Nya tekniska krav på frekvensregleringen i det nordiska kraftsystemet

New technical requirements on the frequency control in the Nordic power system

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- Introduction – Frequency stability
- Reserves
  - FCR-N
  - FCR-D
- Design of requirements
  - Stability
  - Performance

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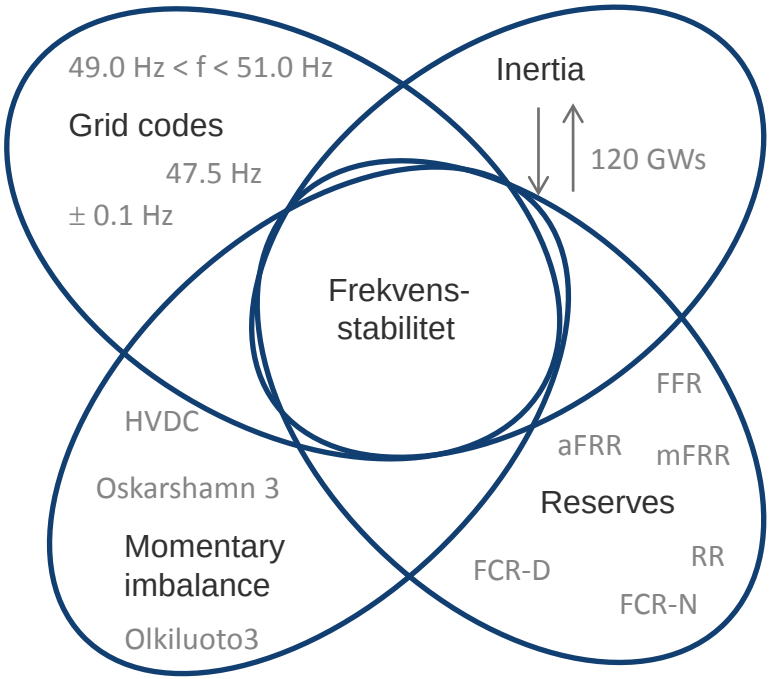
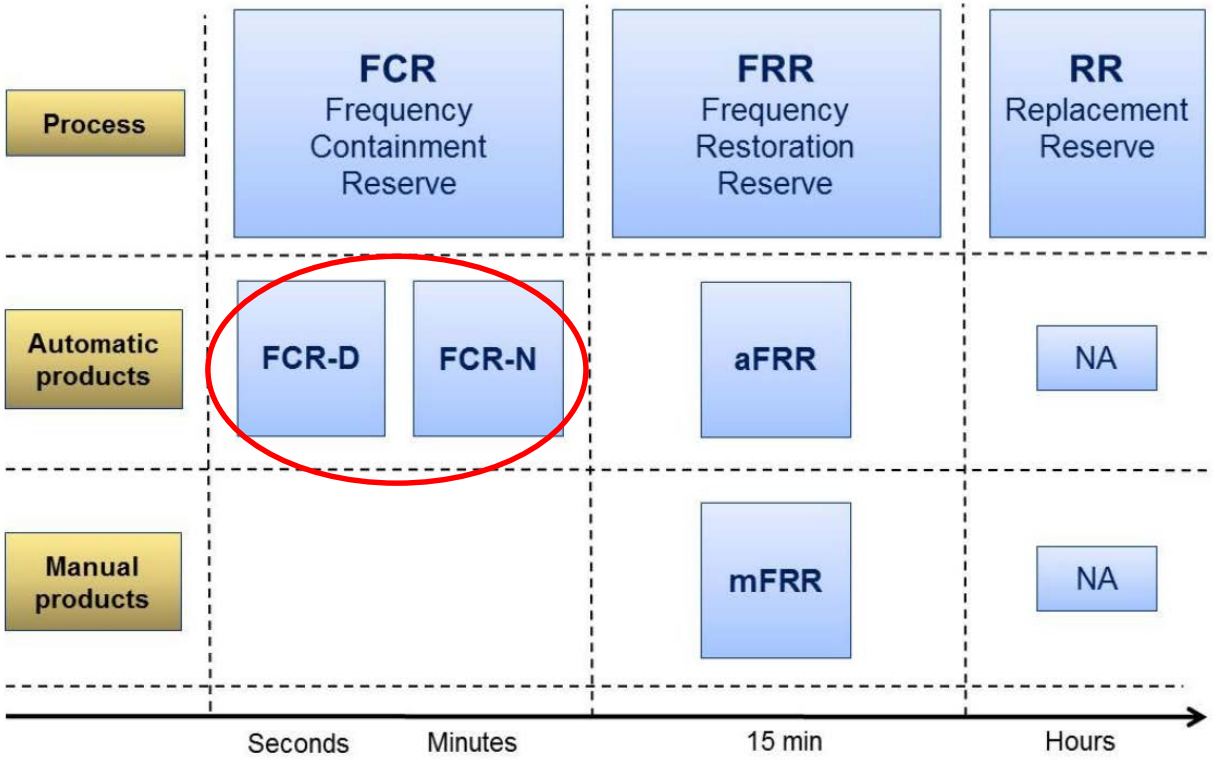
Frequency stability



Reserves



- FCR-D – Frequency containment reserve for disturbance, f < 49.9 Hz
- FCR-N – Frequency containment reserve for normal operation, 50 ± 0.1 Hz

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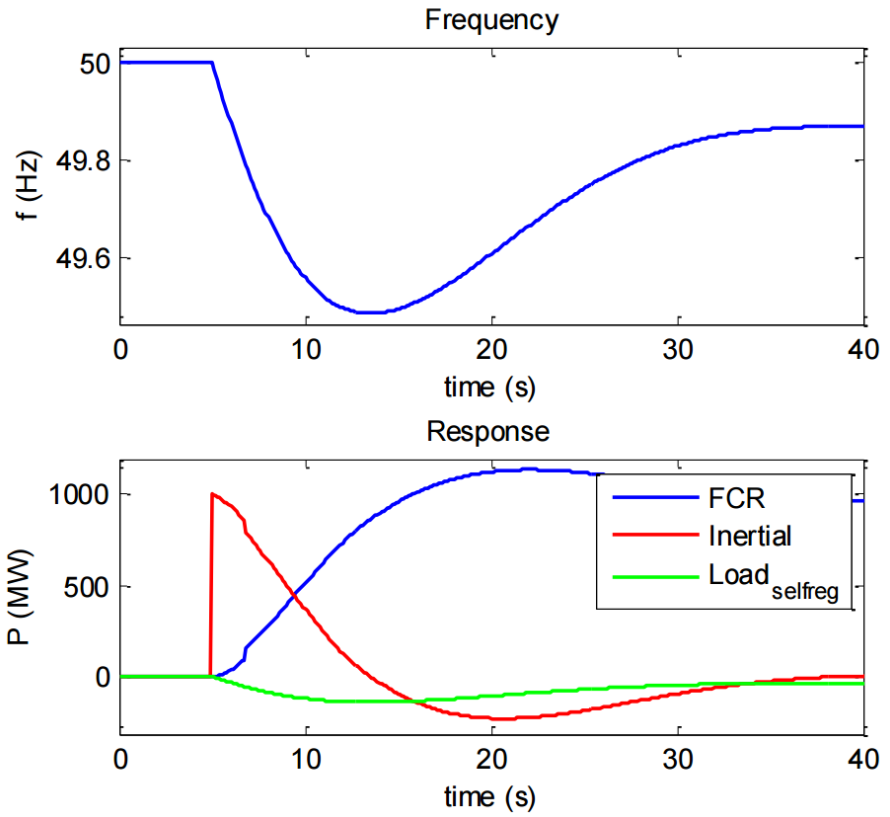
Always power balance

- Inertia
- Primary control
  - FCR-D (also FCR-N)
- Load



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Reserves

- Normal operation
  - FCR-N: Less than 10 000 minutes outside 50 ±0.1 Hz
- Large momentary imbalance
  - Dimensioning incident f>49.0 Hz
  - Oskarshamn 3 ΔP=1450 MW
- Ideally proportional to frequency deviation $\Delta P = -R \cdot \Delta f$

but that is not the case

- $\Delta P = -R \cdot \Delta f \cdot F(j\omega)$ ← **Unwanted dynamics =Challenging**

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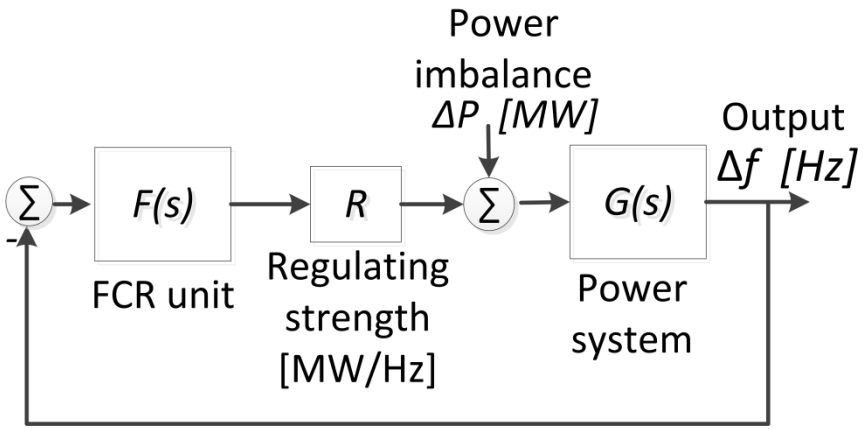
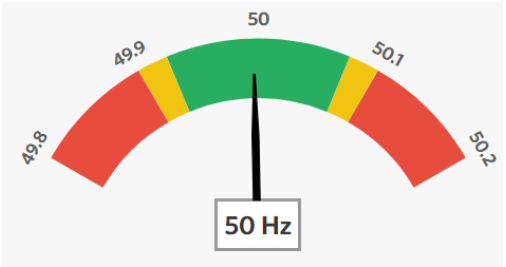
Reserves – Technical requirements

- **Stability**
  - Attenuate frequency oscillations
- **Dynamic performance**
  - Speed to reject disturbances





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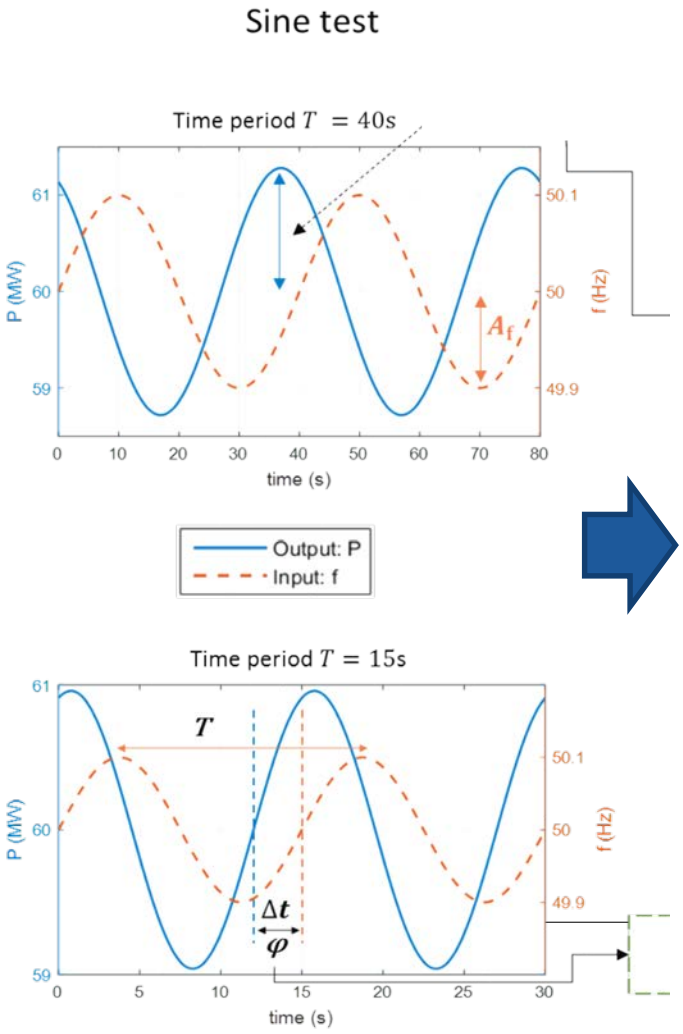
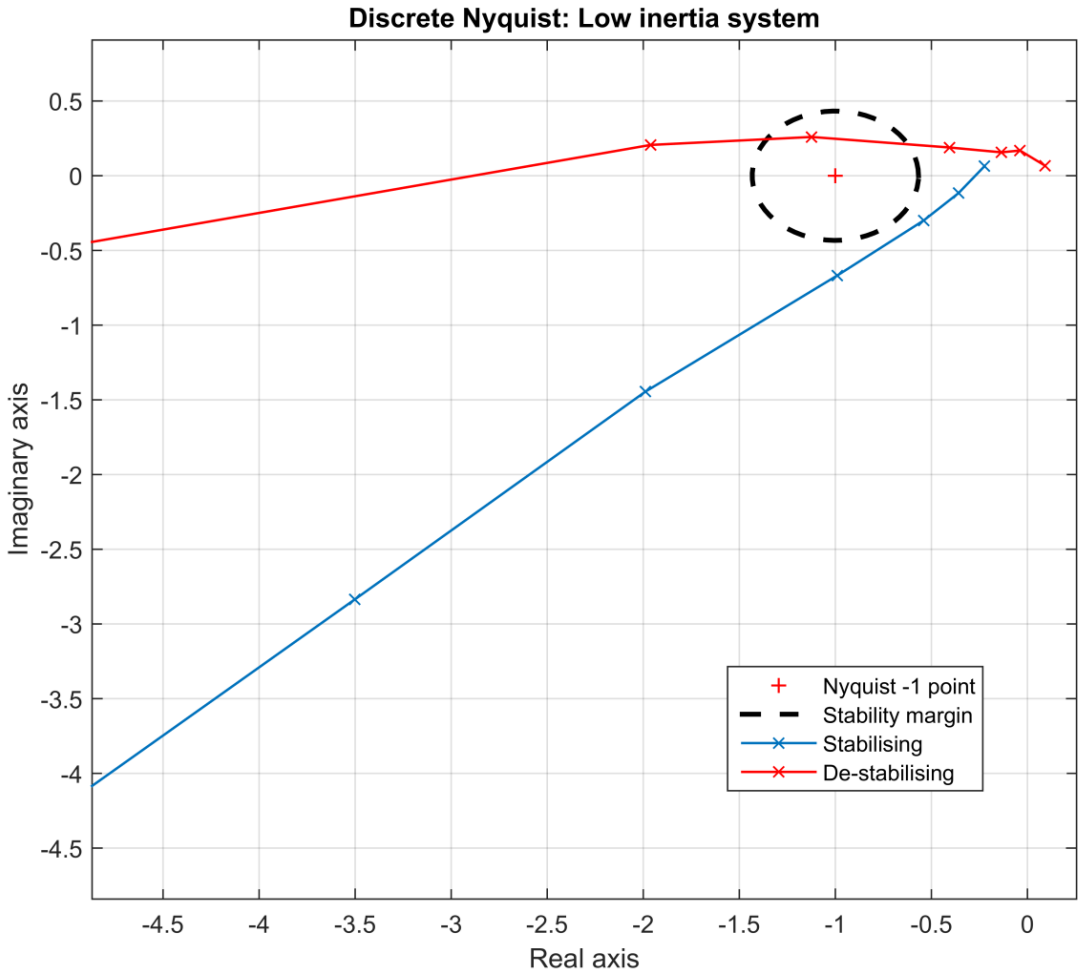
Stability – Sine-in Sine-out

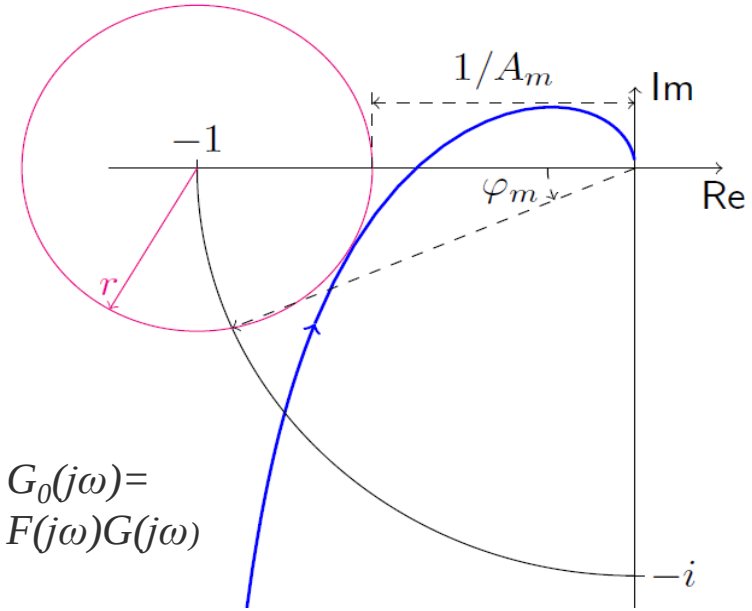




Stability – Less is more

> Nyquist 'loop gain' $G_0(j\omega) = R \cdot F(j\omega) \cdot G(j\omega)$

> *R – Regulating strength in MW/Hz*



> Increased regulating strength may not always be beneficial

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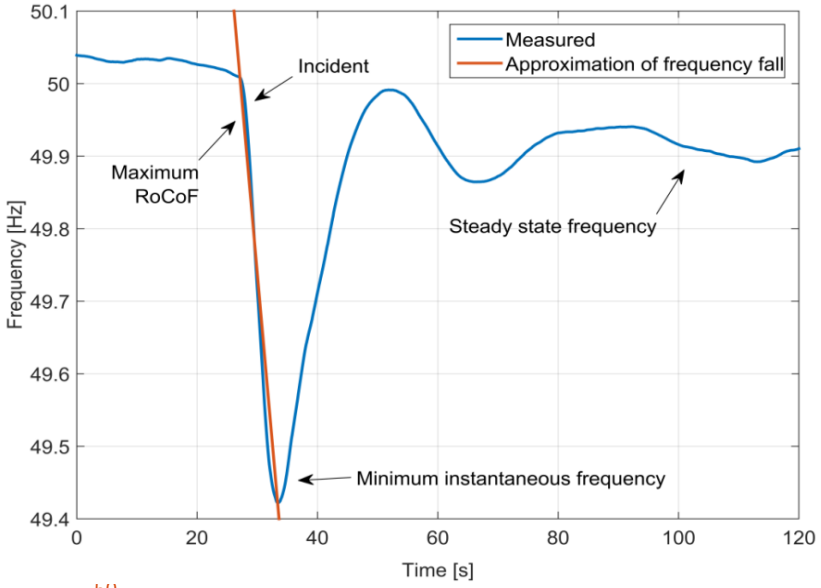
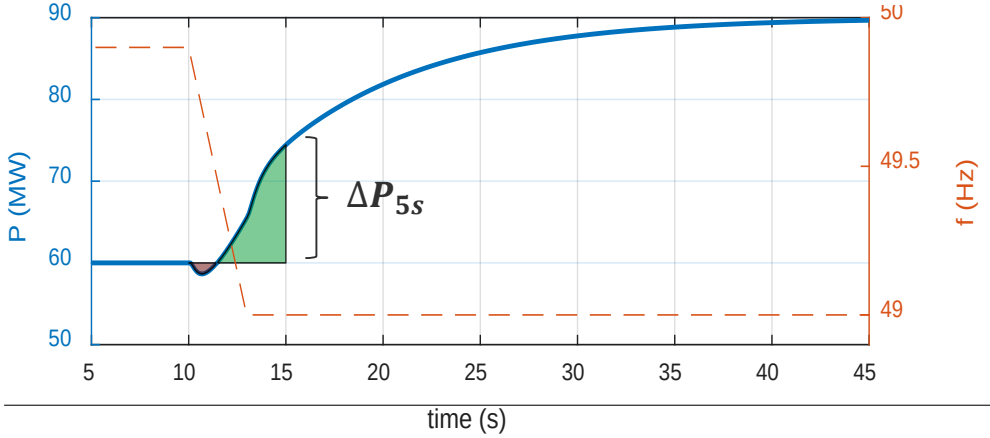
Dynamic performance – FCR-D

- Requirement at T=5 s
  - Power
  - Energy
- Open loop ramp response





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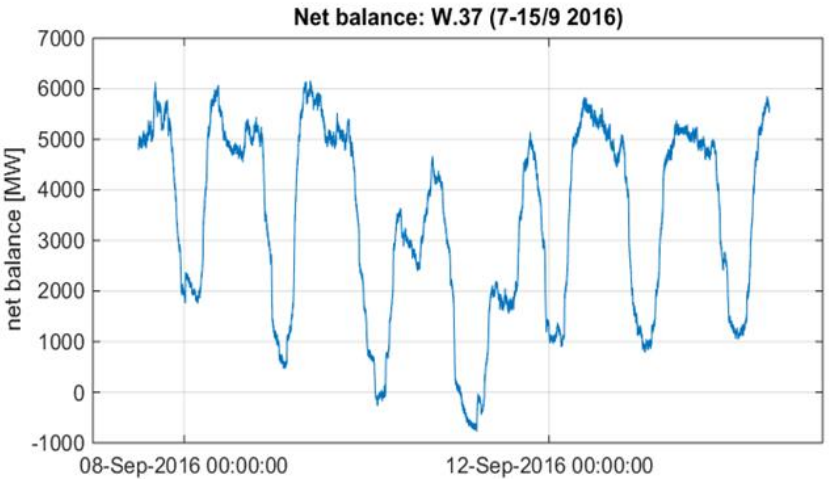
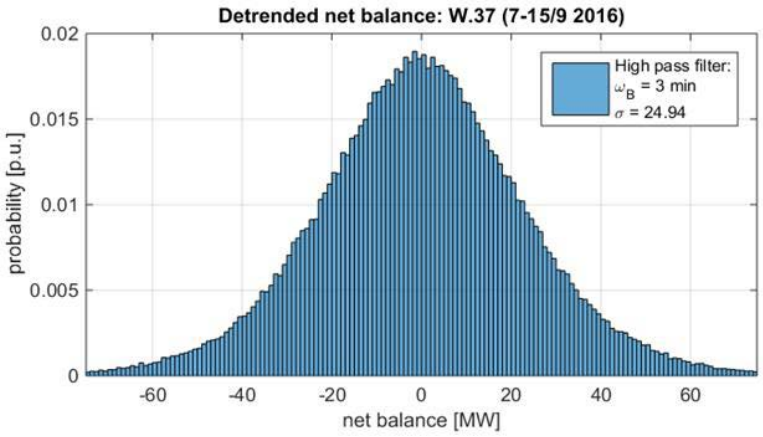
Dynamic performance – FCR-N

> Net power variation





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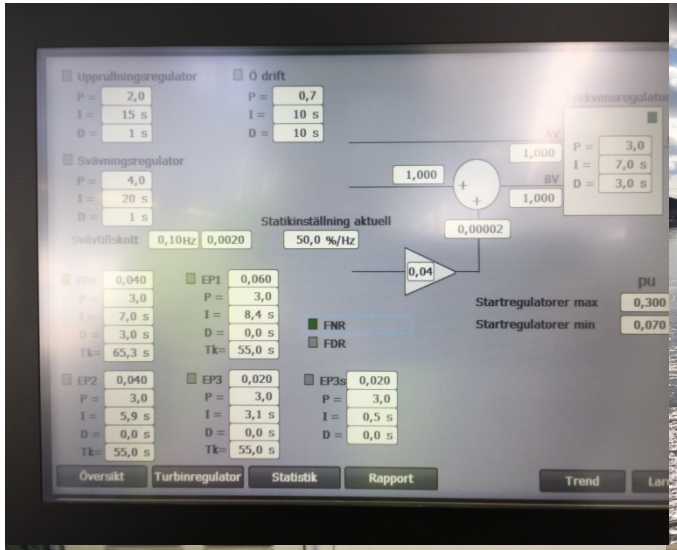



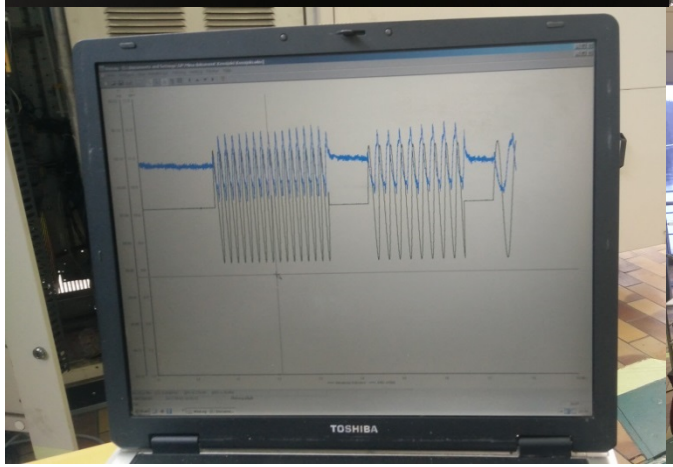


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