THE CHALLENGES INVOLVED IN DEVELOPING A POWER SUPPLY, COMMUNICATION SYSTEM AND DRIVE UNIT FOR A DEEP ICE CORE DRILLING RIG.

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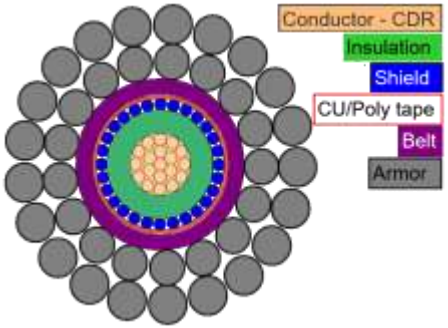
Motivation / Requirements

- After EPICA (1996-2001) interest grew to drill an older ice core.
- Keeping ice coring drill technology alive in Europe.
- More downhole power and date rates, requested.
- Wish of reusing similar / same power supply, motor and modem:
  - Deep and shallow drilling
  - Deep drill and loggers

Early evaluations

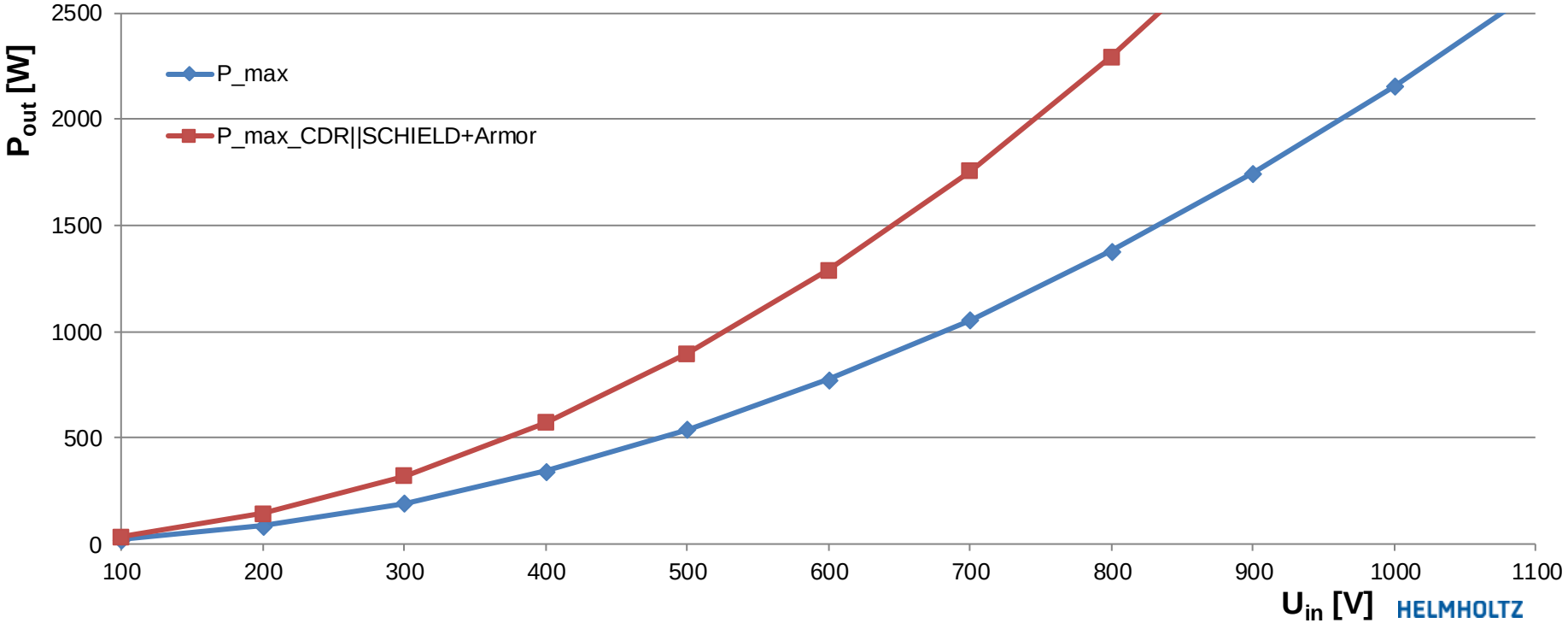


- Winch and Cable dimensions fixed early.
- Investigations into fiber-optical communications.
  - Cable stretch too high during core break / fast travel.
- Wire dimensions optimization, showed that coax in steel armored cable, close to optimum in given dimensions.
  - Higher downhole power require higher voltage!

Power requirement

Higher electrical power then in EPICA / GRIP version.

- Bottleneck: Vicor DC/DC converter, rated for 600W



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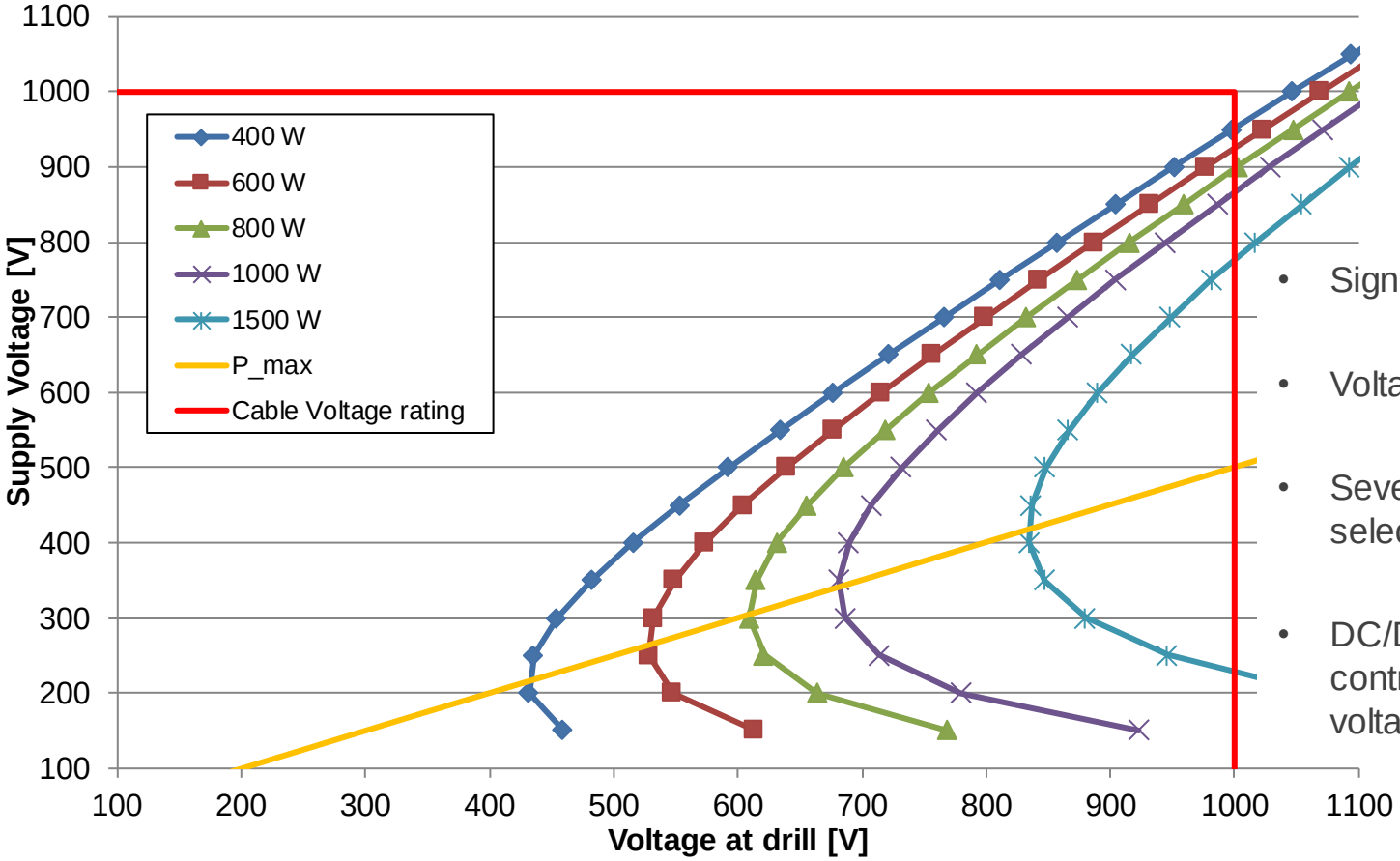
Voltage variations



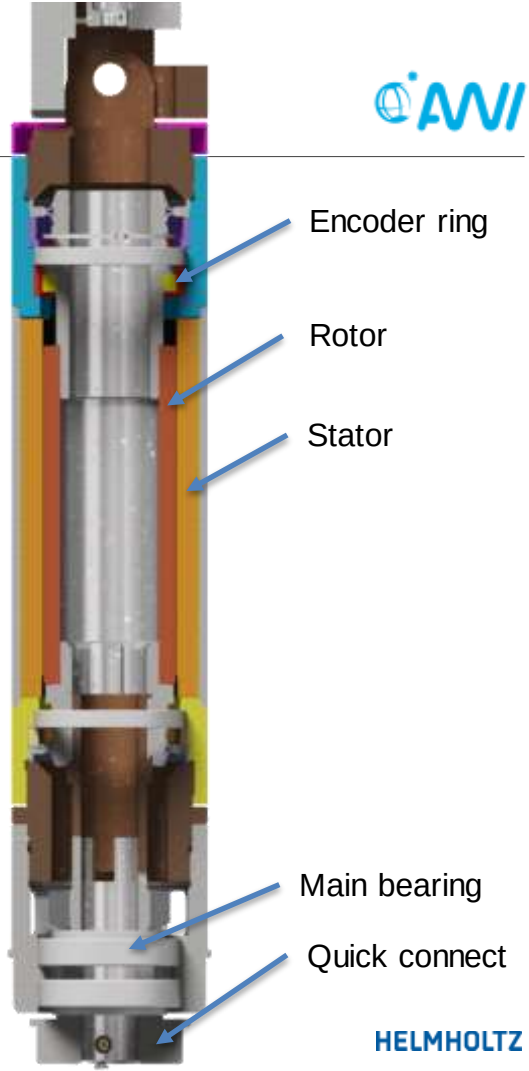
- Significant voltage drop at drill.
- Voltage rating of cable, limits.
- Severe impact on component selection and size.
- DC/DC converter, motor and controller need to accept large voltage range

Selected Motor and Controller

- Cable voltage direct to motor controller
- Direct drive with brushless motor
- Pressure neutral design
- Hollow shaft reducing liquid resistance while winching

- Challenges:
  - Low rotation speeds (10-200 RPM)
  - High torque (60-80 Nm) without gear
  - Custom motor integration

- Problems:
  - Integrated Hall sensors not working
  - Availability of comonents



Electronic Section

- Dedicated pressure housing for electronic
- Integration of high voltage components
  - Power-line modem
  - Wide input range DC/DC 200 – 1000 VDC
  - Selected motor driver up to 740 VDC

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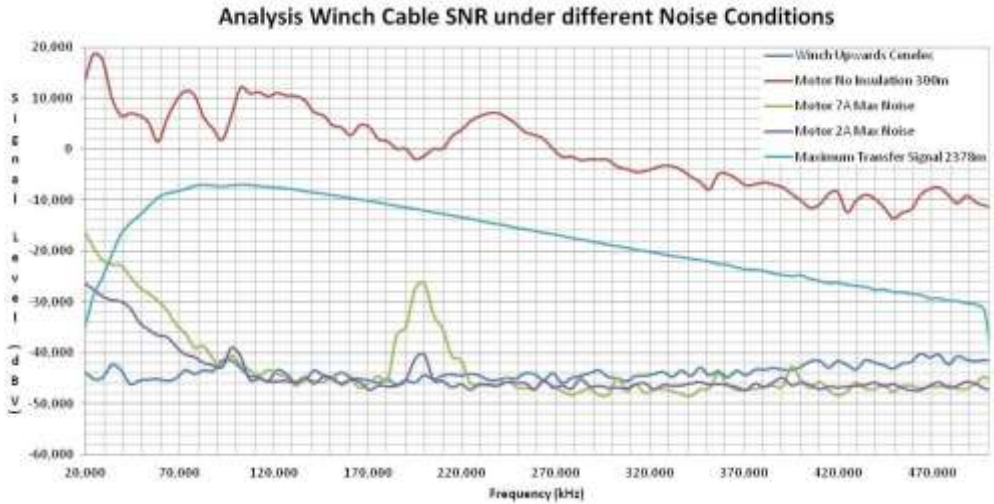
Power-line Communication

- Transparent Ethernet and Serial bridge
- Dimensioning and testing in co-operation with Cipunet®
- Data rates in the range of ~ 20 kbit/s with 300 ms ping latency
- Noise from motor controller challenging to decouple

Source: Lemburg



Winch cable characterization test at Kohnen station in 2018

Field testing during development

- 2016 - Neumayer III
  - Feasibility of motor and controller
  - 101m shallow core
  - Too low supply voltage (195VDC) / COM failure of RS485

- 2017 - EastGRIP
  - 80m shallow core
  - Increased supply voltage 325 VDC
  - Power transmission sufficient for lower torque shallow coring setup
  - RS485 COM working (noisy at high currents)

- 2018 - Kohnen
  - High voltage drive and power-line modem
  - Artificial mechanical load

BEOI Field Seasons

- 2019/20 - Camp Setup
- 2020/21 - Covid Cancelation
- 2021/22 - Pilot hole / Deep drill setup

- 2022/23 - Deep drilling (130 – 804 m)

First time at a drill site
Firm- & Software not finished

- 2023/24 - Deep drilling (804 – 1836 m)

Started to drill /
failing to hold higher torque

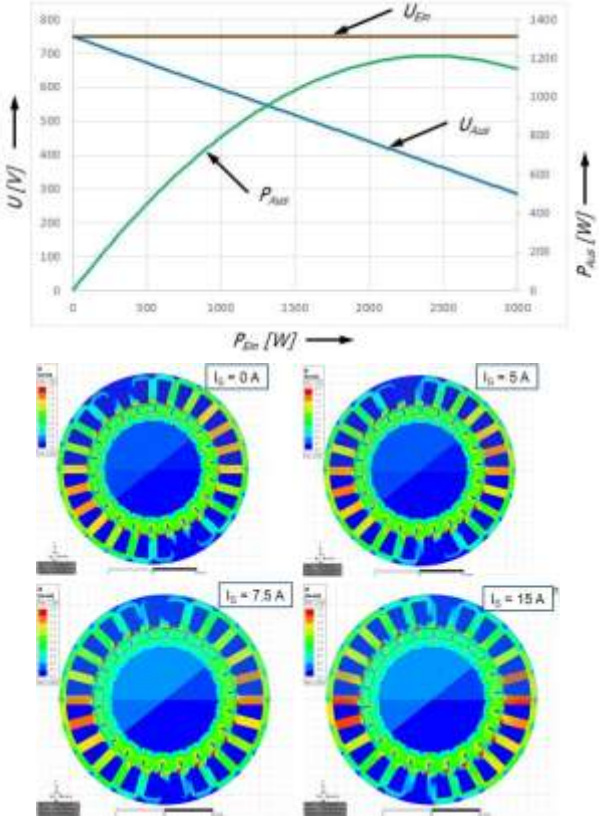
Fallback to NBI Motor for drilling

- 2024/25 - Deep drilling (1836 – 2804 m)

- 2025/26 - Planned (Bed rock / deviation drilling)

Failure Investigation

- Re-evaluation of power delivery
  - Numerical simulation of dynamic voltage behavior on the cable
  - No issues found / better then assumed
- Started with re-design of motor (supplier not responding)
- Re-design showed error in previous assumptions
  - High torque values possible, but with much higher losses as planned
  - Efficiencies drop to < 50% at 65 Nm (P_{mech}: 400W @ 60RPM)



Mitigation Strategy

- Power supply already maximized for given cable
- Motor re-design showed only minor optimization potential in given dimensions
- CDR||Shield + Armor less resistance, but potential impact on modem, not as safe

- Best option of increasing efficiencies by increaseing RPM
- Chip transport is limiting the RPM
- Gear required

Planned next version includes a gear

Challenges:

- Pressure neutral
- Acceptable gear ratio limited by viscosity

Follow-up / related talks

- A new dynamometer for testing ice core drill motors and gears
- Resilient gear design for deep ice drilling systems (Lemburg)

Other Problems Encountered

- Initial contractor lost 90% of engineers (buy out)
- High complexity
  - Physical limits of conductor
  - Highly inter-dependencies between systems
  - Deep knowledge in multiple disciplines required
  - Small engineering teams
- Long project phases problematic for suppliers and spare parts
  1. DC/DC Converter - N/A after Covid supply chain issues
  2. DC/DC Converter - N/A sanctions after Russian invasion
- Covid supply chain shortage
  - Re-design of Main Controller PCB
  - MCU, Components: N/A or price increases up to 100x
- Equipment re-work between Antarctic seasons impossible
  - Global logistic disruptions
  - Air cargo capacity almost zero
  - EU customs bureaucracy

Questions

Thanks for your attention.

Any Questions?

Abstract

- **THE CHALLENGES INVOLVED IN DEVELOPING A POWER SUPPLY, COMMUNICATION SYSTEM AND DRIVE UNIT FOR A DEEP ICE CORE DRILLING RIG.**

We will provide a comprehensive overview on the development process of the electric power train and mechanical drive chain of a deep ice core drill system, with particular emphasis on the challenges encountered during the Beyond EPICE Little Dome C deep ice coring operation.

The covered deep ice-coring drill-system is one of the frequently used, cable-suspended, electro-mechanical ice-core drill types. In such systems, the electrical power and communication are transmitted via the conductors inside the winch cable. The intended drive chain was a brushless motor without a reduction gear.