function is used to represent the data in terms of probability density function (PDF) and cumulative density function (CDF). The Kernel density estimate (KDE) distribution function is used to calculate the probability distribution of overvoltages.

Overvoltage distribution for stress type lightning impulse

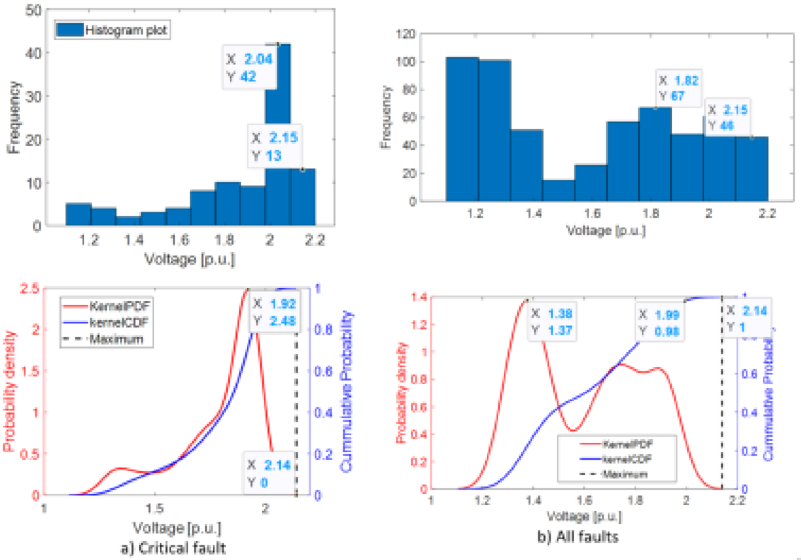

Figure. Histogram, probability density and cumulative probability plots of converter valve AC bus (Node 1) for (a) Critical fault (b) All faults

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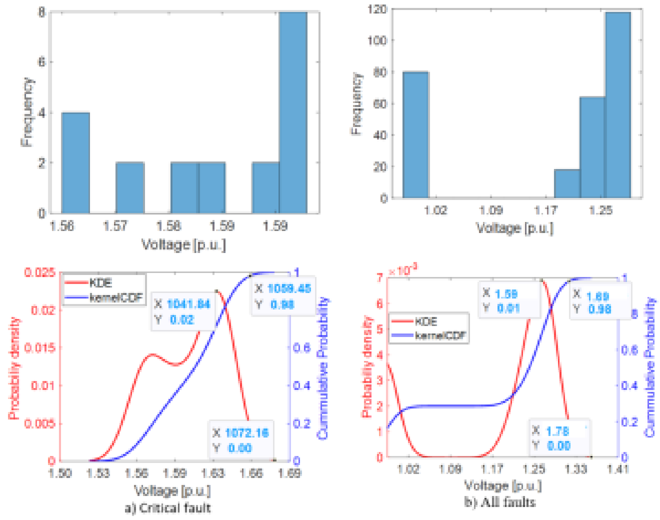
Table 3 Maximum overvoltage and cumulative probability for critical fault and all fault location

Node	Maximum Overvoltage (LIPL) p.u.	LIWL (15% margin) p.u.	2% Probability Overvoltage ($U_{2\%}$) p.u.
AC bus (Node 1)	2.14	2.46	2.00
DC bus (Node 3)	2.26	2.60	2.08

Overvoltage distribution for stress type switching impulse



Histogram, probability density and cumulative probability plots of converter valve DC bus (Node 3) for (a) Critical fault (b) All faults

Table 4 Maximum overvoltage and cumulative probability for critical fault and all fault location

Node	Maximum Overvoltage p.u.	SIWL (15% margin) [p.u.]	2% Probability Overvoltage ($U_{2\%}$) [p.u.]
Valve AC bus (Node 1)	1.42	1.63	1.37
Valve DC bus (Node 2)	1.78	2.05	1.69

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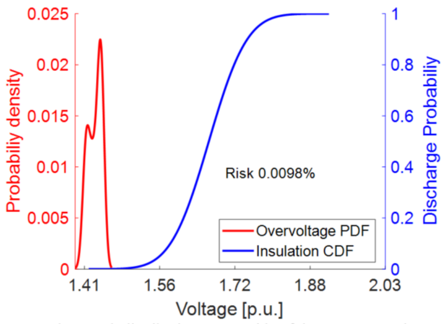
Table 5 Maximum overvoltage and cumulative probability for critical fault and all fault location

Node	SIPL [p.u]	SIWL [p.u]	LIPL [p.u]	LIWL [p.u]	LIWL risk %	LIWL risk all faults %	SIWL risk critical fault %	SIWL risk all faults %
AC bus (Node 1)	1.42	1.6	2.14	2.5	~0	~0	7.69E-08	5.30E-08
DC bus (Node 3)	1.78	2.1	2.26	2.6	~0	~0	9.83E-03	3.90E-05



Conclusion

- The semi-statistical approach is presented using a study case where lightning and switching overvoltage stresses are analyzed. Representative lightning and switching overvoltage are evaluated using deterministic and semi-statistical methods. Difference in overvoltage selection is observed between them.
- The semi-statistical method can assess the risk of failure of insulation. Using the semi-statistical method, the insulation withstand level can be selected based on the required failure rate. Hence, this can be employed for an HVDC system in order to achieve techno-economic insulation design.
- The semi-probabilistic method provides a detail view of the overvoltage distribution on the stations of the HVDC link, allowing a more detail design of the insulation, identifying the risk of flashover of the final design and moreover providing a tool that can help to make judgements of last-minute changes in the station installation.