Paris Session 2022

Semi-probabilistic insulation coordination application and experience

C4

PS2 + Question 9

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Background of semi-probabilistic insulation coordination

What is insulation coordination?

"The selection of insulation strength consistent with the expected overvoltages to obtain an **acceptable risk** of failure" – IEC 60071/ IEEE Std. 1313.1

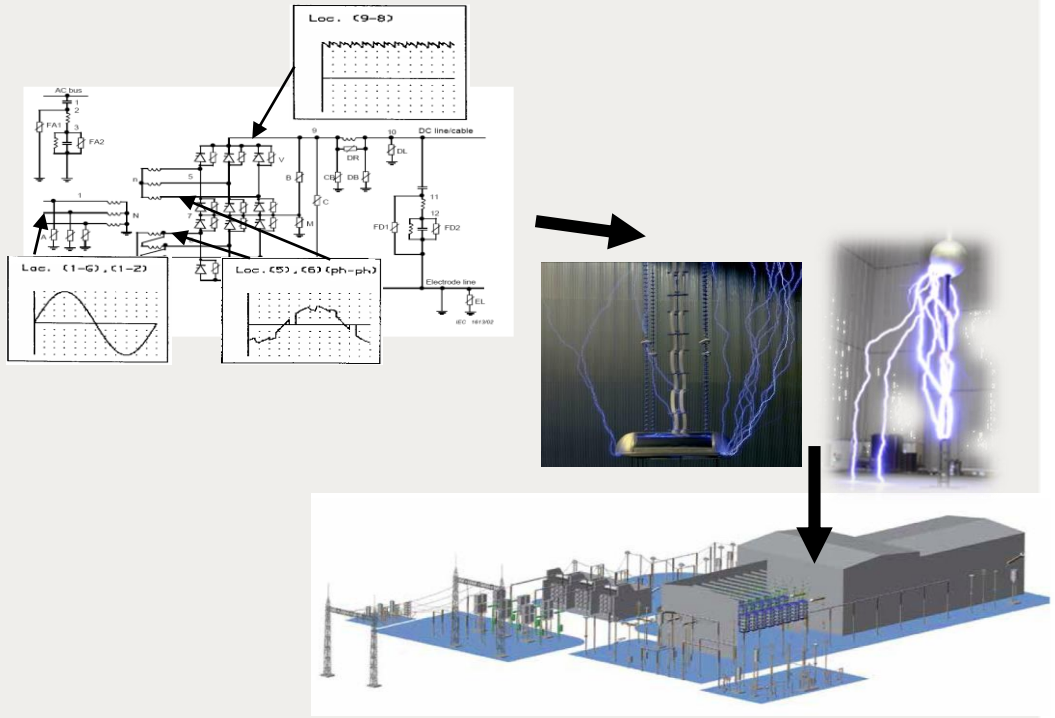
Where in the design?

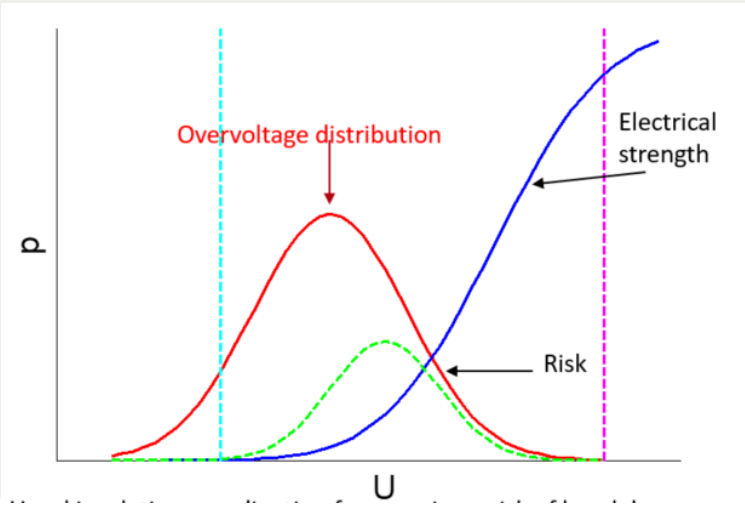
- Overvoltage magnitude and waveshape
- Dielectric strength of the insulation media
- Allocation of equipment in the station – Station design

Standard recommendation:

For designing IEC 60071-2 standard recommends to use a risk of 10%

For designing IEC 60071-5 (IEC 60071-11) standard recommends to use a risk of 2%





Applications - History

HVAC

- Up to **1965** ⇒ **deterministic method** for a maximum overvoltage a sufficient margin is selected
- **1970's** HVAC Transmission lines challenge to use common corridors
  - 345kV system ⇒ 500kV ⇒ 735kV
  ~ 52 years of operational experience using semi-probabilistic approach
- **1973** IEC 60071-1
  - Semi-probabilistic/ probabilistic method introduced
  - Semi as not necessarily all variables are considered probabilistic.
- IEC 60071-4 TR Guide for user's on how to set-up electrical modeling of components and how to apply statistical and semi-statistical by means of numerical programs

HVDC

- Semi-probabilistic method used in air clearance design
  - Dielectric strength of air as Gaussian distribution since first link (**1950**)
- Overvoltage calculation follow **deterministic method**: Maximum voltage with large margin.

HVDC: Semi-probabilistic method vs. conventional process

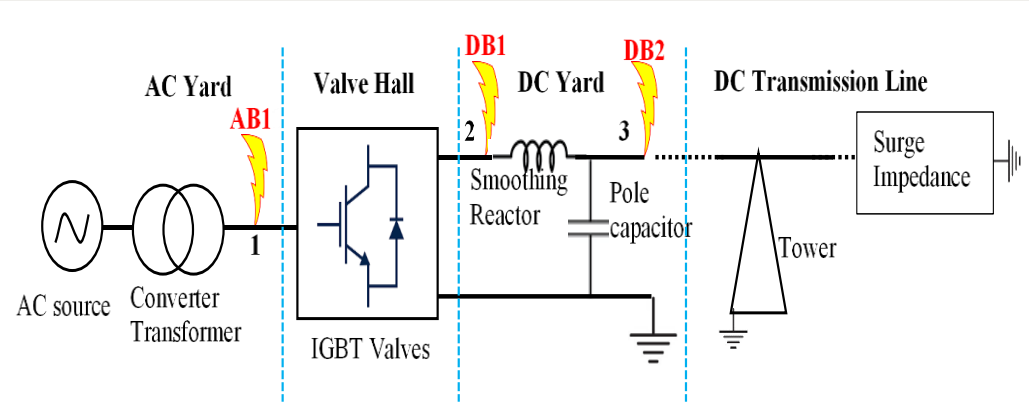
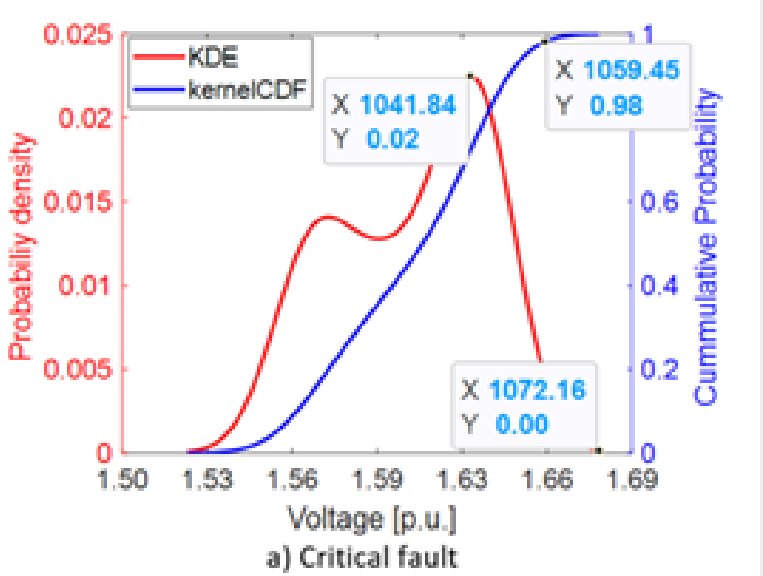
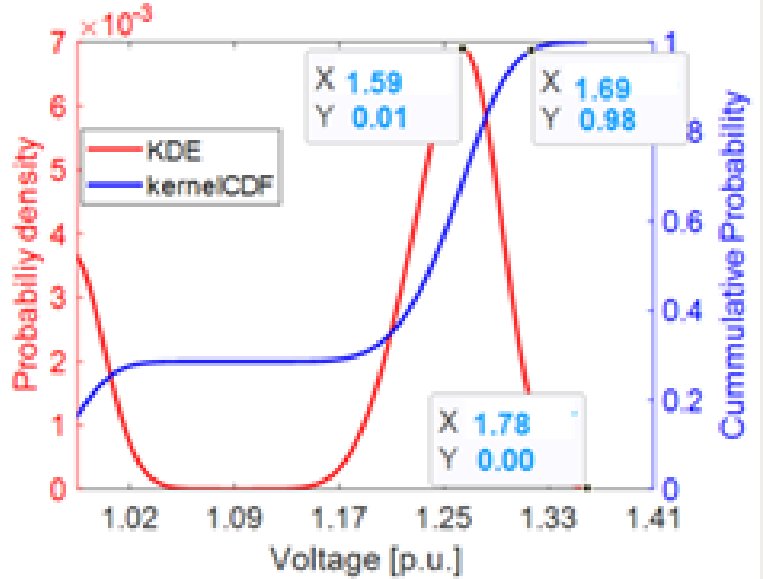


Table 4 Maximum overvoltage and cumulative probability for critical fault and all fault location

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



a) Critical fault



b) All faults

Risk evaluation

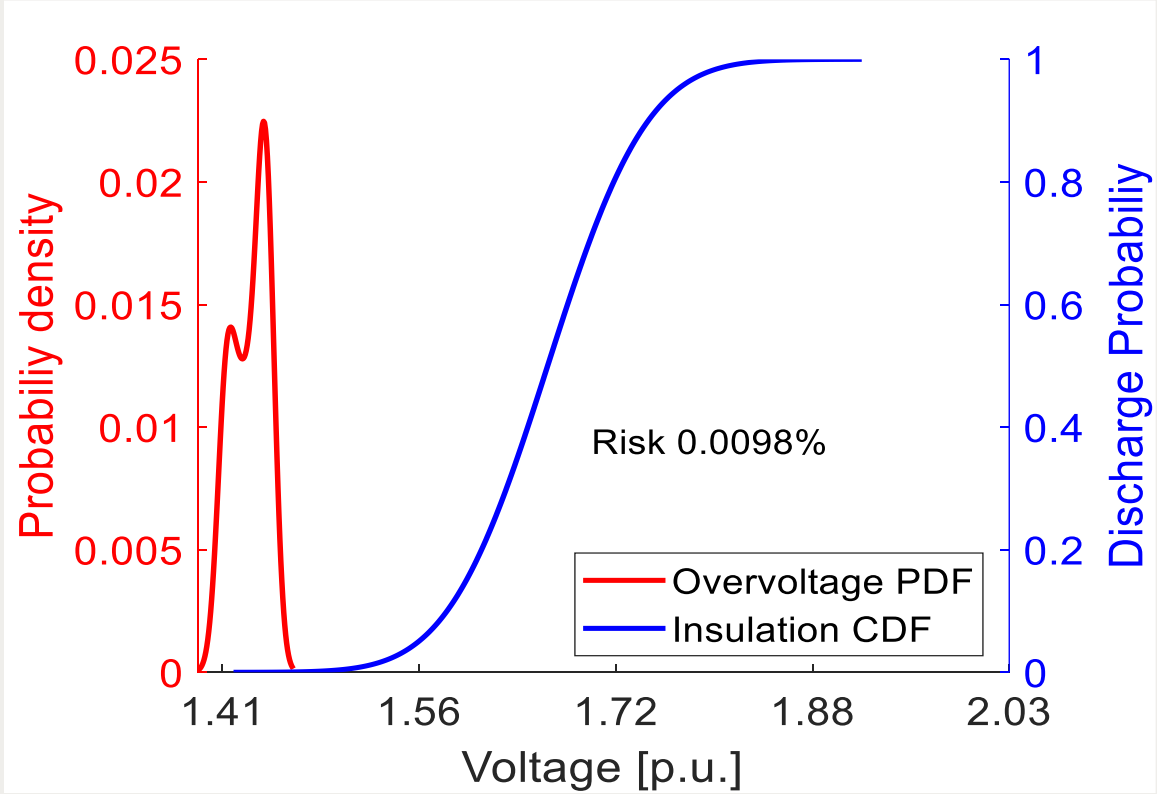


Table 5 Maximum overvoltage and cumulative probability for critical fault and all fault location

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

- We are facing challenges to reduce our carbon footprint, find green energy solutions, and been able to cover the demands on energy consumption worldwide. Challenges that are very similar to those that motivated HVAC power systems in 1970's to increase operational voltages and try to minimize the impact of power lines by using common corridors and introduce probabilistic methods for power systems design.

- Based on the successful 70 years of operational experience of HVDC, designed by using a conventional method, considering the increment on the computational capability of system calculation software and the vast knowledge on HVDC systems, it is necessary to start introducing the use of semi-probabilistic overvoltage calculation for the insulation coordination process and evaluate the risk of station clearance design appropriately.