

# Refurbishment of the Crane in the Reactor Hall at FRM II: Challenges and Lessons Learned

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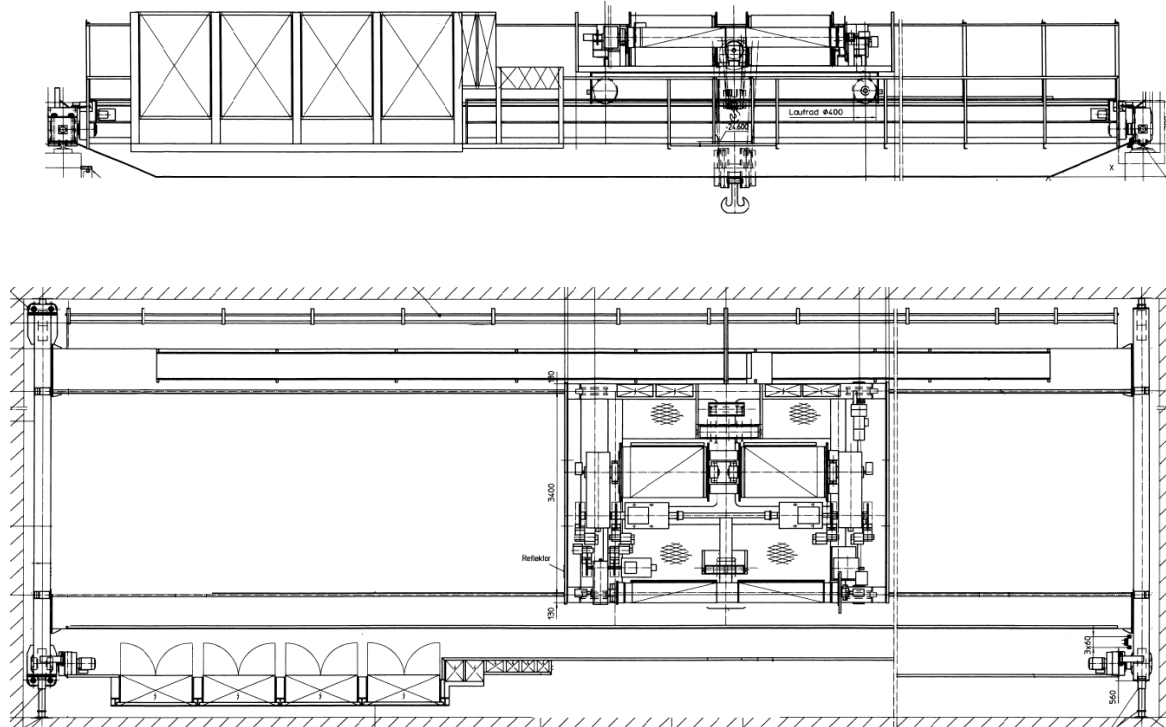
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# Introduction and Overview

- Research Neutron Source FRM II at Technical University of Munich in operation since 2004
- Most of the systems installed in late 1990s
- Crane in the reactor hall is one of the most vital systems

# Introduction and Overview

- Double girder overhead crane with two hoists (3.2 t and 20 t)
- Used for transports within and into reactor hall and reactor pool
- Most important applications:
  - Main hoist 20 t: handling of storage containers for high-level nuclear waste
  - Auxiliary hoist 3.2 t: handling of fuel elements



# Introduction and Overview

- Crane is in operation for more than 25 years:
    - Obsolete control system
    - Maintenance effort is increasing
    - More and more defective components → identical spare parts not available since most components have been discontinued and inventory stocks have been depleted → components need to be replaced with similar or successor components → extensive documentation, testing, and verification work
  - Changes to the German nuclear safety standards (KTA) require extensive modifications to the crane's control system
- ➔ Estimation that replacement of whole electrical and control system is more time and cost effective than continuous repairs and application of necessary modifications

# Project Schedule

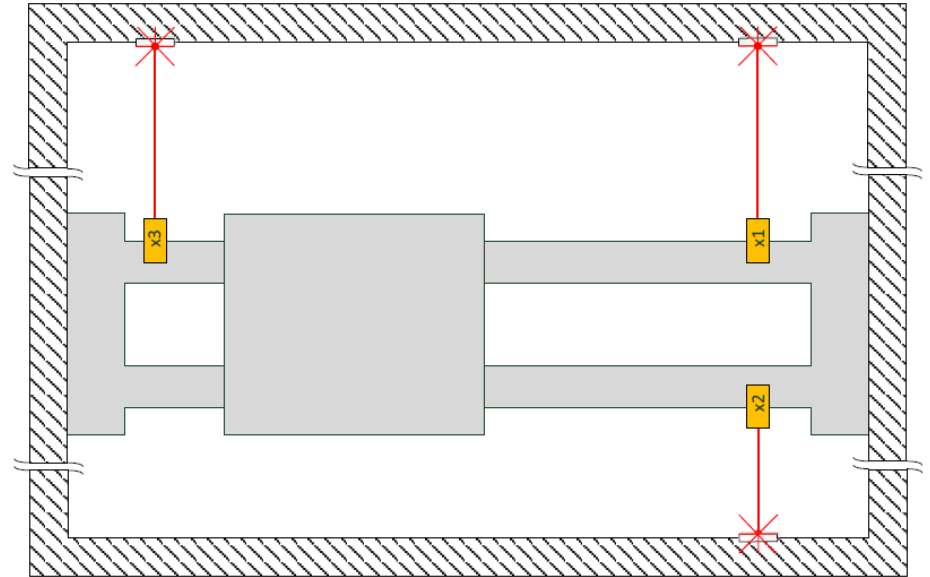
- Internal planning started in 2017
- Official start mid-2019 following a Europe-wide tender
- First version of planning documents finished in August 2020 and transmitted to TSO
- Two revisions necessary before receiving approval by TSO in March 2022
- Factory acceptance test and EMC testing in January and February 2023
- On-site work completed in April 2023
- Acceptance and functional testing completed in May 2023

# Overview of New Control System

- Core components: two independent PLCs, an operational PLC and a safety-related PLC
- Operational PLC: responsible for all standard control functions of the crane
- Safety PLC:
  - Monitoring the operational PLC and all other components and parameters
  - Ensure transition to a safe state in case of inadmissible operating conditions, excess of limitations, malfunction, or failure → sensors and transmissions have to fulfill highest requirements (usually Performance Level d or e according to ISO 13849-1) and high levels of redundancy and diversity

# Example for High Level of Redundancy and Diversity

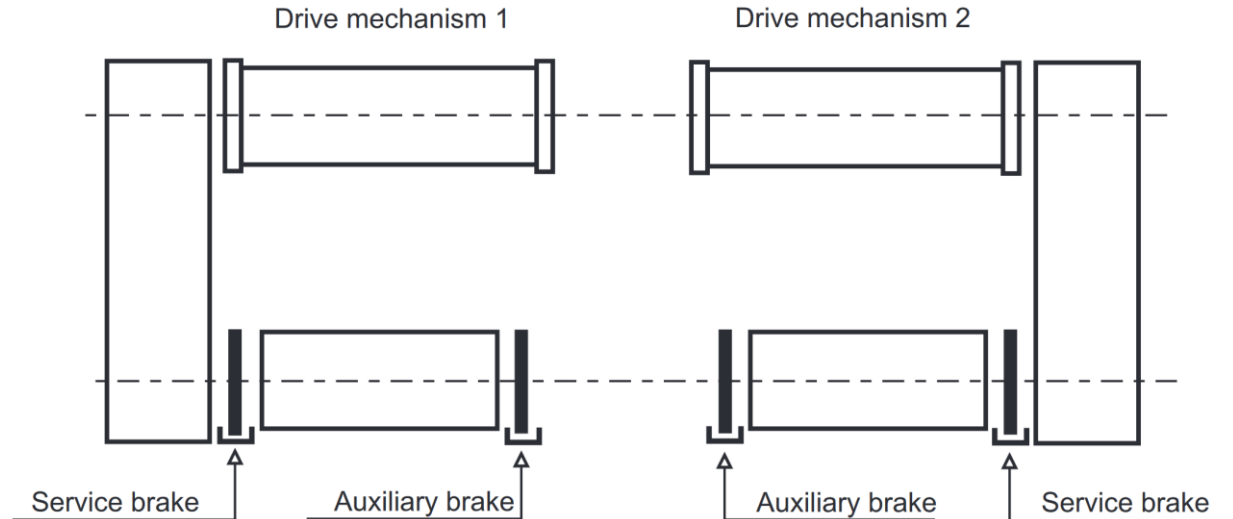
- Position measurement must be precise and failsafe, since the crane is used to transport fuel elements
- Redundancy: parallel and opposite laser sensors
- Diversity: additional encoders on motor shafts are used to determine position
- Deviation between determined position by two lasers or by a laser and an encoder result in immediate safety shutdown





# Hoist Brake System and Encountered Issues

- 4 brakes on 20 t hoist:  
2 service brakes, 2 auxiliary  
brakes
- During regular operation,  
braking is performed by  
frequency converters and  
brakes engage only when the  
crane is almost at a standstill
- Static and dynamic brake test  
had to be performed during  
acceptance test



# Static Brake Test

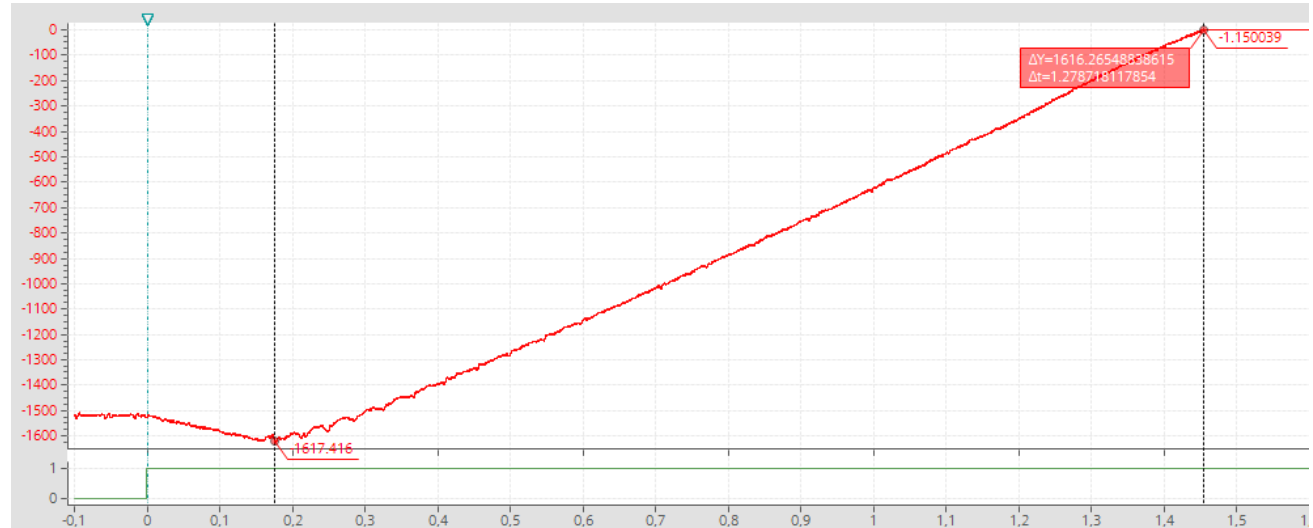
- Static holding force of each individual brake had to be tested
- Test load of 20 t is lifted, and then all brakes except the one being tested are released
- Test conducted for each brake individually
- Each brake was able to hold the load without any noticeable drop → all brakes passed the test

# Dynamic Brake Test

- Load of 20 t is lowered at maximum speed
- Test command issued: frequency converters are abruptly switched off (→ cannot contribute to braking effect) and brakes are activated
- Test done for all brakes together, every possible combination of two brakes, and each brake individually

# Dynamic Brake Test

- $t < 0$  s: moves at maximum, constant speed ( $\approx 1500$  rpm)
- $t = 0$  s: test command issued  $\rightarrow$  frequency converter shuts down almost immediately, brakes require a certain time ( $\approx 0.2$  s) to engage  $\rightarrow$  acceleration
- $t > 0.2$  s: braking effect
- Standstill  $\approx 1.3$  s after brakes engaged



# Dynamic Brake Test

- Results were compared with specifications from initial installation
- Not all such data were available, documentation was incomplete, only values for individual brakes but not for combinations
- One brake was found to be not properly function and need to be repaired
- Braking times did not always meet specifications: partially too short (→ increased mechanical stress), partially too long (→ greater coasting distance)
- Calculation of missing values and repairing defective brake currently ongoing

# Summary

- Refurbishment of the crane went as smooth as reasonably possible
- Remarkable results from brake test
- Similar renovation will be carried out for three additional cranes at FRM II in the near future  
→ experiences and insights gained will contribute to an even better and faster outcome

# Thank you for your attention!