I²G INDEPENDENT INSULATION GROUP

High Voltage Consulting Redefined

Your independent partner for high voltage consulting and testing

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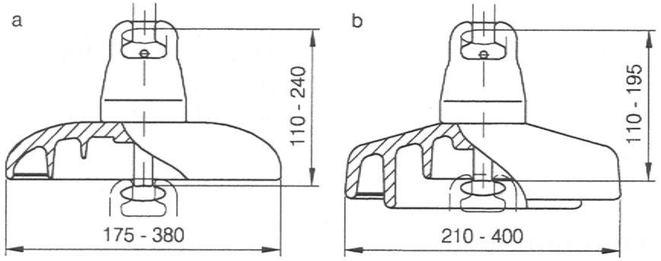
Basics – Insulator Types

1910



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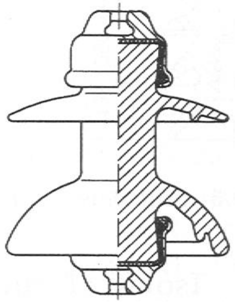

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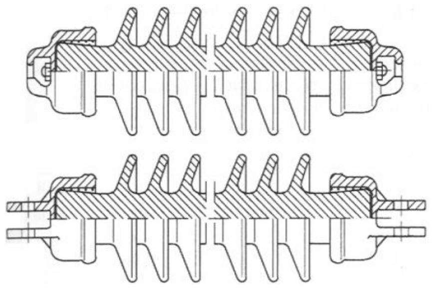

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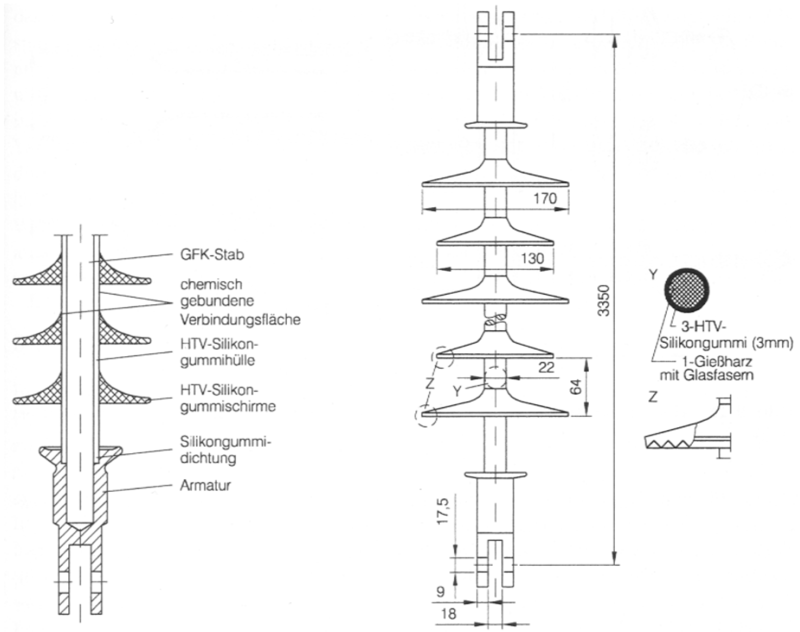
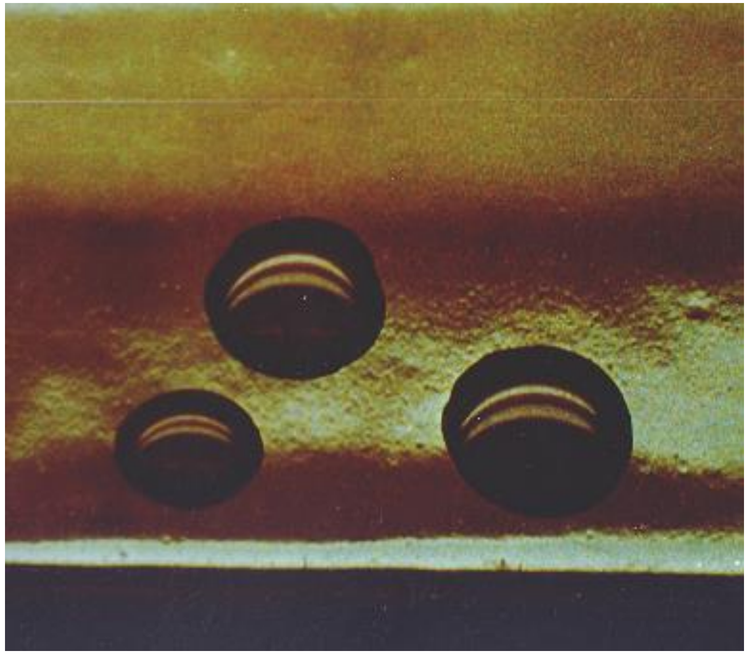
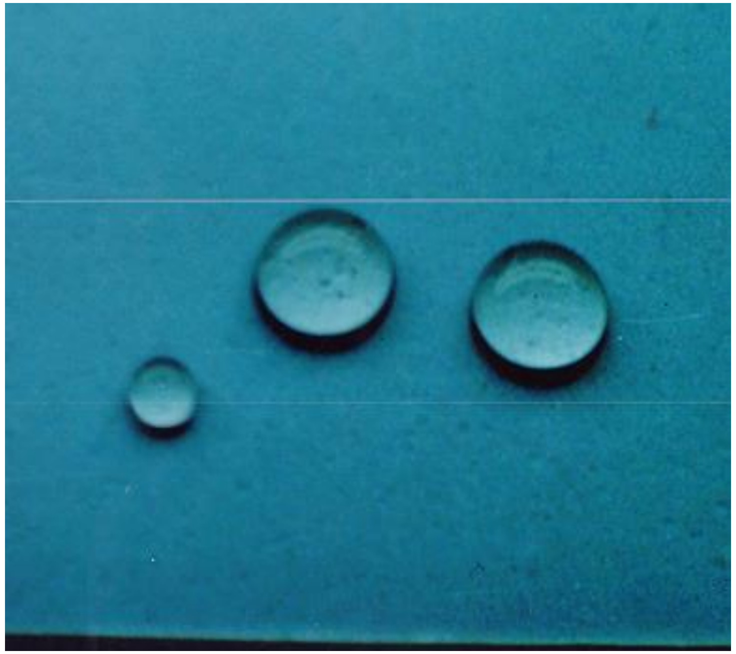


Basics - Materials

New Surface



New **ceramic** surface

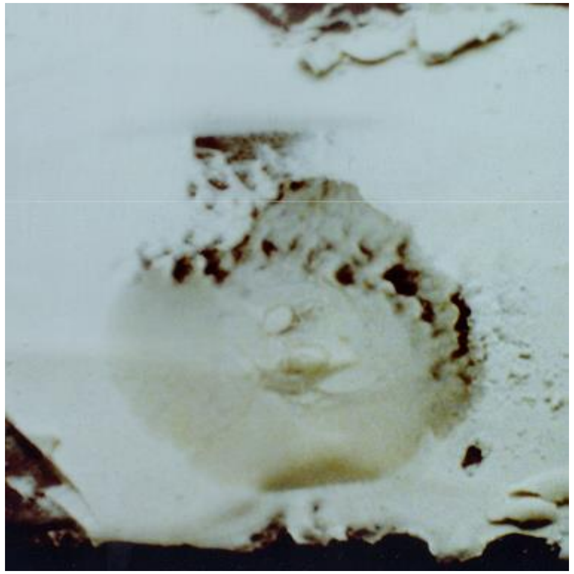


New **silicone** surface

In a new, non-polluted stage most surfaces are
water repellent = hydrophobic.

Basics - Materials

(Pollution Conditions IEC 815)

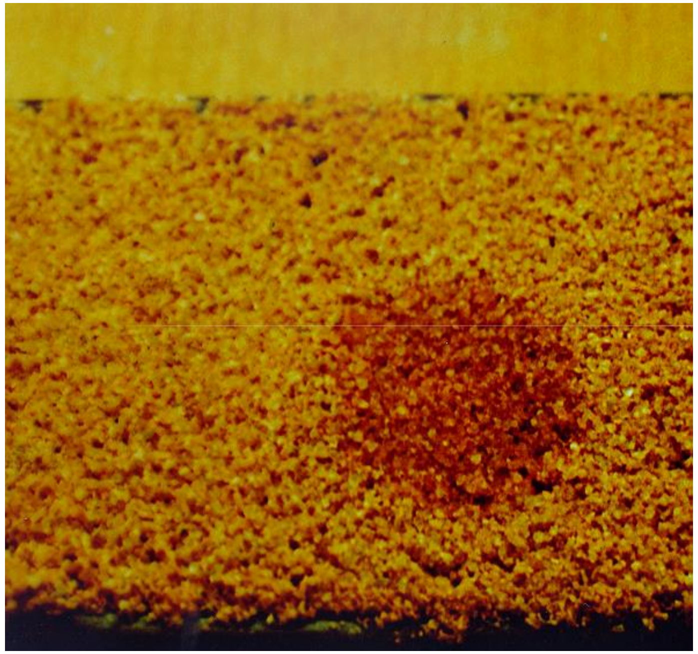


Polluted passiv surface

Polluted active surface

E.G.:The pollution layer on a ceramic/glass/EPR surface is hydrophilic.
E.G.:The pollution layer on a silicone surface becomes hydrophobic.

Basics - Materials

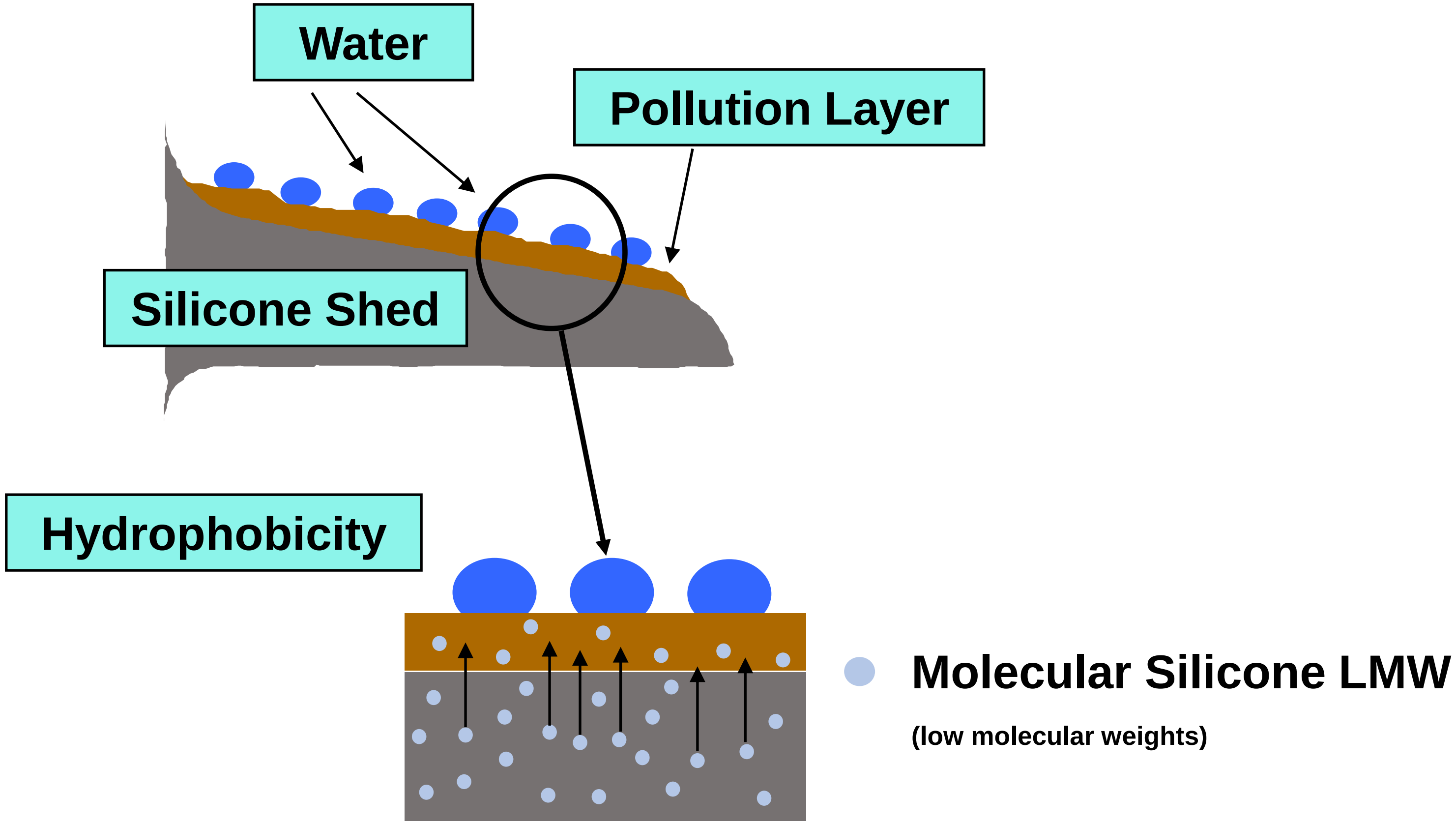


Polluted ceramic surface

Polluted silicone surface

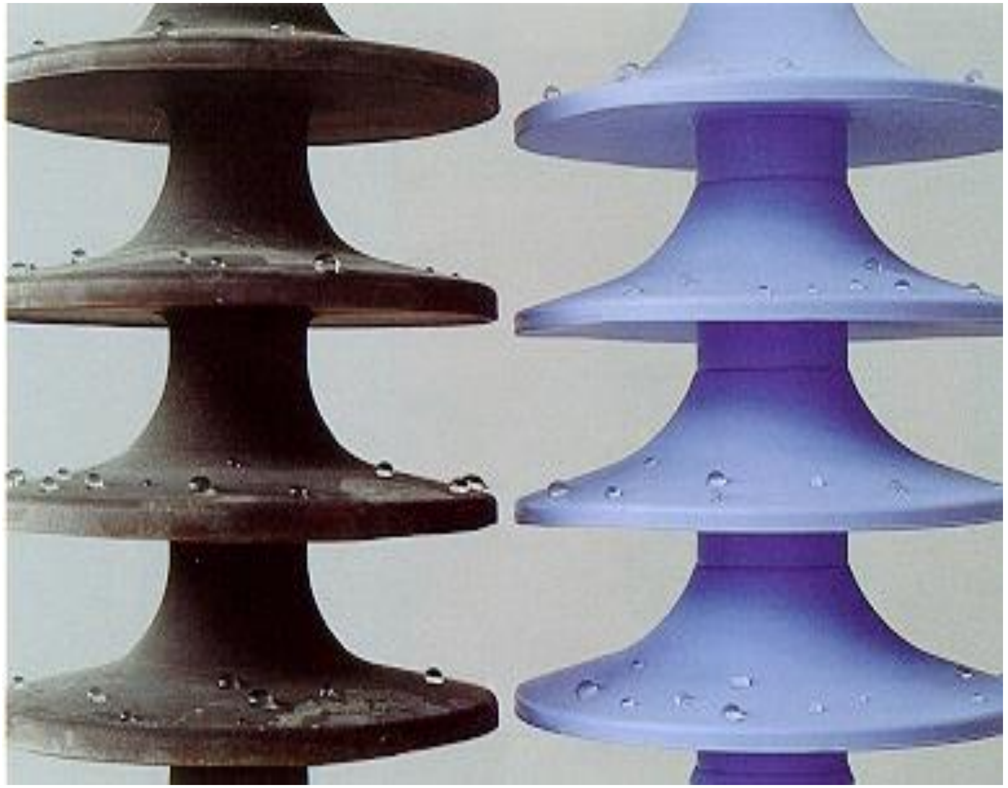
The pollution layer on a ceramic or glass surface is wettable.
The pollution layer on a silicone surface becomes hydrophobic.

Basics - Materials



Hydrophobic Effect

Basics - Materials

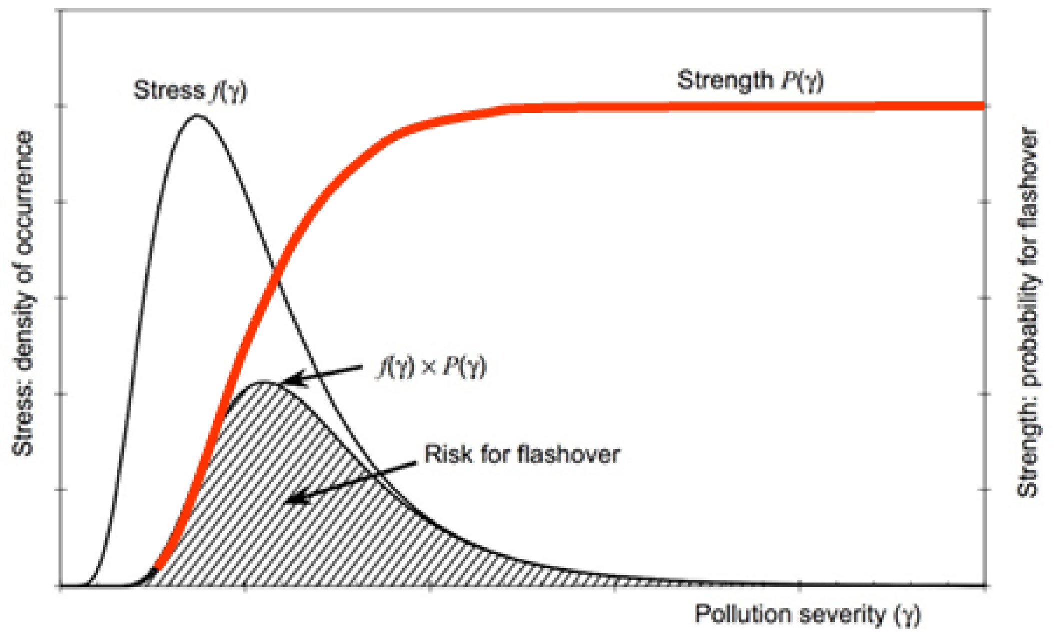


- pollution layer water repellent
- low leakage currents
- low risk of flashover
- low line losses
- no cleaning required

Hydrophobicity

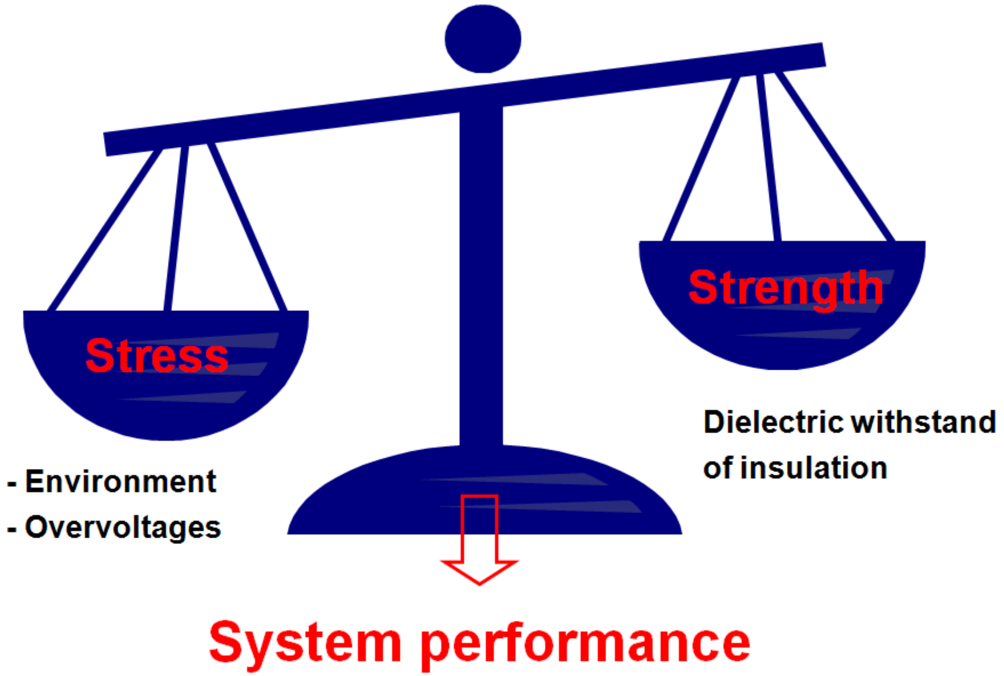
Find solution providing:
"reasonable performance at reasonable cost"

by use of:
"appropriate margin between foreseen environmental stresses and insulator strength"

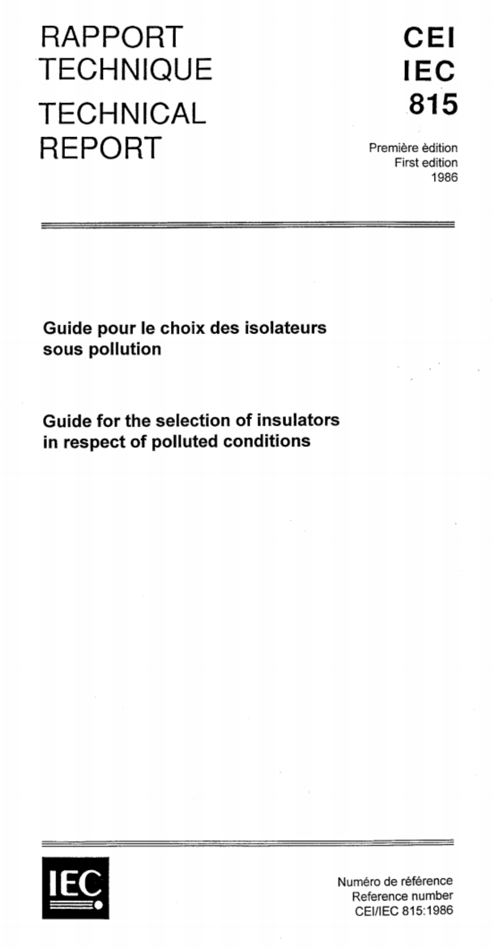


Principles of pollution dimensioning according to the IEC TS 60815-1 and their practical application using Insulation Selection Tool (IST) software program

Insulation coordination



Recently published IEC 60815-1,2,3,4


RAPPORT TECHNIQUE

TECHNICAL REPORT

CEI
IEC
815

Première édition
First edition
1986

Guide pour le choix des isolateurs sous pollution

Guide for the selection of insulators in respect of polluted conditions

IEC

Numéro de référence
Reference number
CEI/IEC 815:1986

Auswahl und Bemessung von Hochspannungsisolatoren für verschmutzte Umgebungen

1. **Definitionen**
2. **Keramik- und Glasisolatoren für AC Systeme**
3. **Kunststoffisolatoren für AC Systeme**
4. **Isolatoren für DC Systeme**

Content

1. **Introduction**
2. **Three general approaches**
3. **Evaluation of site pollution severity**
4. **Deterministic vs. statistical approach**
5. **Insulator Selection Tool (IST)**

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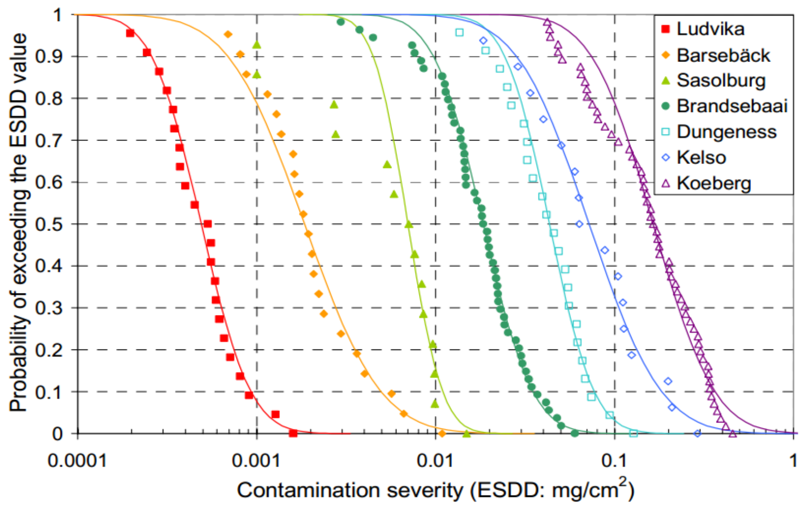
Three general approaches

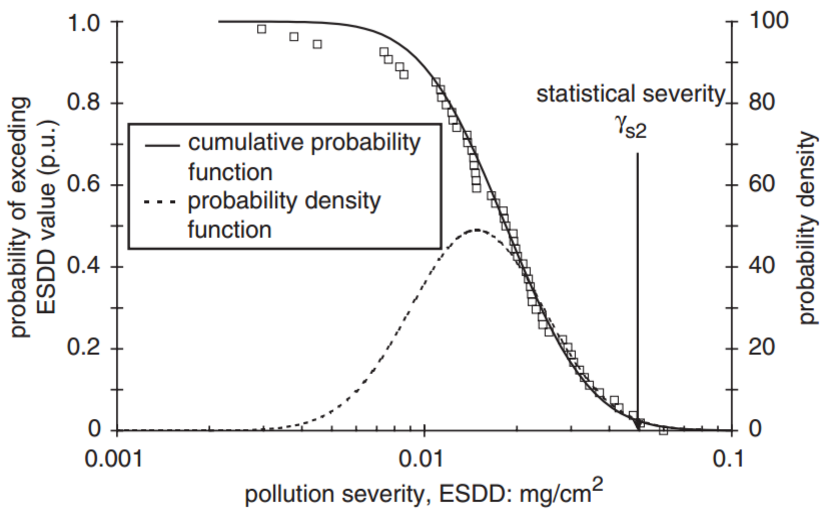
	APPROACH 1 (Use past experience)	APPROACH 2 (Measure and test)	APPROACH 3 (Measure and design)
Method	• Use existing field or test station experience for the same site, a nearby site or a site with similar conditions	• Measure or estimate site pollution severity • Select candidate insulators using profile and creepage guidance hereafter • Choose applicable laboratory test and test criteria • Verify/adjust candidates	• Measure or estimate site pollution severity • Use these data to choose type and size of insulation based on profile and creepage guidance hereafter
Input data	• System requirements • Environmental conditions • Insulator parameters • Performance history	• System requirements • Environmental conditions • Insulator parameters • Time and resources available	• System requirement • Environmental conditions • Insulator parameters • Time and resources available
Decisions	• Does the existing insulation satisfy the project requirements and is it intended to use the same insulation design ? **YES** Use the same insulation design **NO** Use different insulation design, materials or size. Use experience to pre-select the new solution or size	• Is there time to measure site pollution severity? **YES** Measure **NO** Estimate • Type of pollution determines the laboratory test method to be used • Site severity determines the test values	• Is there time to measure site pollution severity? **YES** Measure **NO** Estimate
Selection process	• If necessary, use the profile and creepage guidance hereafter to adapt the parameters of the existing insulation to the new choice using Approach 2 or 3	• Select candidates • Test if pollution performance data is not available for candidates • If necessary, adjust selection/size according to the test results	• Use the type of pollution and climate to select appropriate profiles using the guidance hereafter • Use the pollution level and correction factors for profile design and material to size the insulation using the guidance hereafter
Accuracy	• A selection with a good accuracy	• A selection with an accuracy varying according to the degree of errors and/or shortcuts in the site severity evaluation and with the assumptions and/or limitations of the chosen laboratory test	• A possibly over or under-dimensioned solution compared with approaches 1 or 2 • A selection with an accuracy varying according to the degree of errors and/or shortcuts in the site severity evaluation and the applicability of the selected correction factors

Typical time scales

- Service experience: typically 5-10 years
- Test station experience: typically 2-5 years
- Site severity measurements: at least one year
- Estimation of site severity: weeks-months
- Laboratory testing: weeks-months

Environmental stress





The distribution of the environmental stress is obtained **from site severity measurements**. These distributions are described by a lognormal distribution function. The standard deviation of Ln(ESDD) varies in a fairly narrow range (between 0,4 and 0,8), although the statistical severities (2% values) range over more than two orders of a magnitude.

SPS can be determined by:

1. Measurements in situ
2. Behaviour of insulators in service
3. Simulation (weather conditions)
4. Descriptions of environment

Measurements in situ:

- **Equivalent Salt Deposit Density (ESDD) and Non-Soluble Deposit Density (NSDD) on reference insulator**
- Site equivalent salinity (SES) from leakage current on reference insulator
- **Dust Deposit Gauge Index (DDGIS and DDGIN)**
- Number of flashovers of insulators of different length
- Leakage current on sample insulators

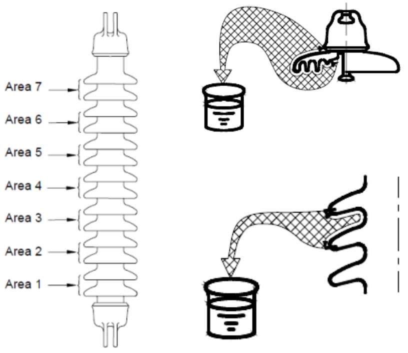
Main pollution parameter: ESDD

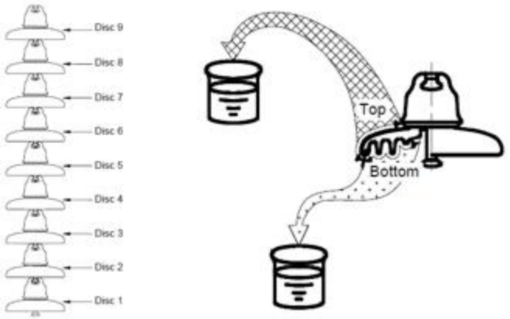
ESDD and NSDD measurements

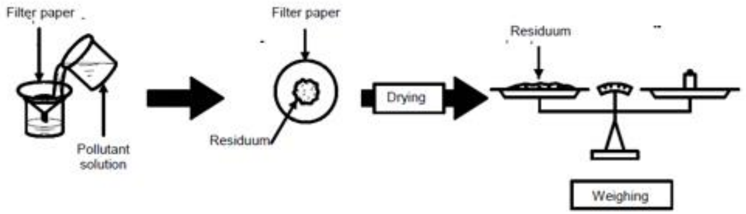
Annex C
(normative)

Measurement of ESDD and NSDD

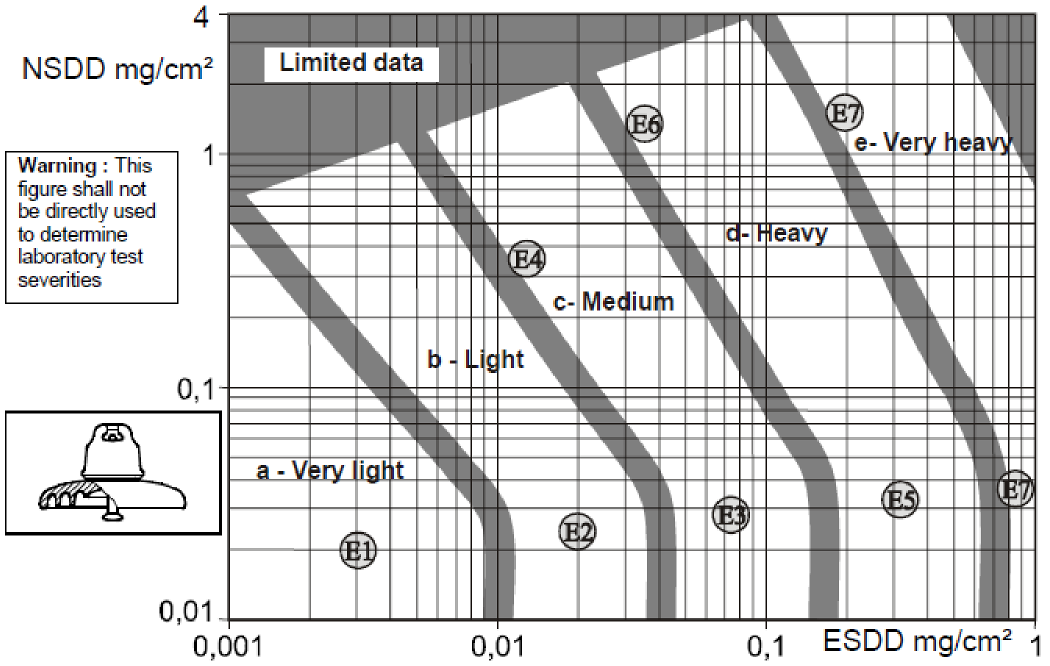
Conductivity -> ESDD
Dry weight -> NSDD



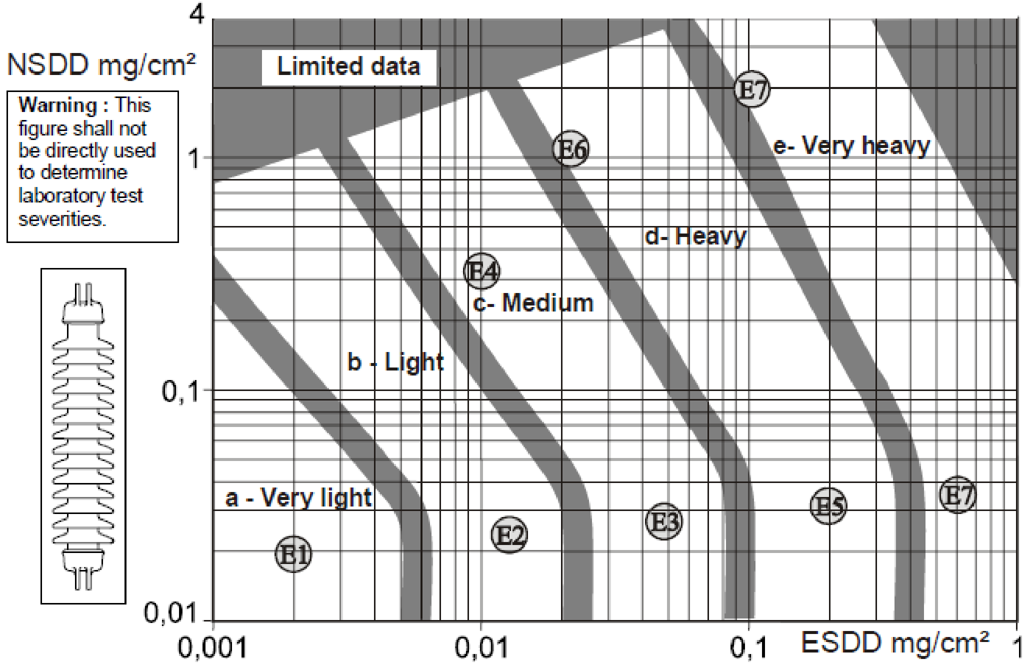




SPS classes



E1 to E7 correspond to the examples in Table 5.



E1 to E7 correspond to the examples in Table 5.

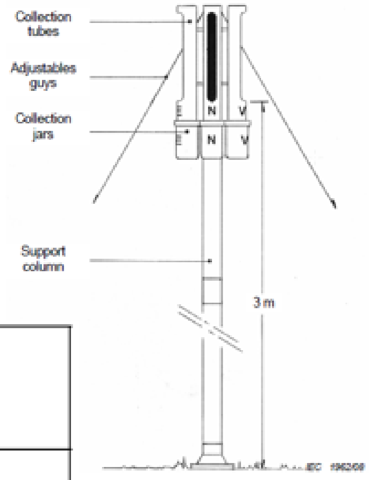
Additional pollution parameter: DDDG

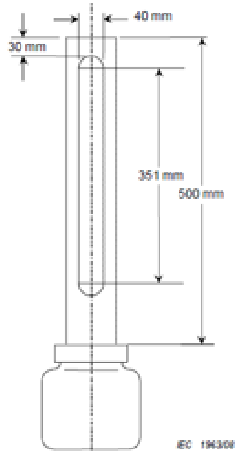
Annex E
(normative)

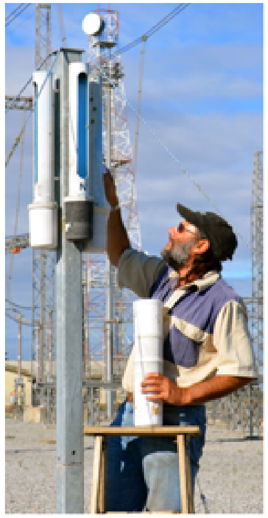
Directional dust deposit gauge measurements

Directional dust deposit gauge pollution index, PI (µS/cm) (take whichever is the highest)		Site pollution severity class	
Average monthly value over one year	Monthly maximum over one year		
< 25	< 50	a	Very light
25 to 75	50 to 175	b	Light
76 to 200	176 to 500	c	Medium
201 to 350	501 to 850	d	Heavy
> 350	> 850	e	Very heavy

Directional dust deposit gauge NSD (grams) (take whichever is the highest)		Site pollution severity class correction
Average monthly value over one year	Monthly maximum over one year	
< 0,5	< 1,5	None
0,5 to 1,0	1,5 to 2,5	Increase by one class
> 1,0	> 2,5	Increase by one or two classes and consider mitigation (e.g. washing)





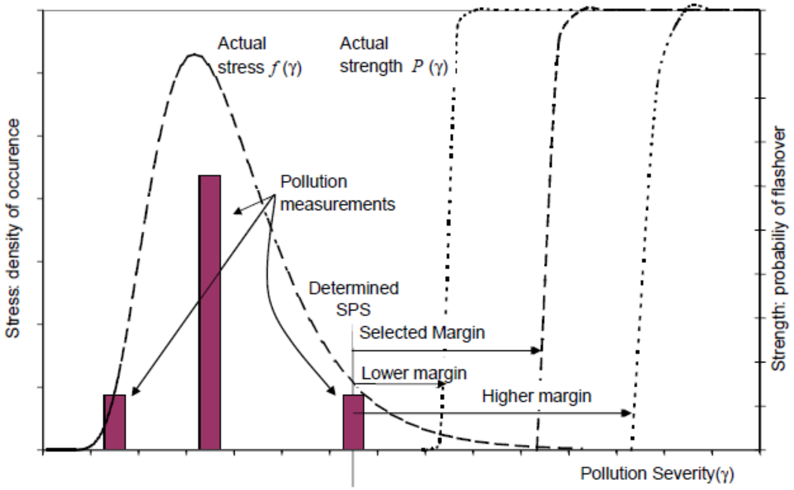


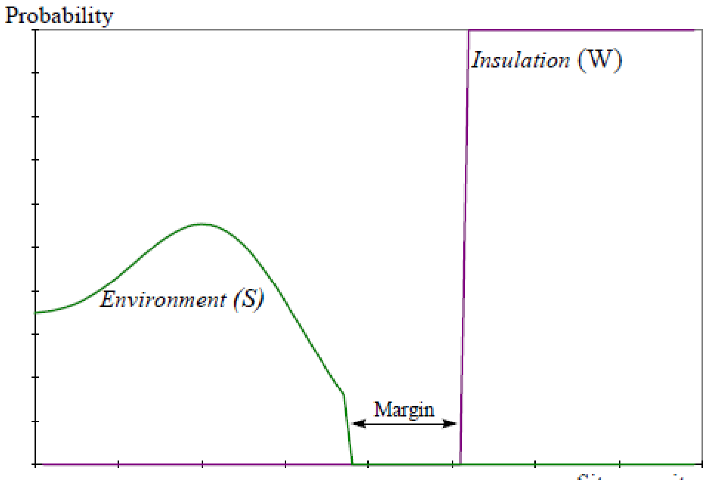
1. Introduction
2. Three general approaches
3. Evaluation of site pollution severity
4. **Deterministic vs. statistical approach**
5. Insulator Selection Tool (IST)

Deterministic and statistical approach

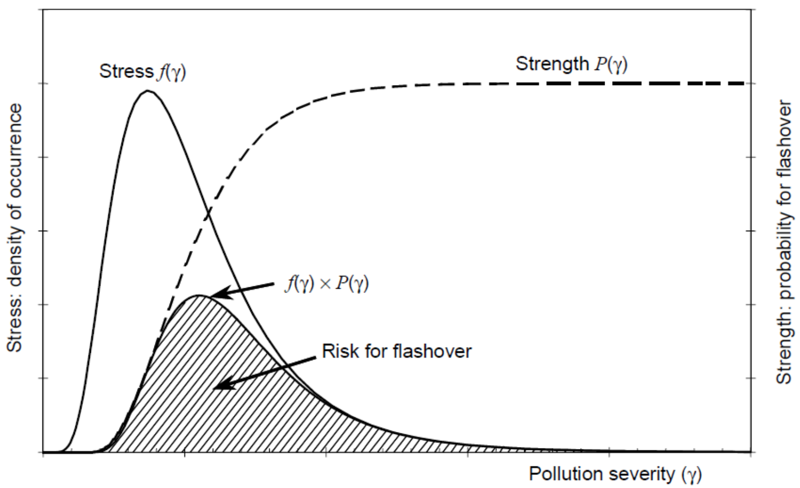
Annex G
(normative)

Deterministic and statistical approaches for artificial pollution test severity and acceptance criteria





An example of the deterministic method.



Source: CIGRE TB 158 (33.04.01)

Deterministic approach

Measurements of pollution

↓

Estimation of Site Pollution Severity

↓

Estimation of Reference Unified Specific Creepage Distance

↓

Verification of profile

↓

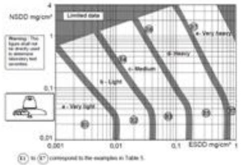
Correction on diameter and altitude

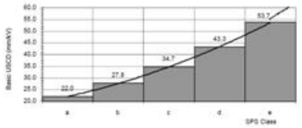
↓

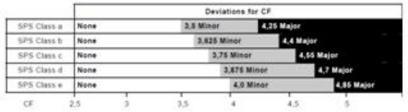
Insulator dimensioned: Creepage distance, length, profile, material

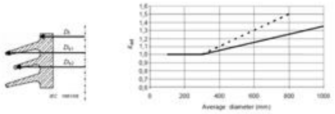
↓

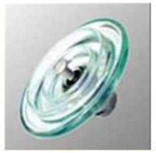
Verification by pollution testing





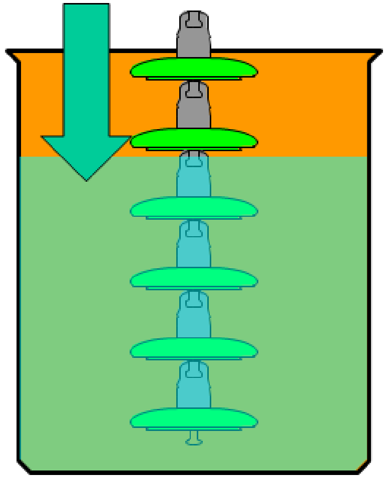






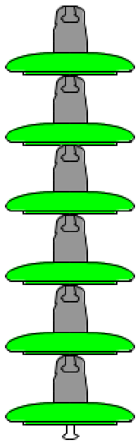
Standard solid layer test

- 1. Dipping in Slurry

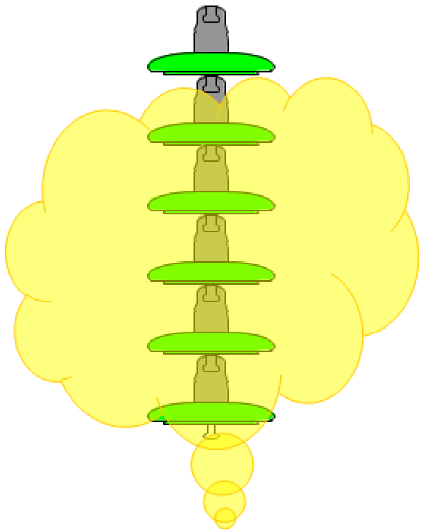


- Salt Water + Kaolin

- 2. Drying

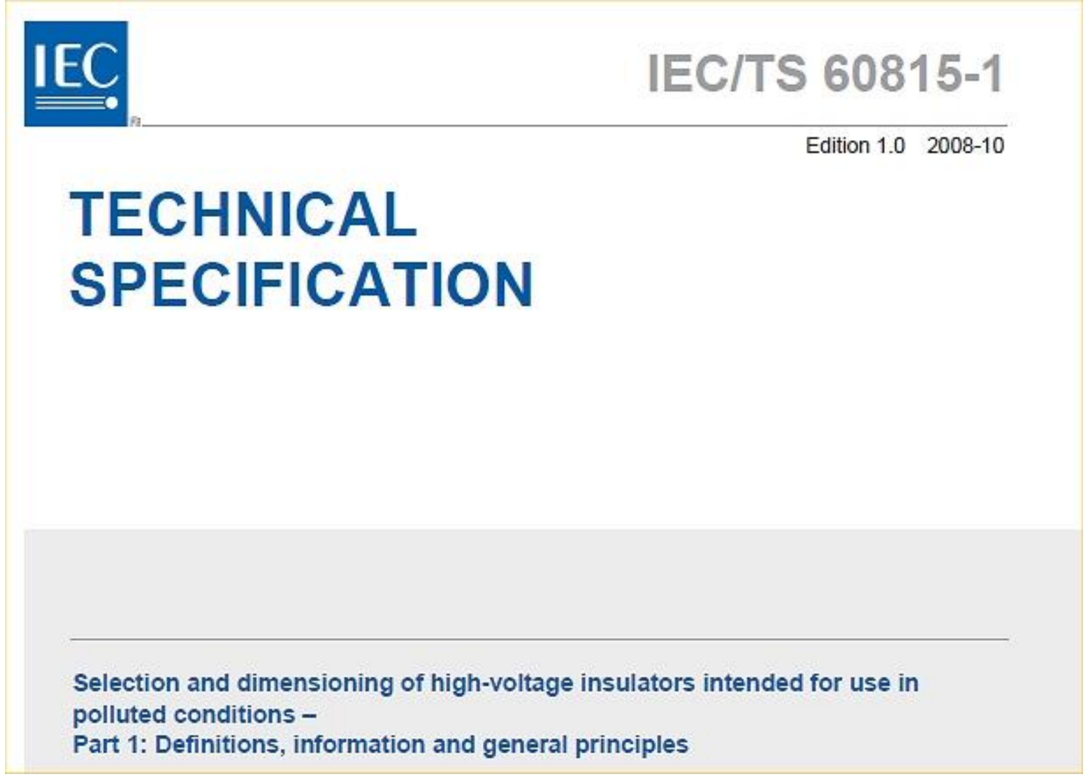


- 3. Wetting (Steam Fog) and Voltage



- 100 min.

Principle of statistical dimensioning


IEC

IEC/TS 60815-1

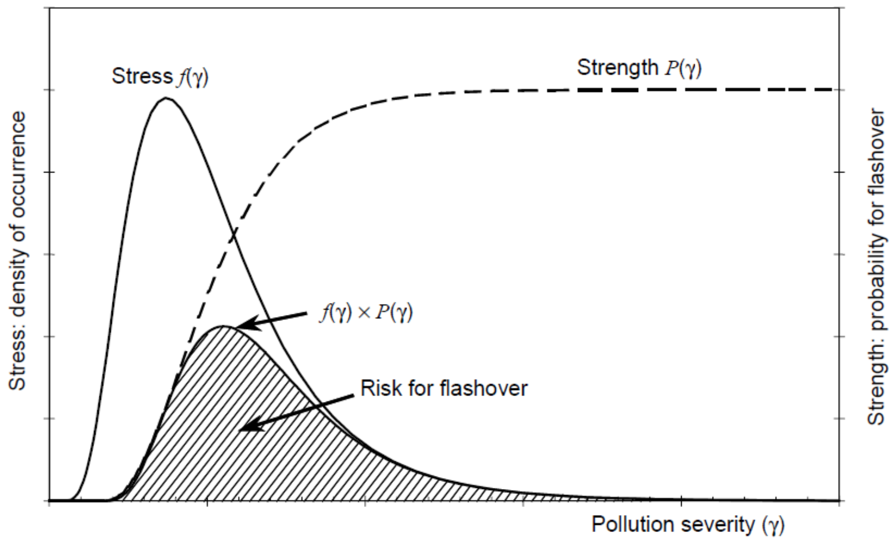
Edition 1.0 2008-10

TECHNICAL SPECIFICATION

Selection and dimensioning of high-voltage insulators intended for use in polluted conditions –
Part 1: Definitions, information and general principles

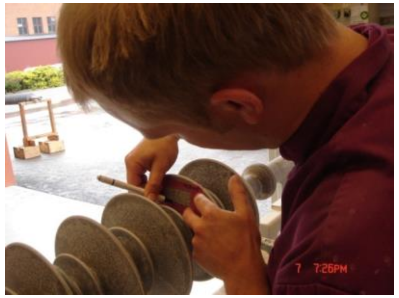
G.3 Statistical approach

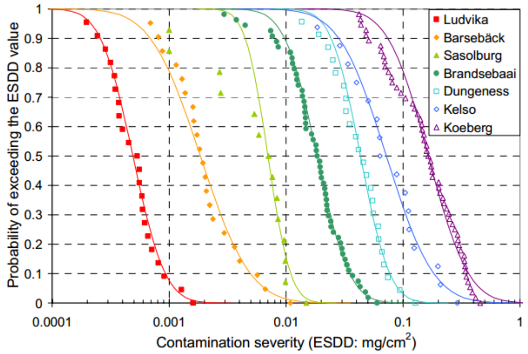
The statistical dimensioning of insulators entails the selection of the dielectric strength of an insulator, with respect to the voltage and environmental stresses (stress/strength concept), to fulfil a specific availability requirement. This is done by evaluating the risk for flashover of potential insulation options and selecting those yielding an acceptable performance.



Statistical approach

- **Distribution of pollution stress f(γ) is obtained from service measurements.**
- Cumulative distribution function P(γ) describing the strength of the insulation, i.e., the probability for flashover at maximum operating voltage, is determined from testing/service experience.
- The two functions f(γ) and P(γ) are multiplied to give the probability density for flashover, and the area under this curve expresses the risk for flashover during a pollution event.
- If the number of pollution events per year is known the risk for flashover per year can be calculated.





Site name	$ESDD_{50}$ (mg/cm^2)	Std. deviation of Ln(ESDD)	Statistical severity (γ_{s2}, mg/cm^2)
Ludvika	0,0005	0,52	0,0014
Barsebäck	0,002	0,77	0,009
Sasolburg	0,007	0,35	0,014
Brandsebaai	0,018	0,54	0,056
Dungeness	0,043	0,45	0,11
Kelso	0,072	0,73	0,32
Koeberg	0,16	0,62	0,59

Statistical approach

- Distribution of pollution stress f(γ) is obtained from service measurements.
- **Cumulative distribution function P(γ) describing the strength of the insulation, i.e., the probability for flashover at maximum operating voltage, is determined from testing/service experience.**
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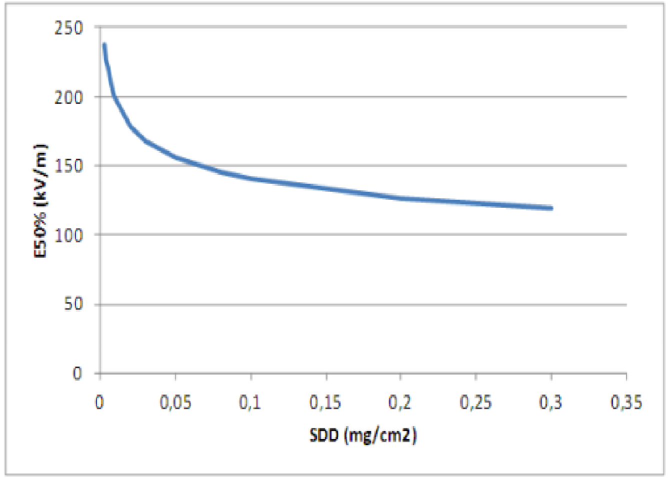
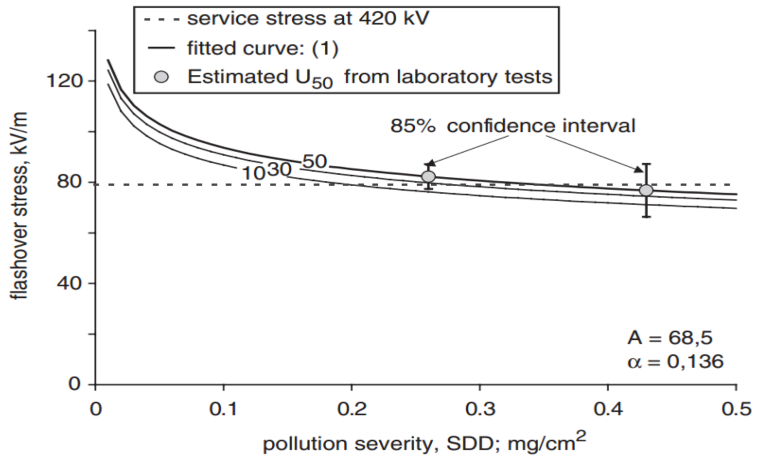
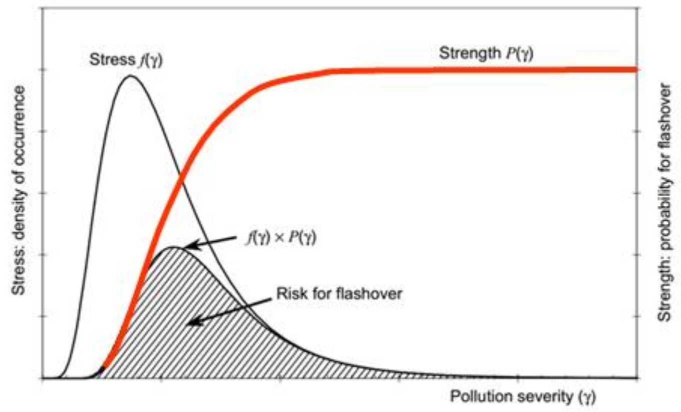
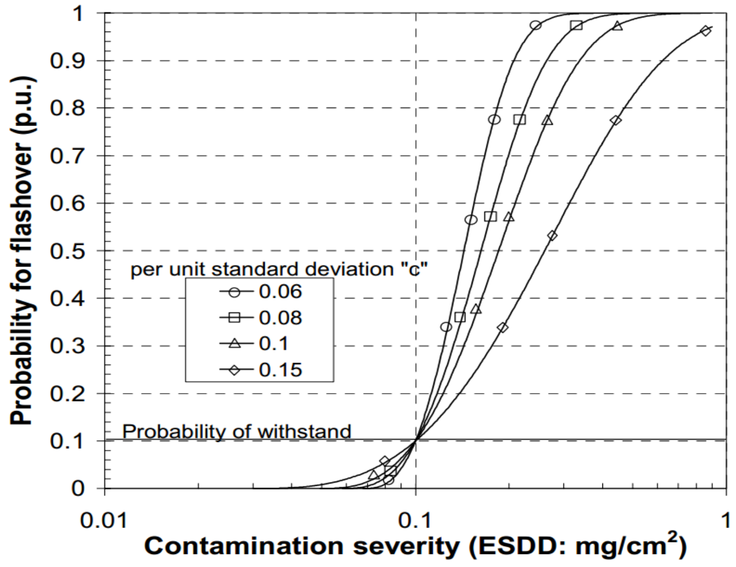


Flashover pollution performance







The probability function for flashover performance is **usually determined through laboratory** variable voltage flashover tests. It can be adequately described by Weibull distribution function and is truncated at 2,5 standard deviation below the U_{50} (the probability for flashover is zero)

Statistical approach

- Distribution of pollution stress f(γ) is obtained from service measurements.
- Cumulative distribution function P(γ) describing the strength of the insulation, i.e., the probability for flashover at maximum operating voltage, is determined from testing/service experience.
- **The two functions f(γ) and P(γ) are multiplied to give the probability density for flashover, and the area under this curve expresses the risk for flashover during a pollution event.**
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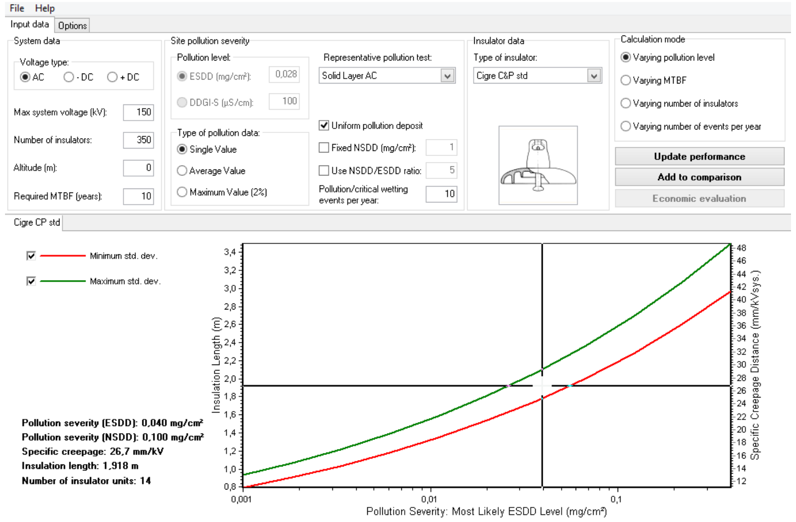

Flow-chart for statistical dimensioning

Measurements of pollution

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Distribution of pollution stress

↓

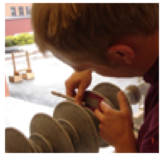
Pollution flashover performance

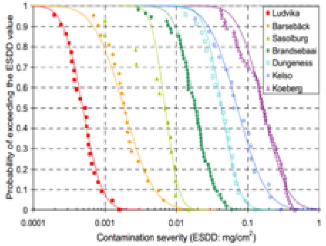
↓

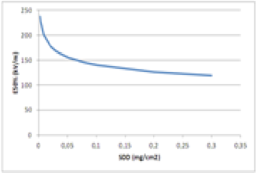
Number of pollution/wetting events

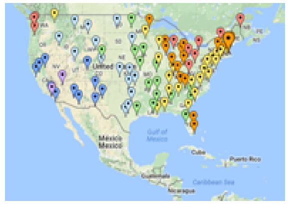
↓

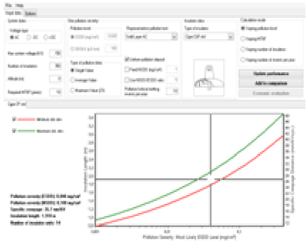
Insulator dimensioned: Creepage distance, length,











Verification of calculations by service records-1

21, rue d'Artois, F-75008 PARIS
http : //www.cigre.org

B2-205

CIGRE 2006

Line Performance Estimator Software: Calculations of Lightning, Pollution and Ice Failure Rates Compared with Service Records

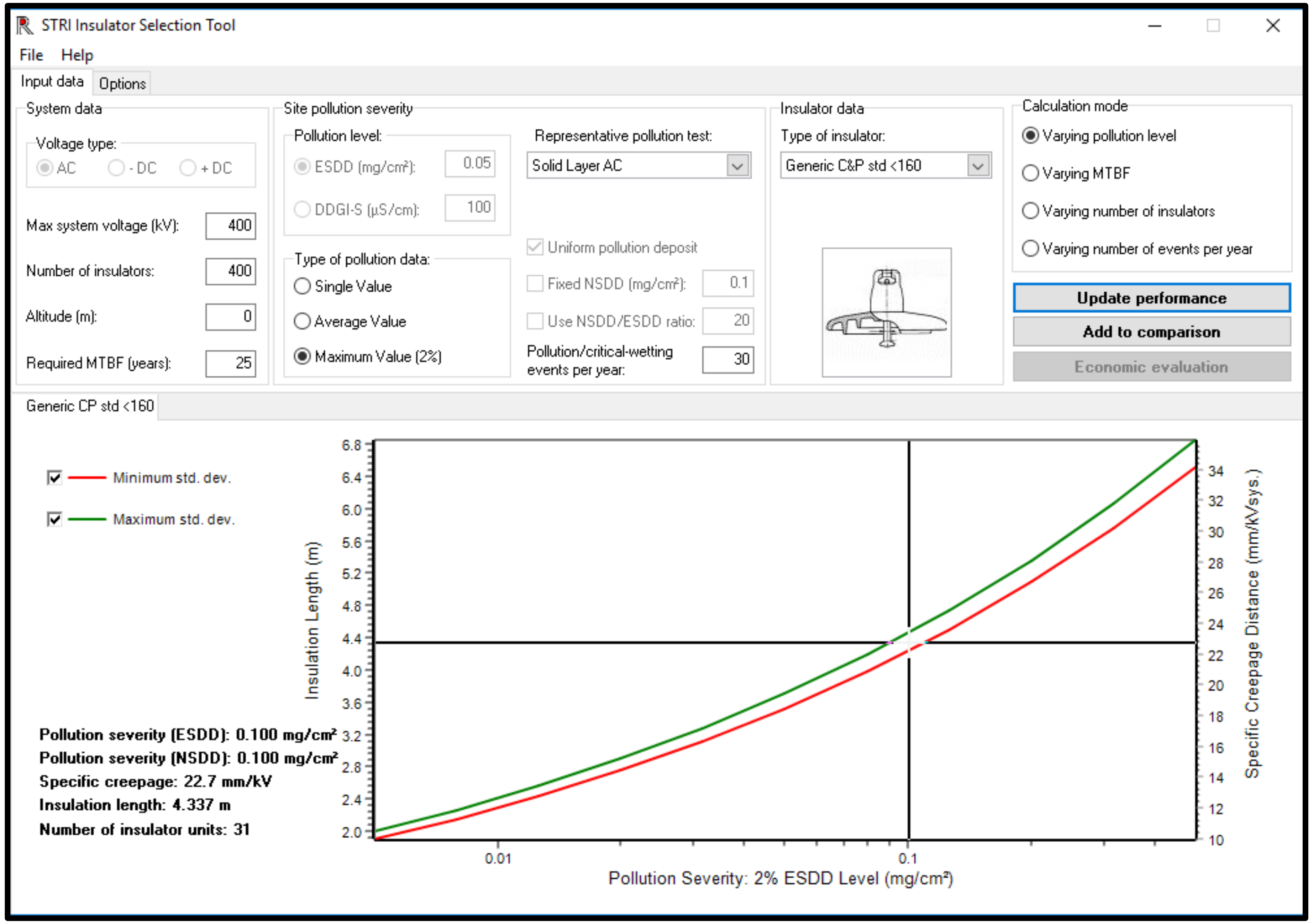
I. GUTMAN* J. LUNDQUIST	K. HALSAN	L. WALLIN	E. SOLOMONIK	W. L. VOSLOO
STRI	Statnett	Svenska Kraftnät	NIIPT	ESKOM
Sweden	Norway	Sweden	Russia	South Africa

Verification of calculations by service records-2

Source	Max. voltage [kV]	Lines	Failure rate per year	
			recorded in service	calculated in LPE
Statnett (Norway)	420	1	0-0,1	0,2
	420	2	0	0,2
	420	3	0	0,01
	300	4	0-0,2	0,1
ESKOM (South Africa)	400	1	0,6	1,0
	400	2	1,0	0,5
	400	3	0,2	0,5
	400	4	0	0,02
NIIPT (Russia)	126	1	0,4	0,4
	126	2	1,4	3,0

1. Introduction
2. Three general approaches
3. Evaluation of site pollution severity
4. Deterministic vs. statistical approach
5. **Insulator Selection Tool (IST)**

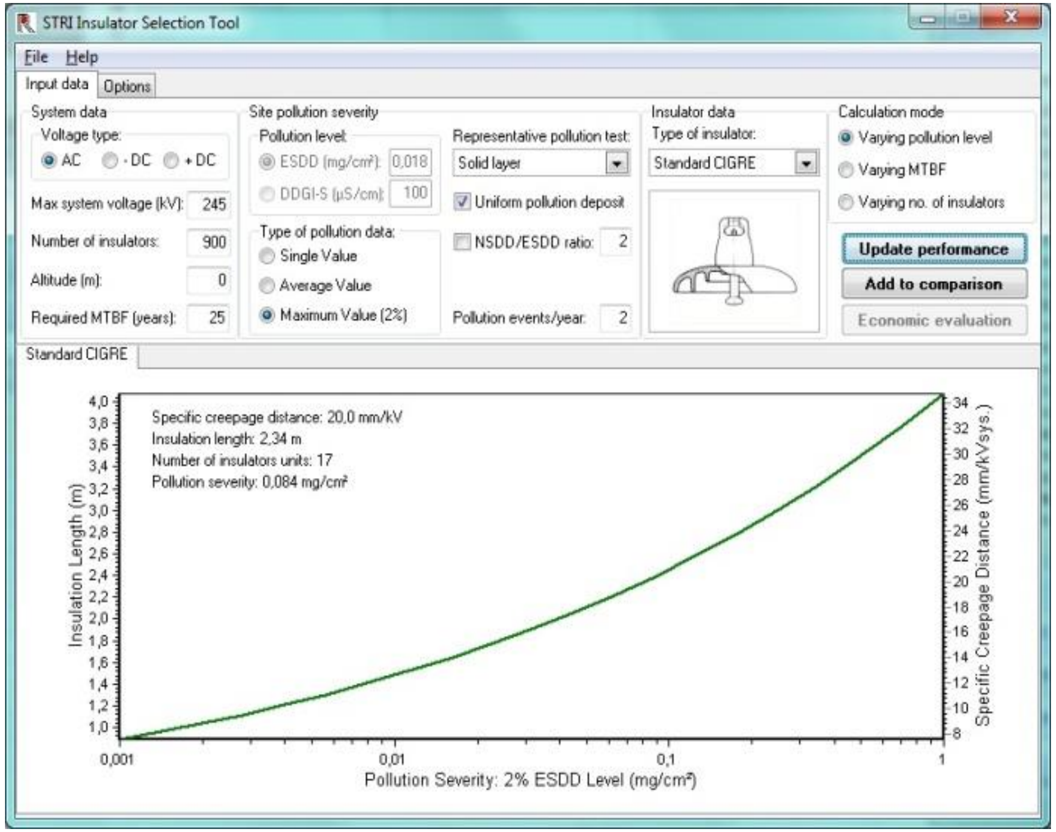
Insulator Selection Tool (IST)



Eskom
Statnett
NamPower
SVENSKA KRAFTNÄT
(주) 평일 PYUNGIL Co., Ltd.
KEPCO
LAPP INSULATORS
איגוד חברות החשמל
SEVES

IST program

- Follows CIGRE/IEC principles for outdoor insulation selection
- Standard pollution parameters (ESDD/NSDD and DDDGI)
- Verified by comparisons with service experience
- Used practically by ESKOM, SEVES, NamPower, Fingrid, Statnett, Svenska Kraftnät, LAPP, Vattenfall, etc.



Benefits

For manufacturers:

- Helps to focus on insulator performance
- Guides and educates customer in selection process
- Can be used as marketing tool
- Provides detailed performance analysis
- Is expandable and can be customized

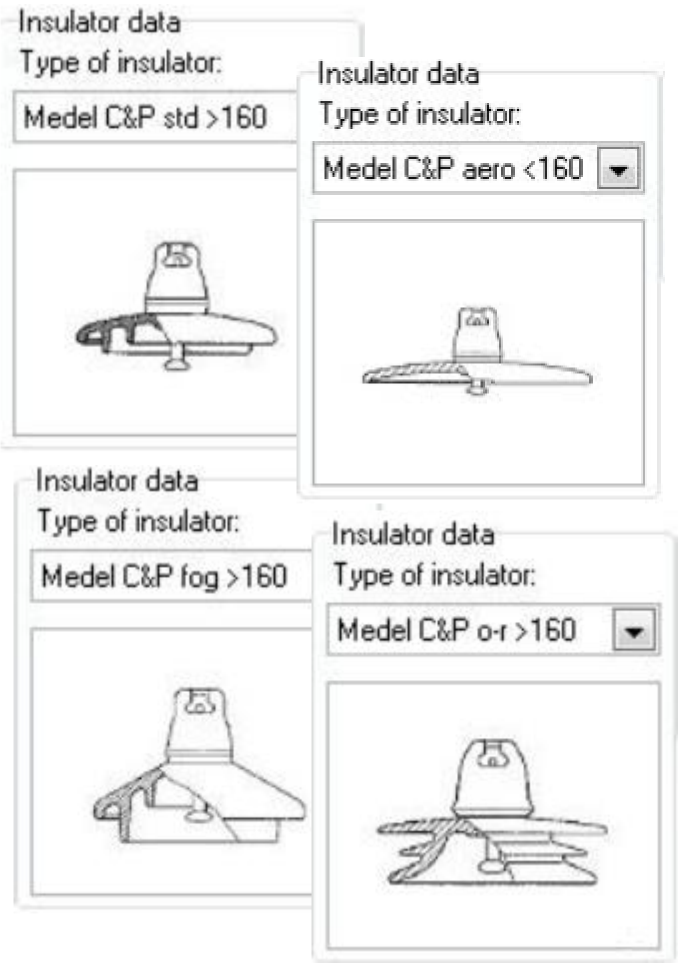
For utilities:

- Improves line availability in polluted areas
- Allows selection of most cost effective solution
- **Is an excellent tool for education**
- Enables technical comparison of different line insulators based on availability requirements

IST: practical applications

- AC
  - ESKOM: refurbishment of 400 kV lines after massive outages
  - Statnett: dimensioning of new lines in northern areas
  - Svenska kraftnät: pollution mapping for refurbishment of substations on the west coast
  - NamPower: refurbishment of 220 kV lines
- DC
  - ESKOM: refurbishment of Cahora-Bassa line
  - Statnett: dimensioning of NordLink
  - Svenska kraftnät: dimensioning of Fenno-Skan 2 and SouthWest Link
  - Axpo Power and Amprion: dimensioning of AC/DC hybrid line
- AC to DC line conversion
  - ≈ 10 feasibility studies

Generic flashover performance curves



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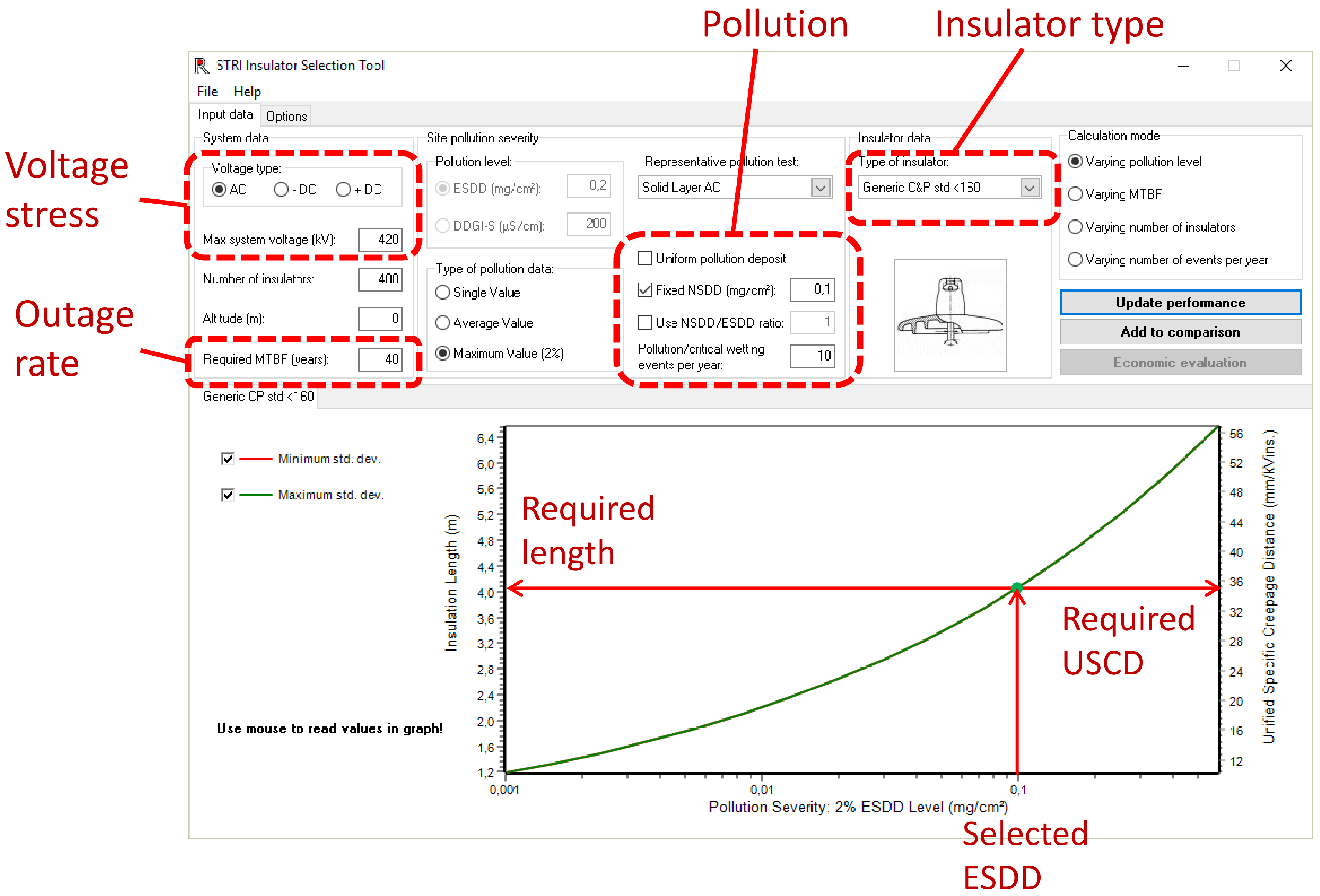
Key inputs and outputs

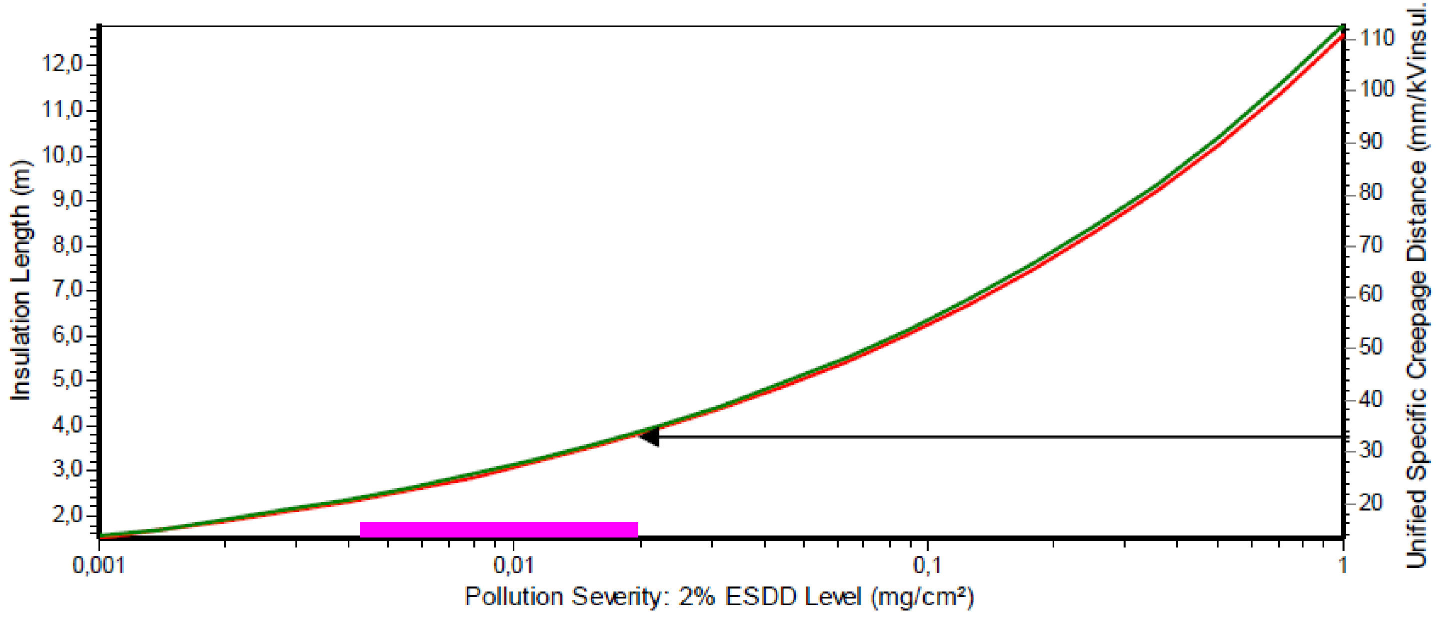


INDEPENDENT INSULATION GROUP

New German North-South ± 400 / ± 500 kV Lines

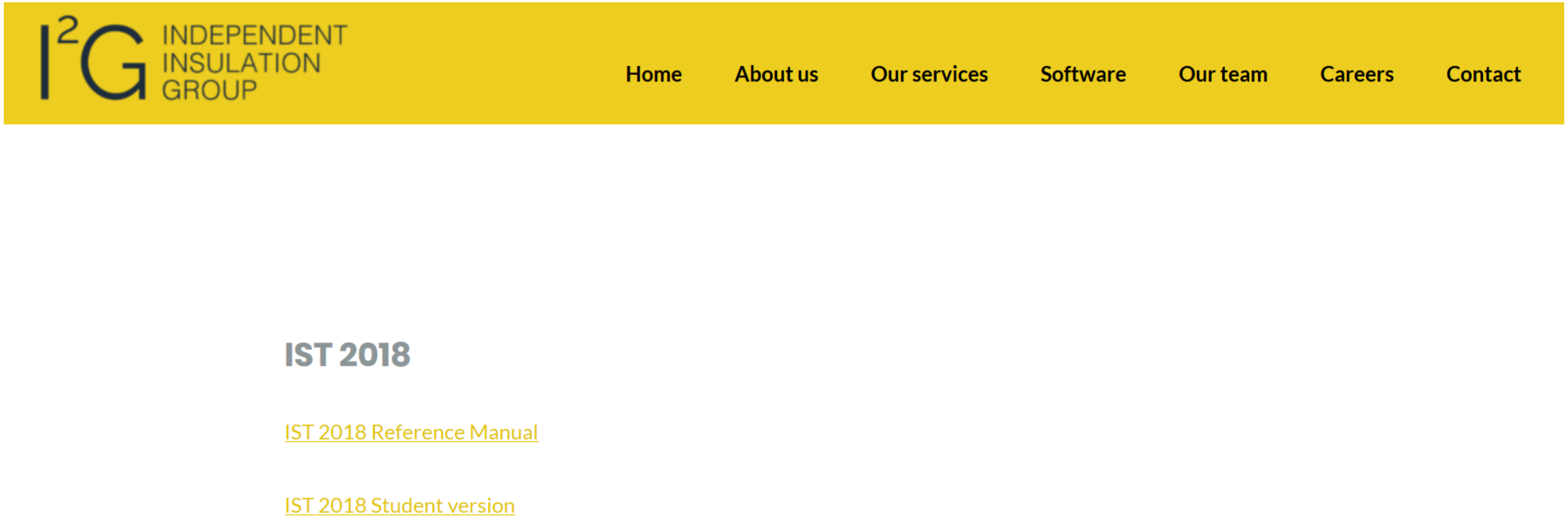
Anzahl Isolatoren:	N = 2000 (im betrachteten Verschmutzungsabschnitt)
Höhe:	h bis 1000 m NN
NSDD/ESDD:	6 (uniform pollution layer)
Verschmutzungsereignisse:	20 / a
Polarität:	POS und NEG
ESDD:	2 % max. Average
Basis:	DC-Solid Layer, STRI R09-600
Profil:	Lapp Al-Fm-Sm-0,6-31

400kV NEG: (das violette Band zeigt die Lage der Verschmutzungsklasse c): o.k.



How to get the program:

https://i2group.se/software/ist/



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