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# A Complex Harmonic Impedance Measurement (CHIME) System for Reduction of Harmonics in the Electricity Grid

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## *Contents*

## *Introduction*

Problem

- ***harmonic mitigation systems need impedance information, for adaptation to local grid situations***

Goal

- ***find an impedance measurement system, able to work in practical situations***
- ***implement this system into a Digital Signal Processor (DSP)***
- ***integrate this into a grid connected Power Electronic Converter***

Approuch

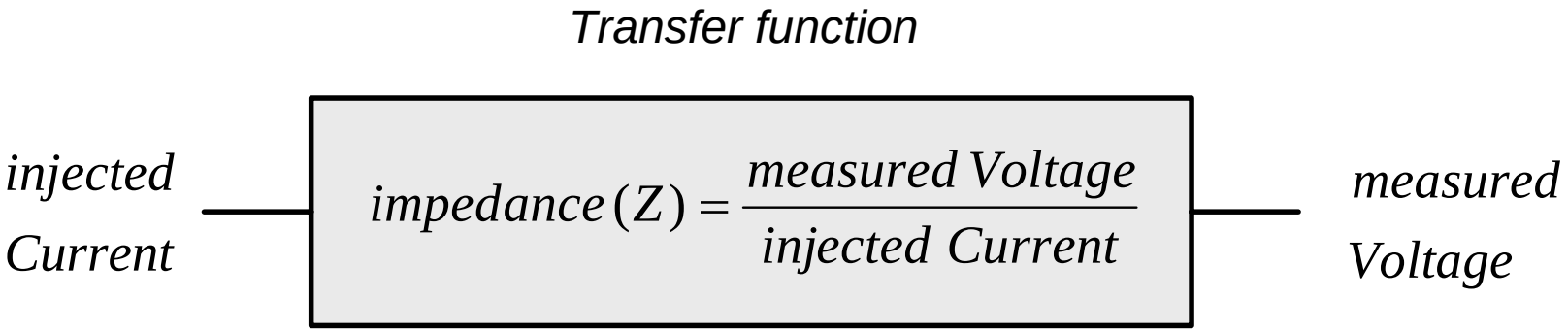
- ***developement of a Complex Harmonic Impedance Measurement system, able to cope with these demands (the CHIME-system)***

## *Characterisations of the CHIME-system*

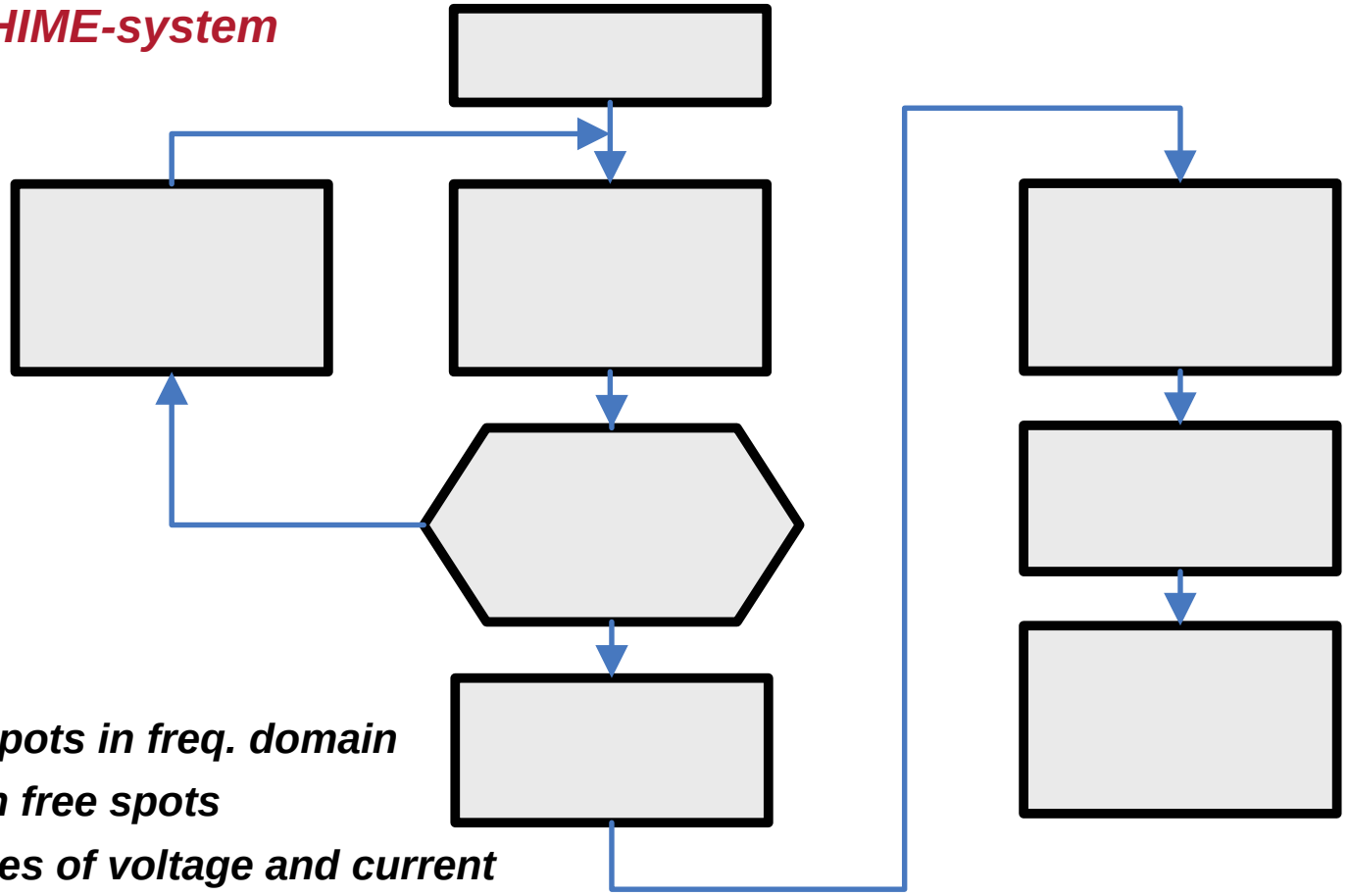
The CHIME-system:

- ***estimate the small signal grid impedance of a number of harmonics***
- ***does measurements while the grid is operating***
- ***has an acceptable level of current emission***
- ***can cope with changing load conditions***
- ***has a cooperation algorithm for multiple CHIME-systems***
- ***can be implemented in a Digital Signal Processor (DSP)***

## *Principle of the CHIME-system*



## *Principle of the CHIME-system*



The CHIME-system:

- ***estimates free spots in freq. domain***
- ***inject current on free spots***
- ***collect time series of voltage and current***
- ***does transformation to frequency domain***
- ***calculates the impedance spectrum***

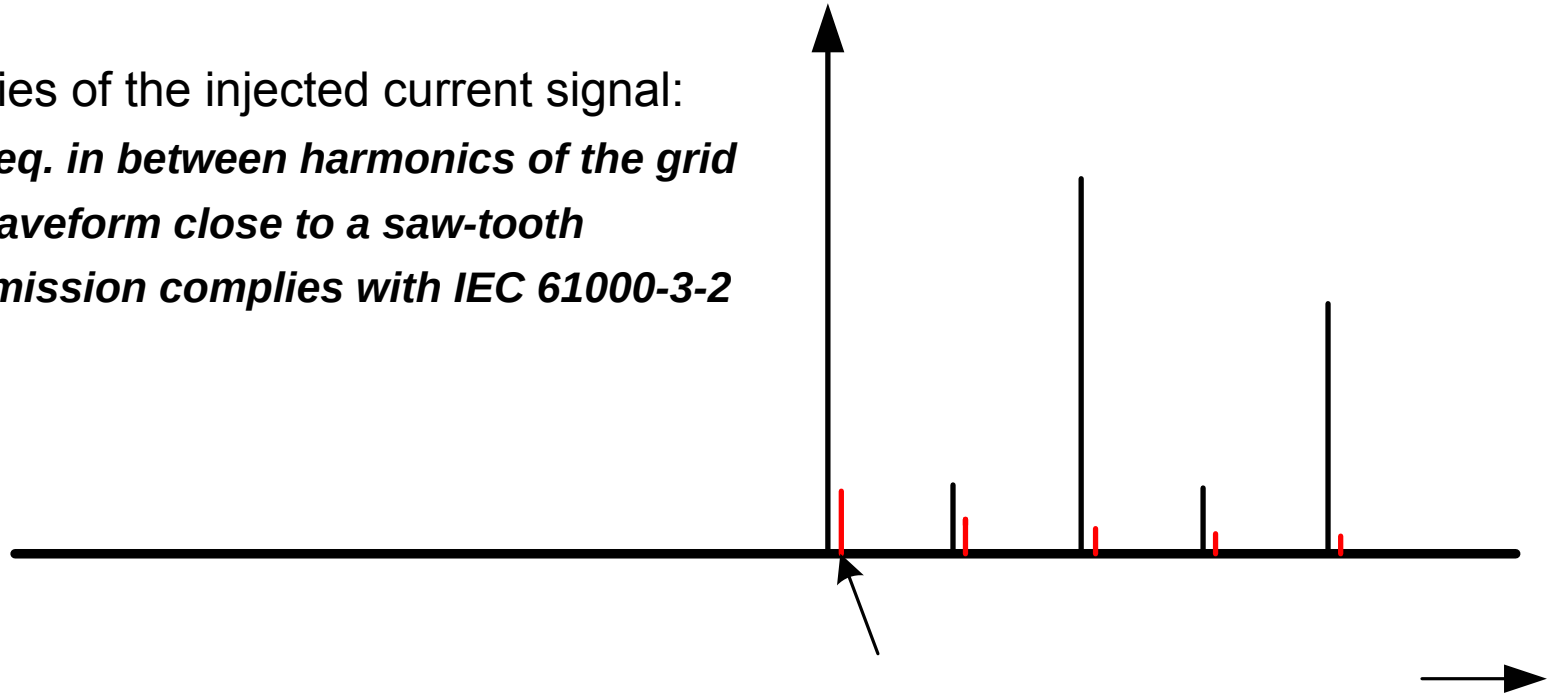
## *Current injection of the CHIME-system*

$$F_{measurement} = hF_{fundamental} + F_{shift}$$

$h$ = ***harmonic number***

Properties of the injected current signal:

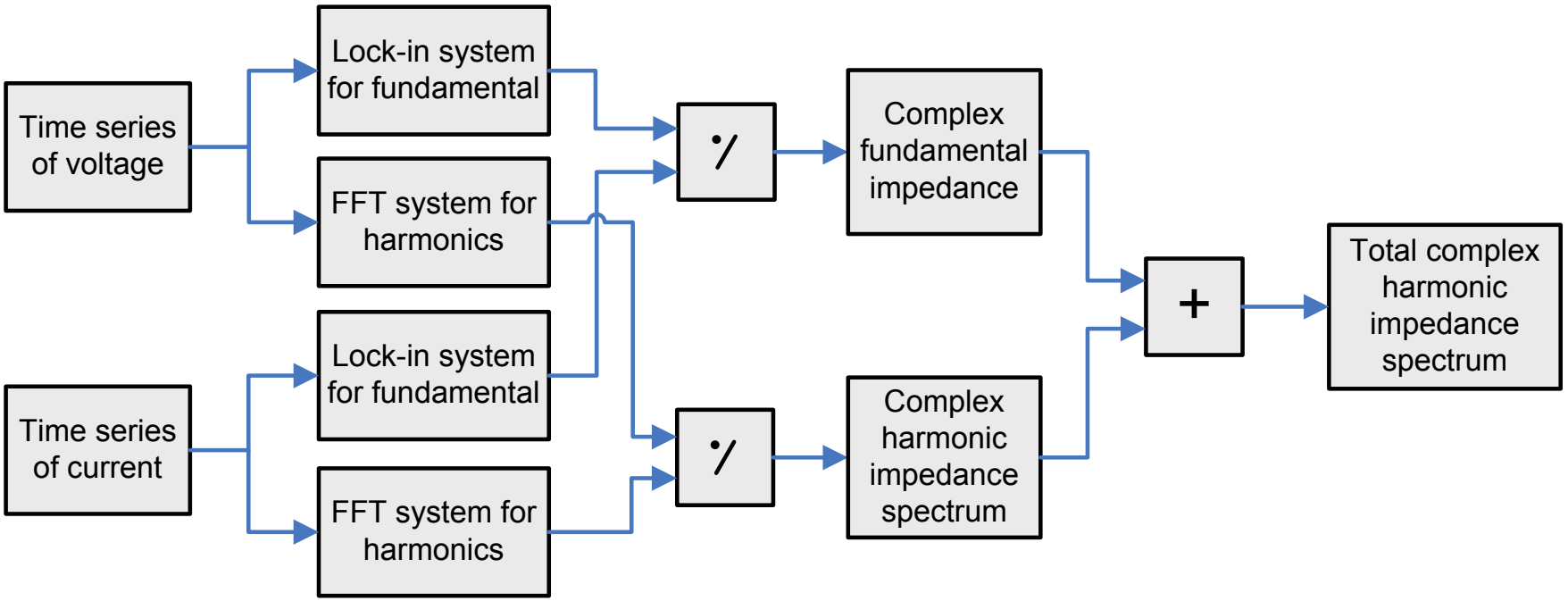
- ***freq. in between harmonics of the grid***
- ***waveform close to a saw-tooth***
- ***emission complies with IEC 61000-3-2***



## *Calculation part of the CHIME-system*

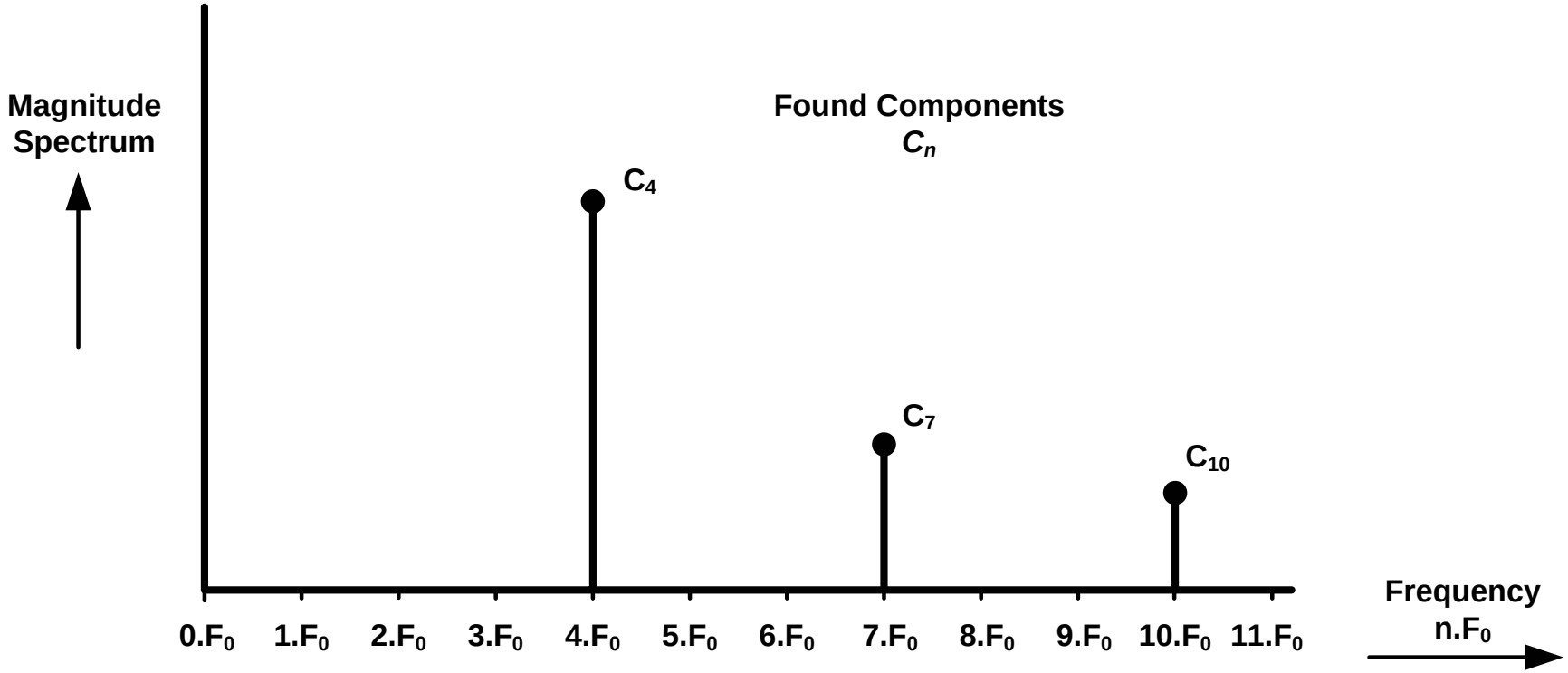
The CHIME-system:

- ***combination of a Lock-in and Fast Fourier Transformation (FFT) system***
  - ***Lock-in method for the fundamental impedance***
  - ***FFT for harmonic impedances***



## *Fast Fourier Transformation (FFT)*

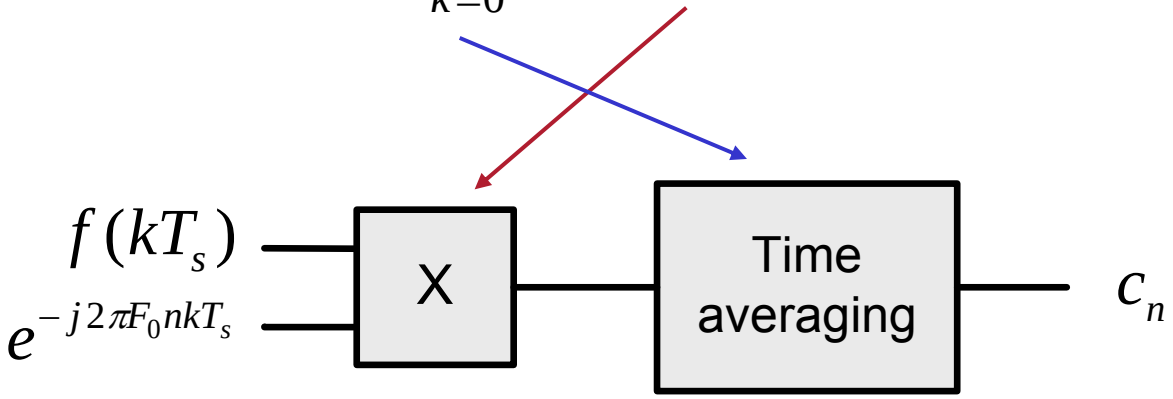
From function of sample time $f(kT_s)$ to function of frequency $f(F_0 n)$



## *Fast Fourier Transformation (FFT)*

From function of sample time $f(kT_s)$ to function of frequency $f(F_0 n)$

FFT coefficients $$c_n = \frac{1}{N}\sum_{k=0}^{N-1} f(kT_s)e^{-j2\pi F_0 nkT_s}$$




$k$ number of the sample

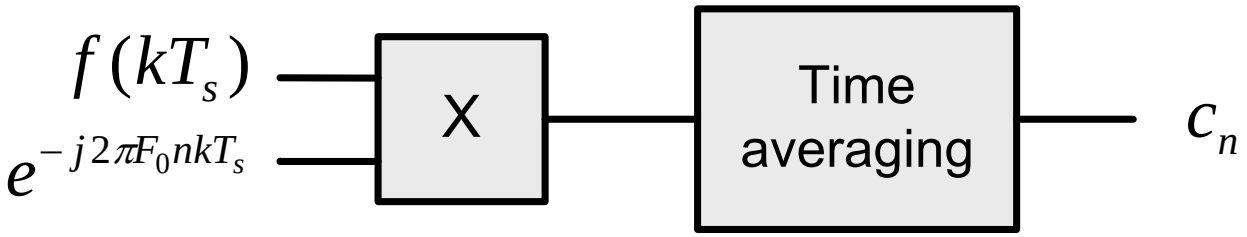
$N$ total number of samples

$F_0$ transformation fundamental freq.

$n$ number of the coefficient

$$c_n = |c_n| e^{j\Phi_n}$$

## *FFT and the Lock-in principle*




Lock-in system: optimized for estimation of one single coefficient $C_n$

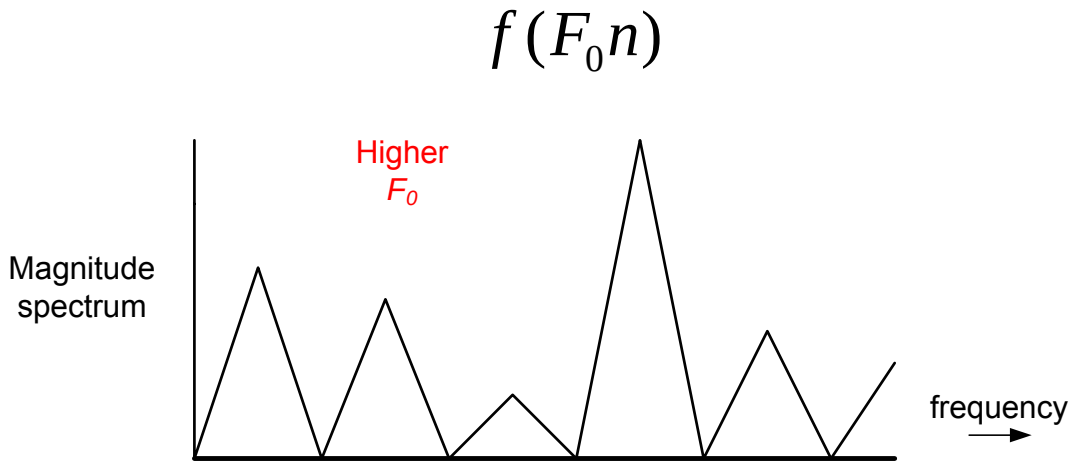
FFT system: estimation of total number of *N* coefficients $C_n$

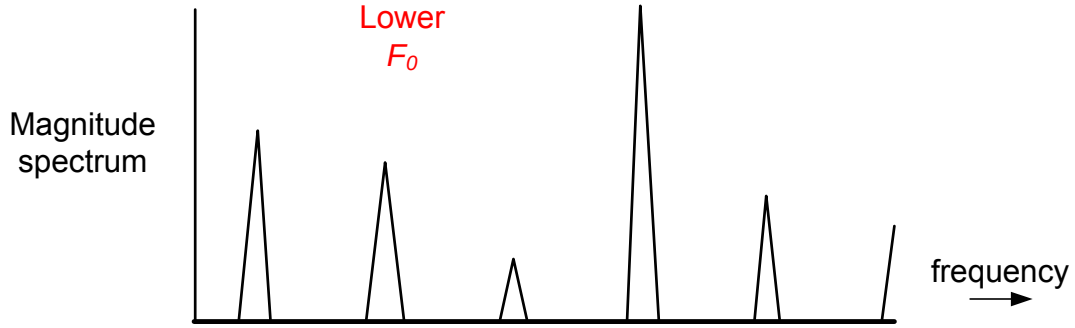
## *Resolution of the FFT (and the Lock-in)*

$$F_0 = \frac{1}{T_s N}$$

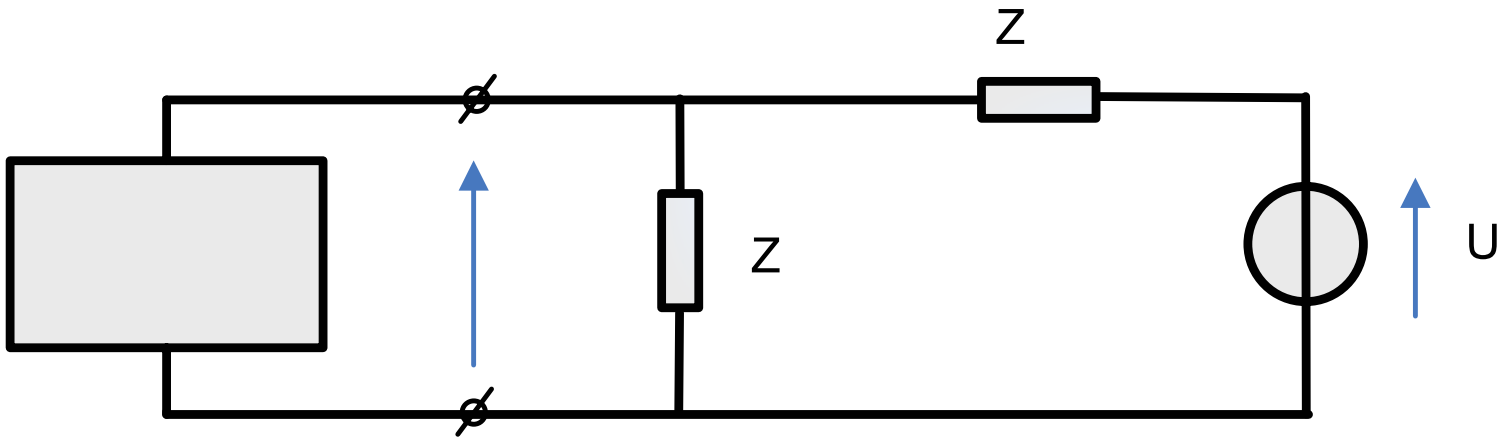
***$F_0$* is the fundamental frequency of the transformation**

| ***$F_0$*** | |
|---|---|
| **Fundamental impedance** | **Harmonic impedances** |
| **125 mHz** | **1 Hz** |



## *simulation of the Chime-system*



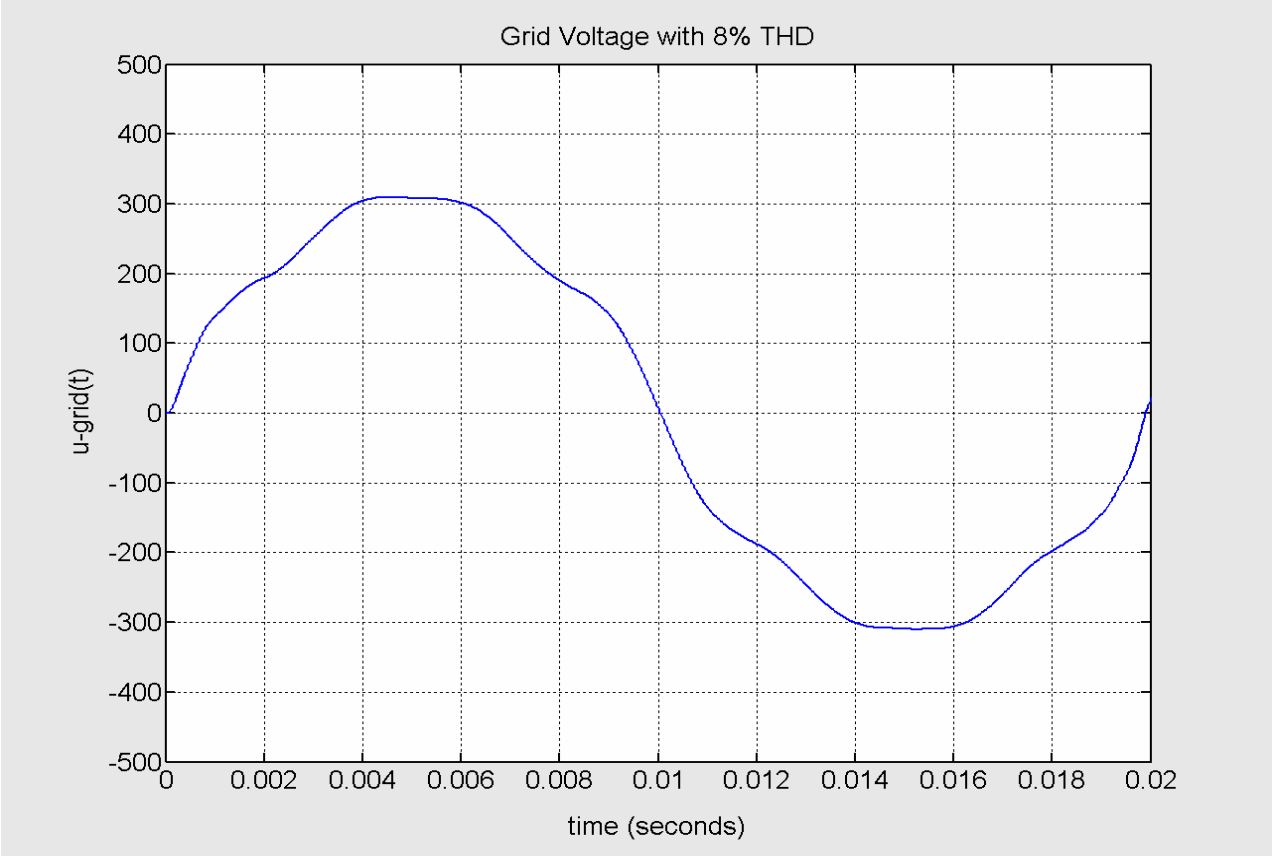

*The measurement system is connected to a low-voltage grid*

$Z_{grid} = 0.4 + j0.25\Omega$ and $Z_{load} = 23 - j100\Omega$ at 50Hz

## *simulation of the Chime-system*

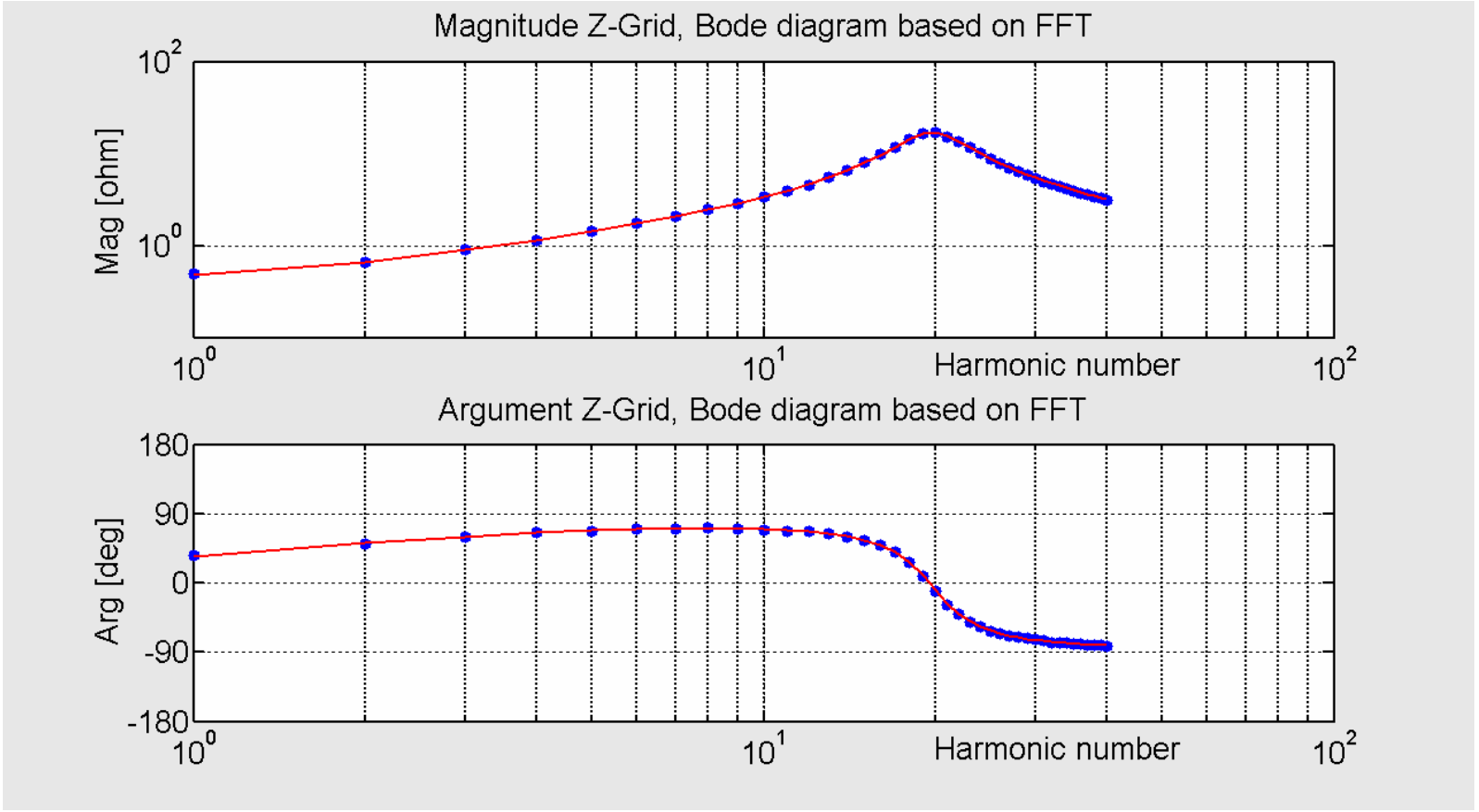
Grid voltage conditions:

- ***THD of 8%***
- ***added white noise of 1%***
- ***frequencies varying ±1%***




*polluted grid voltage, to create a worst-case situation*

## *simulation results*



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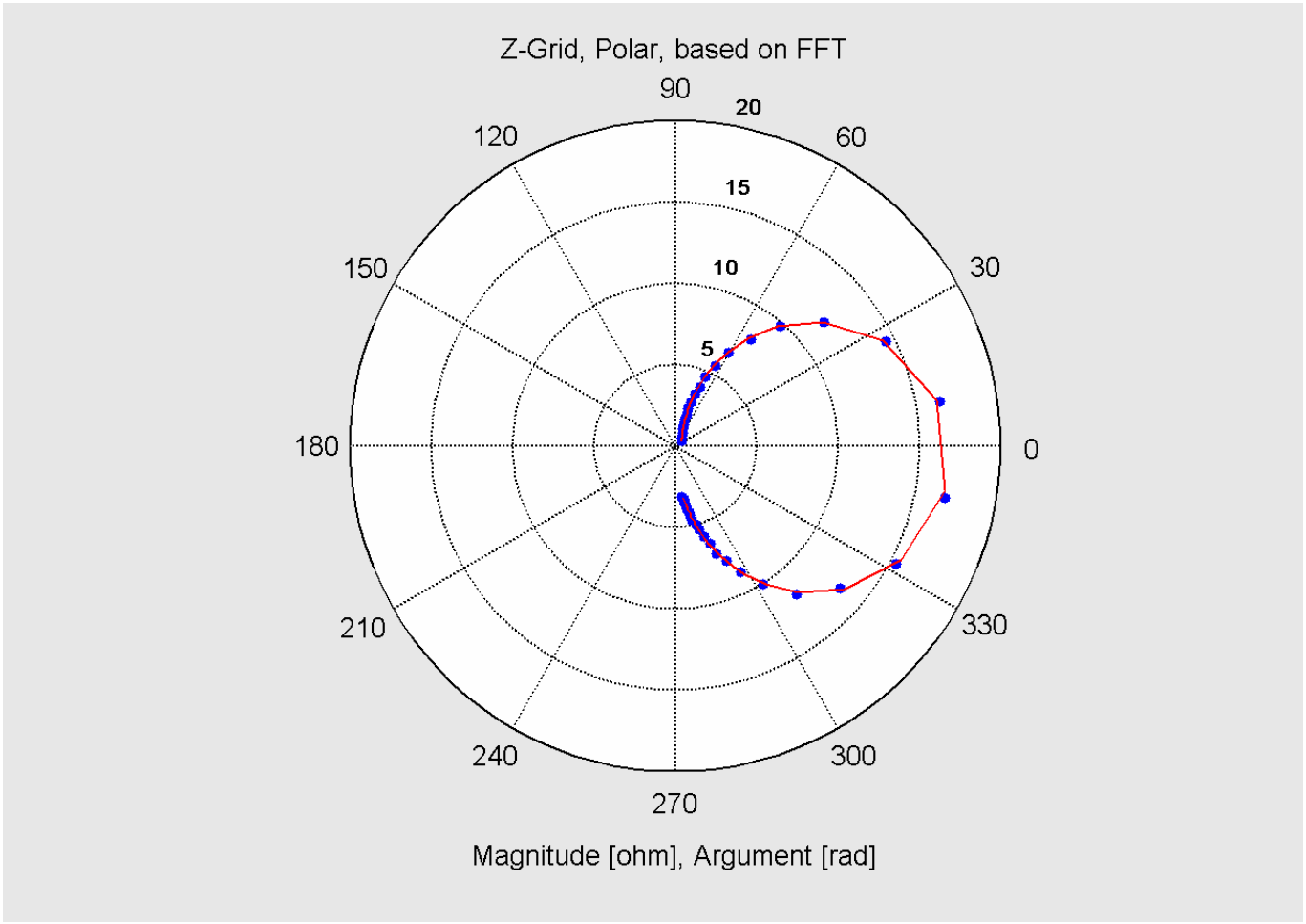
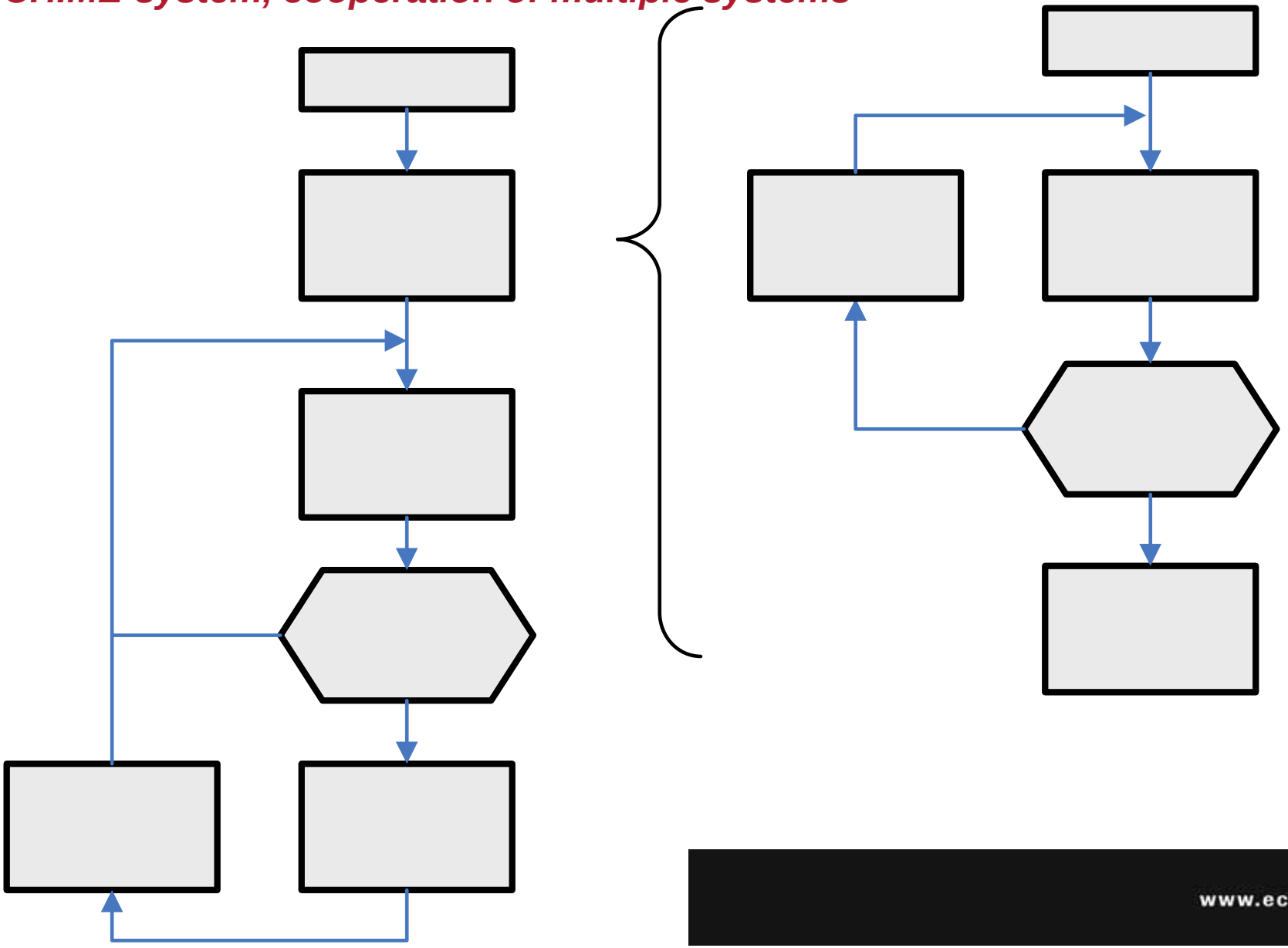


## *CHIME-system, cooperation of multiple systems*



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## *Conclusions*

The CHIME system works with two optimized systems, namely:

- ***a Lock-in system for the fundamental impedance***
- ***a FFT system for harmonic impedances***

**Reason for the split:**

- ***estimation of fundamental impedance ask for much more resolution***

Simulations show that the CHIME system is capable of operating under polluted grid voltage conditions

## *Plan of action*

The CHIME system will be:

- ***implemented in a DSP of a grid connected Power Electronic Converter***
- ***tested in a laboratory and real grid***

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# *Thank you for your kind attention*