ELECTROMAGNETICAL ENVIRONMENT AND SAFETY FOR LARGE SENSITIVE SYSTEMS A NEW APPROACH AND FIRST SOLUTIONS

Daniel SOLEIL (EMCS), Alain ALCARAS (THALES)

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Disturbances protection for sensitive facilities

- Threats :
  - Conducting currents
  - Electromagnetic fields
- Constraints :
  - Safety of people
  - Protection of power installations
  - Protection of sensitive equipments (or functions)
- Topology :
  - Large installations
  - Electronic power systems
  - Electronic sensitive systems

Lightning protection for sensitive facilities

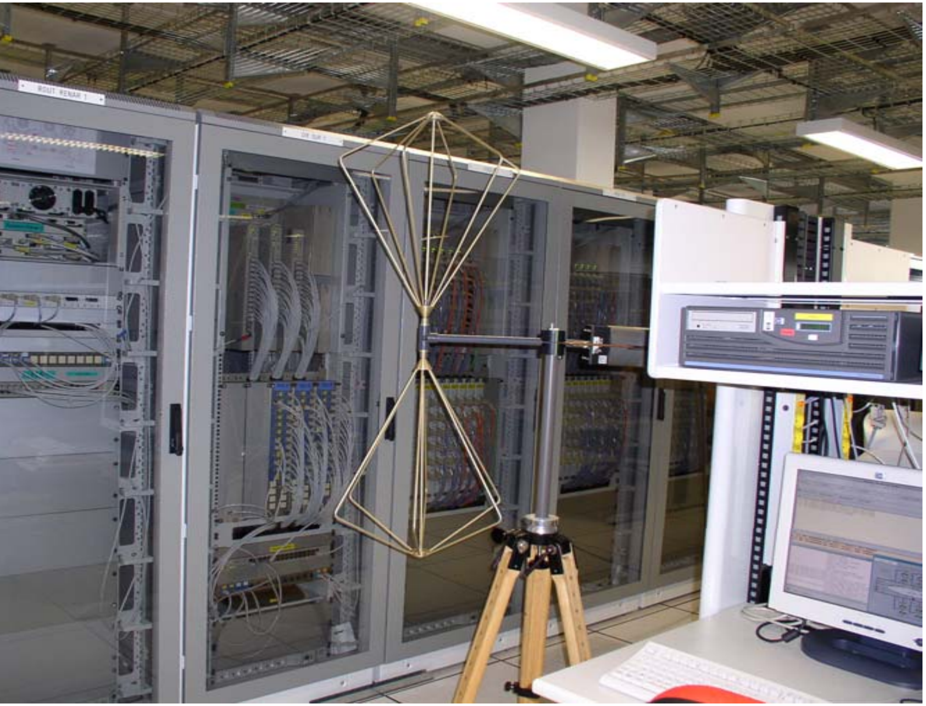
- Threats :
  - Direct effects from main lightning current
  - Indirect effects (EM radiation, secondary lightning currents
- Constraints :
  - Safety of people
  - Protection of power installations
  - Protection of sensitive equipments (or functions)
- Topology :
  - Direct effects : Ligthning Protection System (LPS)
  - Indirect effects : EMC System
  - Interface D/I effects : Surge Protection Device (SPD)

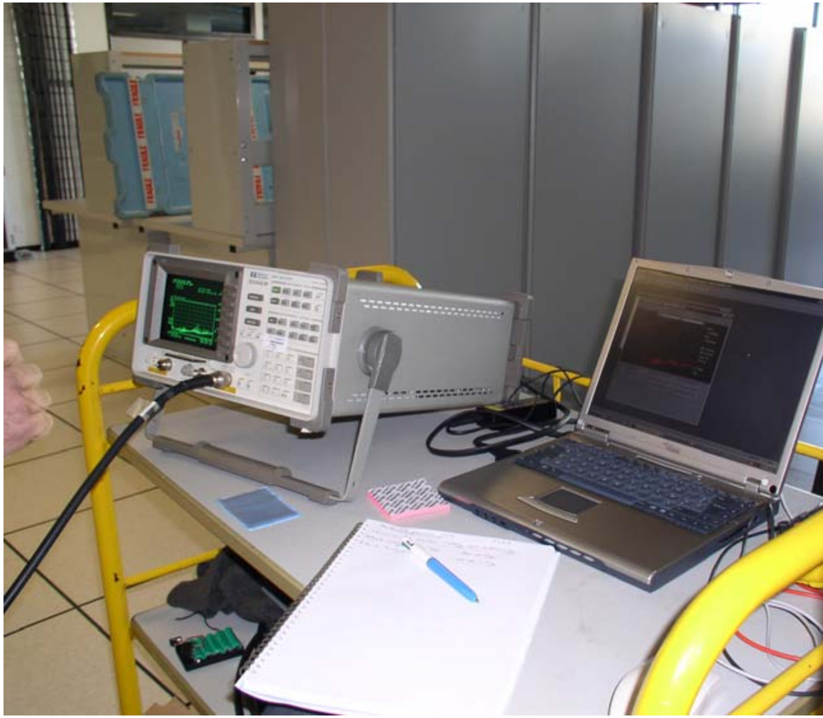
Current method for sensitive structure

Standard, Regulation, Guide

$\Rightarrow$equipotential network (low Z)

Military, aeronautical and spatial domains



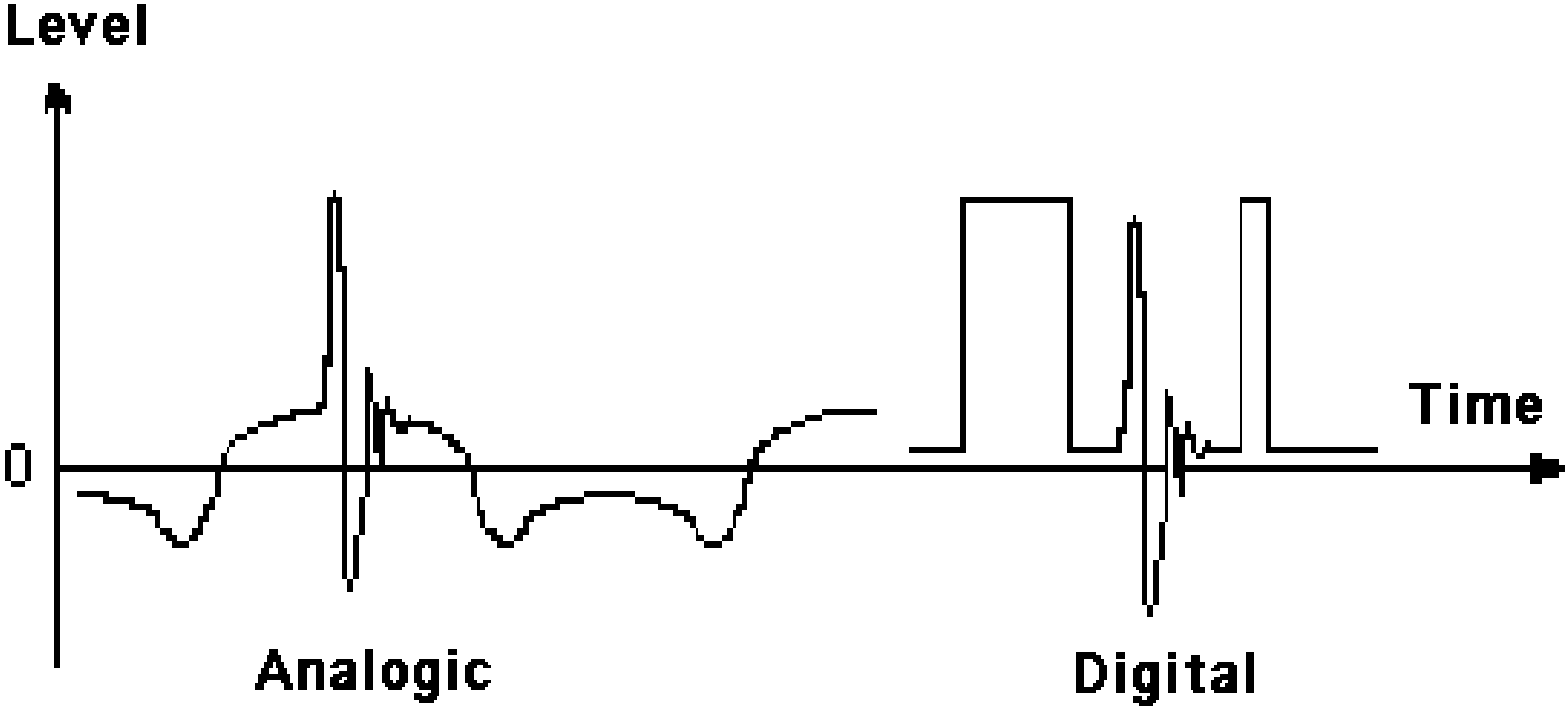


EMC System (Indirect effects)

- State of the art :
  - Research based on test, metrology and complex calculation
  - Standards at the project stage

- "Zero Method" (MZ) seen by DGA, Thales, Onera :
  - Complement of current method
  - Matched for sensitive facilities

MZ APPROACH : S/N RATIO

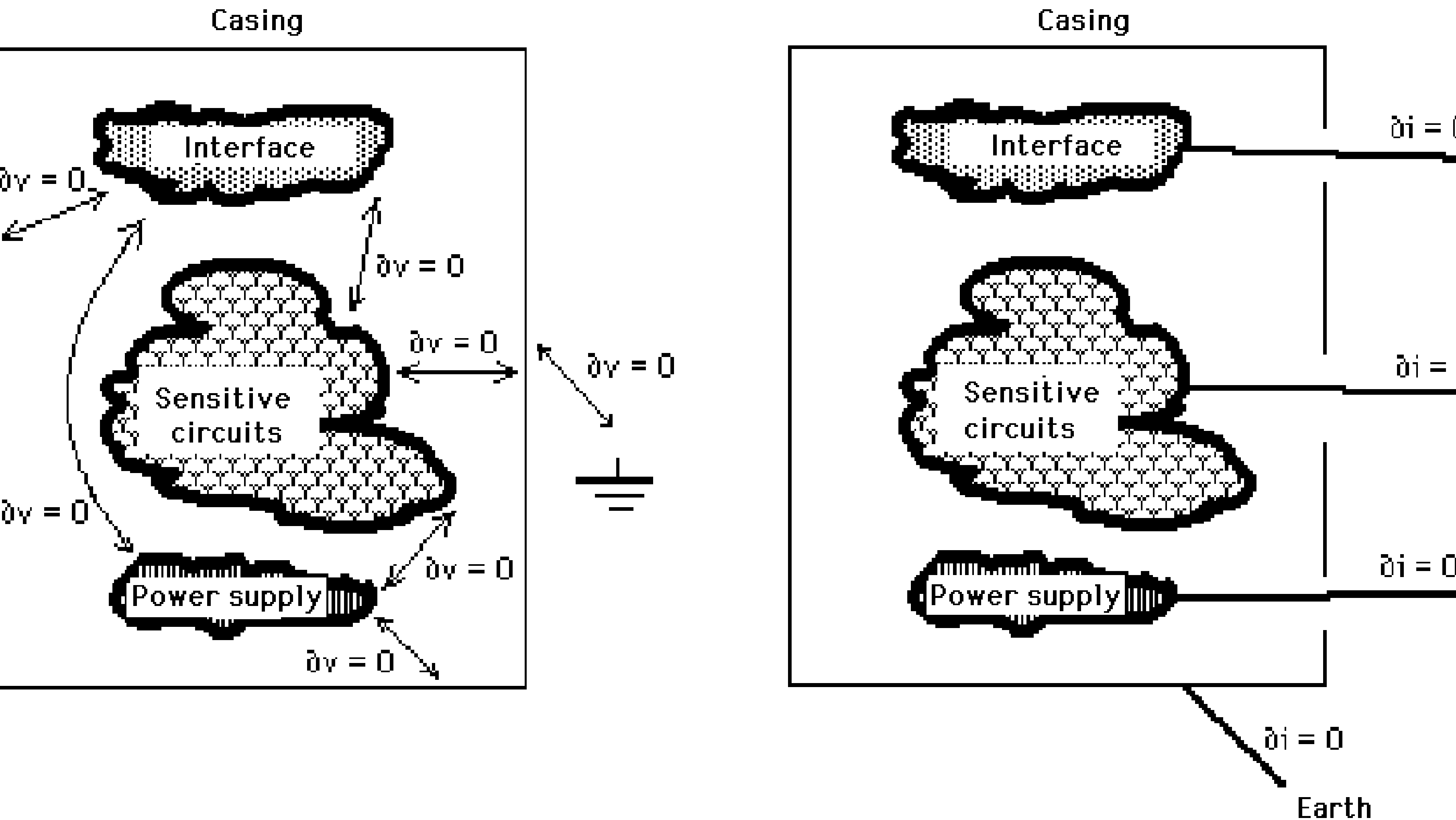


occasional (O) or permanent (P)

Electrostatic discharges (O)
Atmospheric discharges (O)

Industrial parasitics (P)
Radio frequencies (P)

THE ZERO METHOD : v = 0 and i = 0



THALES - Daniel SOLEIL

6 CONVENTIONAL REFERENCE POTENTIALS

Casing,

Ground,

Zero for electronic parts,

Zero for communications

DC Energy,

AC Energy.

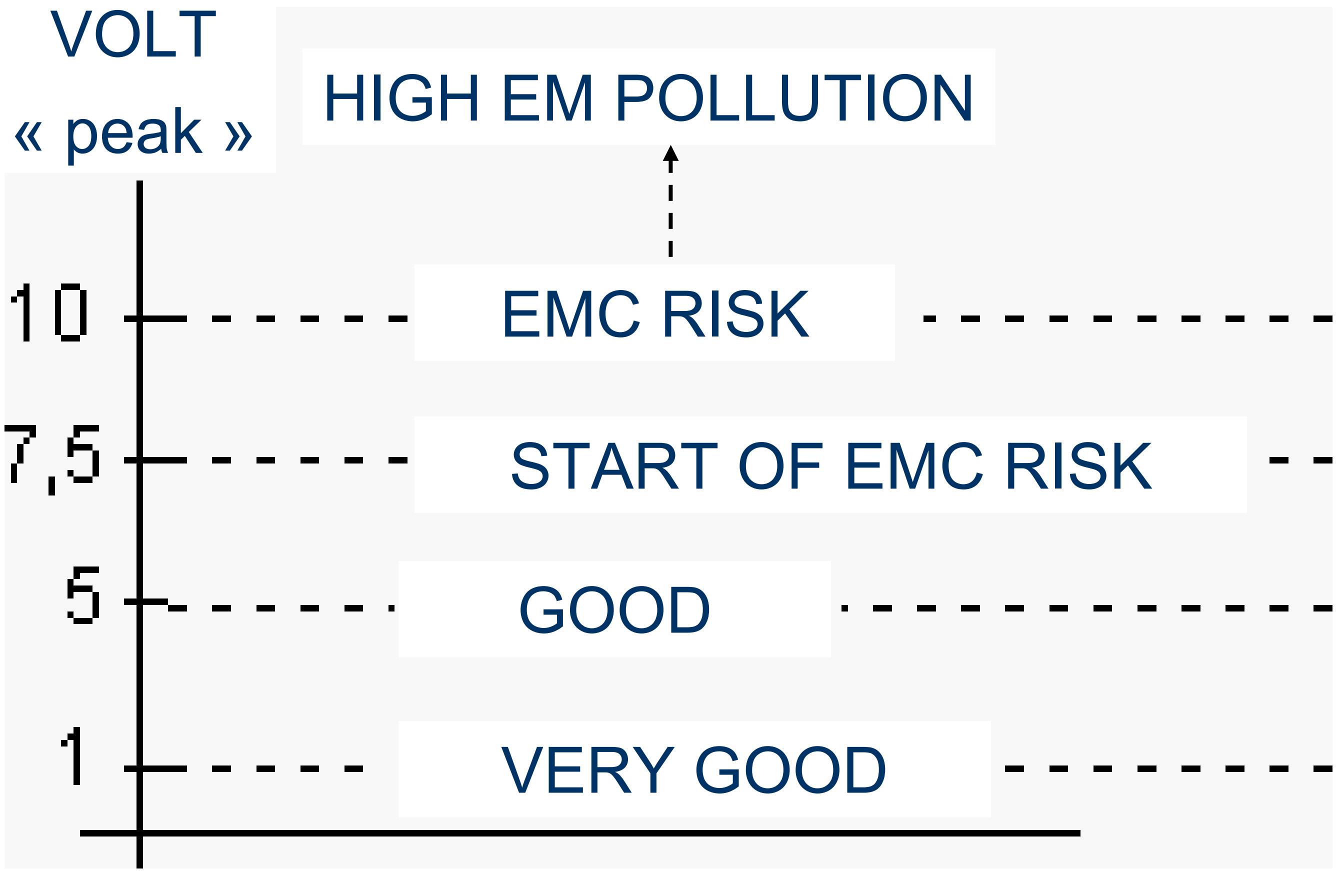
As a result : Zero Method Concept for EMC System

> No parasit current circulate in reference potential conductors

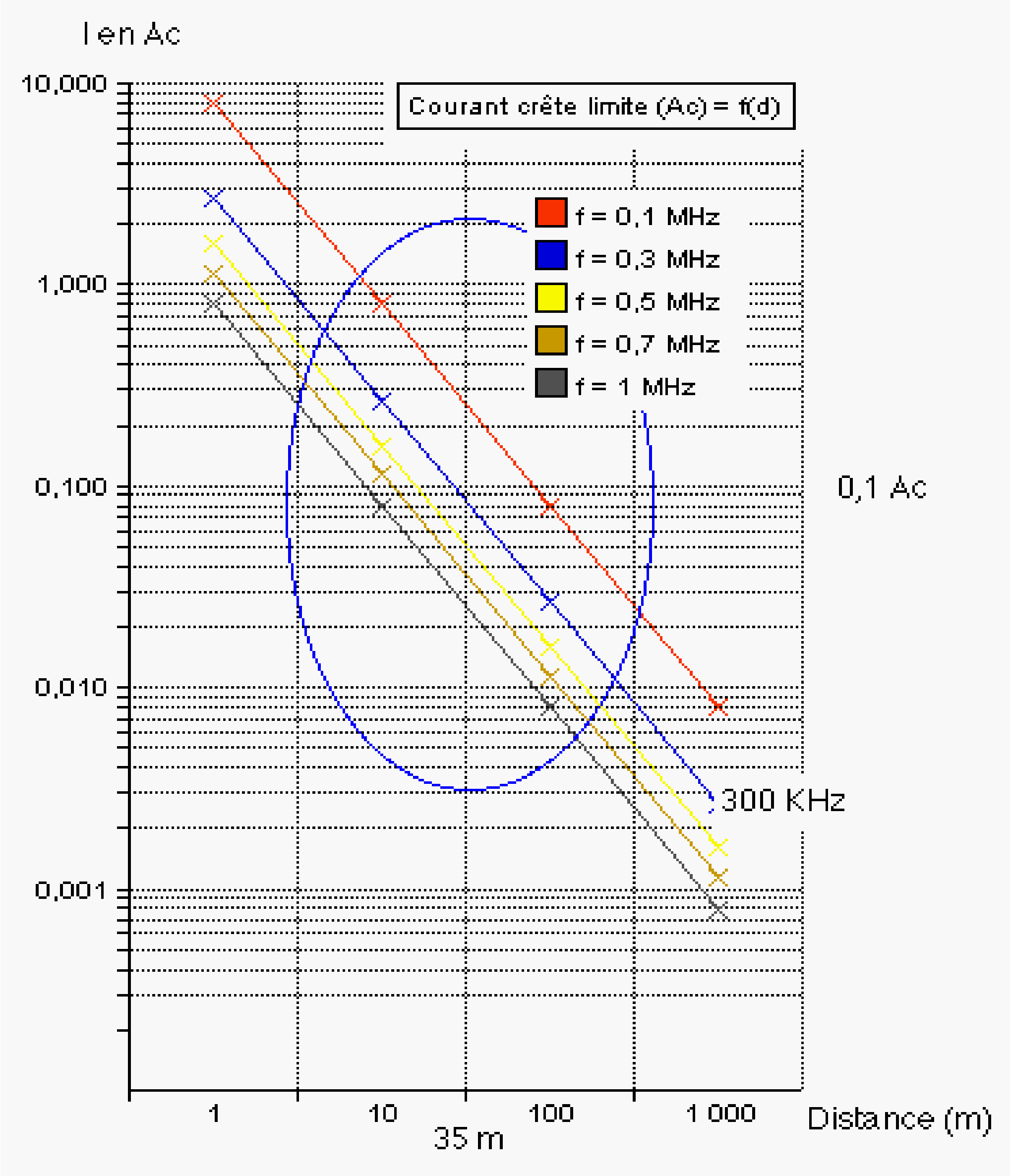
> No parasit voltage exist between different reference potentials

- Lightning and industrial domains : 10 kHz - 10 MHz
- Applicable on higher frequencies (IEMN, HIRF, …)

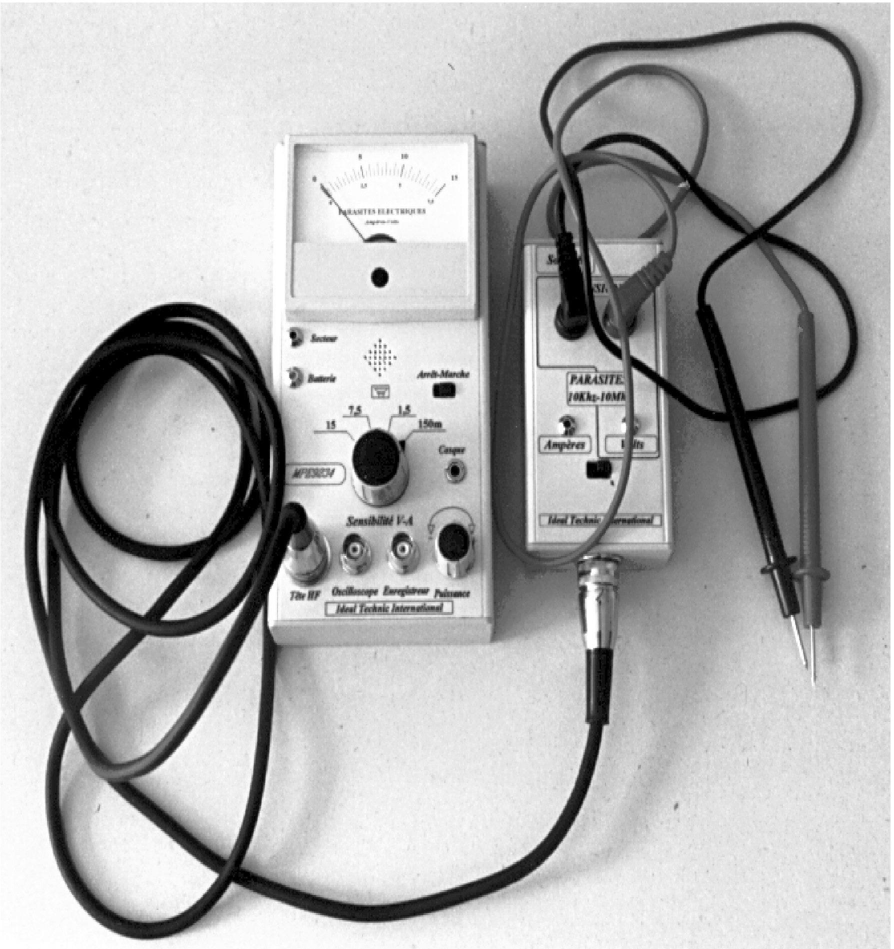
"Zero" : What does it mean in practice ?



I = 0 : EXPERIMENTAL CURRENT DATAS



“PERTURBOMETER” (®)



HF voltmeter and Ammeter probes

10 KHz - 10 MHz range

Peak measurement < 10 Vp and < 10 Ap

Audio, scope and recorder ports

Internal battery

A MAIN RESULT : THE DYNAMIC EQUIPOTENTIALITY

$V = zi$ → $v = 0$

2 WAYS

CLASSICAL MANNER

Z → 0

EXPENSIVE

ZERO METHOD

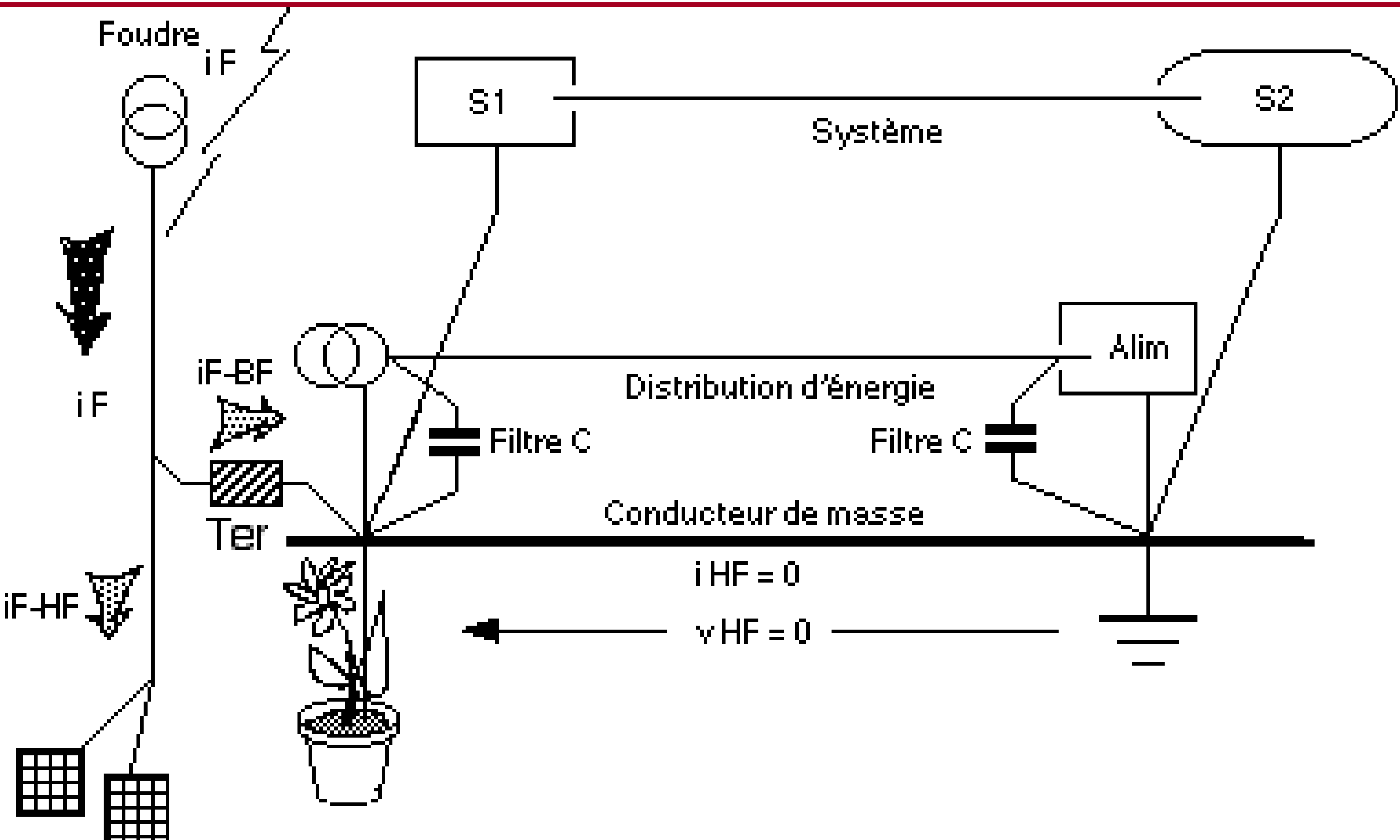
i → 0

EASY AND SAFETY

Some solutions for large sites by Zero Method

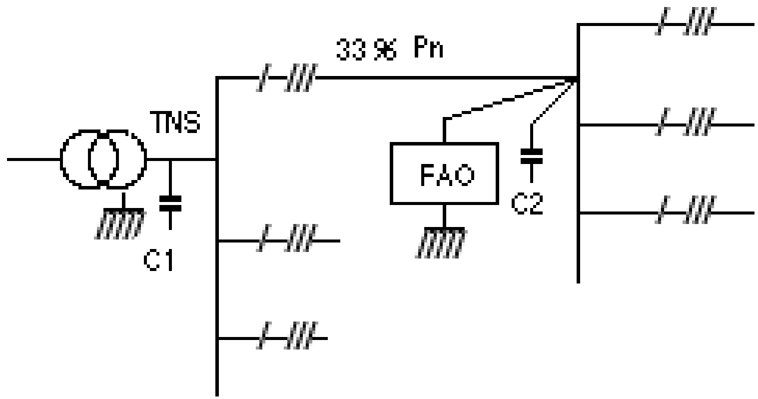
=> ISOLATION BETWEEN L.P.S AND THE SENSITIVE GROUND NETWORK

=> FILTERING OF SOURCE POWER AND POWER DISTRUBITION HARDENING

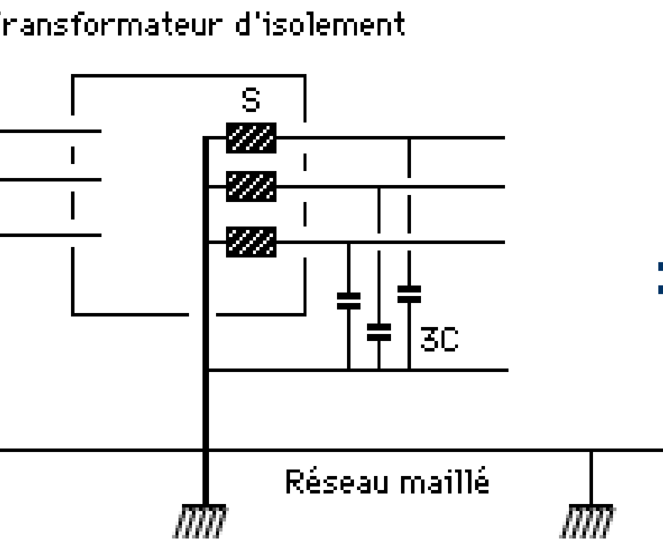


Power distribution filtering and hardening : Theory (1/4

Analysed configuration

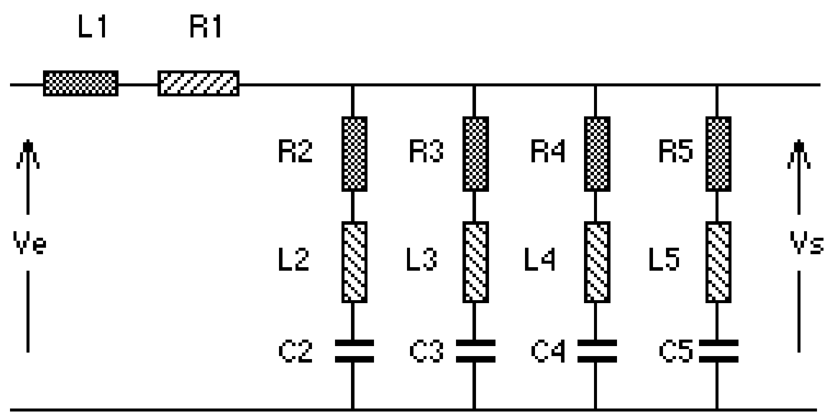


Example case



=>

Example modeling
(existing elements + added components



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Power distribution filtering and hardening : Theory (2/4

2 Typical situations are met :

- Filtering of the power source in differential mode
  - Correction of the "cos ϕ"
  - Attenuation effectiveness in differential mode
- Attenuation in common mode with TNS Neutral mode distribution
  - Attenuation effectiveness in comon mode

2 Theorical studies :

- Analytical relation related to the "cos ϕ" correction
- Analyical relation of differential and common attenuations

Power distribution filtering and hardening : Theory (3/4)

Analytical relation for "cos ϕ" correction

$$\mathrm{Pap}(\mathrm{Origin}) = \sqrt{\mathrm{Pac}^2 + \mathrm{Pr}_L^2} \text{ and } \mathrm{Pap}(\mathrm{End}) = \sqrt{\mathrm{Pac}^2 + X^2}$$

$$\text{with } X = X_L - X_C \text{ and } \mathrm{Xc}(\%) = 100 \frac{X(c)}{\mathrm{Pap}(\mathrm{Origin})}$$

Main results

- Insertion up to 20% of reactive power does not raise difficulties
- Practically, 5% per zone are necessary (majority of the case)
- Approching formulation : C (µF) = P (kVA)

Power distribution filtering and hardening : Theory (4/4)

Analytical relation for Attenuations (D & C)

$$\frac{Ve}{Vs} = \frac{1}{1 + z_1 y_2}, \text{ with :}$$

$$z = R + jX \text{ et } X = Lw - \frac{1}{Cw} \text{ and } y = \frac{1}{R + jX} \text{ or } y = \frac{R - jX}{R^2 + X^2}$$

$$\frac{Ve}{Vs} = 1 + (R_1 + jX_1) + \left(\frac{R_2 - jX_2}{R_2^2 + X_2^2} + (indice3) + (indice4) + (indice5) \right)$$

$$\text{Considering } \frac{R_2 - jX_2}{R_2^2 + X_2^2} = \frac{R_2 - jX_2}{Q_2}, \text{ idem for indice 3 … 5.}$$

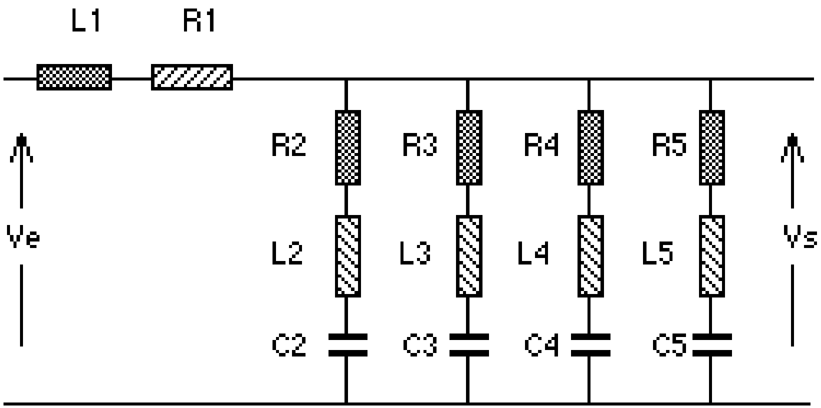
$$\frac{Ve}{Vs} = 1 + \frac{R_1 R_2}{Q_2} + \frac{R_1 R_3}{Q_3} + \frac{R_1 R_4}{Q_4} + \frac{R_1 R_5}{Q_5} + \frac{jX_1 R_2}{Q_2} + \frac{jX_1 R_3}{Q_3} + \frac{jX_1 R_4}{Q_4} + \frac{jX_1 R_5}{Q_5}$$
$$- \frac{jR_1 X_2}{Q_2} - \frac{jR_1 X_3}{Q_3} - \frac{jR_1 X_4}{Q_4} - \frac{jR_1 X_5}{Q_5} + \frac{X_1 X_2}{Q_2} + \frac{X_1 X_3}{Q_3} + \frac{R_1 X_4}{Q_4} + \frac{R_1 5_5}{Q_5}$$

We get now

$$\frac{Ve}{Vs} = 1 + \left(\frac{R_1 R_2 + X_1 X_2}{Q_2} \right) + (- -_3) + (- -_4)(- -_5) + j\left(\frac{X_1 R_2 - R_1 X_2}{Q_2} \right) + (- -_3) + (- -_4) + (- -_5)$$

$$\text{and finally } Att = \frac{1}{\sqrt{r^2 + i^2}}$$

Application : Filtering of the Main DB (1/2)



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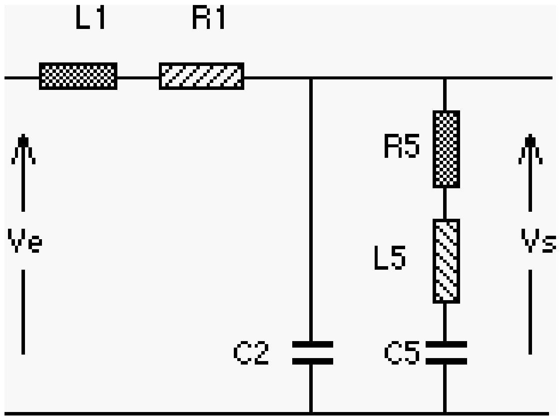
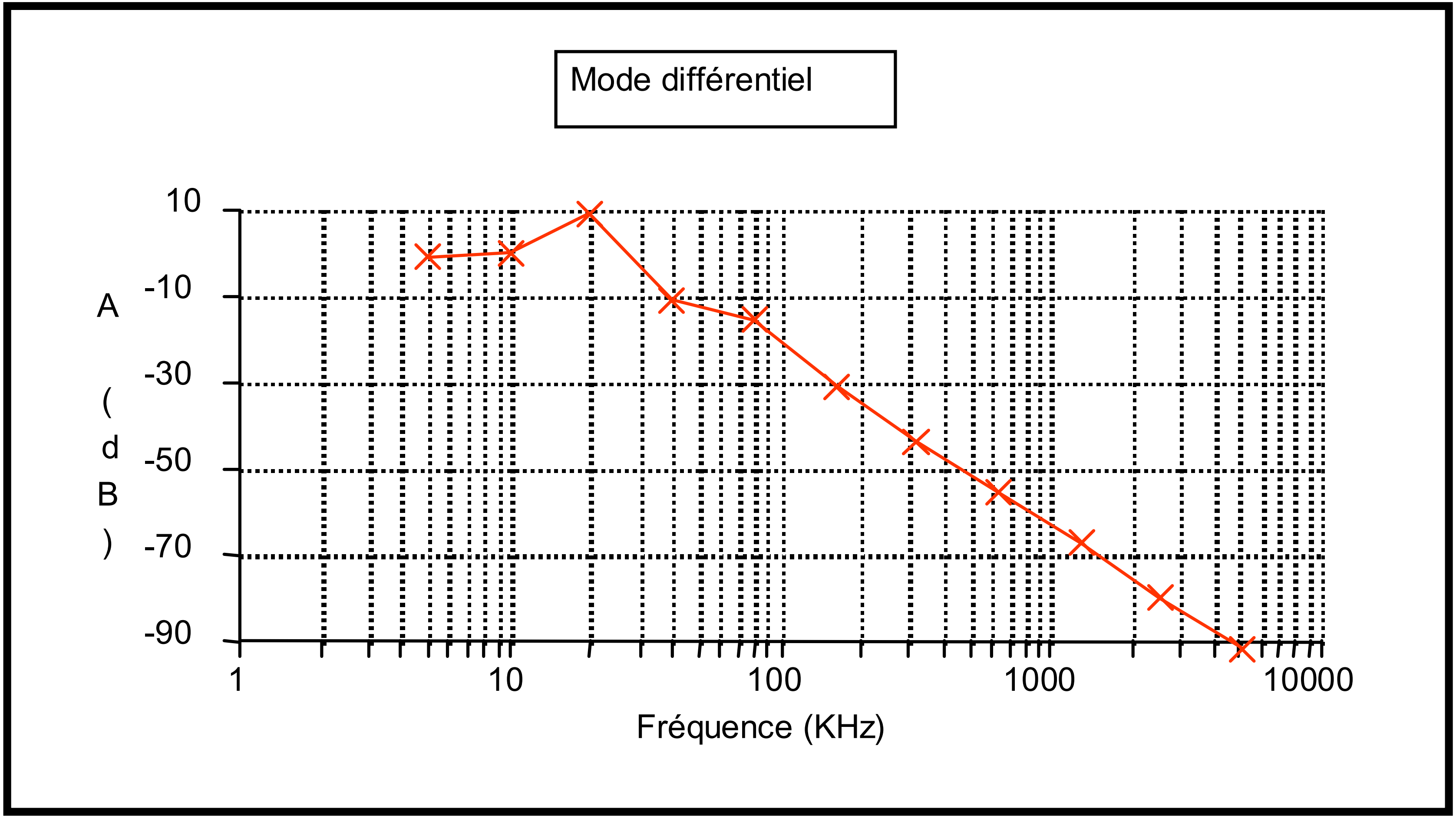


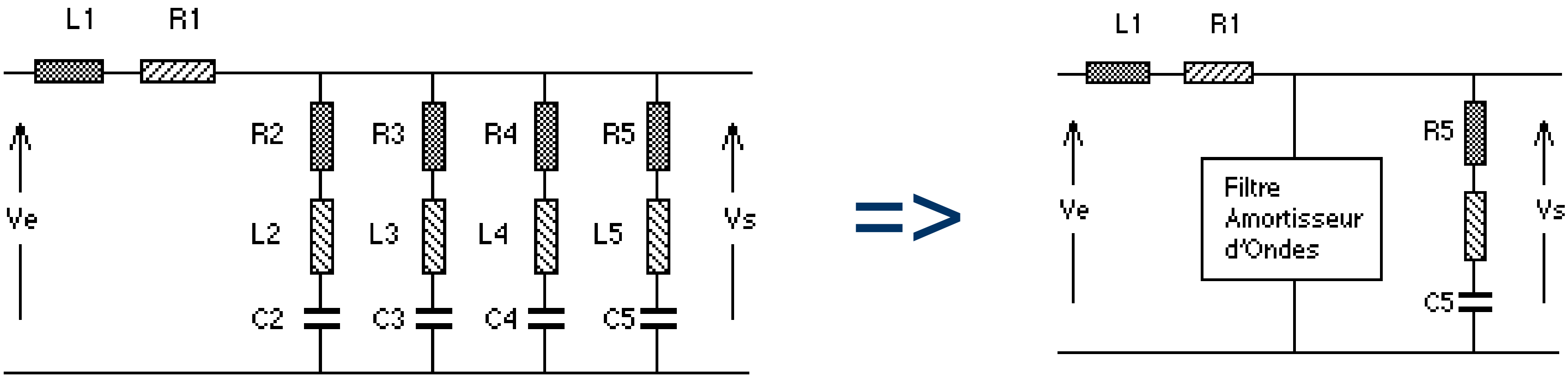
Type	Filter « 1 »	Filter « 2 »	Filter « 5 » Differential source
L (µH)	80	-	400
R (Ω)	0,019	-	0,170
C (µF)	-	250	-

- Fil "1" : Transformer characteristics (250 kVA)
- Fil "2" : Capacitor for "cos ϕ" correction
- Fil "3" : User impedance in differential mode

Application : Filtering of the Main DB (2/2)



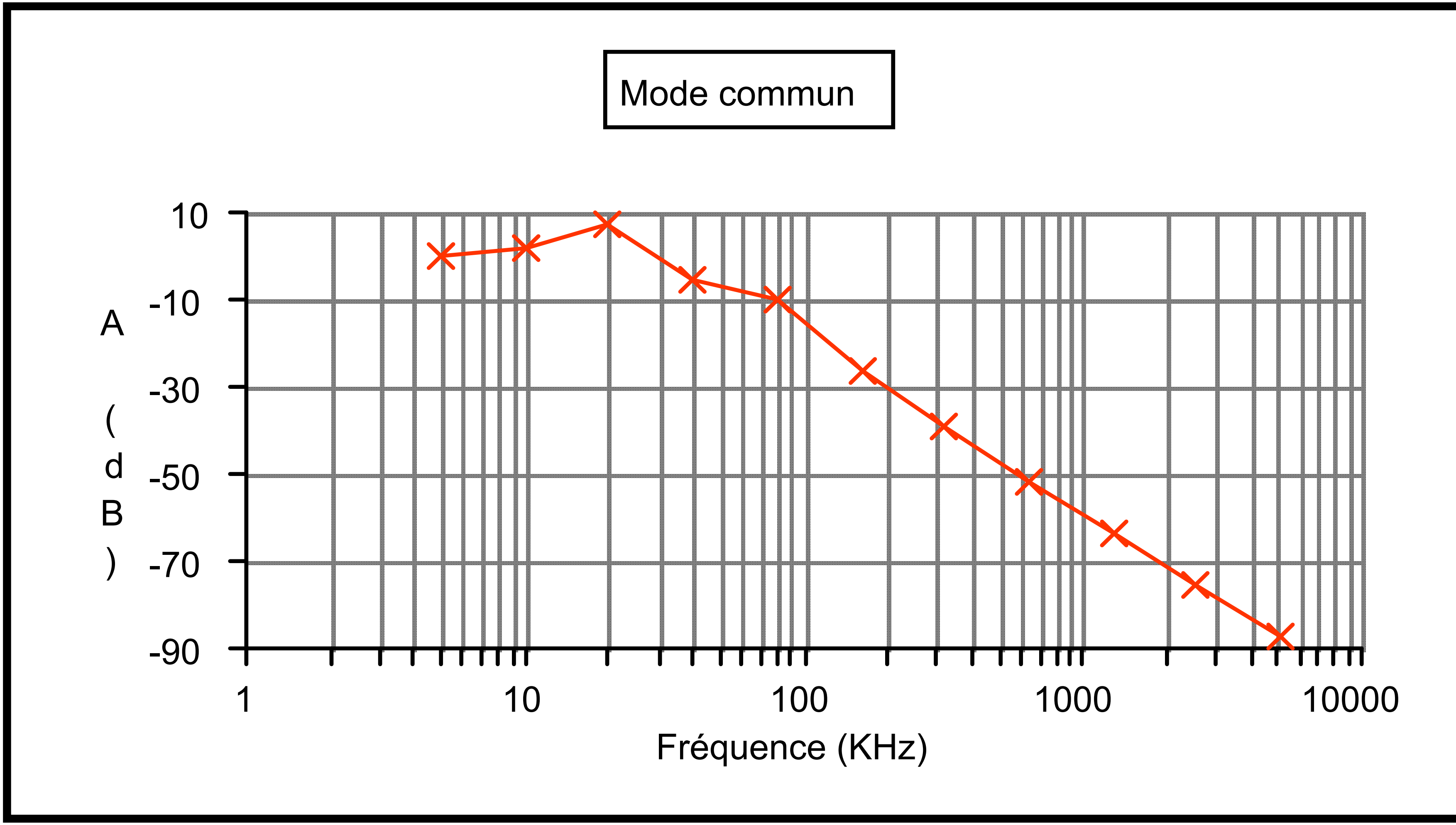
Application : Distribution hardening (1/3)



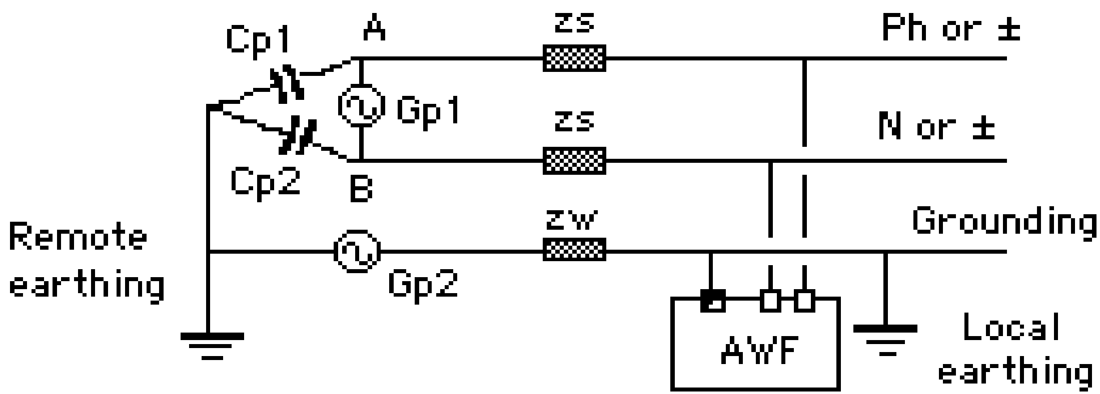
Type	Filter « 1 »	Filter « 2 »	Filter « 3 »	Filter « 4 »	Filter « 5 » Distrib common mode
L (µH)	50	40	-	-	250
R (Ω)	0,015	4,7	47	-	1000
C (nF)	-	220	1000	470	50

- Fil "1" : Distribution board characteristics (80 kVA)
- Fil "2", "3", "4" : Wave Absorbing Filter (FAO)
- Fil "3" : User impedance in common mode

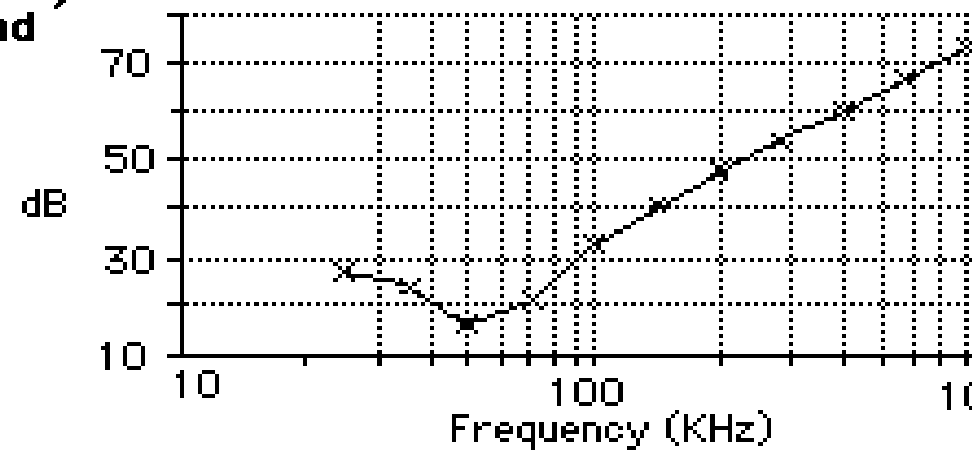
Application : Distribution hardening (2/3)



ABSORBER WAVE FILTER (AWF)



$$\text{Noise att} = 20 \log \left(\frac{V \text{ Neutral/Gnd}}{V_0 \text{ Neutral/Gnd}} \right)$$



Example : “AWF” Triphase

NEW « EMCS » COMPONENTS (3/3)

Power distribution filtering and hardening : Perfomance

<u>ter attenuations</u>

TNS neutral mode => No parasite voltage on CM (MDB)

Significant rate of attenuation for F > 30 kHz

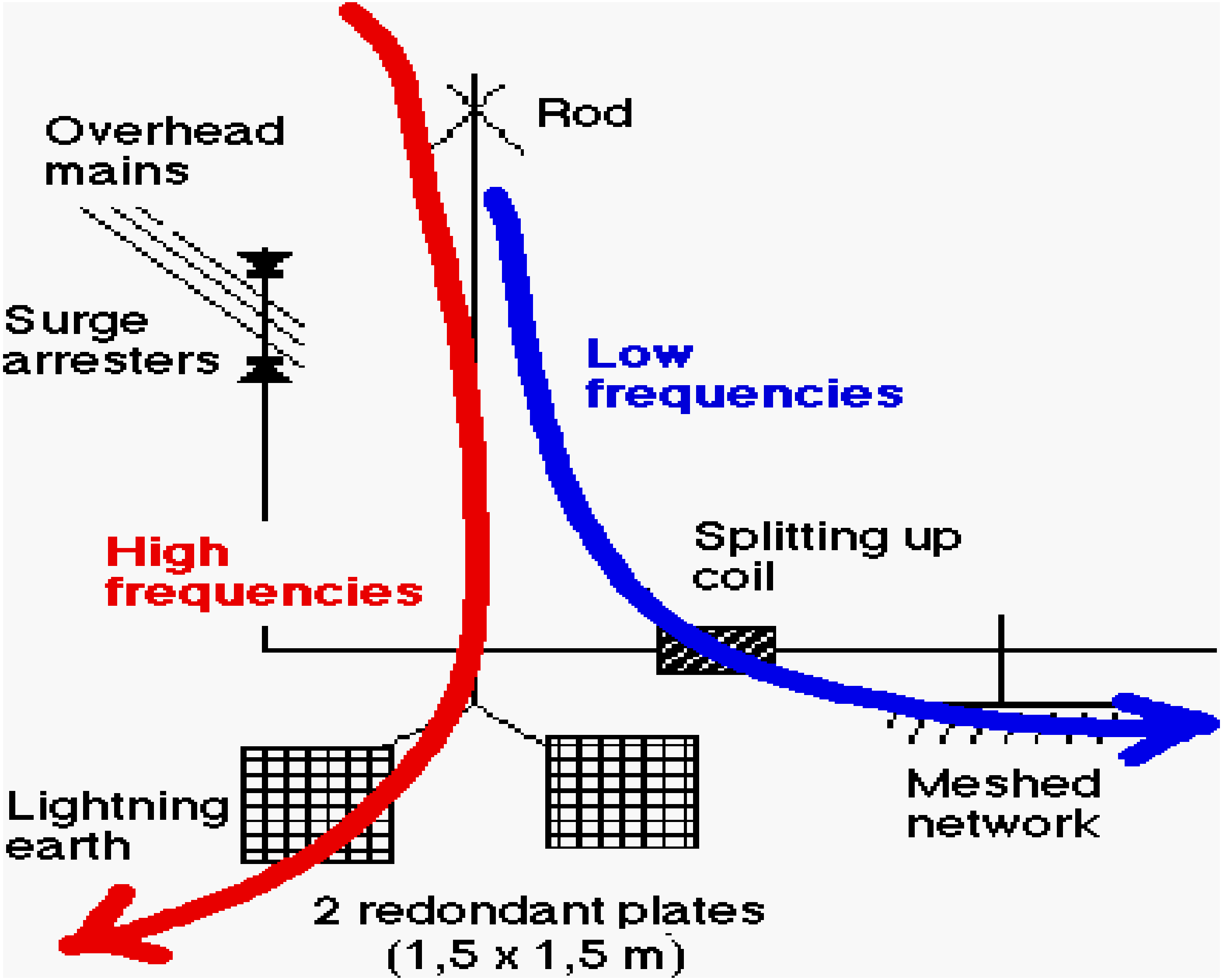
For F > 200 kHz : att > 40 dB => **Good against Lightning**

& C mode)

<u>equent Experimental Results</u>

tial parasit voltage reduced **from 10 Vp to 0.1 Vp**

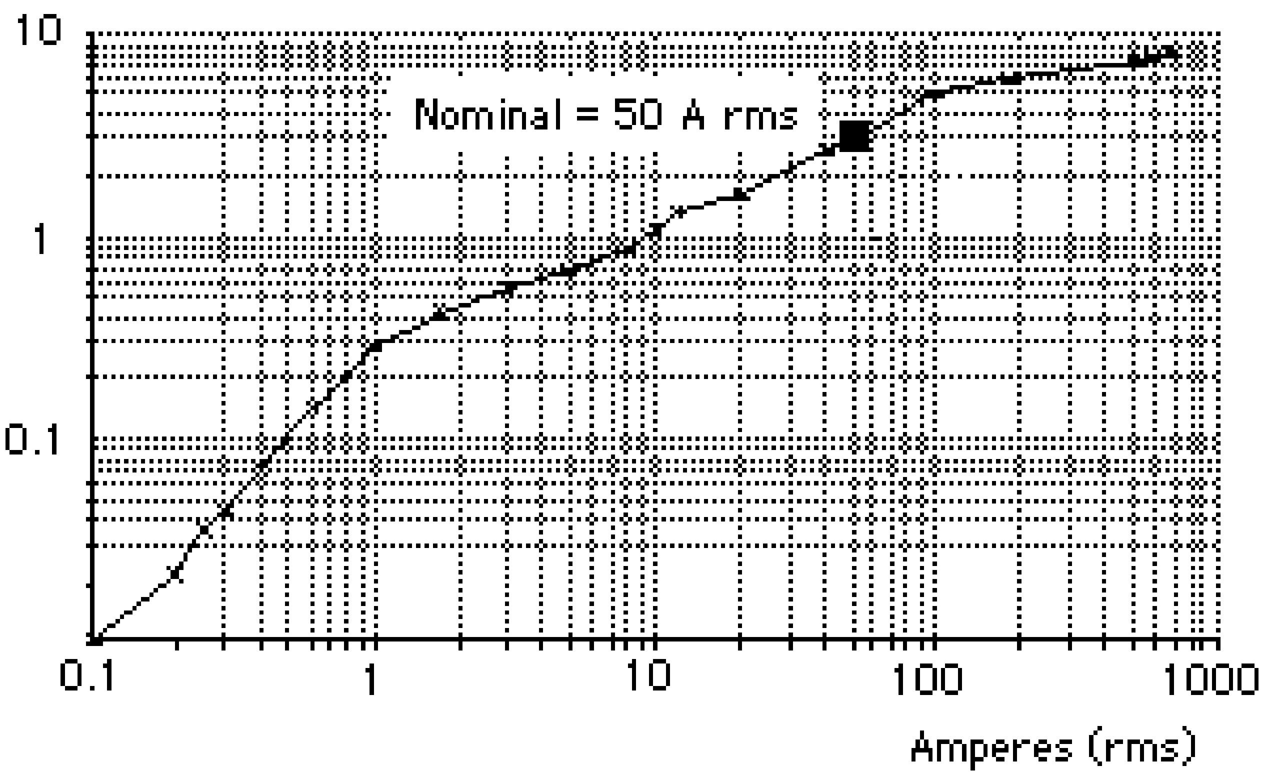
DERIVATED ATMOSPHERIC DISCHARGES (1/4)



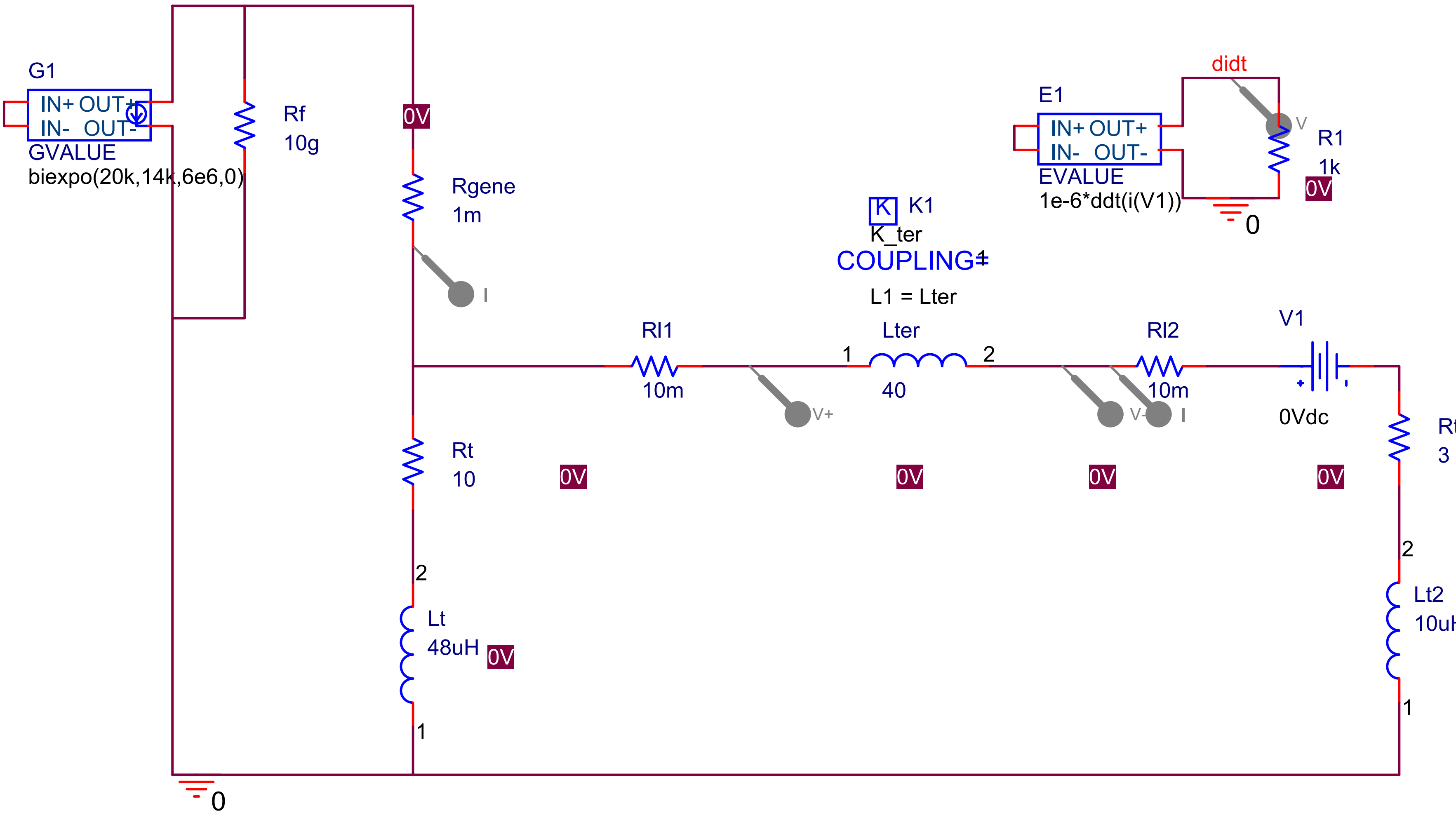
SPLITTING UP COIL (2/4)

Example: "TER 50 A"

- 120 x 150 x200 mn
- Weight: 5 Kg
- 2 screws Ø 6 mm



PSPICE Modelling



Isolation earthling / sensitive ground network (4/4)

Electric safety Conformity with the human safety requirements.	At 50 Hz, 50 A: Z = **50 mΩ** Drop voltage **: 2,5 V eff.**
Direct Lightning Protection 1) Equipotentiality at low frequency 2) Attenuation of the impulse and the high frequencies. 3) Resistance to the Lightning overvoltage.	1) In low frequency : Z < **1 Ω**. 2) Light attenuation of the impulse amplitude **(15%)**. For di/dt, reduction of approximately **20%** For di^2/dt^2 , reduction of approximately **30 dB**. 3) TER develops an overvoltage approximately **6 times** less than a traditional coil linear.
EMC Protection Attenuation from EMC parasites collected by the lightning protetcion system.	For the high frequencies (F > 10 kHz) TER bring an attenuation from approximately **20 dB**.

Main conclusions 1/3

<u>Quasi-perfect equipotentiality</u>

Implies the absence of HF current in a conductor.

<u>Experimental regulation of electromagnetic disturbances</u>

Cos Ø correction capacitor in star configuration for a quasi-null HF impedance.

Isolation between the lightning current and the sensistive ground networks

<u>Responsibilities</u>

It is possible that this concept becomes a tool to better define responsibilities.

<u>Point of view of the customer and the user</u>

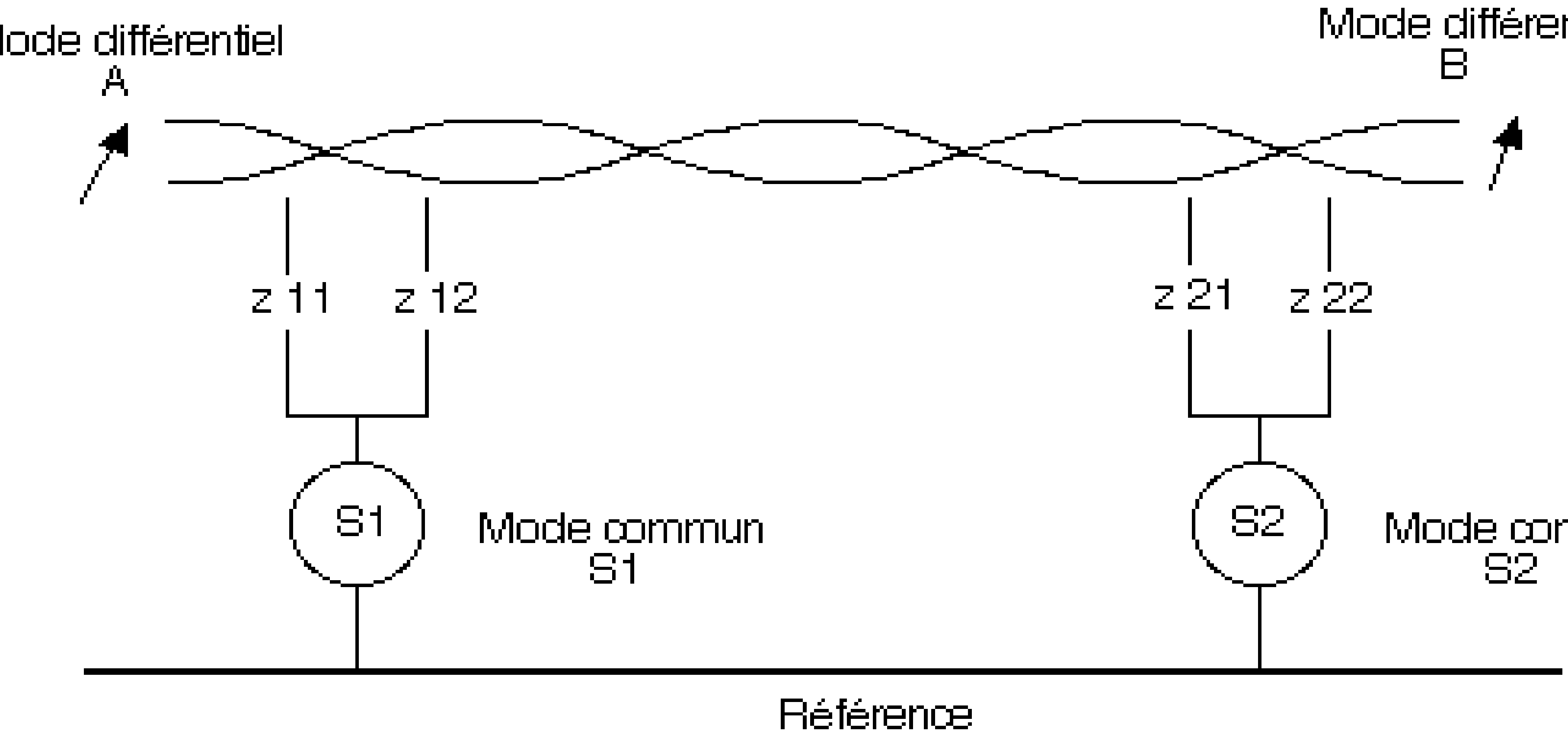
Positive financial assessment of exploitation thank to the effectivness protectio carried out.

Concept easy to understand.

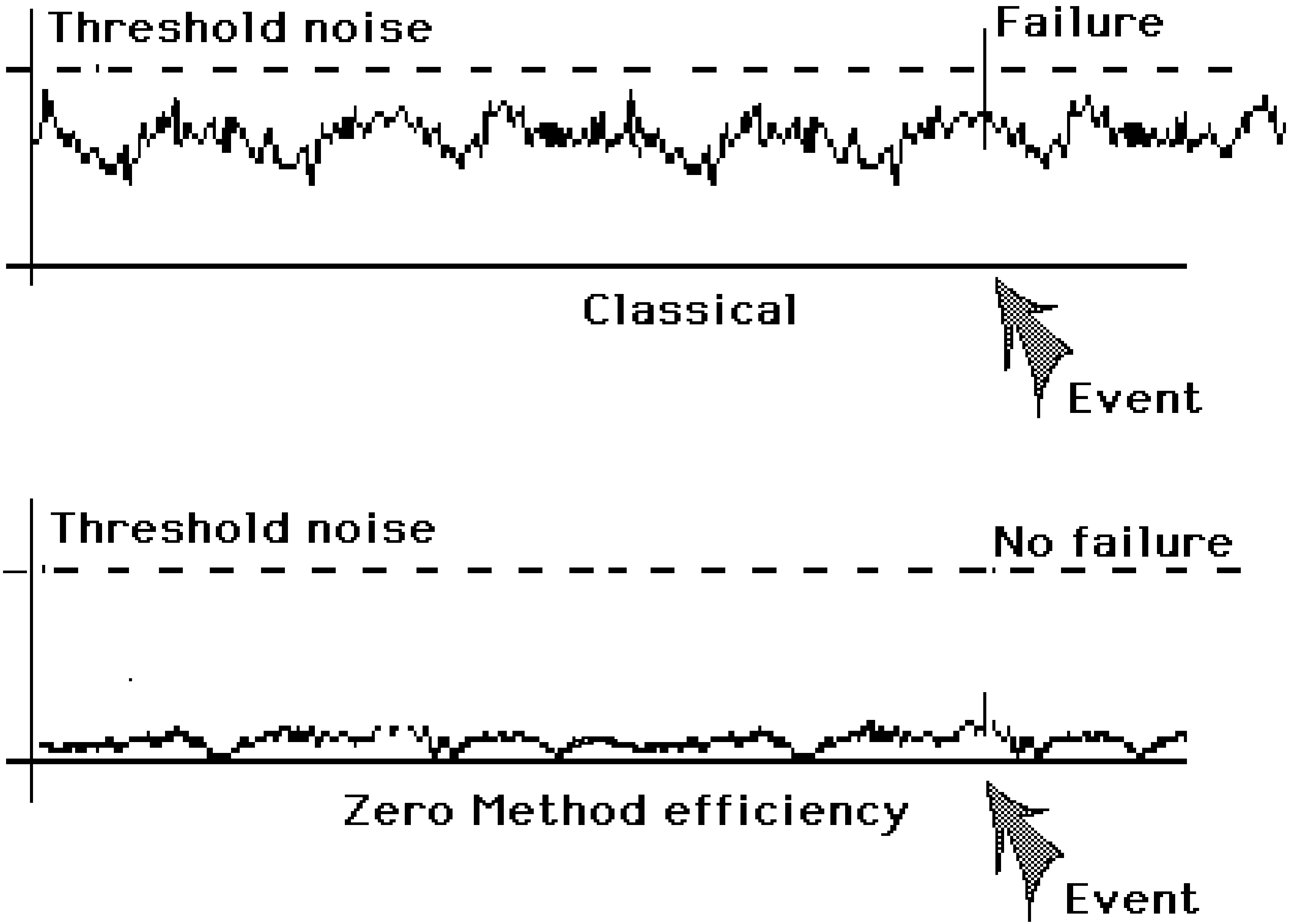
<u>" System " approaches of Electromagnetic Compatibility by the Zero Method</u>

This method is worth to be explored (capacity to lead to a methodology of coherent and universal analysis in the field of the EMC system).

TRANSFERT CM => DM 2/3



OTHER APPROACH FOR “0 FAILURE” 3/3



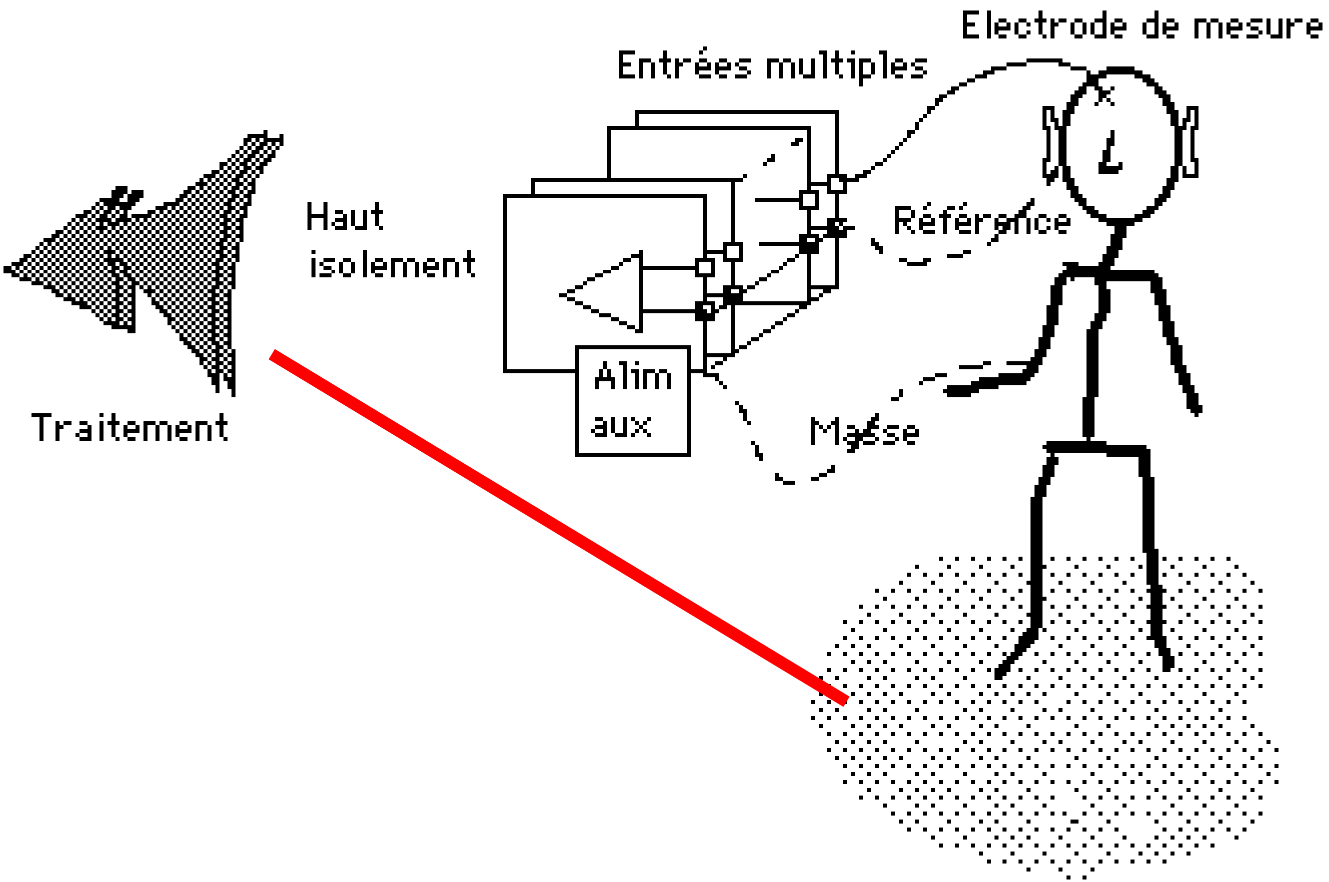
REFERENCES -1

SUBWAY MATRA VAL OF LILLE

70 vehicles, some are

anormally disturbed

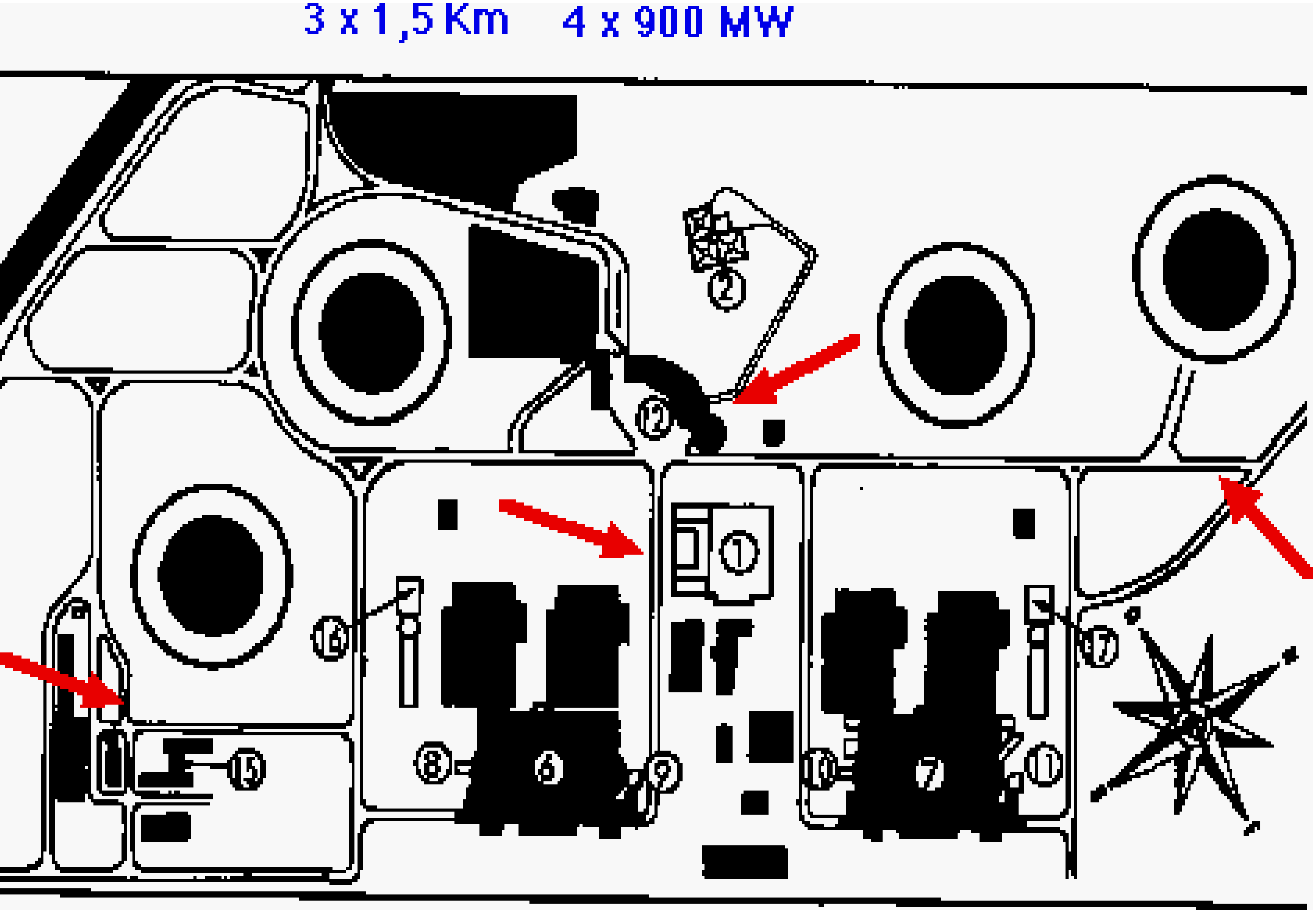
EPILEPTOLOGY UNITS SEEG AND MEG

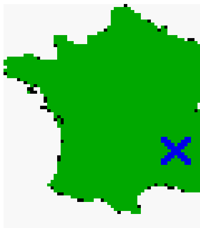


REFERENCES -3

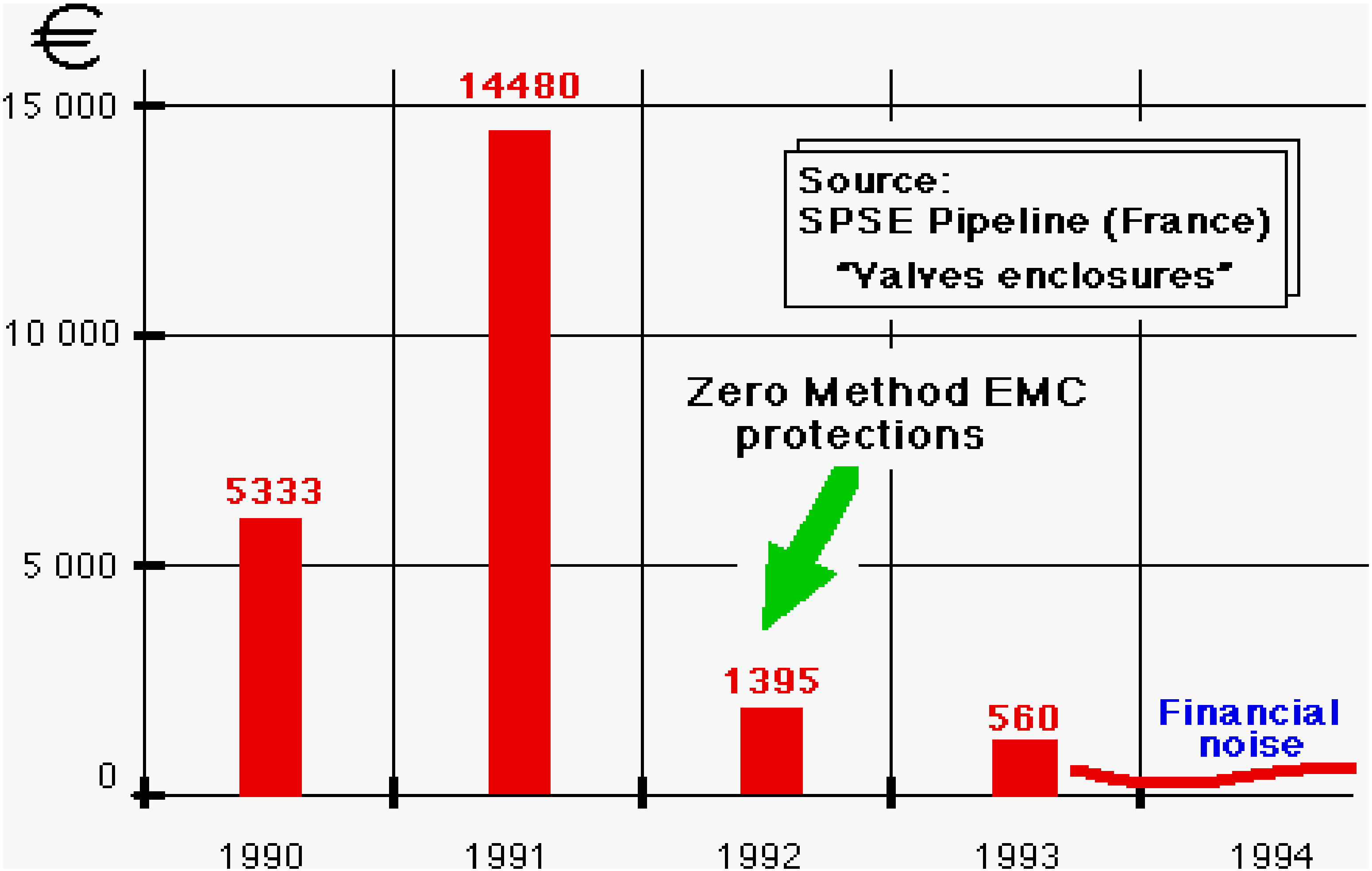
REFERENCE 4- Protected rooms

EDF NUCLEAR POWER PLANT IN CRUAS





COSTS : Pay out < 2 years for SPSE Pipelines



THANKS YOU
FOR YOUR ATTENTION !