MV Power Cable Diagnostics by Frequency Domain Spectroscopy

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Frequency Domain Spectroscopy

- **Measurements of insulation capacitance and losses in a frequency interval**

Frequency Domain Spectroscopy

- **Accurate measurements of capacitance and loss at several frequencies in a selected frequency range**
- **Ageing in insulating materials affects the polarisation process, i.e. the capacitance and loss frequency characteristics**
- **A wide frequency range gives more information and makes it possible to separate**
  - **different types of insulation materials**
  - **different types of ageing**
  - **influence of accessories**

Application PILC Cables

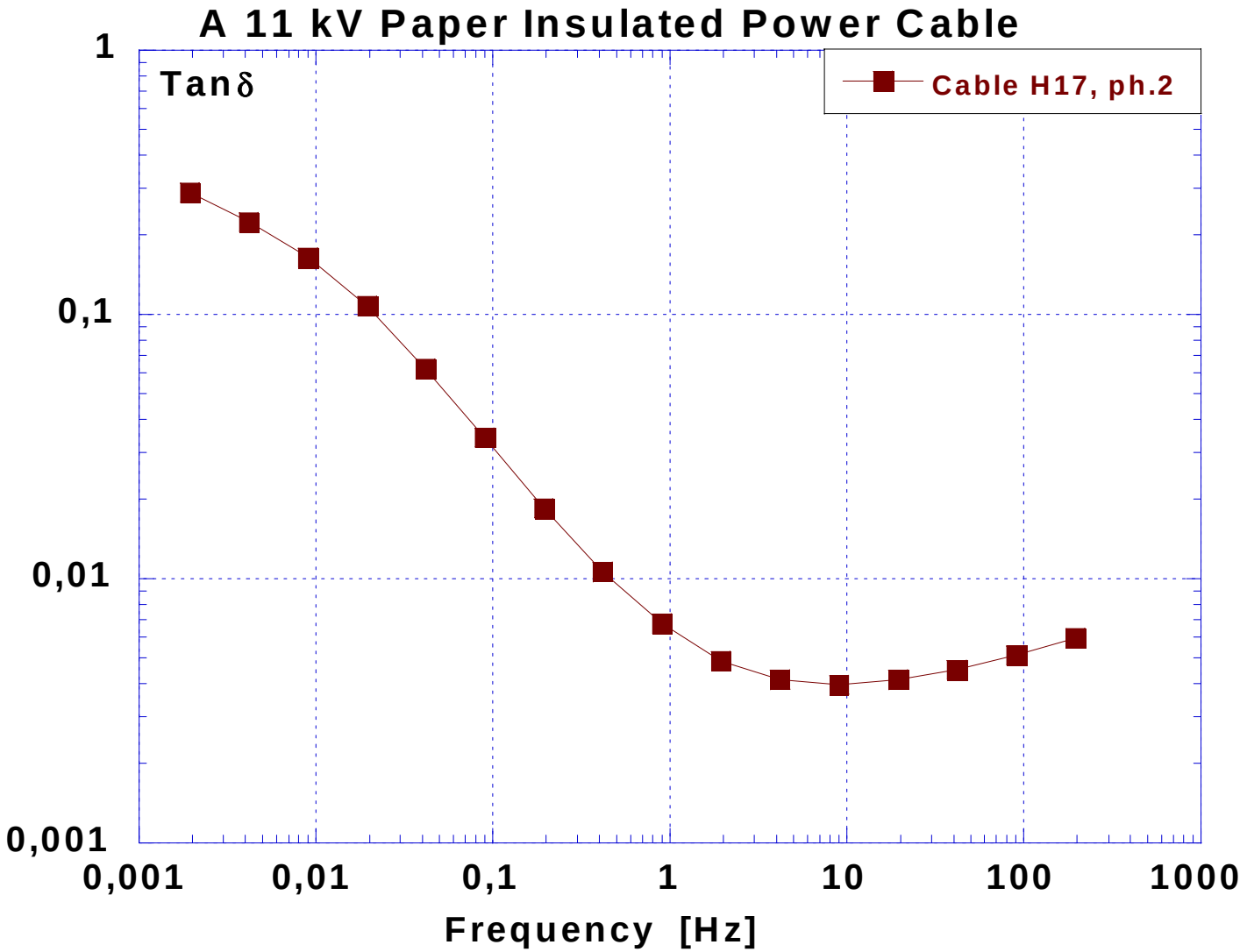
Dielectric response methods, e.g. frequency domain spectroscopy, and partial discharge measurements are complementing each other

Dielectric response methods detect aging products such as moisture while partial discharge measurements finds local defects

Application PILC Cables

- **Moisture**
  - **is generated by aging**
  - **accelerates the aging process**
- **Moisture is detectable by frequency domain spectroscopy measurements**
- **To detect moisture in paper insulation and other cellulose materials (e.g. transformer pressboard) low voltage measurements is preferably**

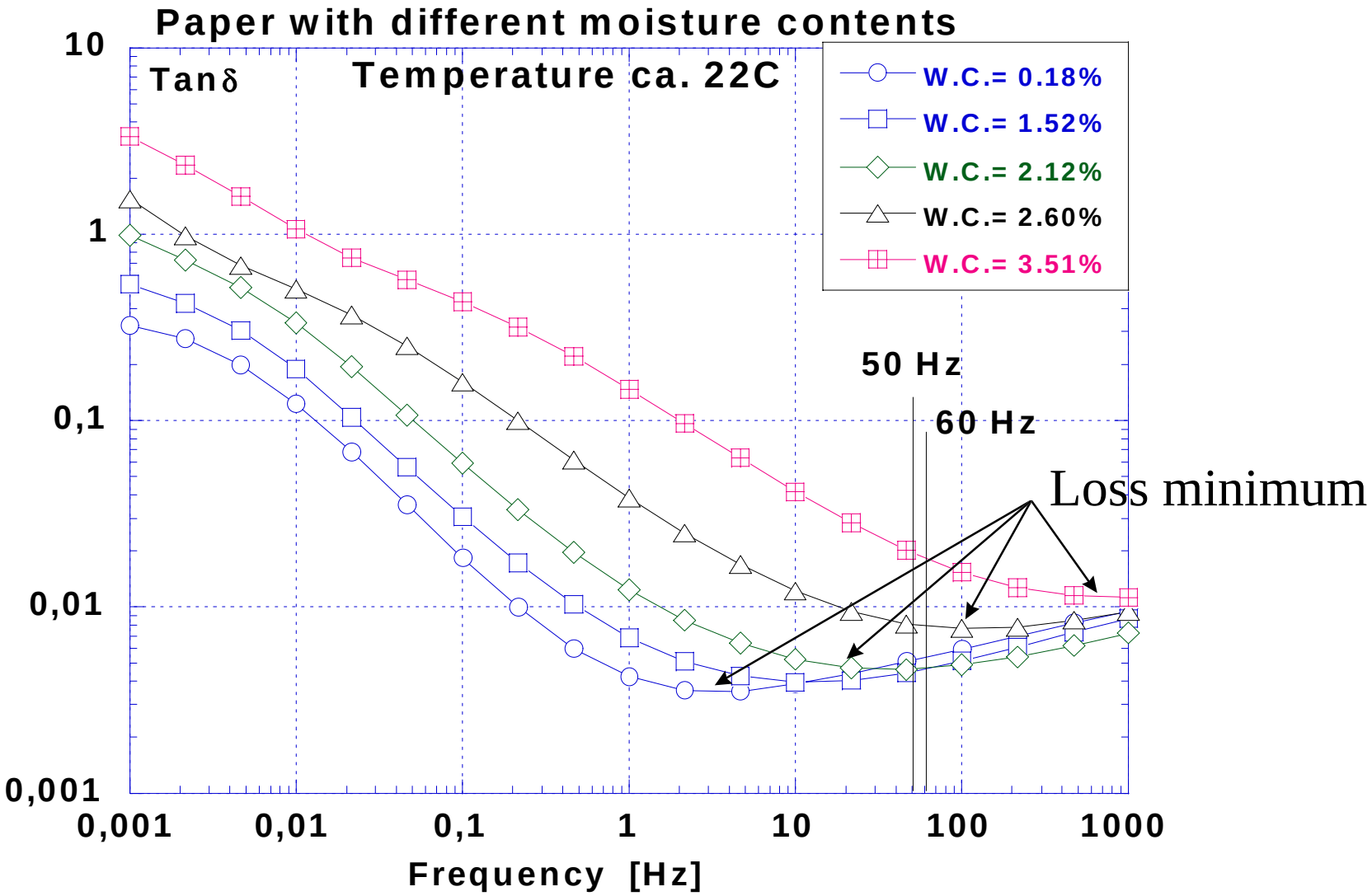
IDA 200 Measurement at 120 Vrms



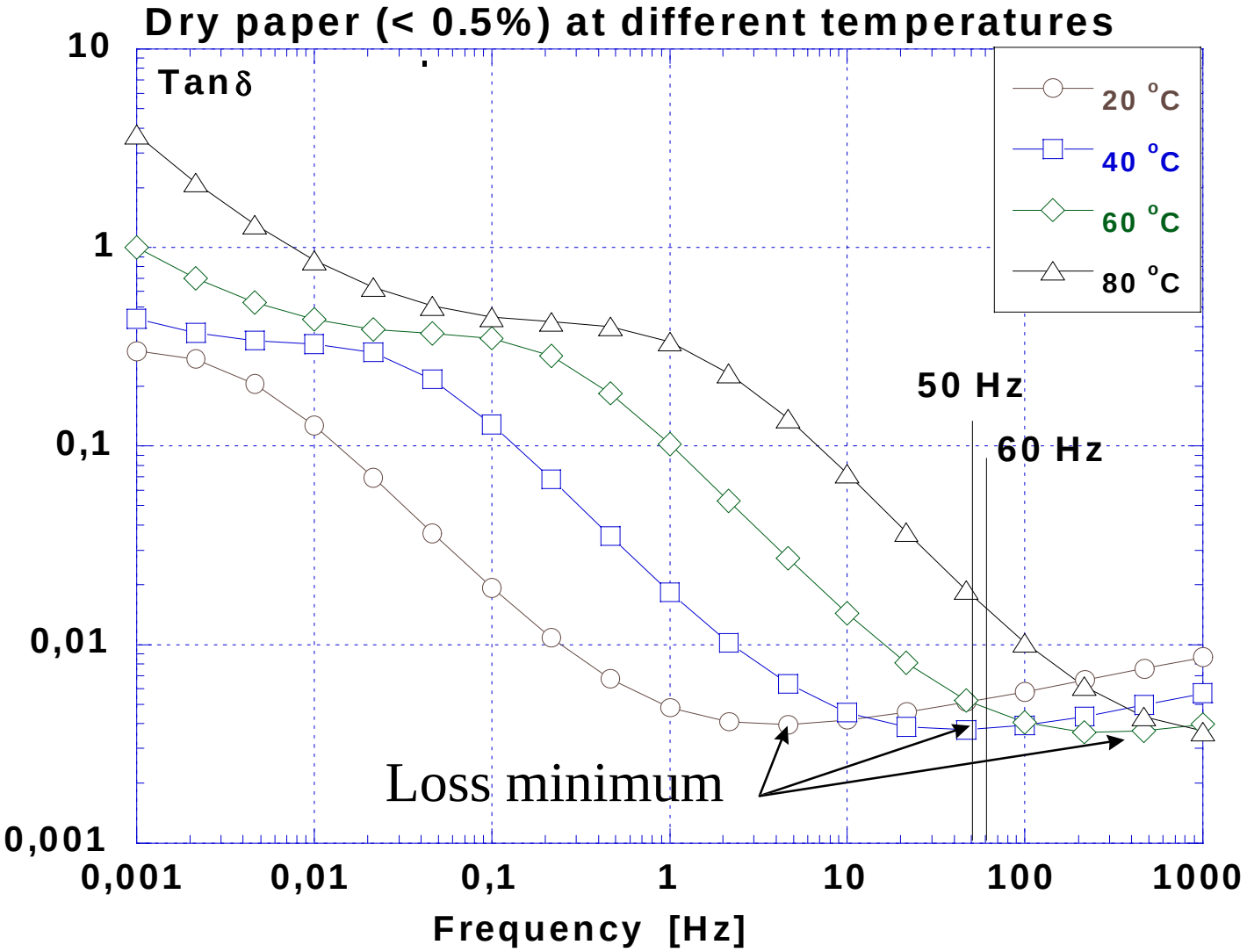
Impregnated Cellulose Paper

- **Moisture content**
- **Temperature**
- **Type of paper**
  - **High density pressboard**
  - **Low density pressboard**
  - **Type of Kraft paper**
  - **and more**

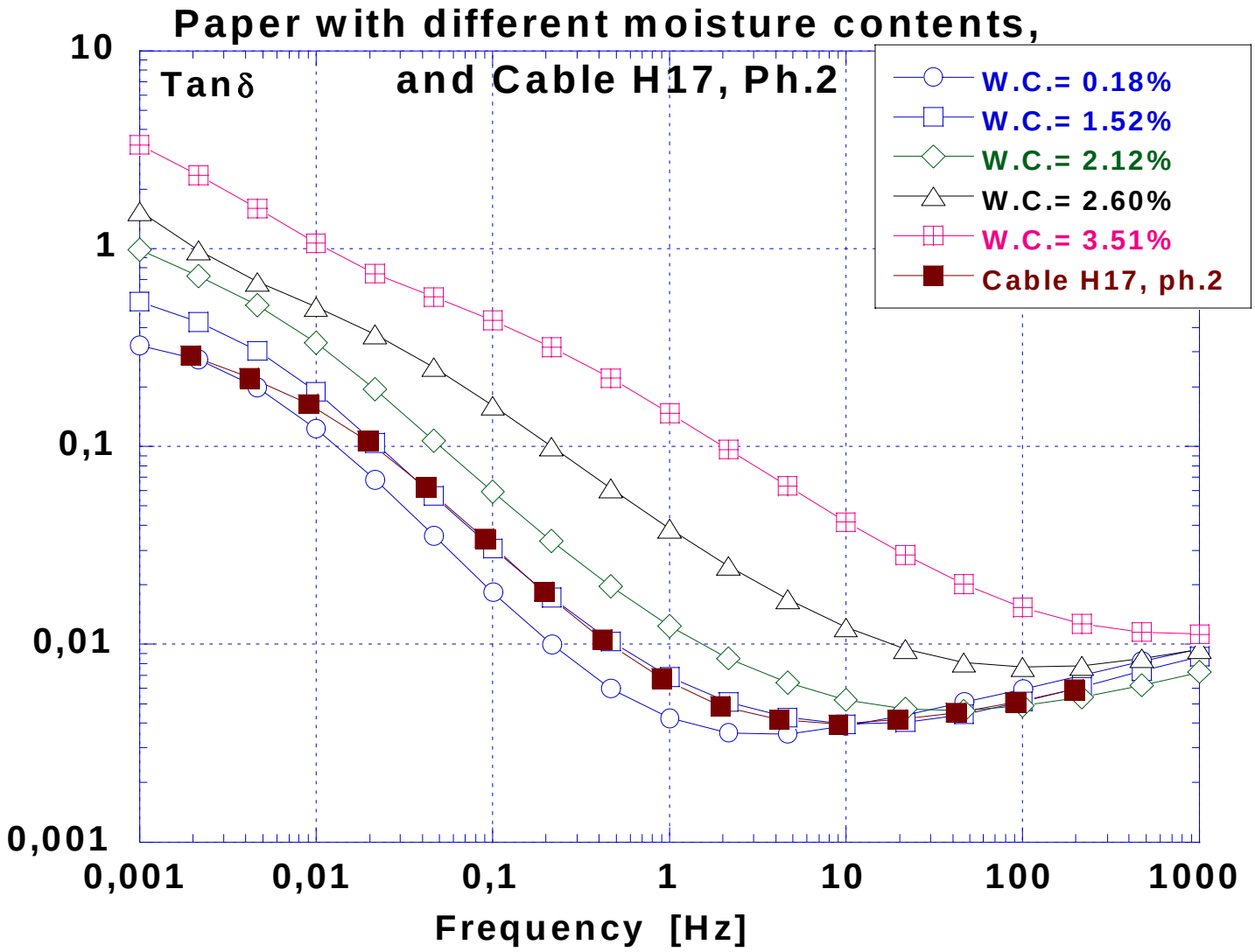
Effect of Moisture



Effect of Temperature



Determination of Moisture Content



Determination of Moisture Content

Moisture content = Approximately 1 % (OK)

Observations made:

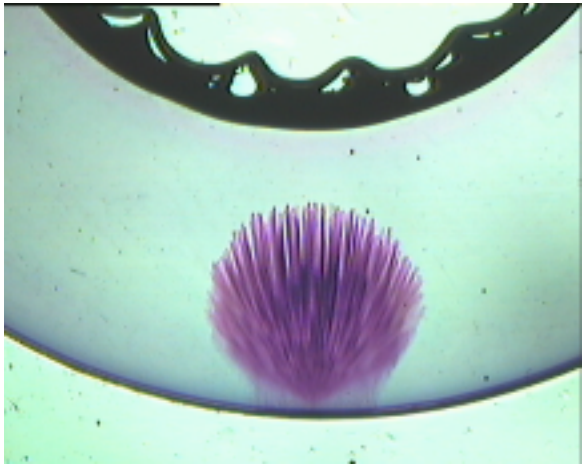
- **The “loss minimum” increases with moisture content**
- **The “loss minimum” seems to be almost independent of temperature**
- **The “loss minimum” seems to be almost independent on type of Kraft paper**

Summary

- **The frequency domain spectroscopy technique is a good tool to estimate the average moisture content in PILC cable**
- **By use the “loss minimum” loss value, the influence of temperature and type of Kraft paper is minimized**
- **The frequency domain technique, that record the characteristic frequency dependence in capacitance and loss make it possible to separate moisture from accessories or leakage currents**

Application MV XLPE Cables

- **Water trees are growing in the insulation and lower the electrical withstand**
- **The water tree aging process is very slow**
- **A heavily aged cable fail if the insulation stress is increased (Lightning impulses, faults, etc)**



Application MV XLPE Cables

- **Voltage tests shorten the cable life significantly**
- **Non-destructive diagnostics saves money**

- **Preferably measured at high voltage levels**
- **Non-destructive diagnostics (no voltage test)**

- **IDA200 with an external high voltage unit**

Measurement Procedure

(Medium Voltage XLPE Cables)

- **Measurements of short frequency sweeps around 0.1 Hz at several voltage levels up to service voltage level, Uo**
- **Preliminary judgement of the cable**

If the cable is judged "good", a slightly higher voltage levels can be used in order to detect aging in some cable designs

The Response of Water Tree Deteriorated XLPE Cables

VDP Response (Voltage Dependent Permittivity)

A voltage dependent increase of loss and capacitance.

TLC Response (Transition to Leakage Currents)

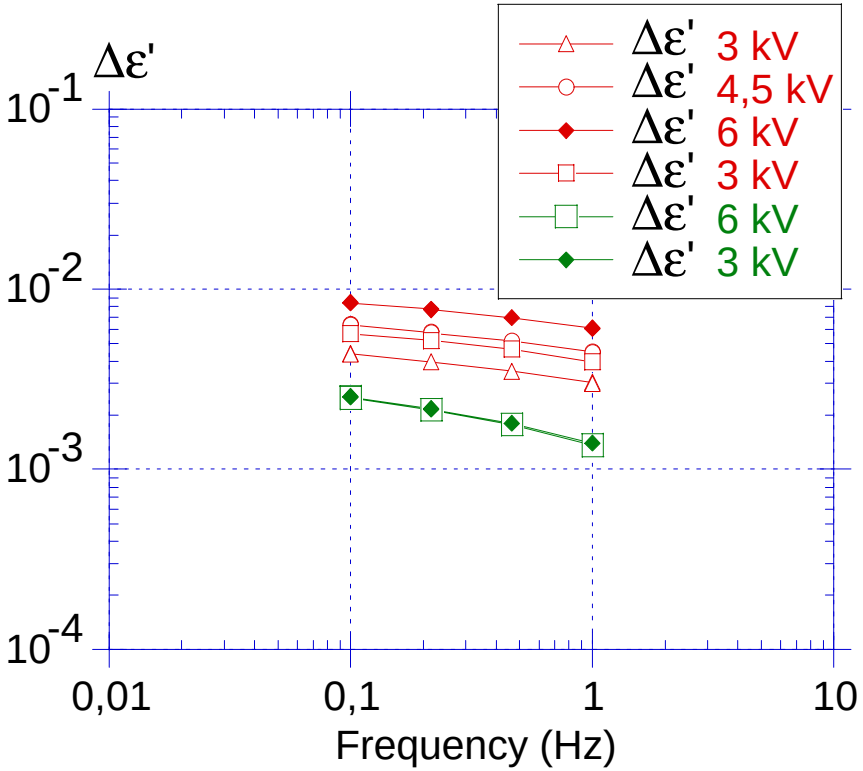
A VDP response at initial low voltage levels. At a higher voltage level, the response changes characteristics. Leakage currents are added.

LC Response (Leakage Currents)

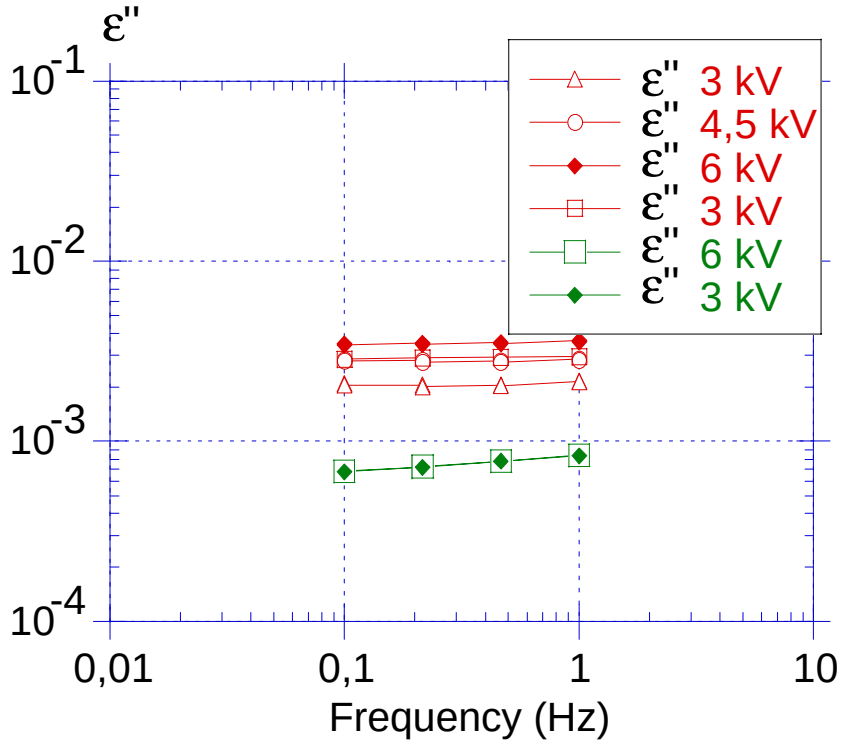
Leakage currents through water trees are present already at low voltage levels.

VDP response: A voltage dependent increase of loss and capacitance

Capacitance part

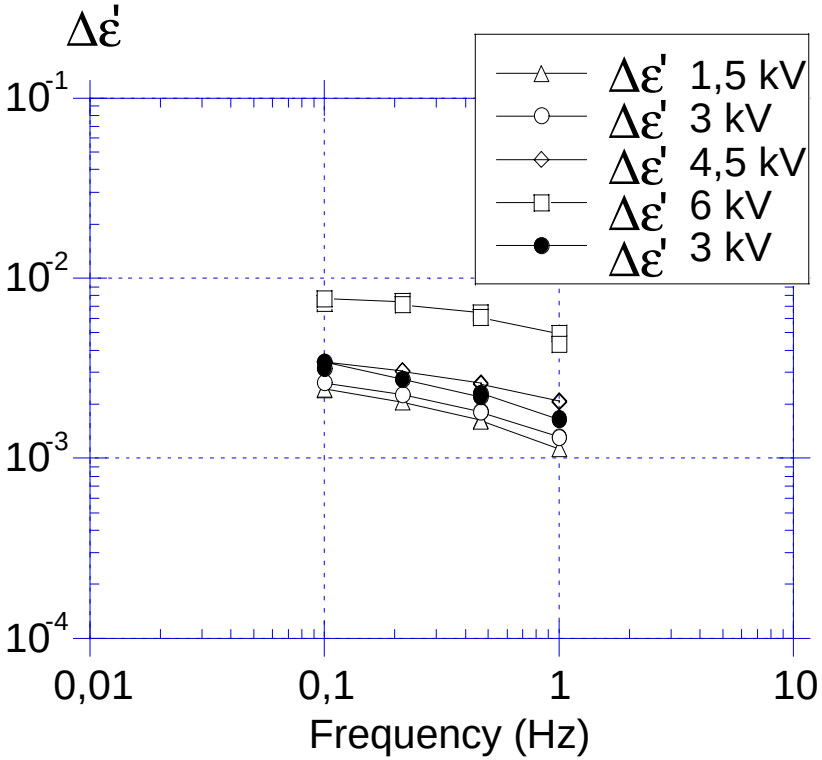


Loss (Tanδ) part

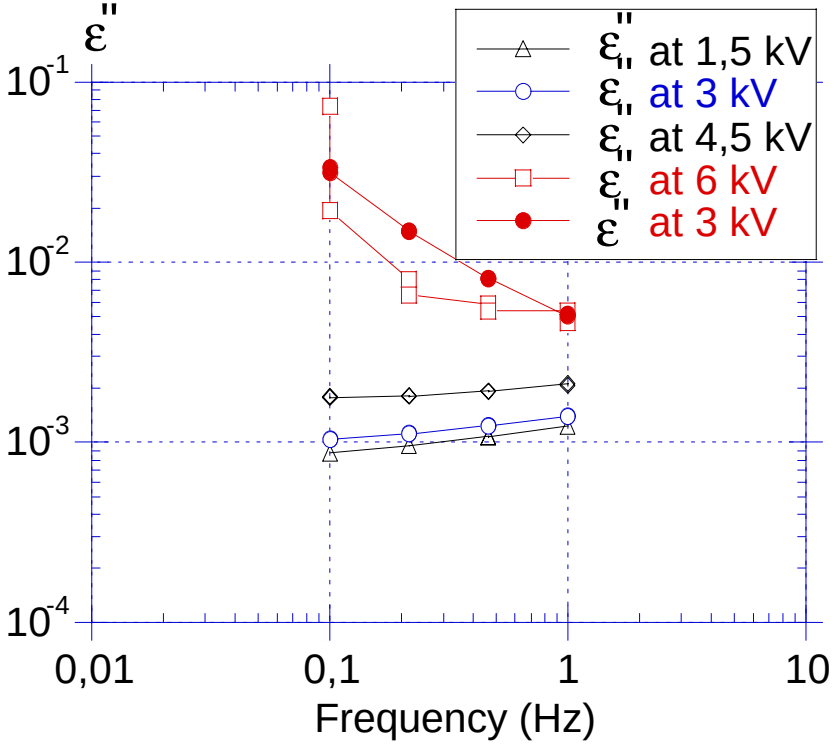


TLC response: The response change characteristics. A leakage current is added

Capacitance part

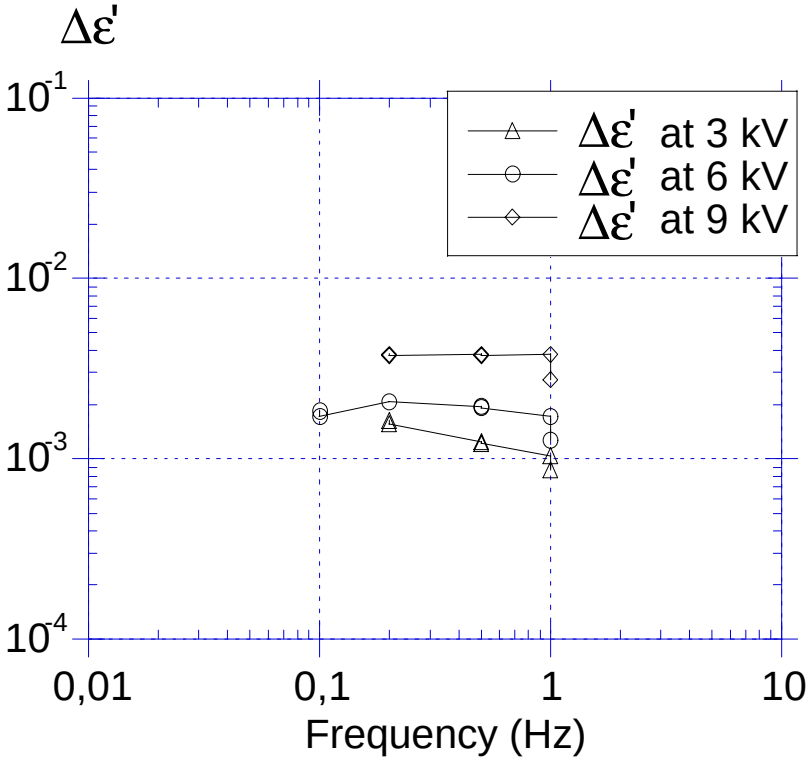


Loss (Tanδ) part

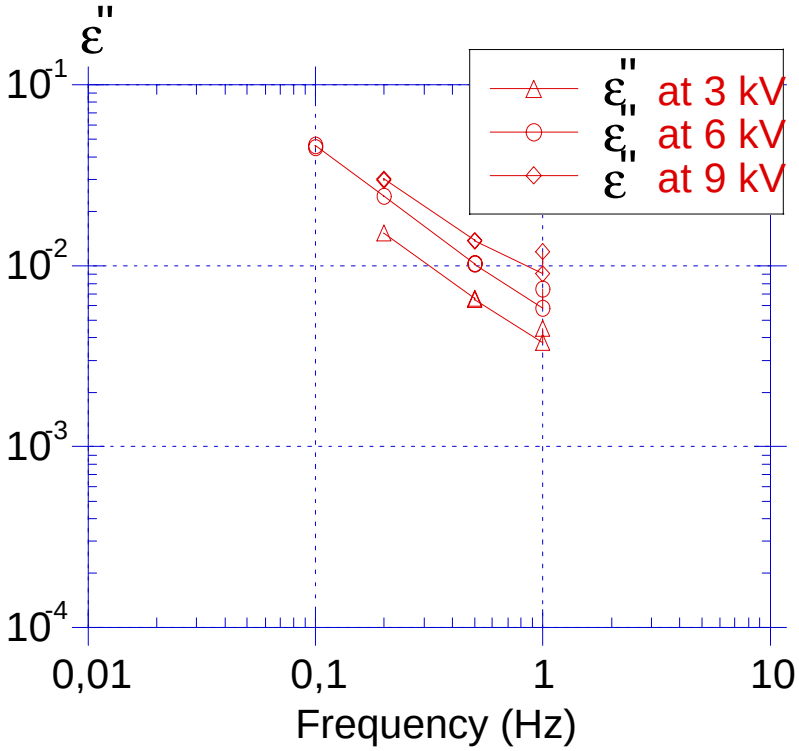


LC response: Leakage current through water trees present at low voltage levels

Capacitance part



Loss (Tanδ) part

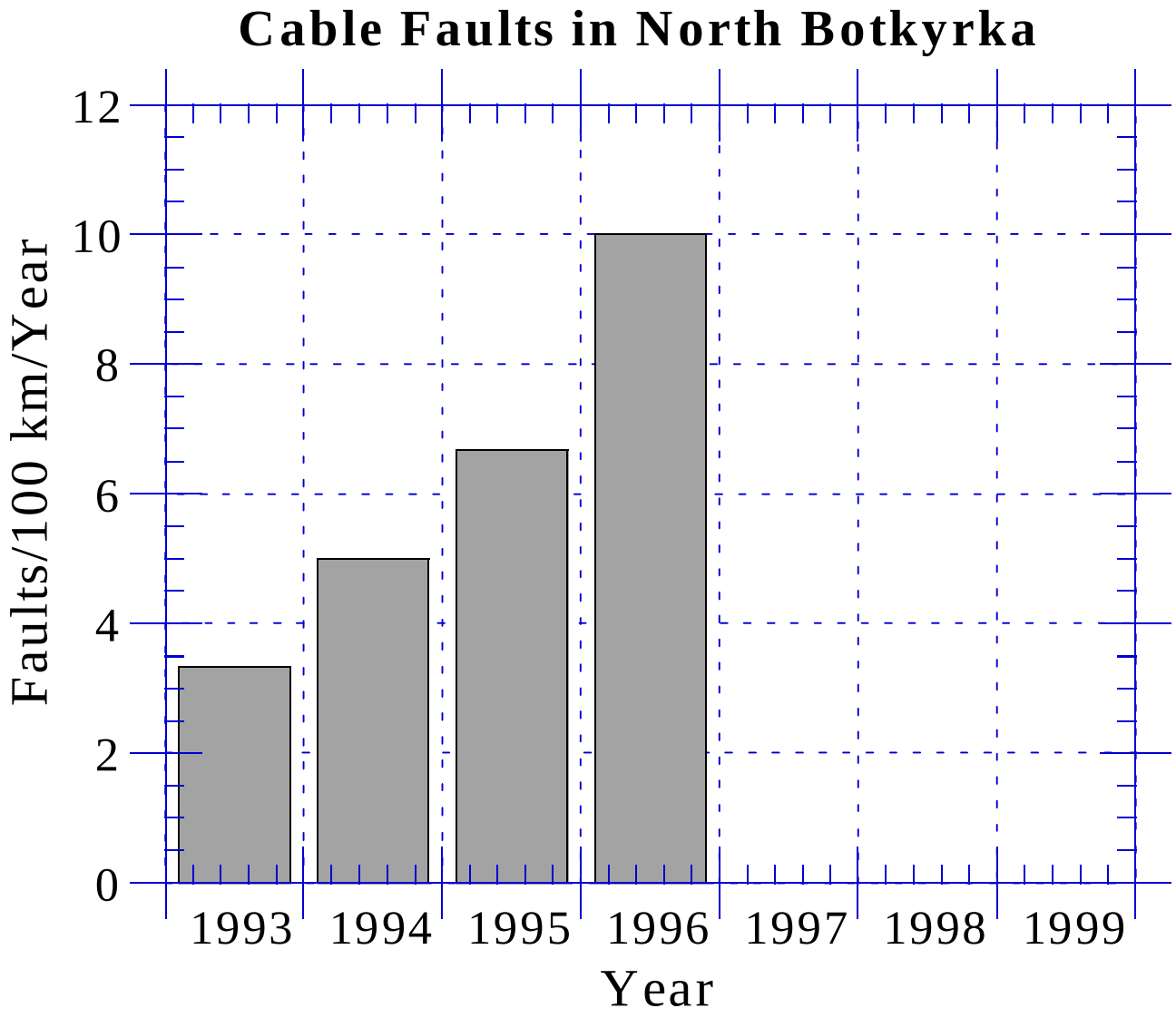


The loss curves have -1 slope in the log-log diagram

Medium Voltage XLPE Cables

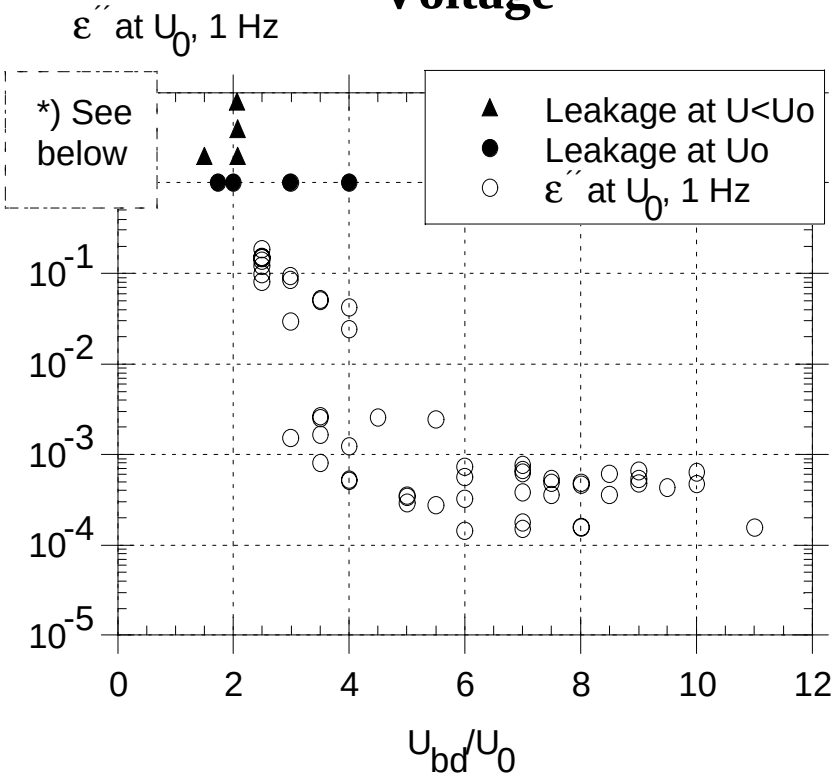
- **Relatively low voltage levels are used in order to ensure non-destructive measurements.**
- **By non-destructive measurements cable replacement can be scheduled and delayed.**
- **The response of water trees are identified and classified into three different groups**
- **By recognise the response of water trees, influence of accessories can be separated**

IDA200 and an external high voltage unit

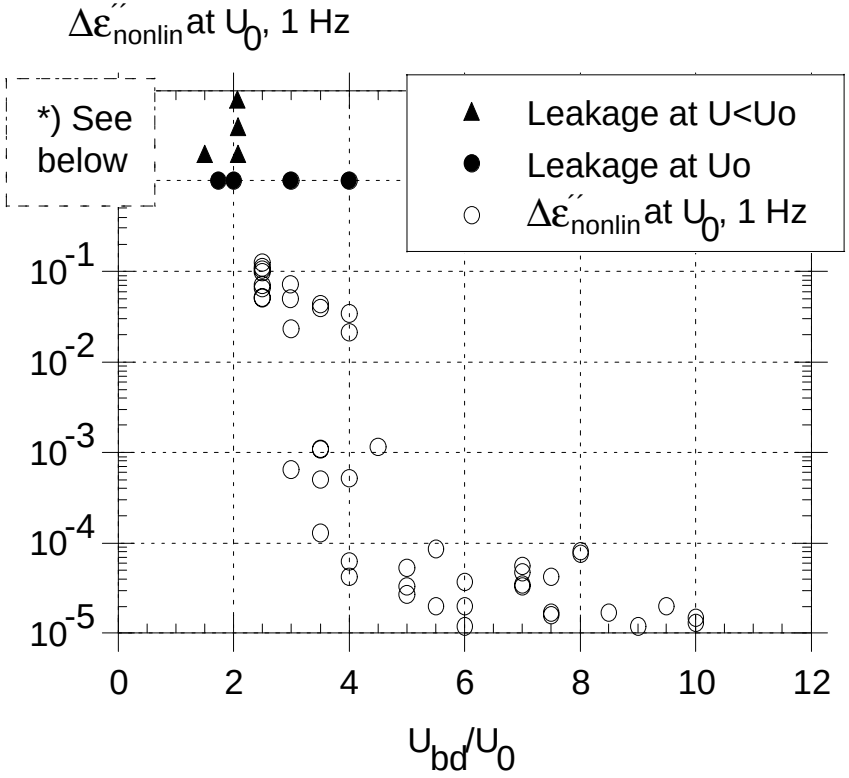

Cable Faults in North Botkyrka
Faults/100 km/Year
0
2
4
6
8
10
12
1993
1994
1995
1996
1997
1998
1999
Year

Measured Response versus ACBD Level

Loss versus Breakdown Voltage



Voltage Dependence in Loss versus Breakdown Voltage



***) Cable samples with leakage currents are placed in the upper part of the graph without any loss value associated**