

Reinhold Environmental Ltd.



2009 APC Round Table & Expo Presentation

July 12-14, 2009, in The Woodlands, TX

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High frequency power supplies

2009 APC Round Table Conference, Houston

Per Ranstad, Anders Karlsson

Environmental R&D

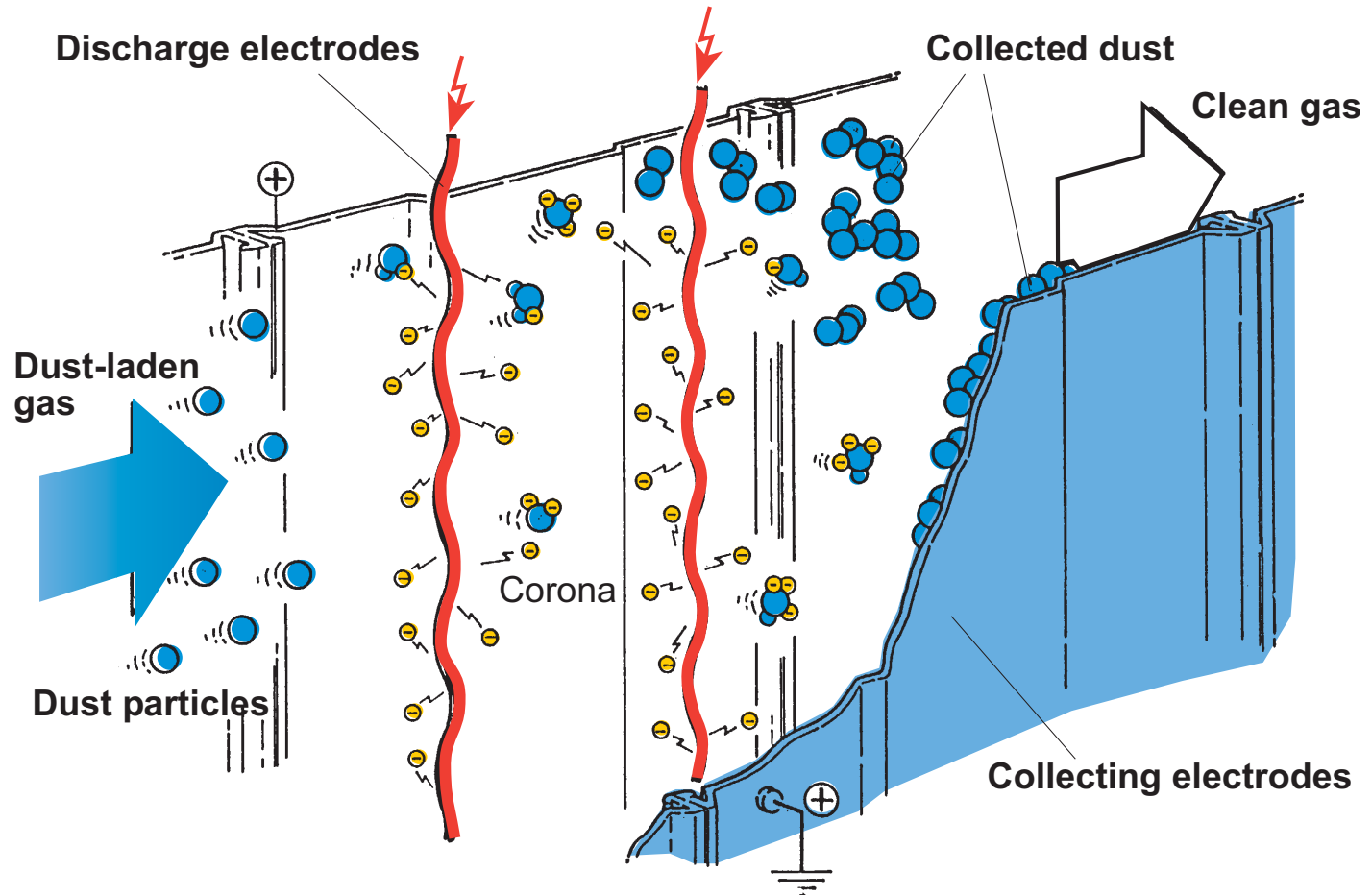
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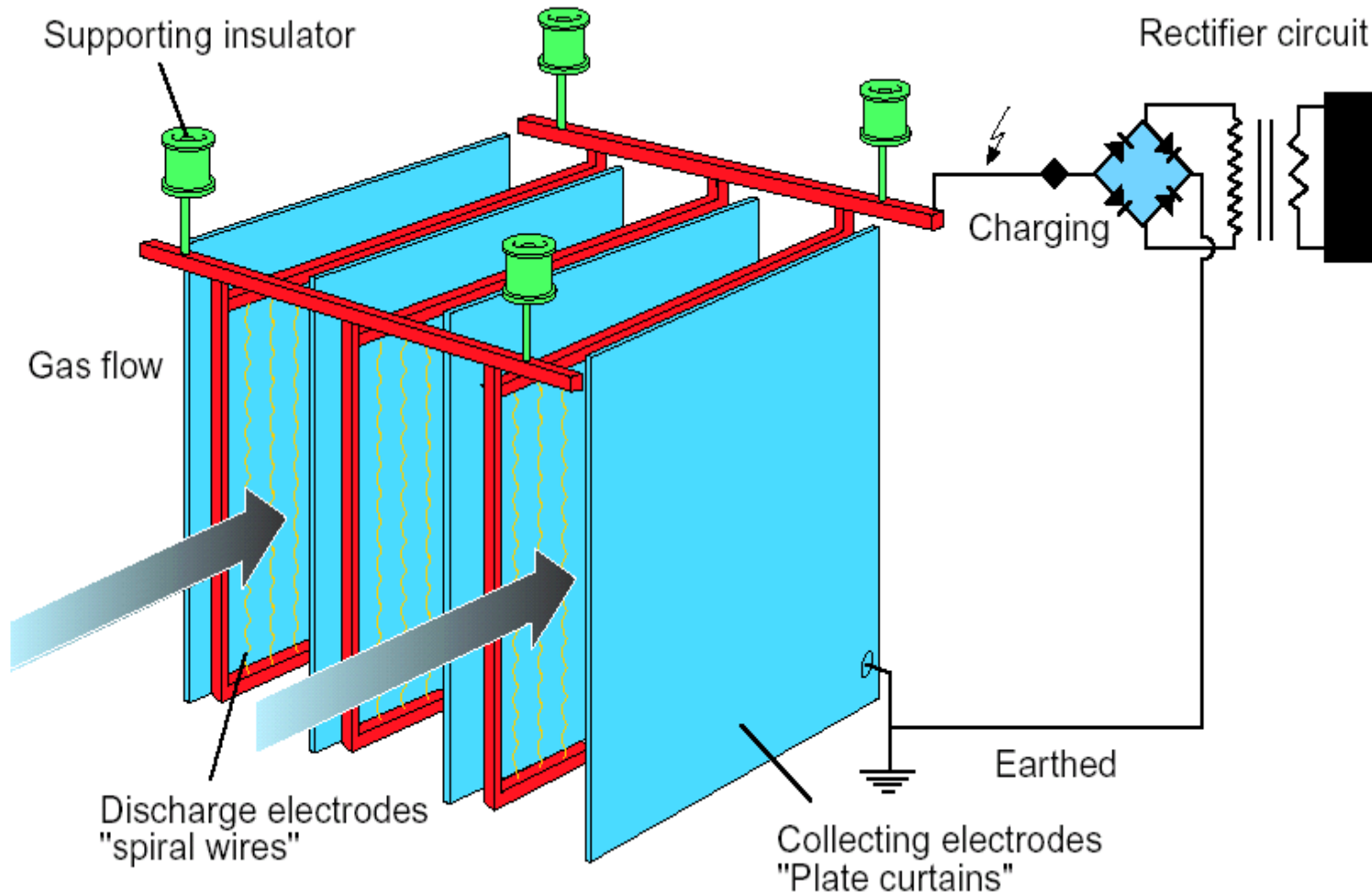
ALSTOM

- Introduction 10min
- ESP Voltage 15min
- ESP current 15min
- Line distortion 10min
- Discussion 10min

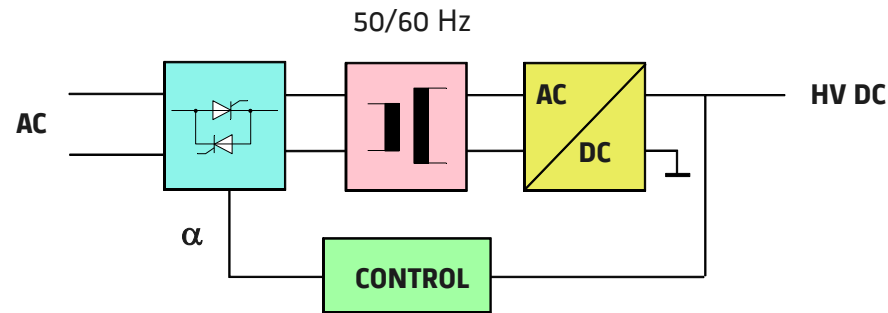
- Introduction
- ESP voltage
- ESP current
- Line distortion
- Discussion

Dust collection principle

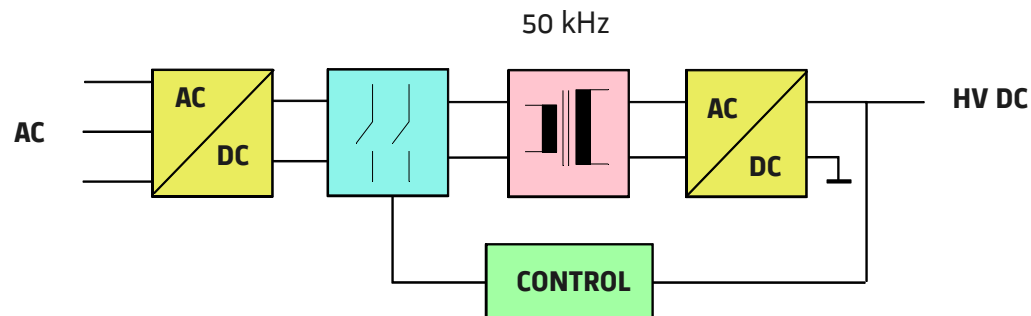




- Mains Frequency Power Supply

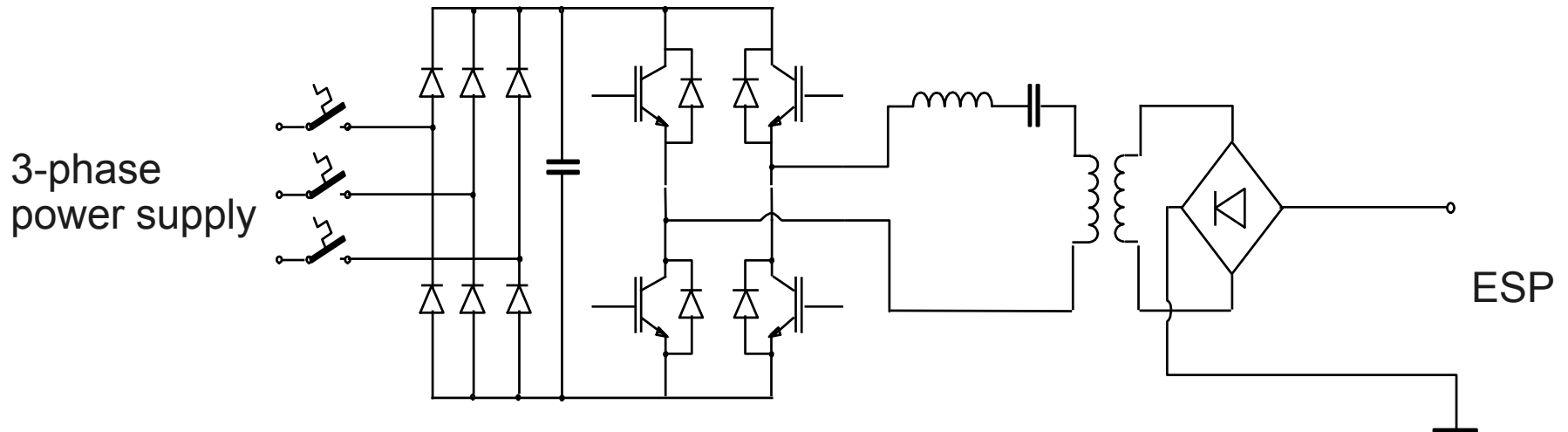


- High Frequency Power Supply



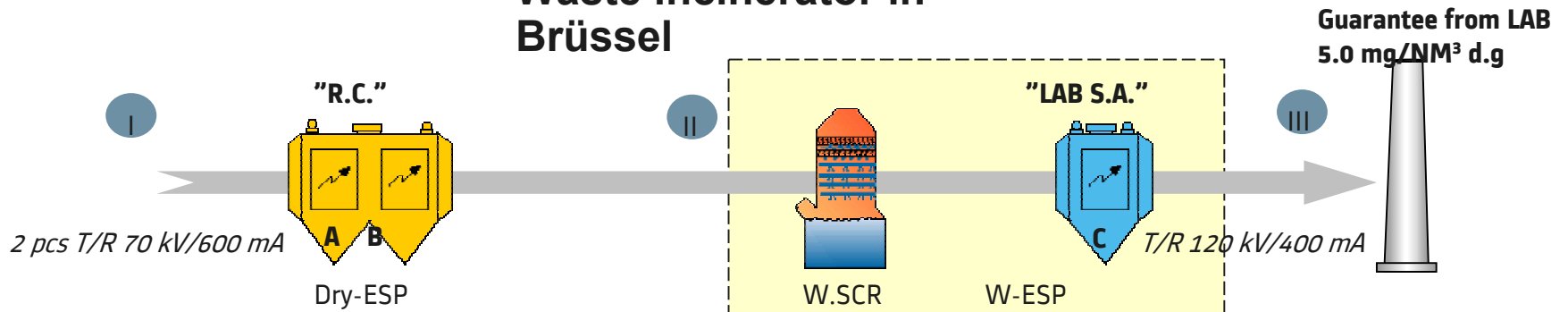
Comment: In the HFPS technology, the mains is rectified and then chopped to a higher frequency
This high frequency AC is then rectified to give a smooth output voltage to be supplied to the ESP

Typical circuit diagram



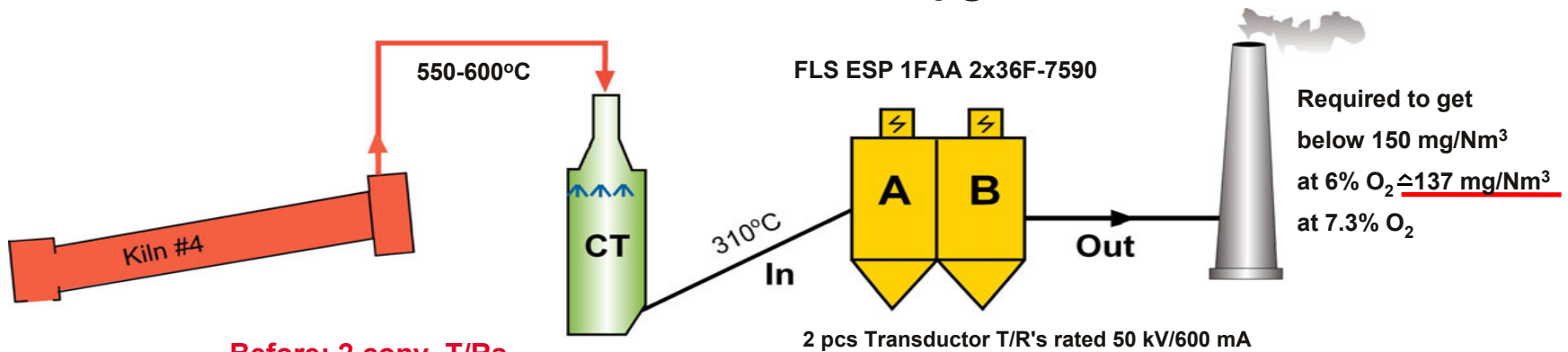
SIOMAB #3 - upgrade with SIR

Waste incinerator in Brüssel



	Dust I	T/R readings	Dust II	T/R readings	Dust III
"Base Line" 3 conv. T/R's	2.5g/Nm ³	A:40kV/220mA B:38kV/300 mA P _{Tot} =23kW	60-70 mg/Nm ³	C: 60kV/60mA P _{T/R} =4kW	13-15 mg/Nm ³ d.g
SIR 80/250 in C only	---"	---"	---"	75kV/80mA P _{SIR} =7kW	7-10 mg/Nm ³ d.g
SIR 70/800 in A&B also	2.85g/Nm ³	A:41kV/500mA B:38kV/750 mA P _{Tot} =49kW	30-35 mg/Nm ³	80kV/120mA P _{SIR} =11kW	2-4 mg/Nm³ d.g

Dumont Wautier - Belgium Limekiln #4, SIR upgrade



Before: 2 conv. T/Rs

	Dust - In	T/R - readings	Dust - Out
Lime	~ 50 g/Nm ³	A: 36 kV/400 mA B: 27 kV/500 mA P T/R = 32 kW	250-300 mg/Nm ³ at 7.3% O ₂

After: 2 SIRs 70 kV/800 mA in A&B, no mech. upgrade

Lime	~ 50 g/Nm ³	A: 47 kV/800 mA B: 37 kV/800 mA P SIR = 67 kW	~125 mg/Nm ³ at 7.3% O ₂
Dolomite:	x ~ 50 g/Nm ³	A: 47 kV/800 mA B: 37 kV/800 mA P SIR = 67 kW	~75 mg/Nm ³ at 7.3% O ₂

Goal achieved!



ESP: R.C., 2 chamber with 4 fields + MIGIs

Fuel: Import Coal + SO₃ - injection

Before upgrade

- Discharge electrode: weighted wire
- T/R: 4 pcs conv. 70 kV/1250mA
- Dust em: 150 – 200 mg/Nm³ at **100 kW**

After upgrade

- Discharge electrode: ribbon
- 8 pcs SIRE 70kV/800mA
- Dust em: 20 – 25 mg/Nm³ at **220 kW**

Alt. Investment
MEUR or
for 20 mg/Nm³:
!!!

Ext. with 1 field for **1.9 MEUR** + 5w downtime à 1.0

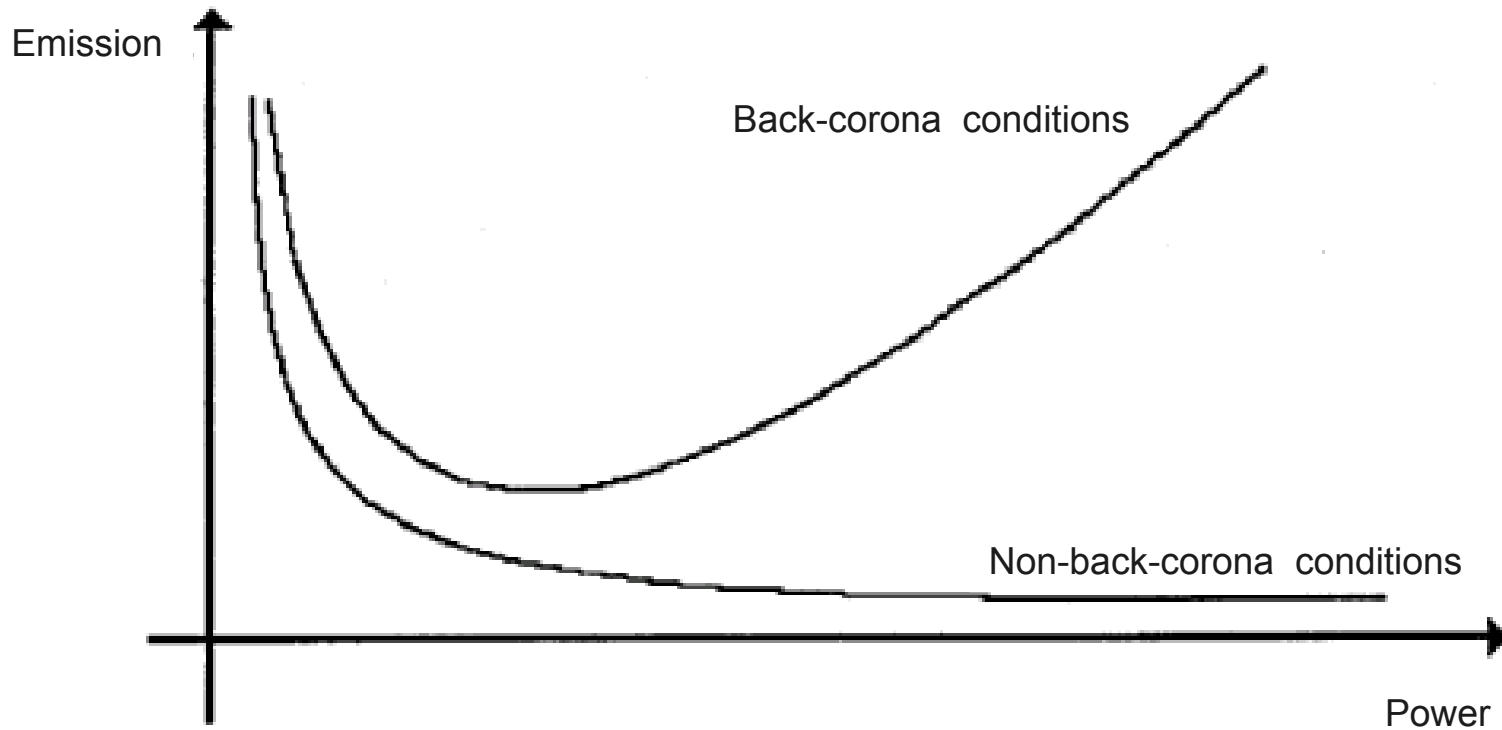
Inst. of 8 SIRs for **0.35 MEUR** + 1w downtime à 0.2 MEUR

Based on more than 1700 installed High frequency power supplies

- Higher current density
 - Higher corona current
 - Improved charging of dust particles
 - Higher holding forces
 - Less reentrainment
- Increased voltage
 - Higher E-field
 - Improved particle drift (migration velocity)

Comment: The HFPS technology gives both a higher average voltage and a higher current.

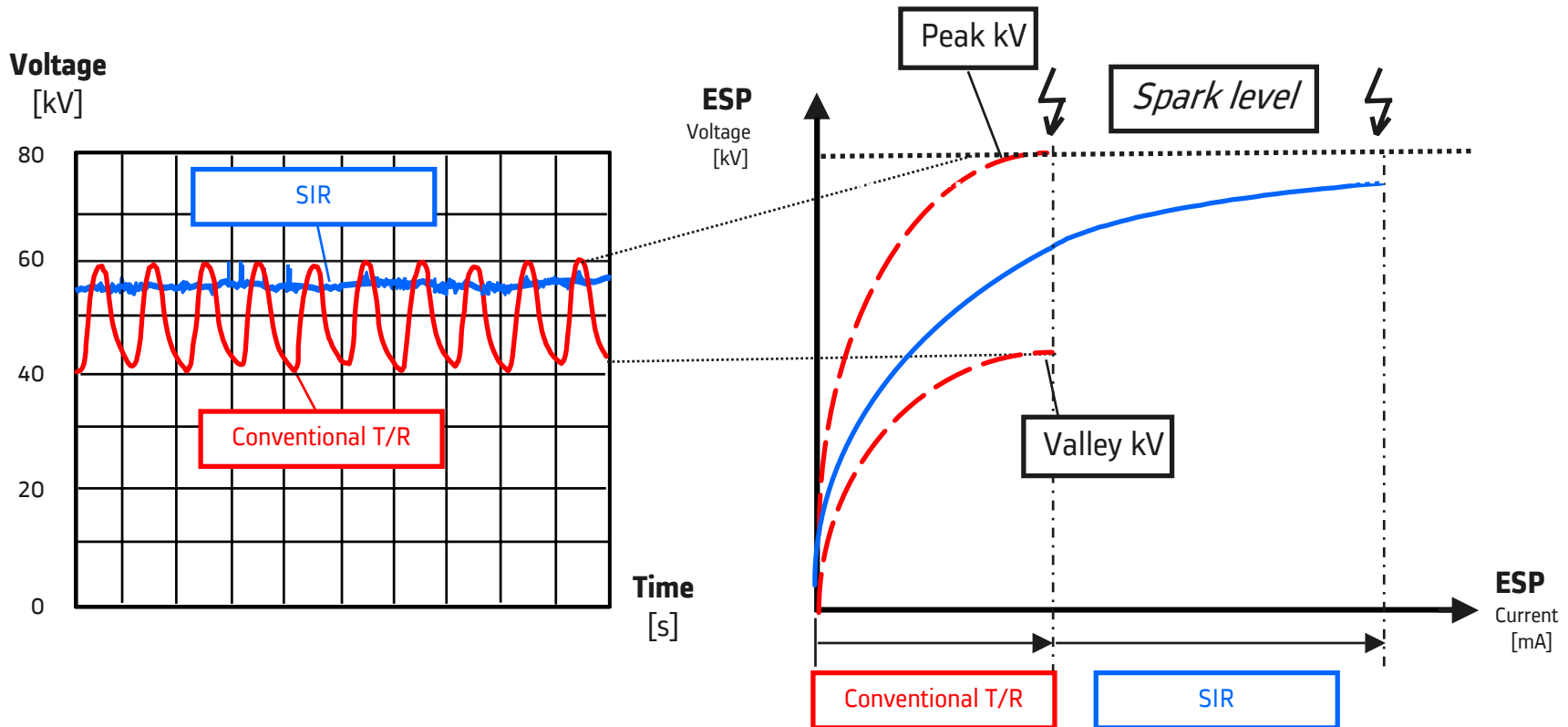
Dust emission vs Power input



- Introduction
- ESP voltage
- ESP current
- Line distortion
- Discussion

HFPS vs. Conventional T/R

Electrical Performance – Output Voltage



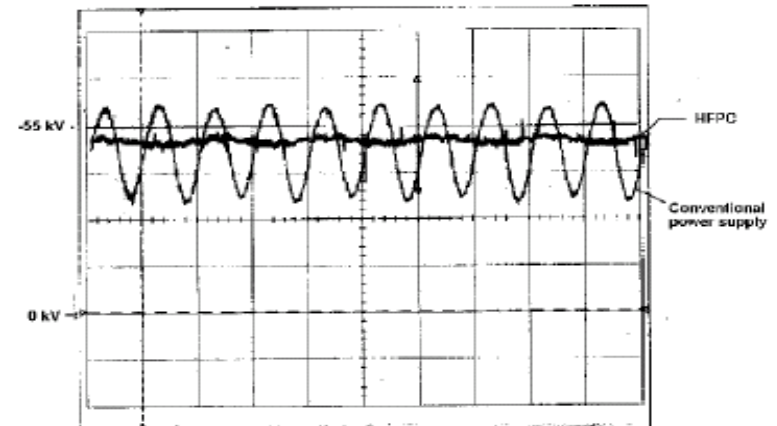
Comment: The HFPS technology gives a higher average voltage compared to a conventional T/R (for the same current)

ESP voltage, HFPS vs conventional

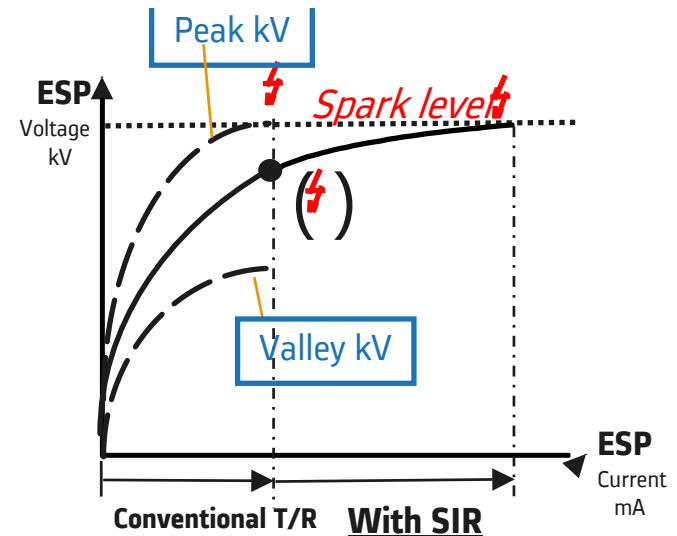
Due to the non-linear current voltage dependency,

$$I = I_0 (U - U_{\text{onset}})^n, U > U_0, n > 1 \quad (2)$$

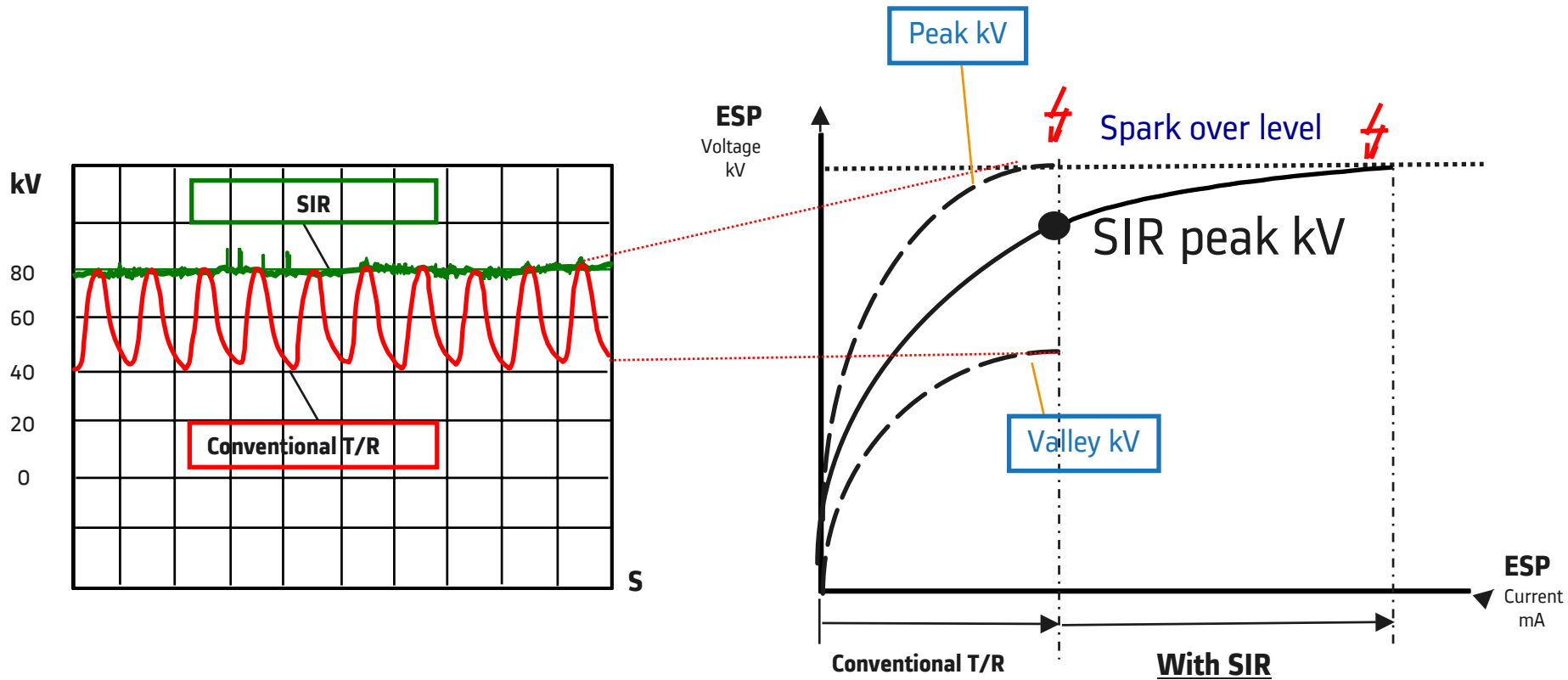
will the high frequency power supply give a higher average voltage compared to the mains frequency power converter for the same current.



Ex: $U_{\text{ONSET}} = 20 \text{ kV}$, $I(60\text{kV}) = 1\text{A}$, $n=2$
 1: $I = 1\text{A}$ (50%), 0.1A (50%)
 $U(1\text{A}) = 60\text{kV}$, $U(0,1\text{A}) = 32.6\text{kV}$
 $\Rightarrow U_{\text{AVG}} = 46.3\text{kV}$, $I_{\text{AVG}} = 0.55\text{A}$
 2: $I = 0.55\text{A}$ (100%),
 $U(0.55\text{A}) = 49.7\text{kV}$
 $\Rightarrow U_{\text{AVG}} = 49.7\text{kV}$, $I_{\text{AVG}} = 0.55\text{A}$



- Introduction
- ESP voltage
- ESP current
- Line distortion
- Discussion

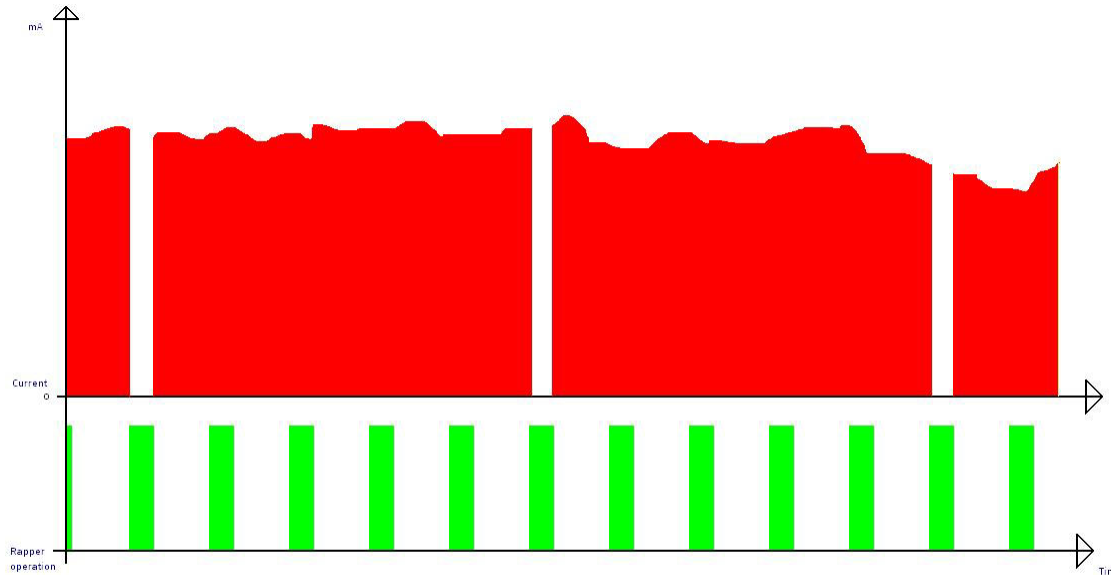


Holding forces, given by E-field and current

- Higher current density
 - Higher holding forces
 - Less reentrainment
 - Rapping
 - Higher acceleration needed
 - Adapt current during rapping
 - Power Controlled Rapping, PCR

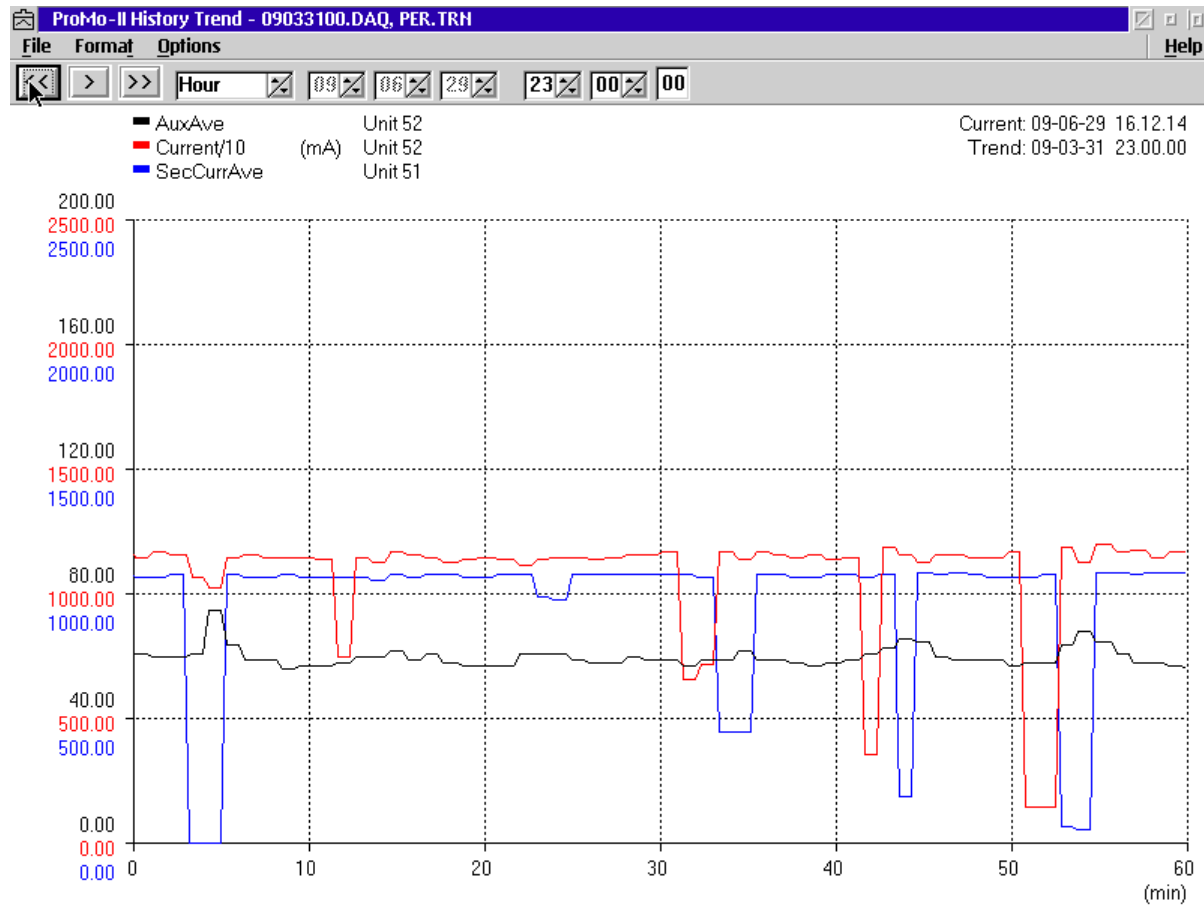
Comment: Separation in time, benefit from high holding forces when collecting dust, adapt the holding forces when rapping (PCR)

Power Control Rapping

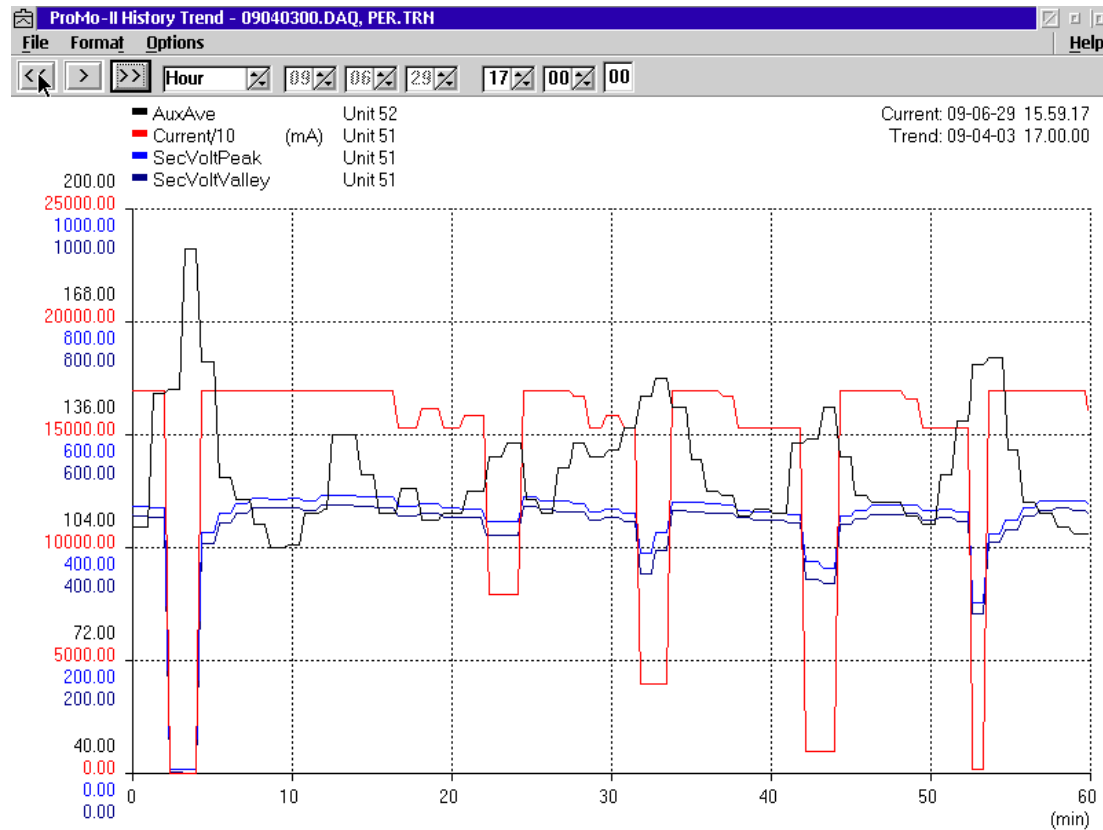


Red is secondary current.
Green is rapper operation.

PCR, sequence



PCR, rapping peaks



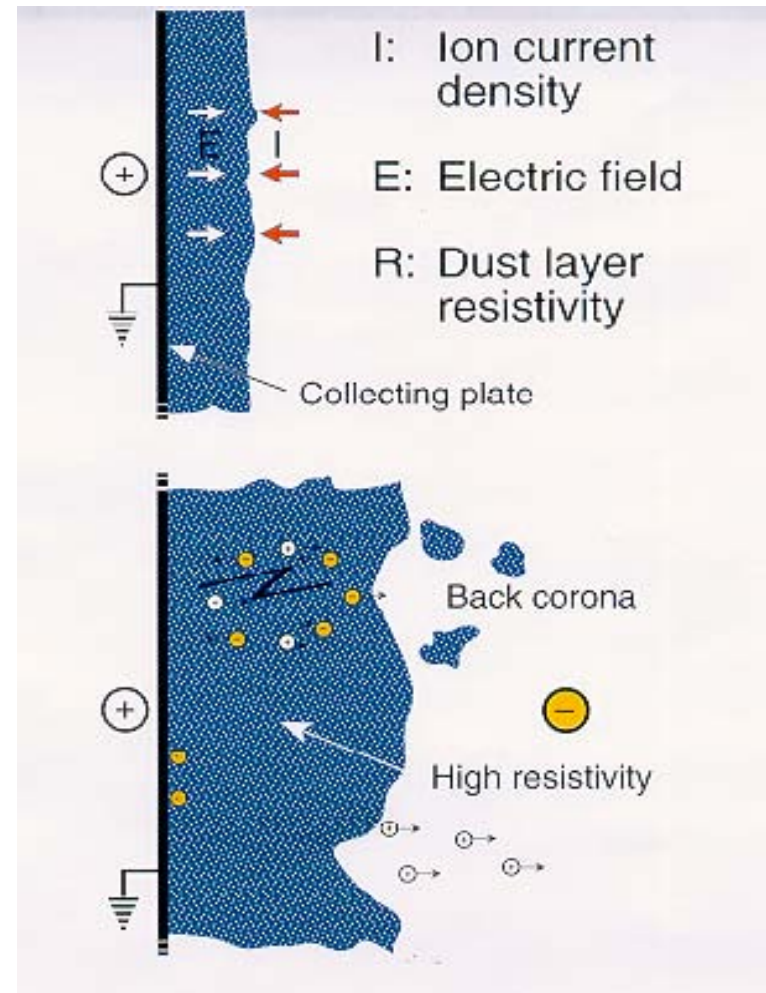
E-field

$$E = R \times i$$

Voltage

d Dust layer thickness

$$U = d \times E$$



Comment: Dust layer voltage is determined by current, dust layer resistivity and dust layer thickness

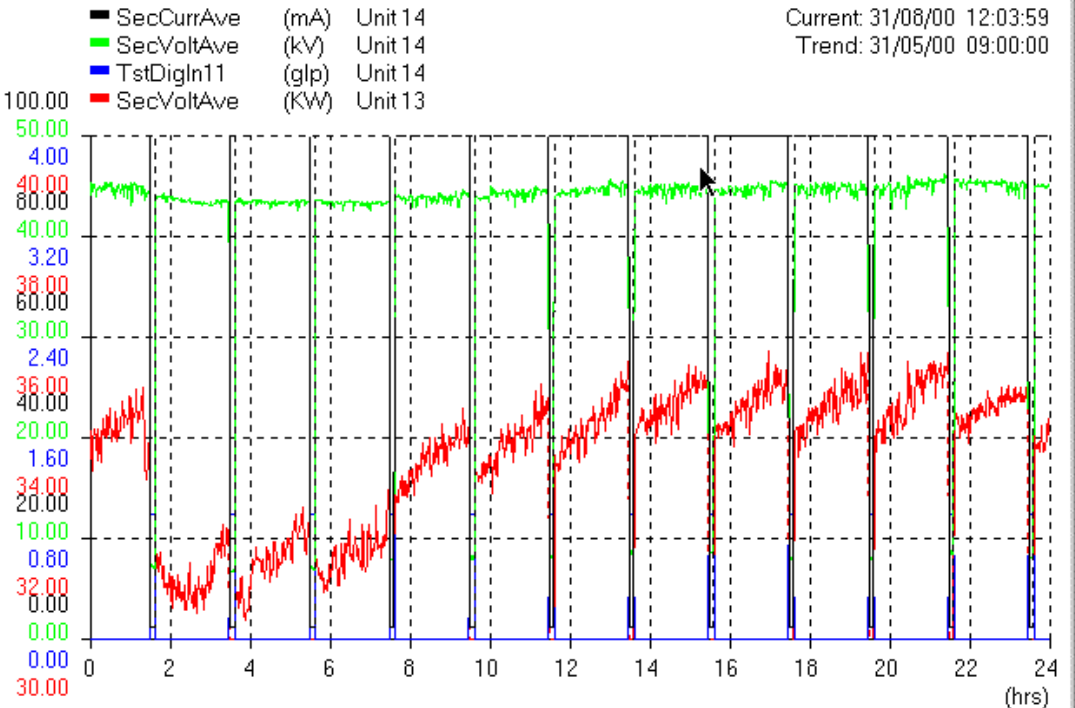
ESP Fundamentals



Impact from dust-layer thickness



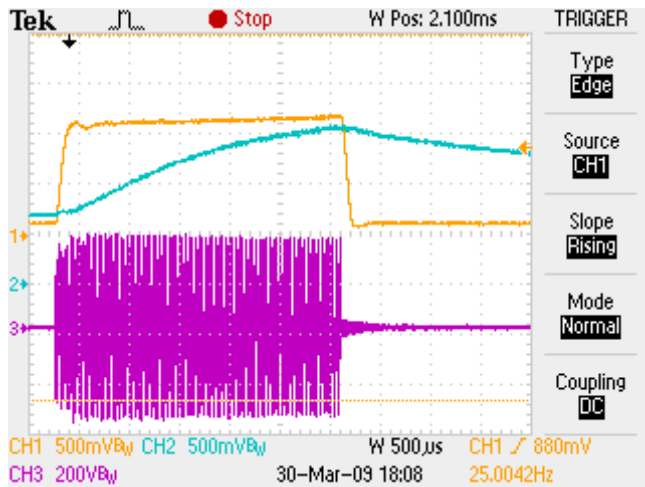
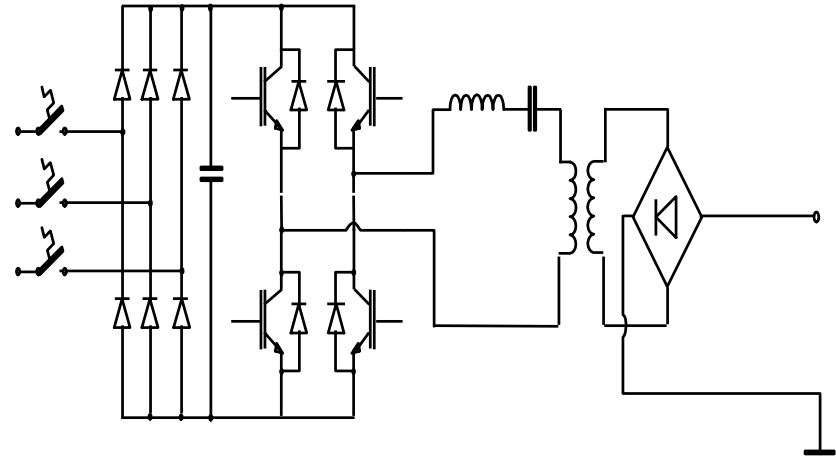
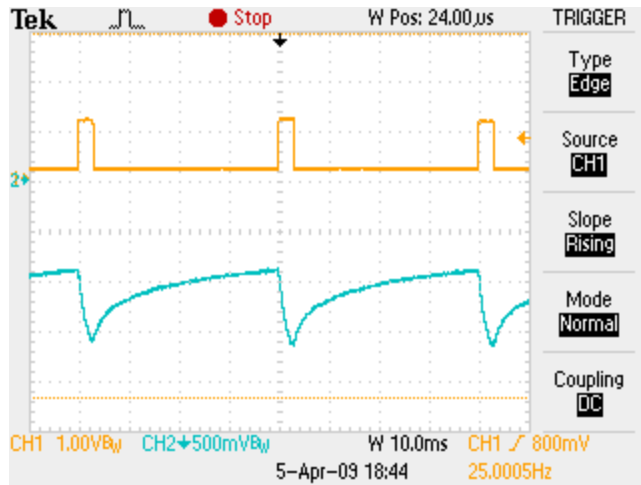
Note the drop in kV after PCR every two hours. This is a second field and this drop is a good Sign of working Power Control Rapping



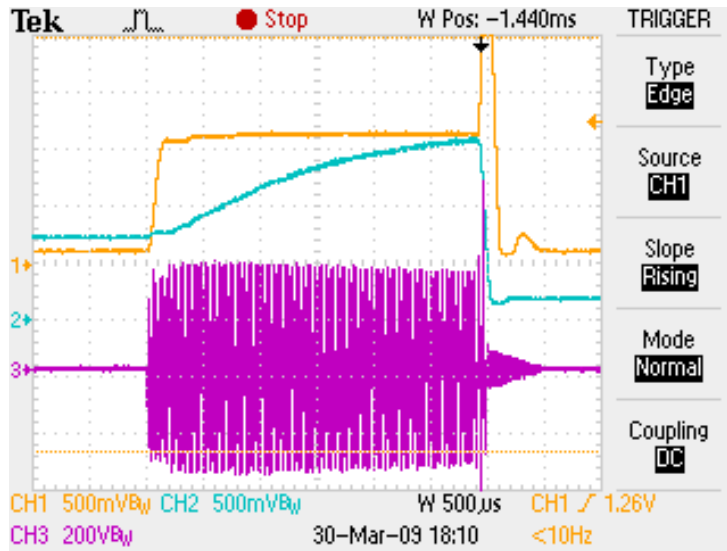
Comment: Note the drop in kV after PCR every second hour.

The ESP voltage is often a valuable indicator of the rapping efficiency

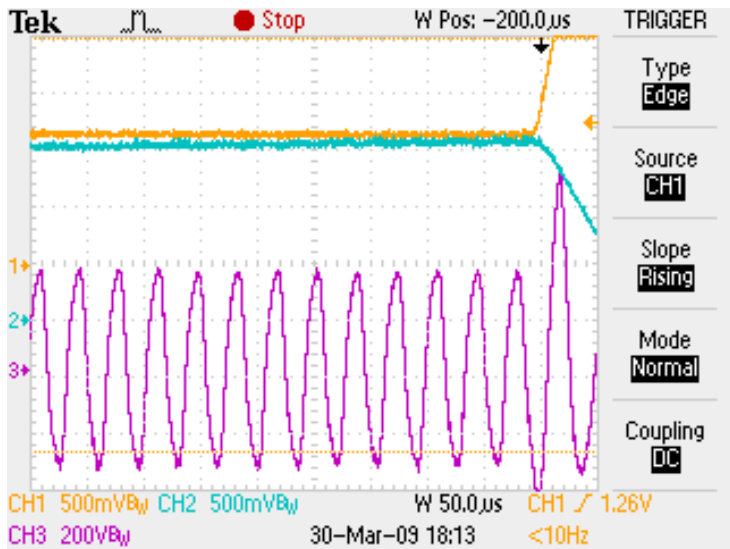
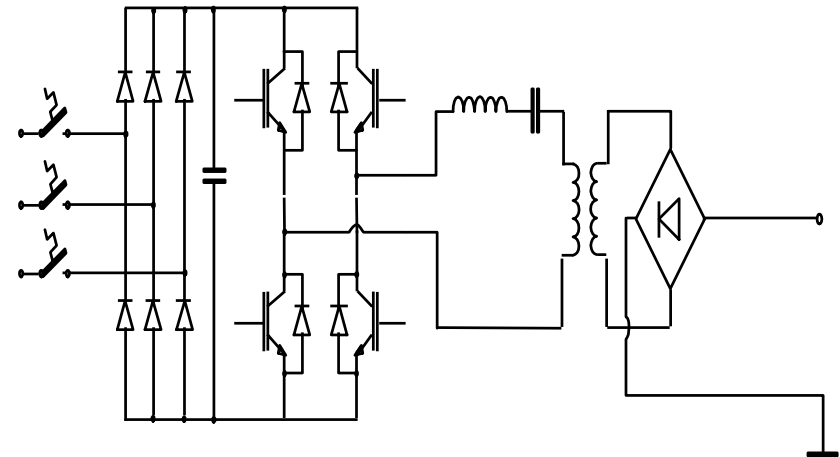
Intermittent energization, pulse mode



Intermittant energization, sparking I

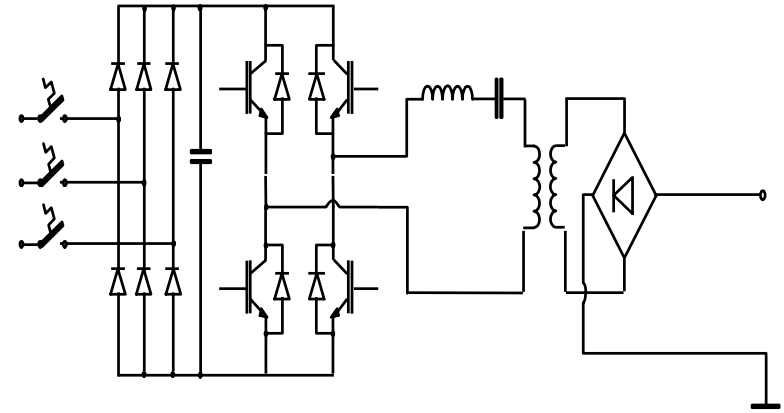
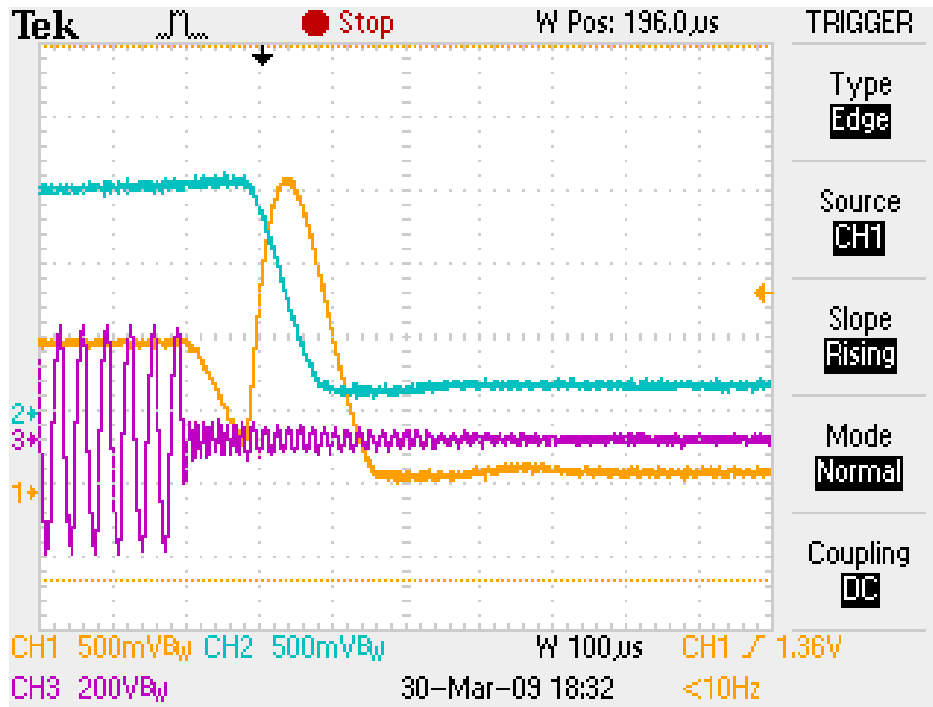


500us/div



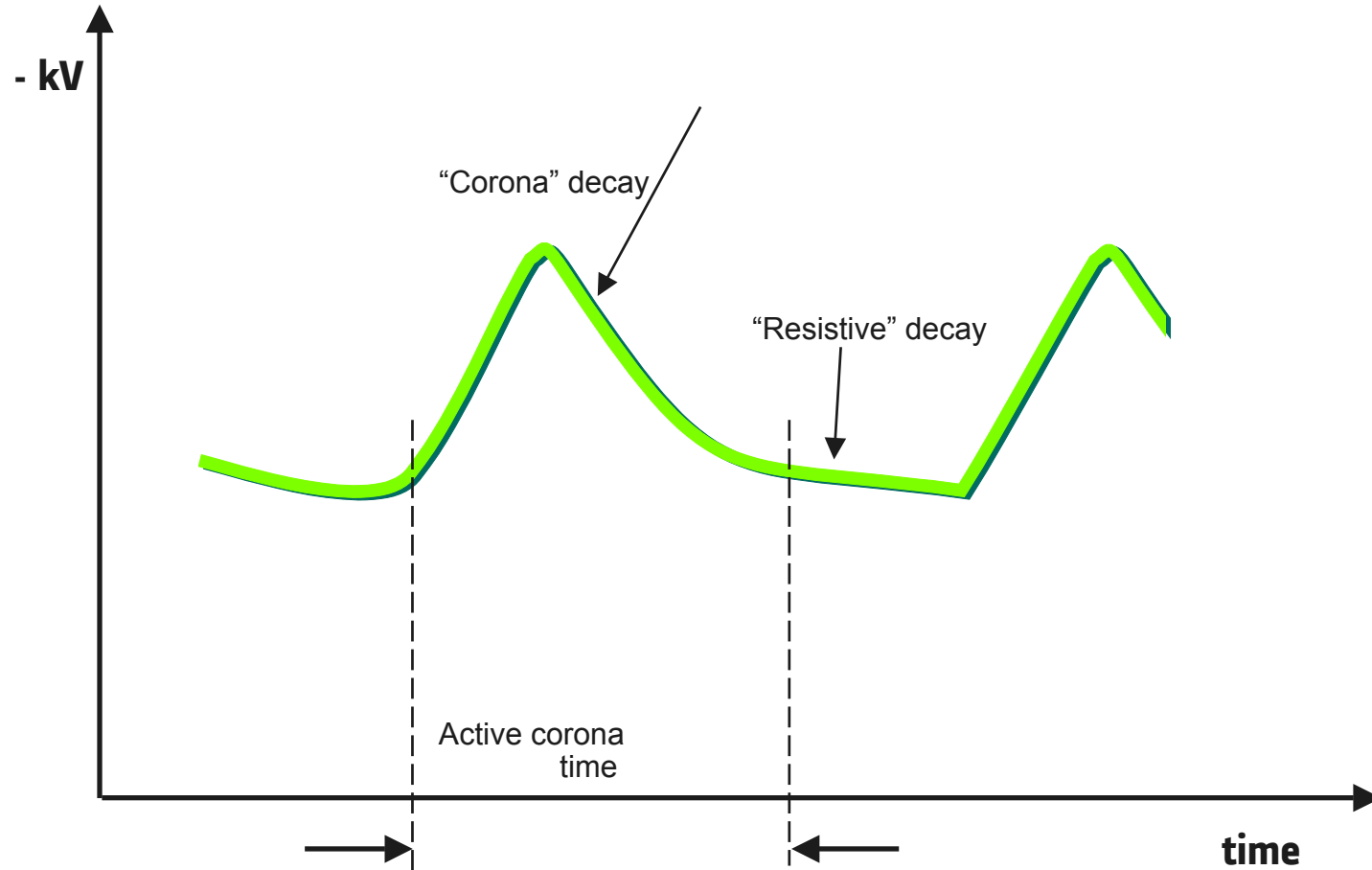
50us/div

Intermittant energization, sparking II

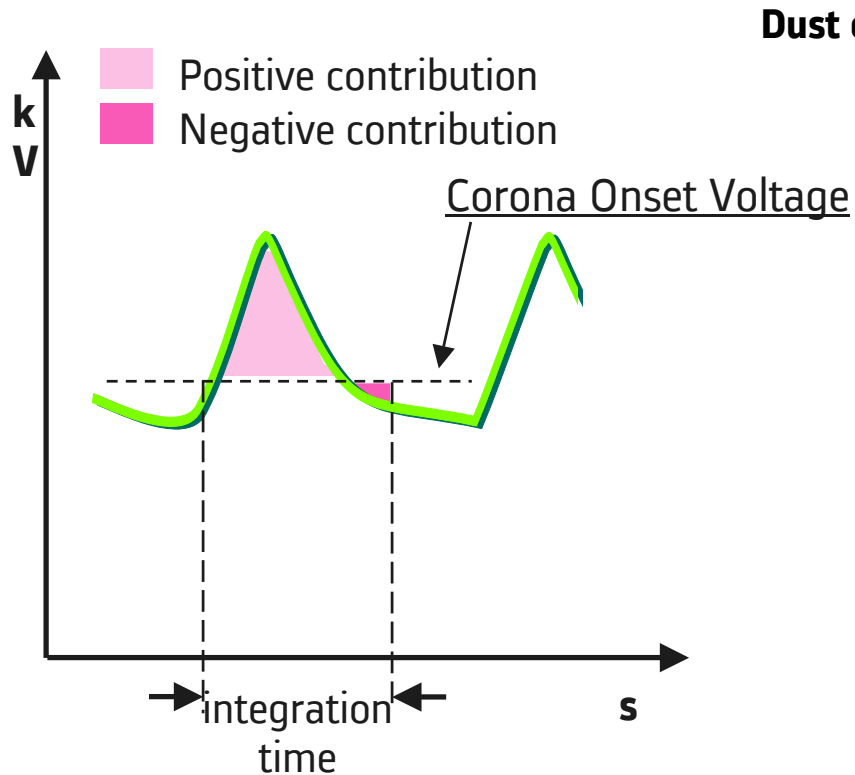


500 μ s/div

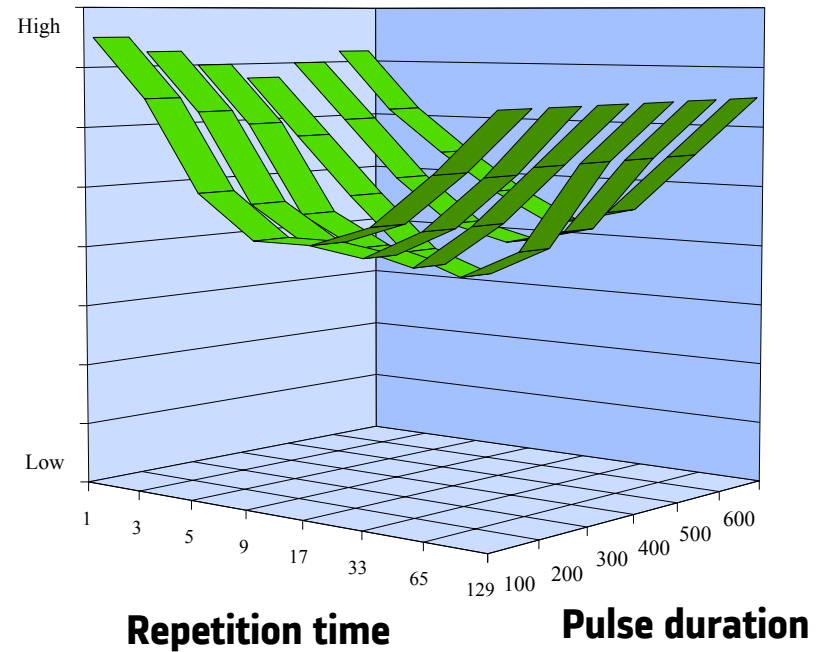
EPOQ operation



EPOQ operation

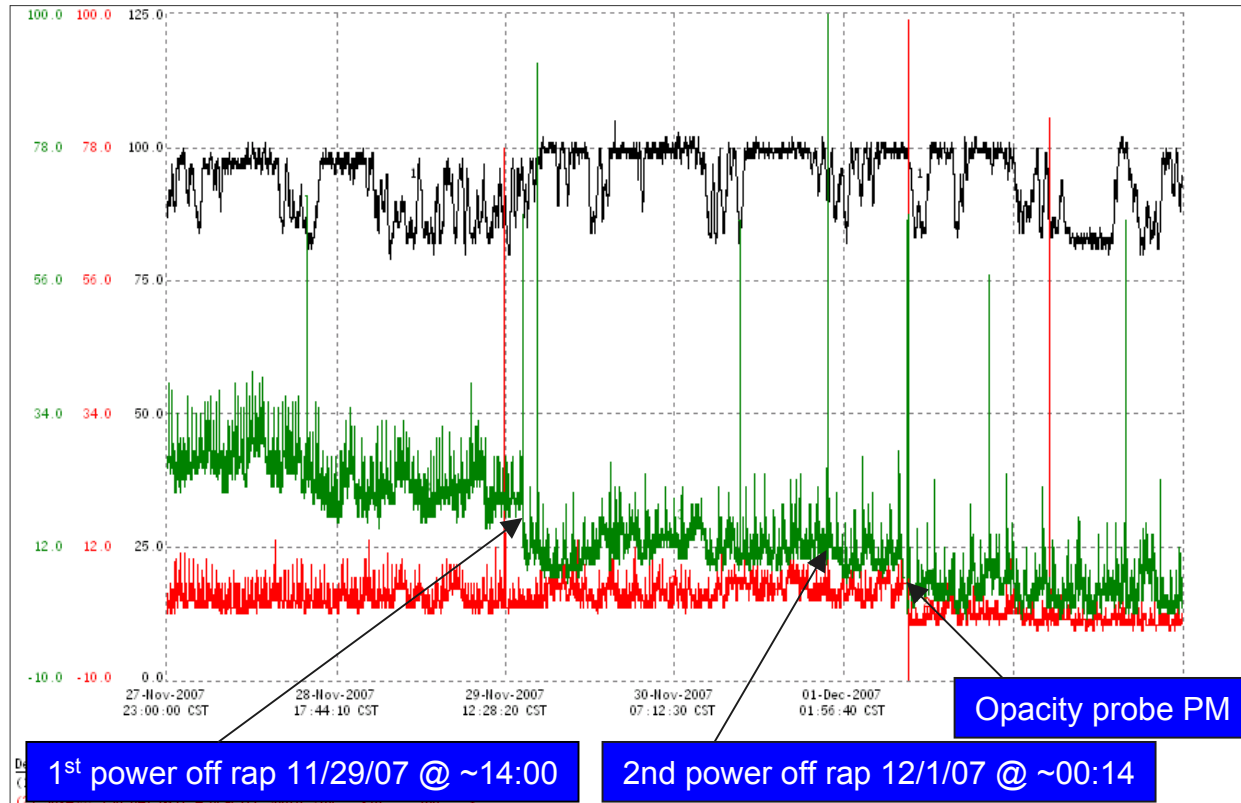


Dust concentration



Comment: Realtime optimization algorithm for pulse mode operation

Impact from PCR and Pulse optimization



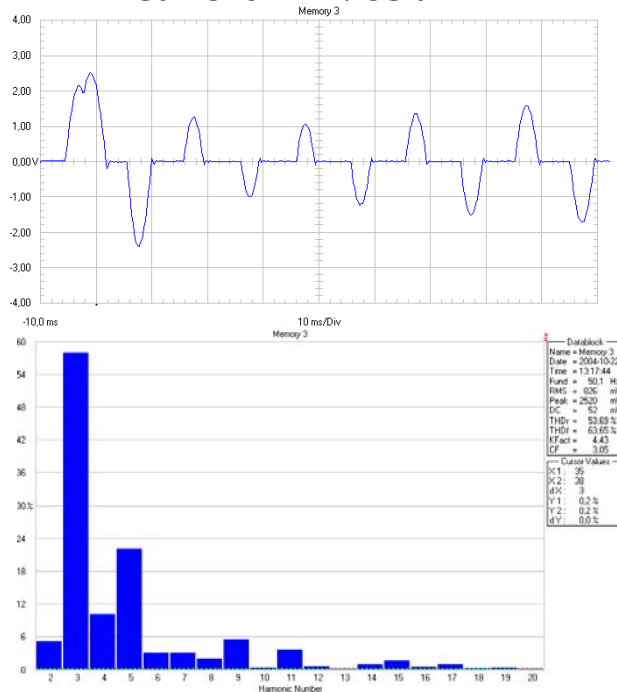
Comment: Combining PCR and EPOQ reduces emission significantly.
Reduced holding forces (rapping), lower resistivity, less back-corona, more power

- Introduction
- ESP voltage
- ESP current
- Line distortion
- Discussion

- HFPS units are designed for compliance with most modern harmonic distortion limits
 - EN 61800 for Europe
 - IEEE-519 for the USA
 - Other countries have similar standards (Australia: AS 2279, England: G5/3)
- Comparison of primary current waveform (from field measurements)

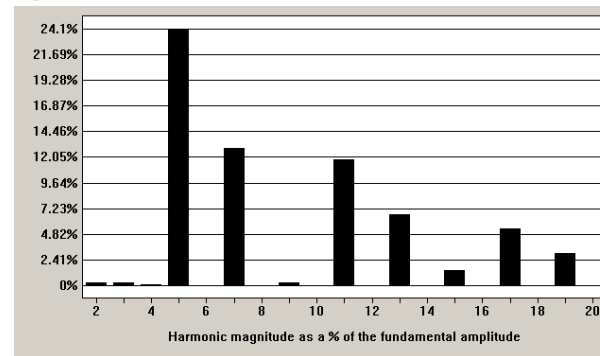
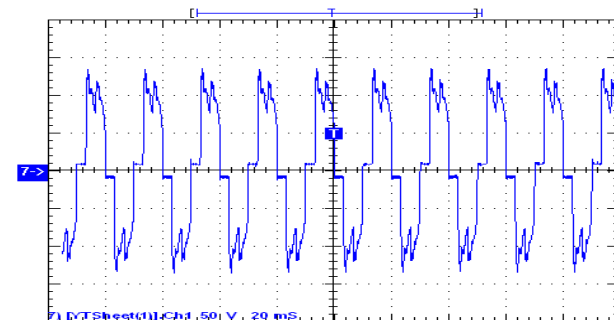
Mains Frequency Power Supply

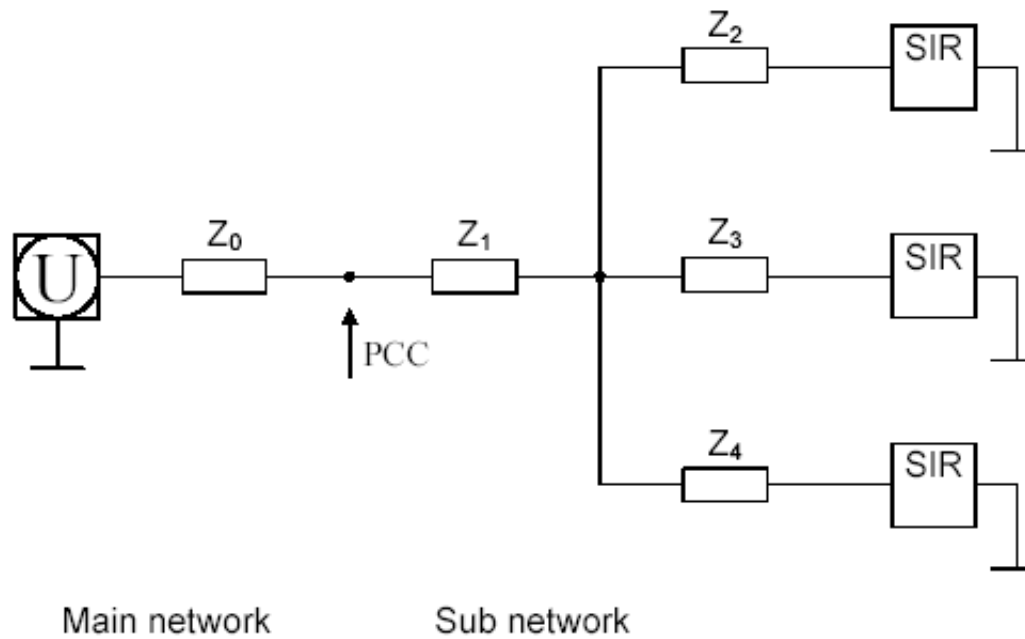
Current THD: 63%



High Frequency Power Supply

Current THD: 32%





- Introduction
- ESP voltage
- ESP current
- Line distortion
- Discussion

To fully utilise the benefits enabled by HFPS

- Higher ESP voltage
 - Make sure that sparking happens between the electrodes
 - Check: Ducts, Connection points, Screens etc
- Higher ESP current
 - Cleaning of plates is important
 - Control the holding forces by means of ESP-current (during rapping), PCR
 - Reduce high resistivity dust build-up

Reduced emissions

Areas of interest

- Control algorithms
 - Pulsing
 - Rapping
 - Spark control

- Pulse mode
 - Amplitude
 - Shape

Future improvements

www.alstom.com

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