



VSL

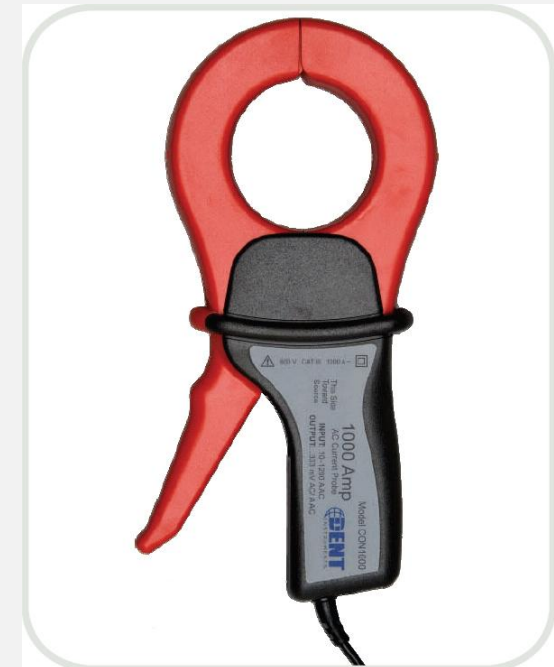
# Openable core current transformer for measurements up to 400 kV

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# Openable core current transformer. Why?

- Non-invasive current sensors are of great practical use in the field.
- Accurate current calibrations usually involve breaking the electrical circuit.
- Faster installation
- Reliability of the grid
- Live connection would mean no down time.



# Design criteria

## Elpow Aim

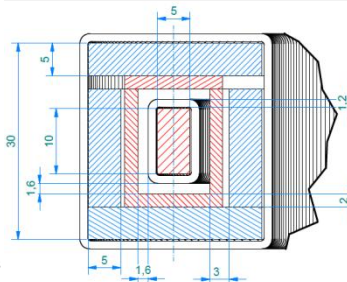
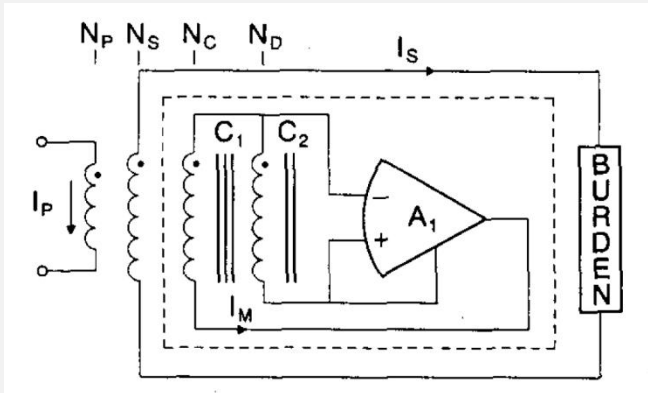
- 400 kV
- Remote readout
- 10 times better than 0.2 class CT
- Ratio  $< 50$  ppm and  $< 50$  uRad
- Live Connection

## Additional

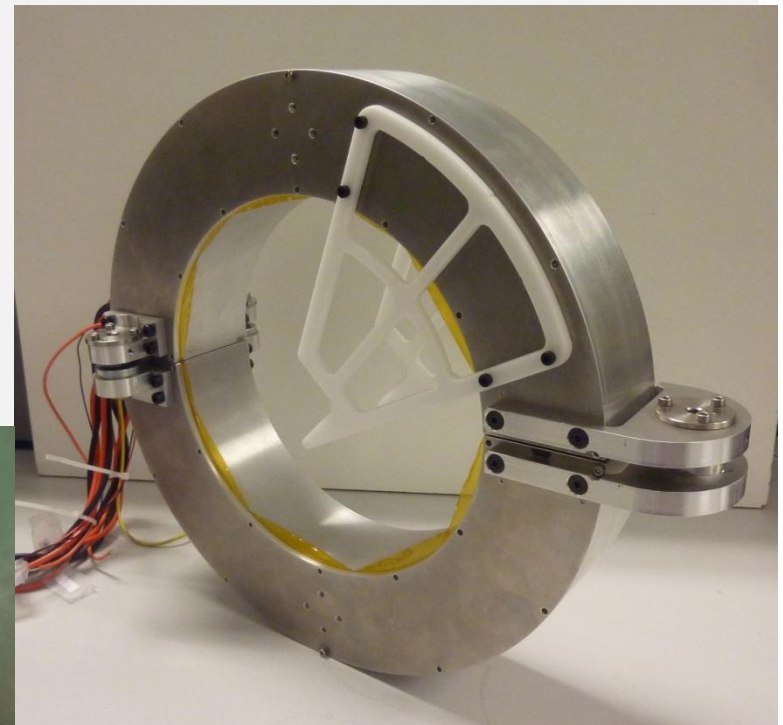
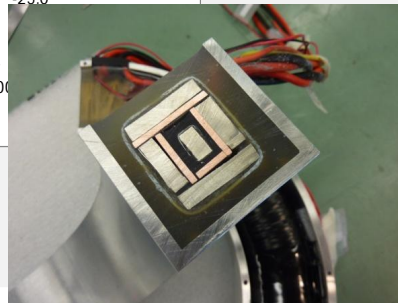
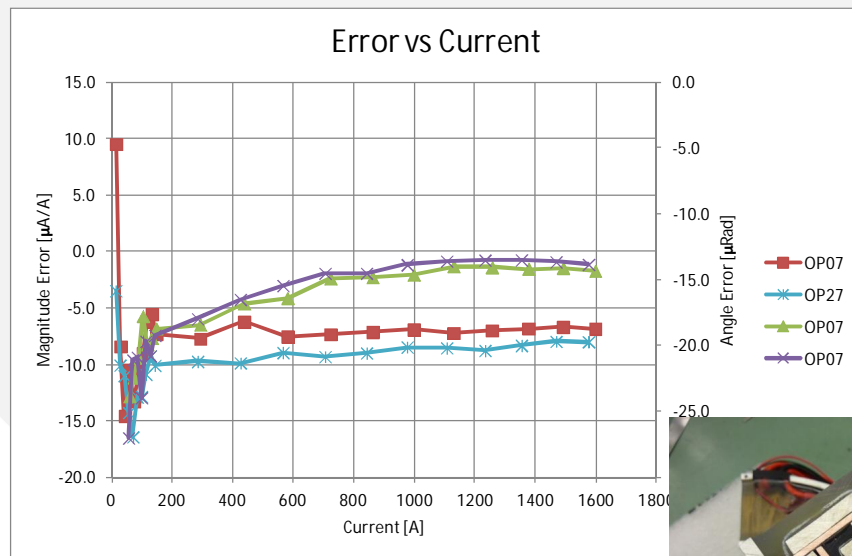
- 2000 Ampere primary current
- Ratio 1:400  $\rightarrow$  5 A
- Cross section  $\approx 20$  cm
- Measurement Duration  $\rightarrow$  Supply



# Enhanced core CT



Developed in  
JRP ENG07 HVDC



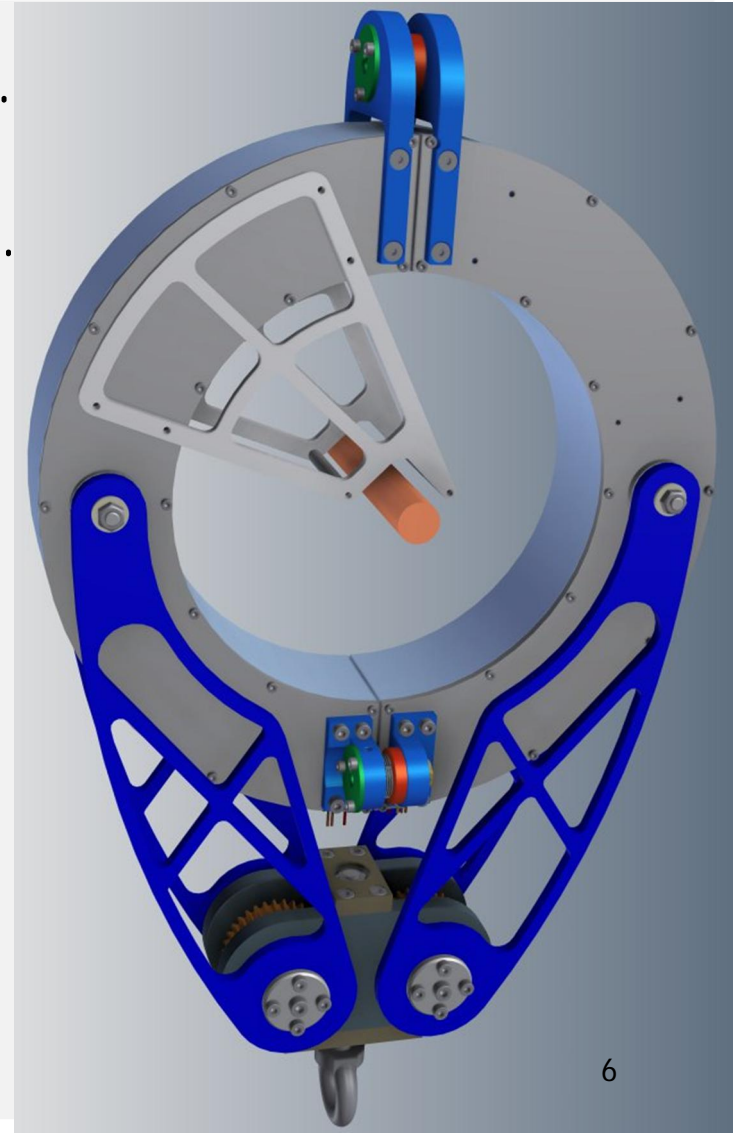


# ELPOW work

- 400 kV → Corona Ring
- Live connection procedures
- Read-out
  - ADC
  - Communication
  - Timing
  - Powering
  - Size

# Live connection

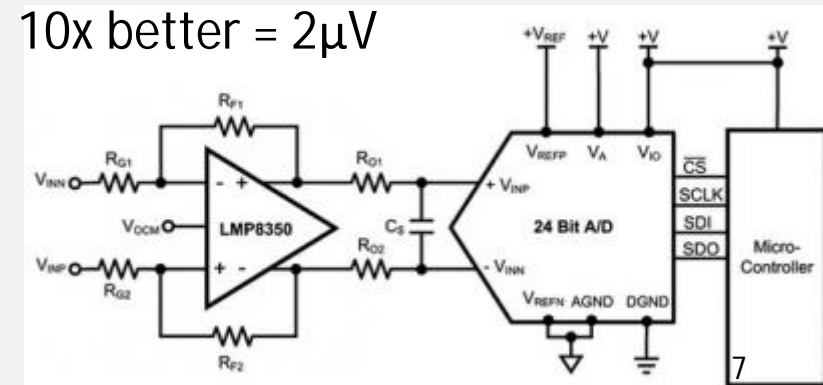
- Dutch grid won't allow live connection.
- Other counties have to be investigated.
- Pole mounting (too heavy)
- Installed by (isolated) man lift.





# ADC

- Shunt
  - 5A shunt  $\rightarrow$  1V for FS output  $\rightarrow$  0.2 Ohm  $\rightarrow$  5W
  - Temperature dependence
  
- ADC resolution
  - Dynamic range (lack of ranges on the CT) 2000A-20A
  - 10 time better than 0.2 class
    - 2000A = 1V - 20A = 0.01V
    - 0.2% of 0.01Vrms  $\rightarrow$  0.00002 V
  - 24 bit
  
- Voltage reference
  - LTZ1000?



# Communication

- Options
- Bandwidth
- Depends on information to be transferred.
- Only Values or samples? Sampling rate? Processing power?



	Range	Bandwidth	Isolation
Bluetooth	-	-	++
WIFI	+	+	++
Optical fiber	++	++	+







# Timing



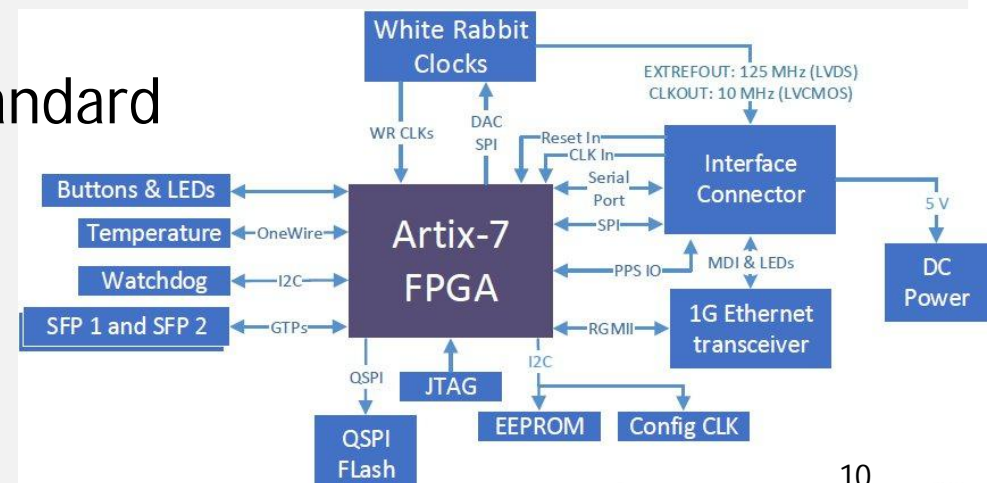
- Phase < 50 uRad @ 50 Hz
- $2\pi * f = 314 \text{ rad/sec}$
- $0.00318\dots \text{ Sec/ Rad} \rightarrow < 50 \text{ uRad} = < 159 \text{ nSec}$
- 1 uRad  $\rightarrow$  3 nSec
- Max Jitter = 15 nSec

	Accuracy	Indoor	Isolation
GPS	100n-10n	-	++
PTP	100u-5n	++	++
WR	<1n	++	+

Standard Ethernet	Software IEEE 1588	Hardware Assisted IEEE 1588	
NTP	1588 PTP	1588 PTP	
TCP/IP/UDP		TCP/IP/UDP	
Standard MAC	Custom FPGA or $\mu$ Controller		Standard MAC
Standard PHY	PHYTER	Precision PHYTER with HW 1588 Timestamps + Clock + GPIO	
100 ms	100 $\mu$ s - 10 $\mu$ s	100 ns - 50 ns	5 ns
Human Control		Process Control	Motion Control
Precision Control			

# Read-out

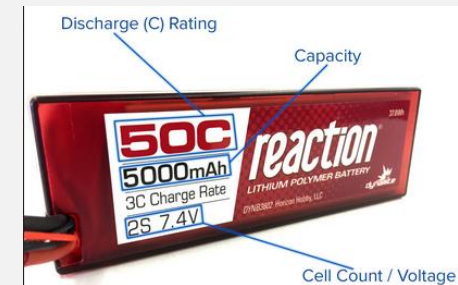
- Compact off the shelf board
- Offering < nSec timing using White Rabbit
- Can be daisy chained
- Functionality can be expanded
- Optical Communication is standard
- Relative low cost



# Powering

- Using a CT to snoop power from the overhead line.
- Using the capacitive current to ground
- Battery powered
- Power over fiber

	Max power	Duration	Isolation	complexity
CT	+	++	++	++
Leakage	-	++	++	+
Battery	++	--	+	--
PoF	+	++	+	-



Power-Over-Fiber Kit  
<https://www.lumentum.com>



# Conclusion

- Corona protection needs to be added.
- The CT will be installed by (isolated) man lift.
- Read-out
  - White rabbit board with add on ADC board
  - 24 bit ADC
  - Timing < nSec
  - Powering either PoW or CT snooping