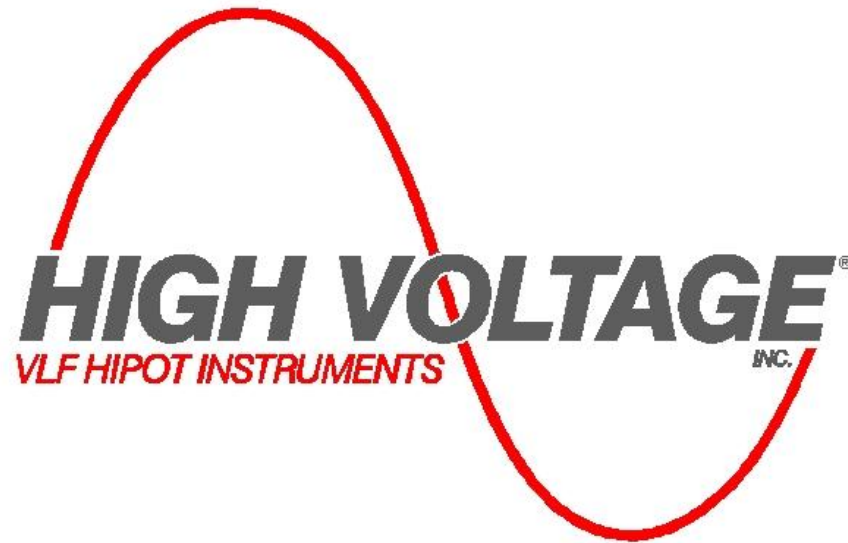


**Monitored VLF Withstand Tests  
Using  
Tan Delta and Partial Discharge  
At  
HV & EHV Voltages**





VLF HV OUTPUT

L FILTER

L FILTER

C SHUNT



VLF TANK

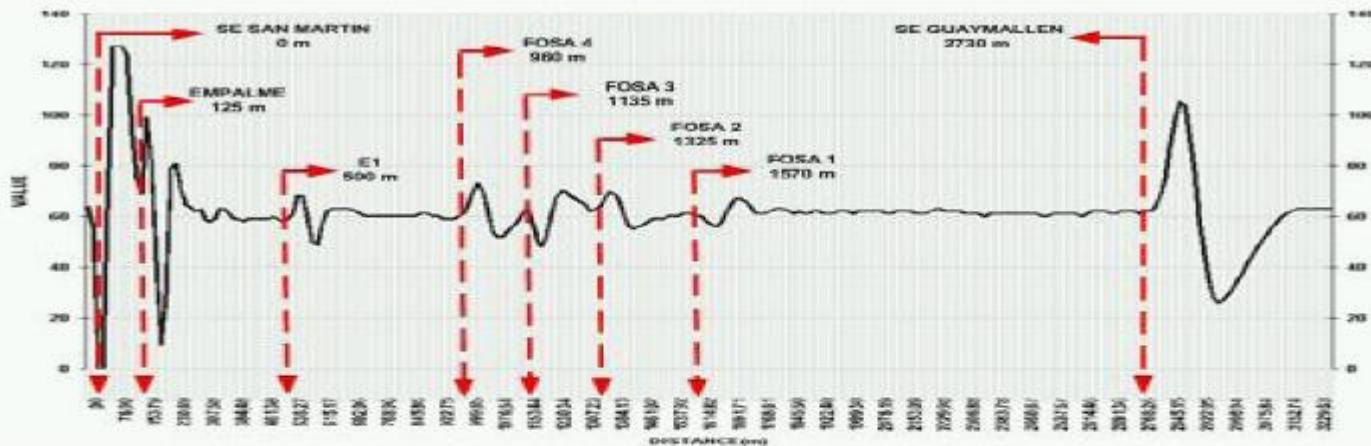
C FILTER

COUPLING CAPACITOR

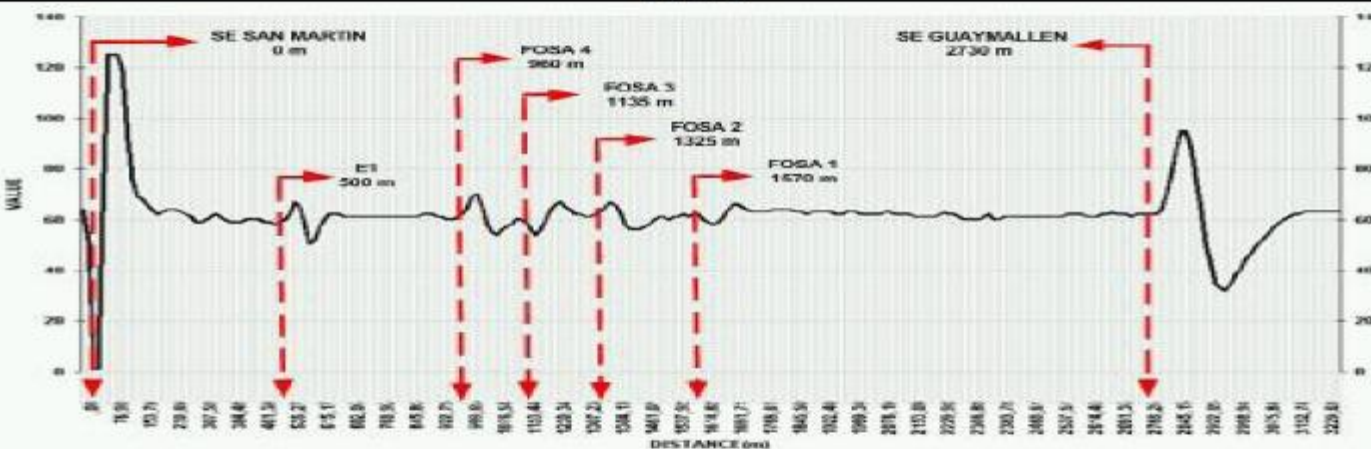
# Tests

- Differential Conductor Reflectometry
- VLF Tan Delta
- VLF Withstand
- VLF Partial Discharge
- Measurements on ground system
- X-ray Analysis at conflictive points
- Infrared Thermography
- PD Acoustic Method external terminal
- PD Ultrasonic with Magnetic Sensors

### FASE R



### FASE S



### FASE T



Rango: 4 km, Ganancia: 54 db, Tensión: 5v, Ancho de pulso: 500 ns, Vp/2: 80 m/μs.

# What to test with 200 kV peak?

## Tan Delta & Partial Discharge Test

$U_{RMS}$ (kV)	$U_{O RMS}$ (kV)	$U_{O PEAK}$ (kV)	$\frac{1}{2} \cdot U_{O PEAK}$ (kV)	$1 \cdot U_{O PEAK}$ (kV)	$1.5 \cdot U_{O PEAK}$ (kV)	Max. k factor tested with 200 kV peak
69	40	56.5	28.2	56.5	84.7	3.5
110	64	90.5	45.2	90.5	135.7	2.2
132	76	107.5	53.7	107.5	161.22	1.8
150	87	123	61.5	123	184.5	1.6
220	127	179.6	89.8	179.6	269.4	1.1
275	160	226.3	113.1	226.3	339.4	0.8
330	190	268.7	134.3	268.7	403.0	0.7
380	220	311.1	155.5	311.1	466.6	0.6
500	290	410.1	205.0	410.1	615.1	0.4

# Case Study on 132 kV, XLPE Insulated Cable

**Withstand  
Test**

$U_{O\text{ RMS}}$ (kV)	$U_{O\text{ PEAK}}$ (kV)	$\frac{1}{2} \cdot U_{O\text{ PEAK}}$ (kV)	$1 \cdot U_{O\text{ PEAK}}$ (kV)	$1.5 \cdot U_{O\text{ PEAK}}$ (kV)	Max. k factor tested with 200 kV peak
76	107	53	107	161	1.86



Conductor Cross-Section		Capacitance	Max. Distance in (km) Tested with VLF-200CMF		
$mm^2$	Kcmil	$\mu F/km$	@0.1 Hz	@0.05 Hz	@0.01 Hz
630	1250	0.18	4.1	8.3	20.8
1000	2000	0.27	2.7	5.5	13.8
2000	4000	0.39	1.9	3.8	9.6

# Case Study on 220 kV, XLPE Insulated Cable

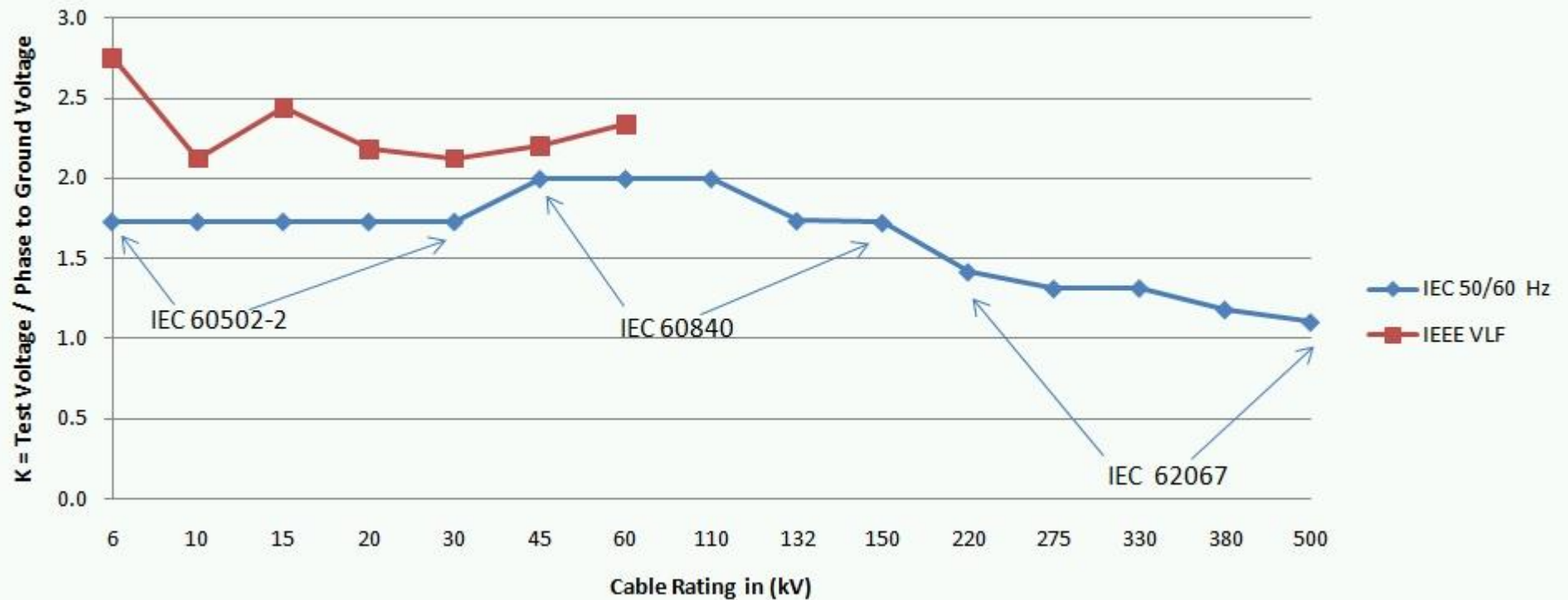
Withstand  
Test ?

$U_{O\text{ RMS}}$ (kV)	$U_{O\text{ PEAK}}$ (kV)	$\frac{1}{2} \cdot U_{O\text{ PEAK}}$ (kV)	$1 \cdot U_{O\text{ PEAK}}$ (kV)	$1.5 \cdot U_{O\text{ PEAK}}$ (kV)	Max. k factor tested with 200 kV peak
127	179.6	89.8	179.6	269.4	1.1

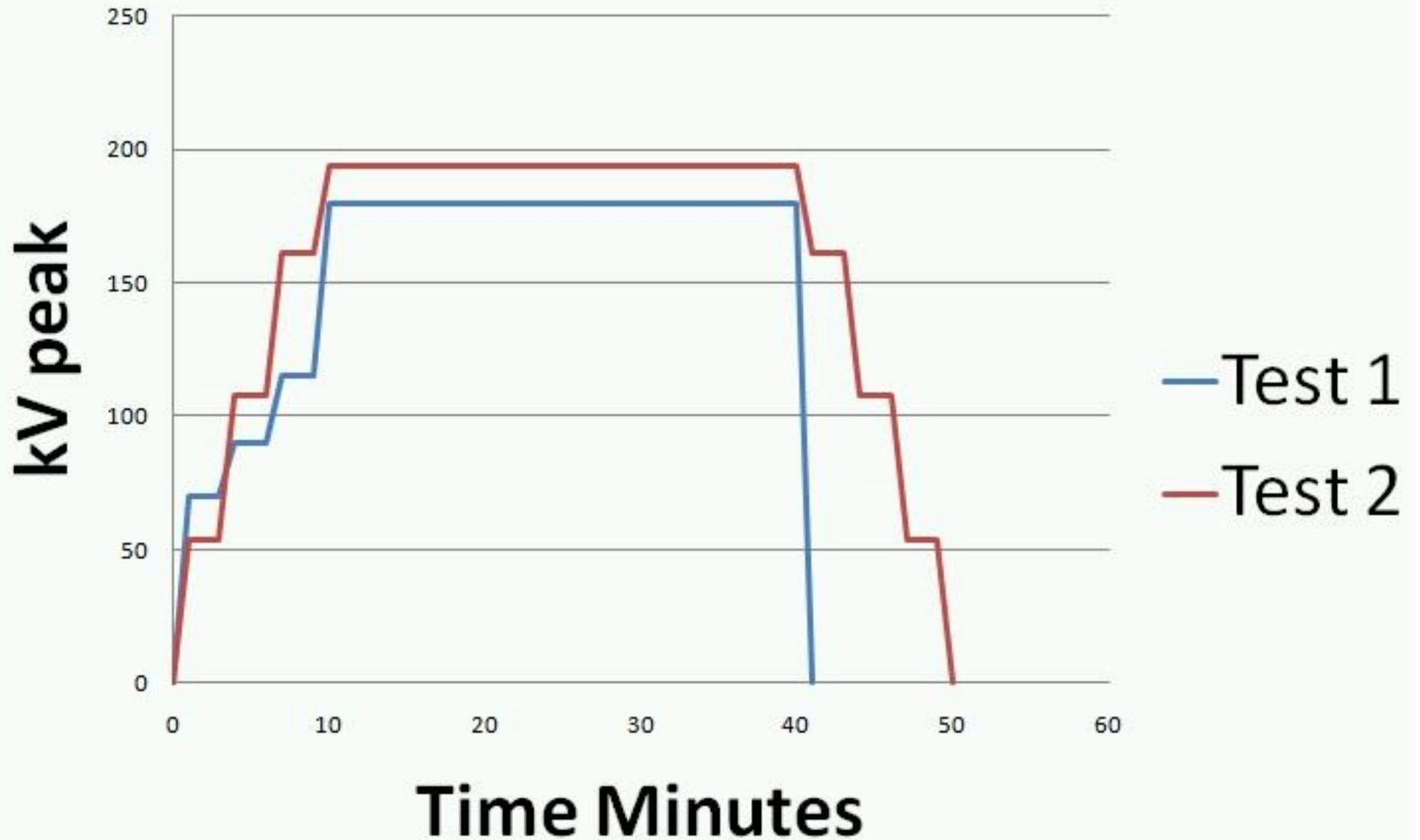


Conductor Cross-Section		Capacitance	Max. Distance in (km) Tested with VLF-200CMF		
$mm^2$	Kcmil	$\mu F/km$	@0.1 Hz	@0.05 Hz	@0.01 Hz
630	1250	0.15	5	10	25
1000	2000	0.19	3.9	7.8	19.7
2000	4000	0.27	2.7	5.5	13.8

## After Installation Test Voltages: 50/60 Hz Vs. 0.1 Hz

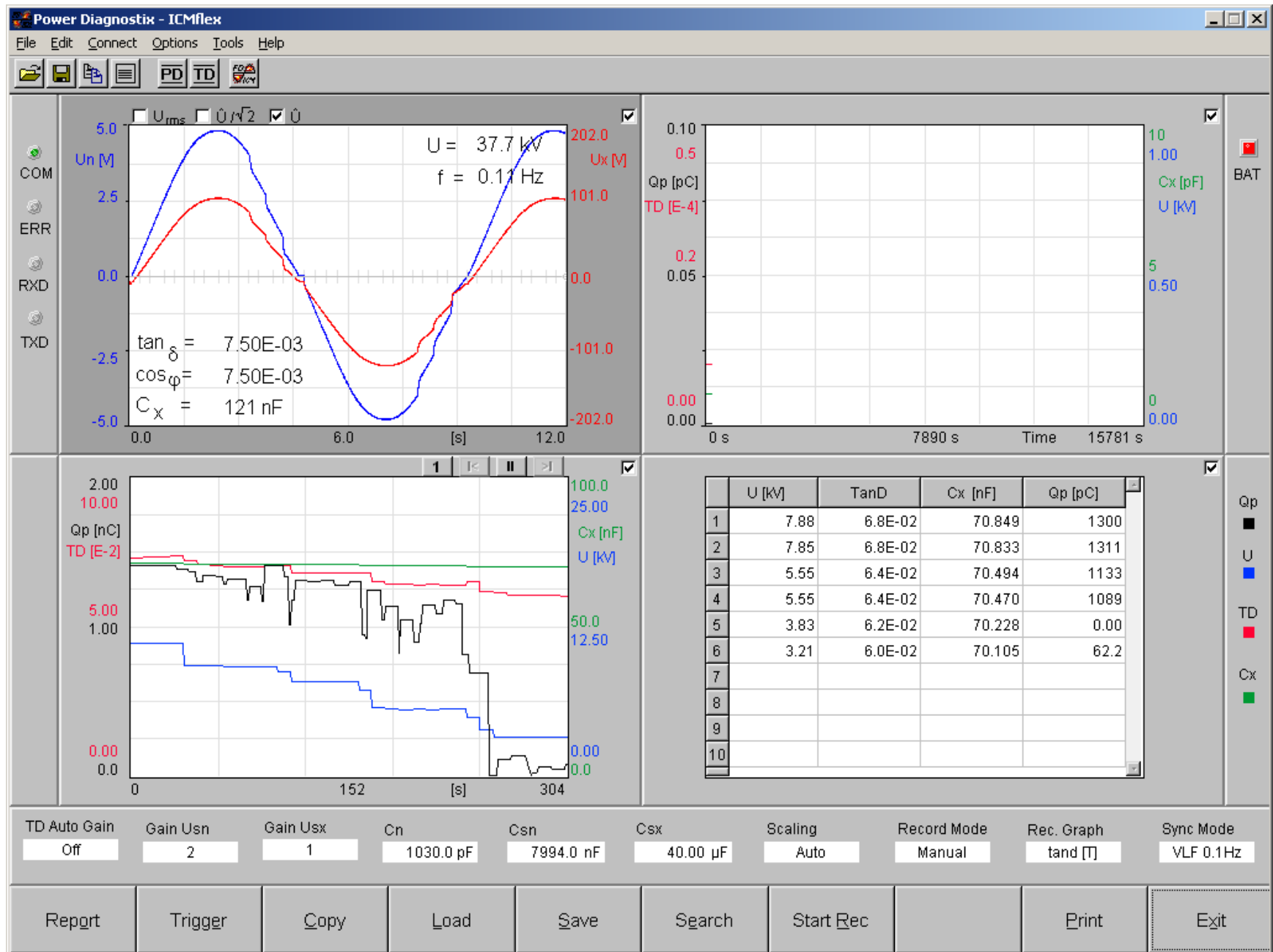


# 132 kV Test Plans





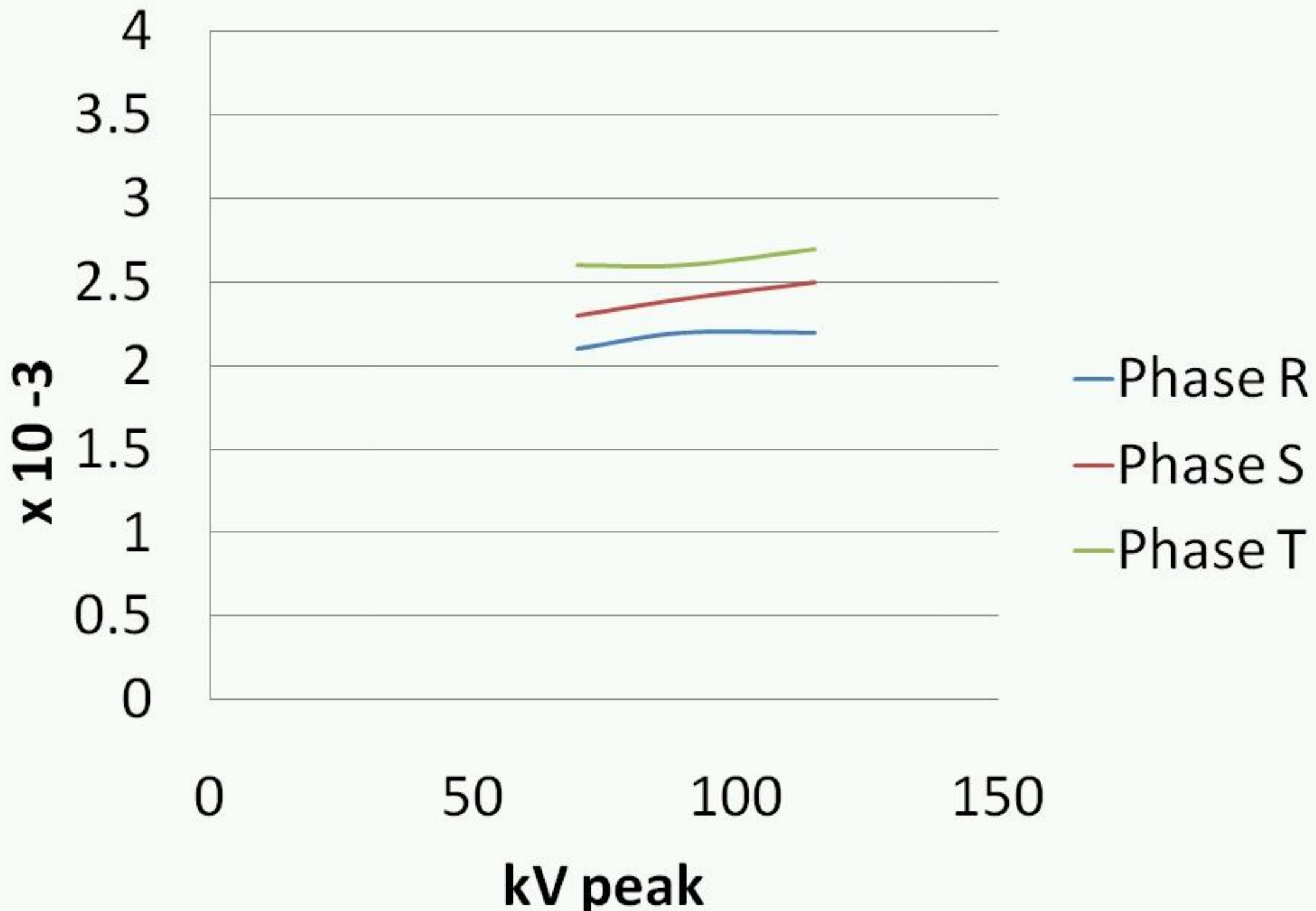
# TD Screen



# Tan Delta Test

		Tan Delta x 10 <sup>-3</sup>		
kVpeak	Hz	Phase R	Phase S	Phase T
70	0.05	2.1	2.3	2.6
90	0.05	2.2	2.4	2.6
115	0.05	2.2	2.5	2.7

# Tan Delta



# TD Interpretation

TD Stability

TD vs Voltage

Absolute Value of TD

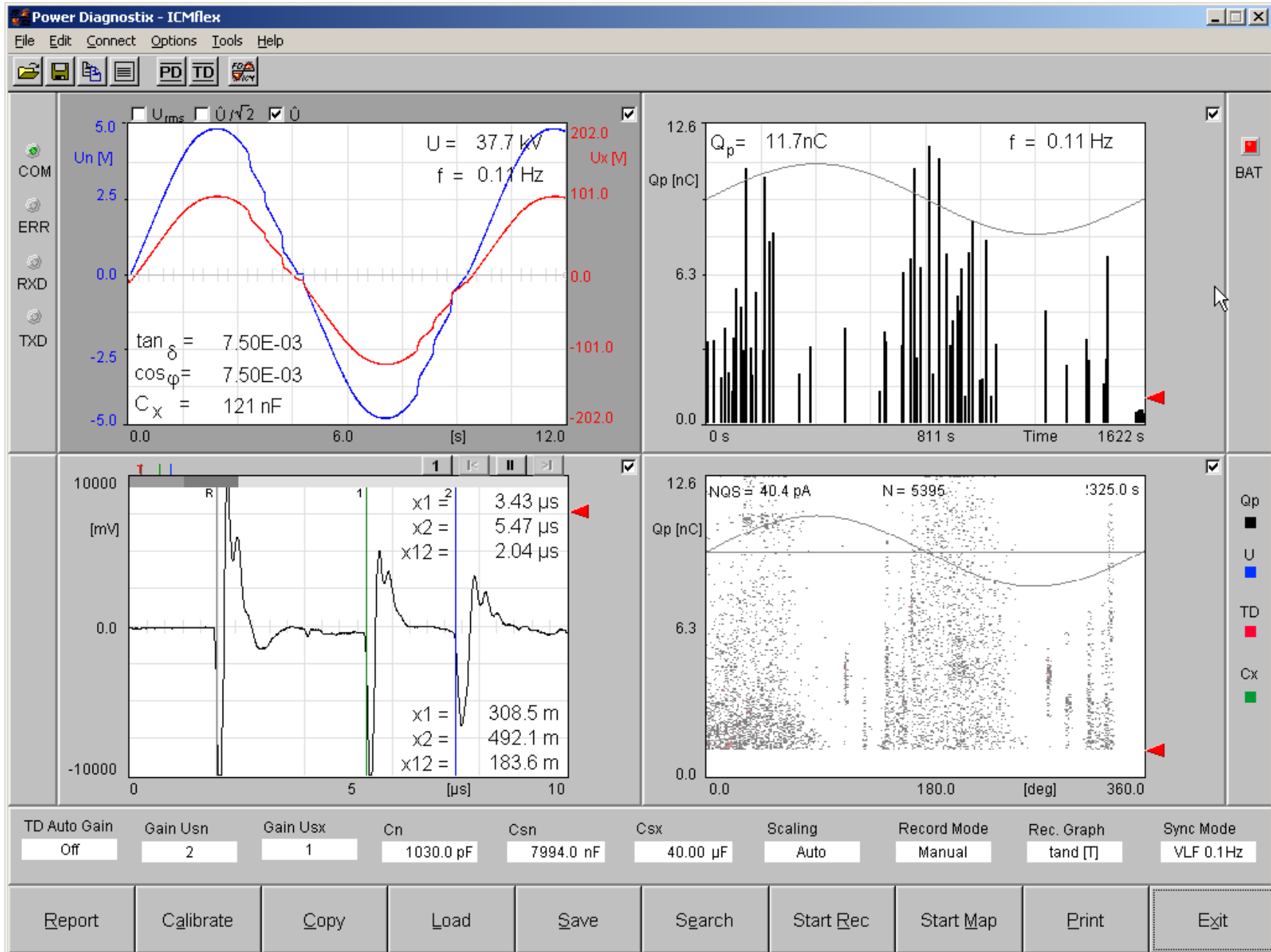
History



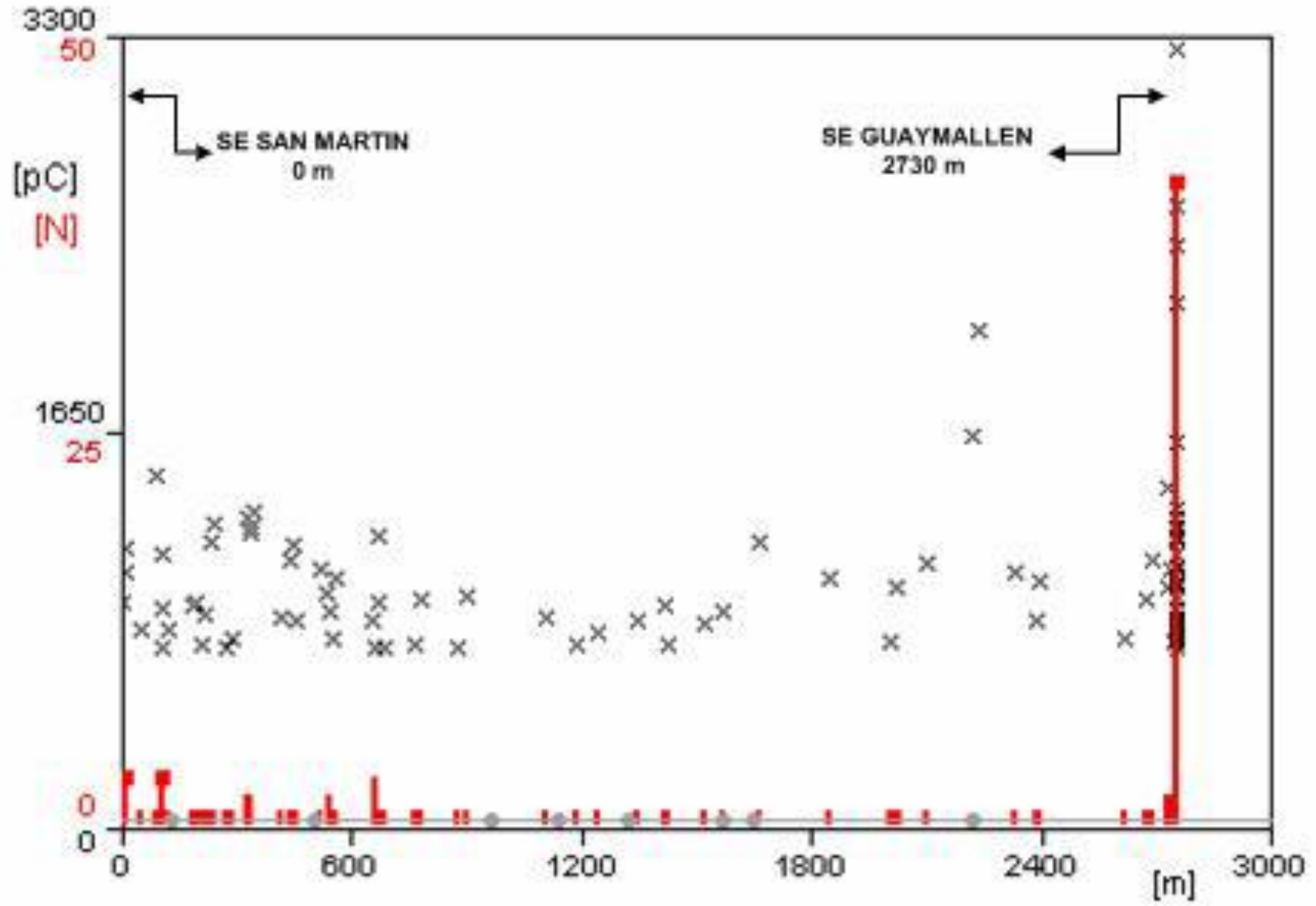
# PD Setup and Calibration

- Cable Map?
- TDR
  - Length
  - Splices
  - Propagation velocity
- Calibration
  - Inject 0.5, 1, or 2 nC signal
  - Verify TDR info

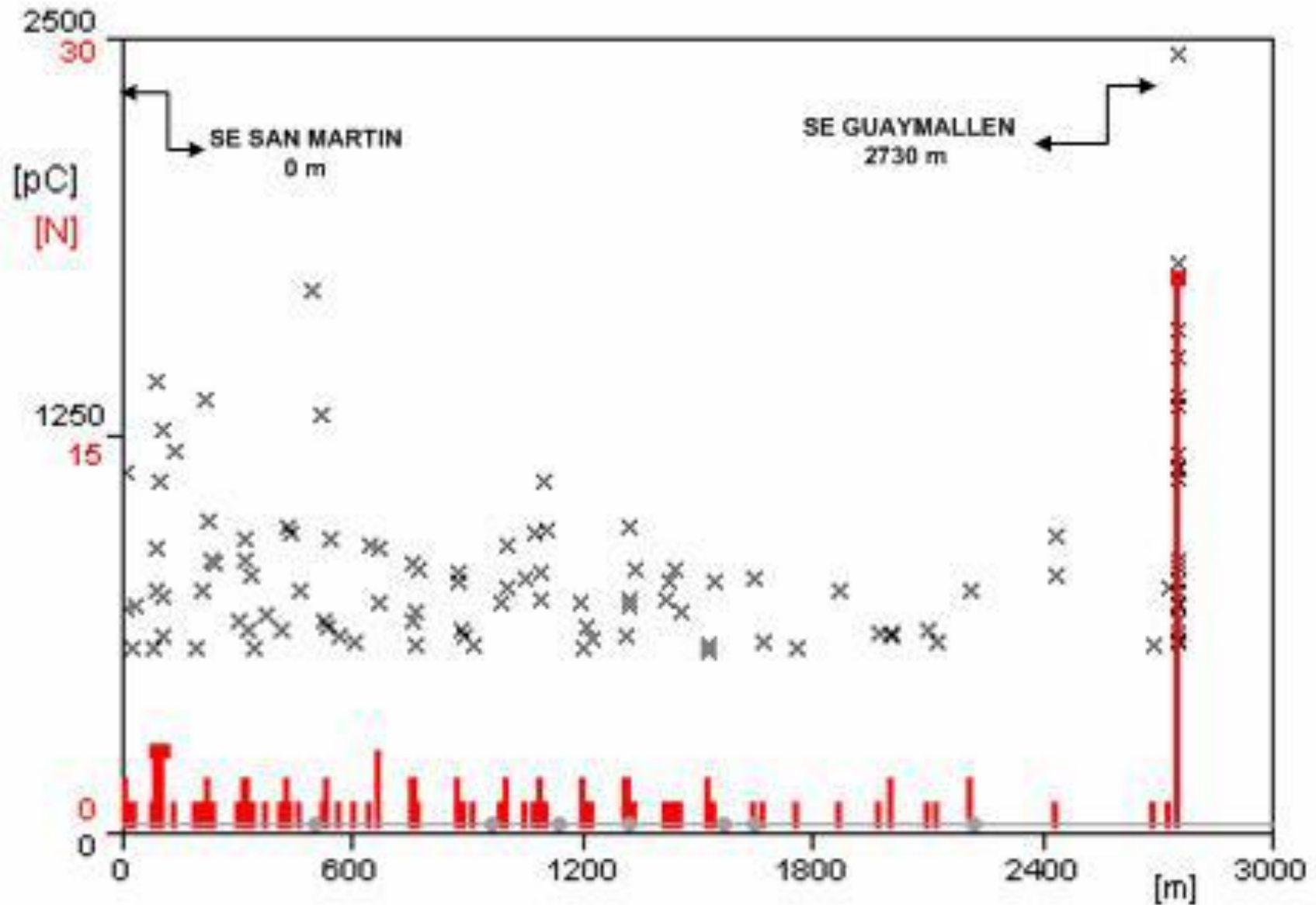
# PD Screen



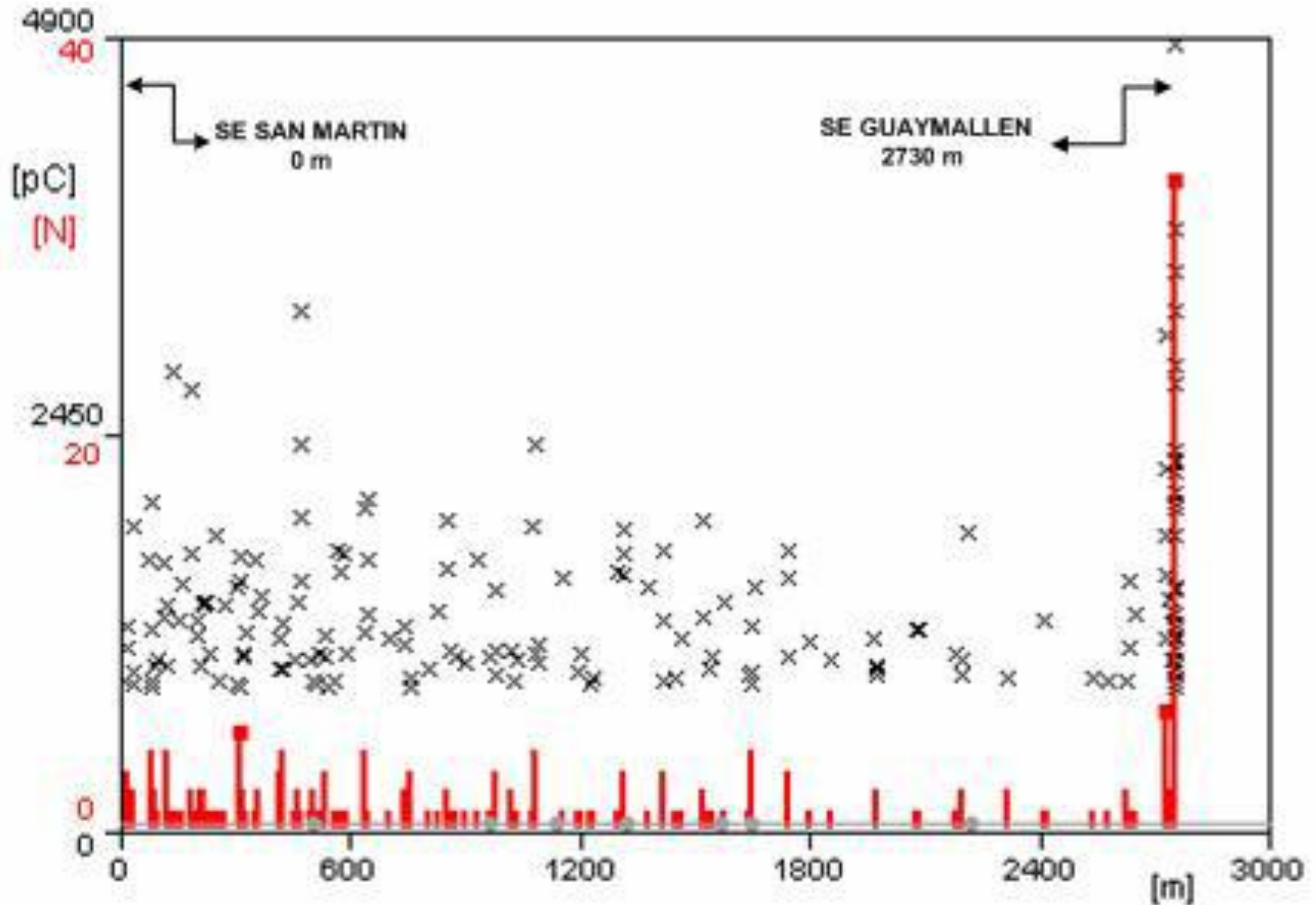
# Phase R PD Map



# Phase S PD Map



# Phase T PD Map



# PD Interpretation

- Voltage
- PD Level
- Frequency
- Location
- Discharge Pattern (phase resolved)
- Phase to phase
- Year to year

VLF  
TD & PD  
Just another Meter