Using Tools & Engineering Services to Solve Motor and Inverter Problems

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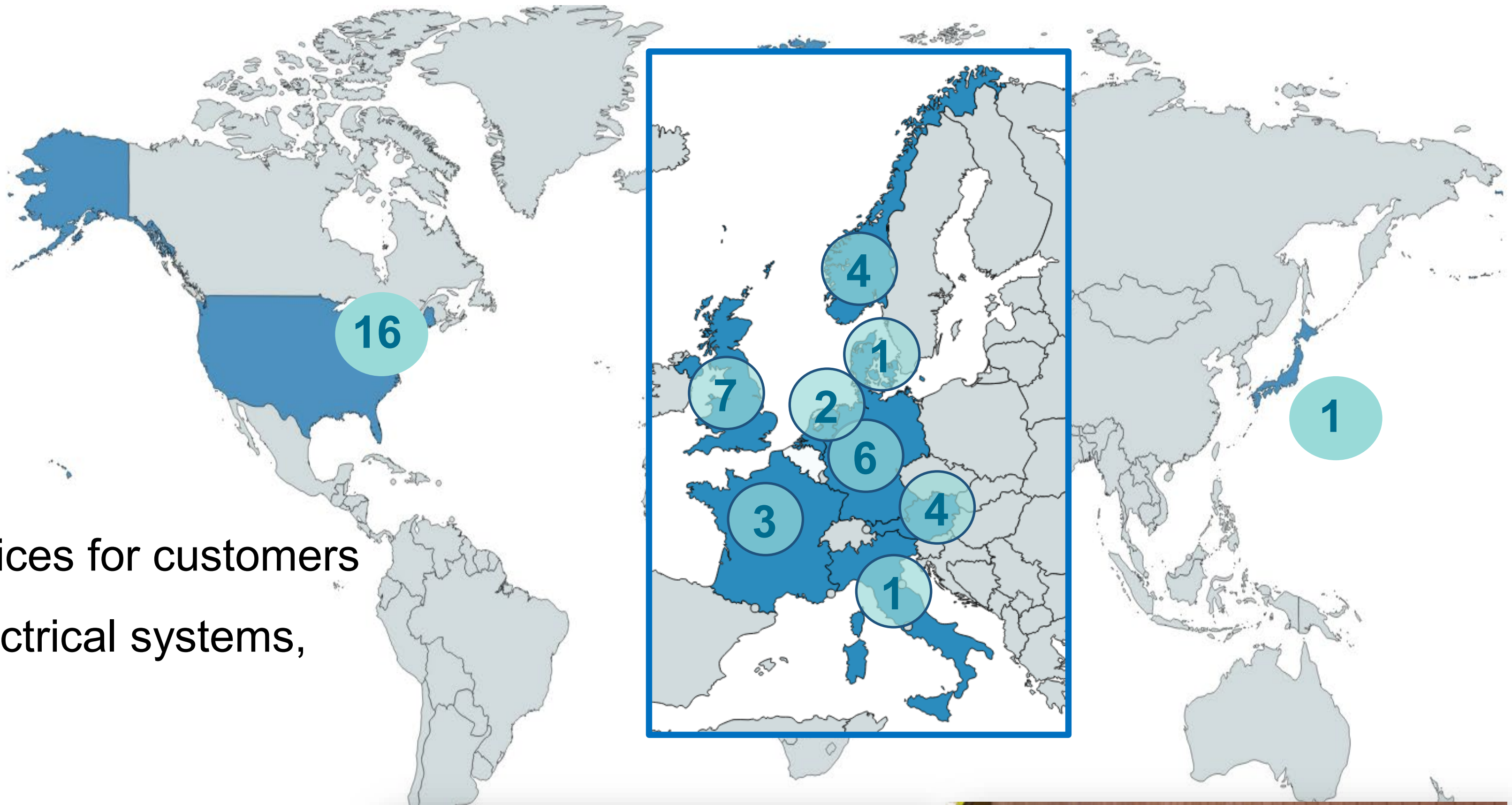
HBK’s Engineering Services team has the eDrive tools and expertise needed to quickly address customers’ needs.

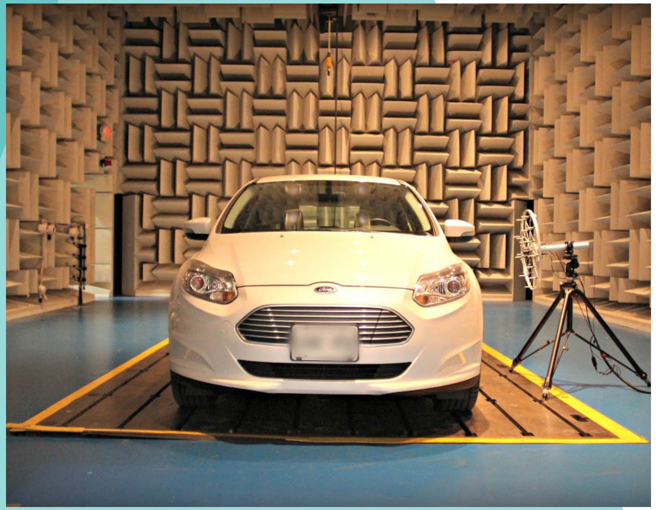
This presentation will give a brief explanation of motor parameters that often correlate to NVH issues, and an example of how the eDrive system was deployed in the field.

Engineering Services
Global Footprint

- 16 in NA (Canton, MI)
- 28 in EMEA
- 1 in JAPAN (Tokyo)

Our team specializes in consulting services for customers who need help with noise, vibration, electrical systems, force, and/or strain.





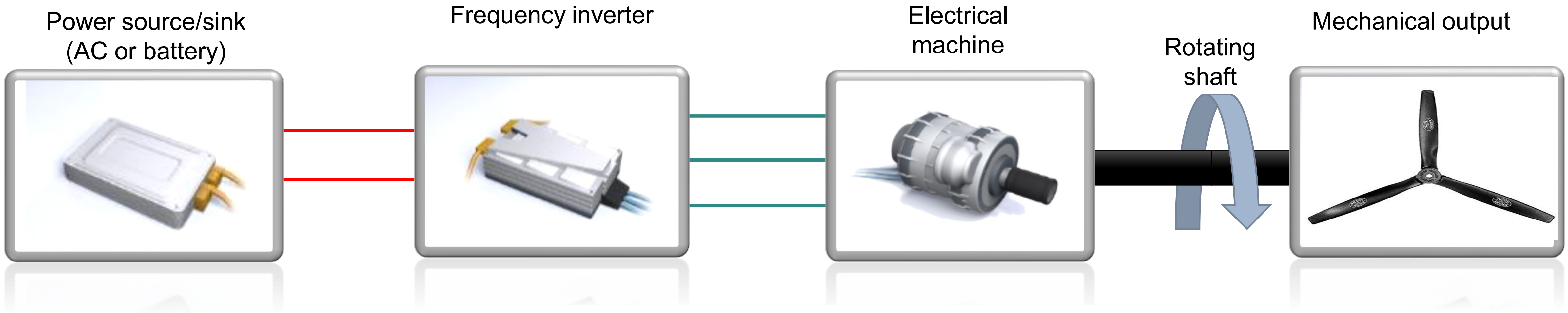
Electric Motors and NVH Implications

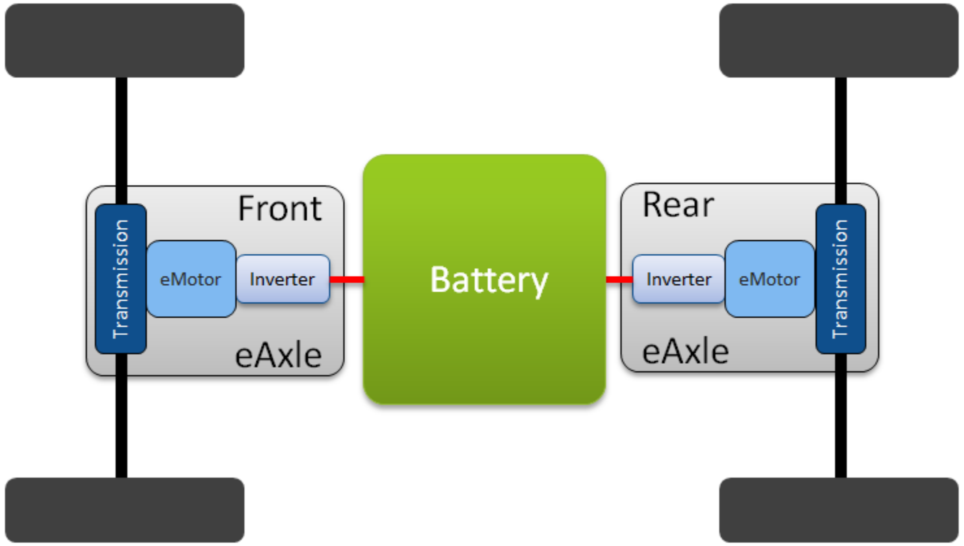
- Electric motors are being used in industries like automotive and aerospace to improve or replace traditional energy sources. Benefits can include mass, packaging, thermal performance, and cost.

- In these new applications, motors cause Noise & Vibration issues which can be very foreign to users. In the case of vehicles, removal of the Internal Combustion Engine (ICE) reduces the background noise which masks other noise sources. Introduction of an electric motor and inverter presents new higher frequencies which drivers may not understand.

- HBK has developed tools and expertise to face these challenges. The Engineering Services team has also applied these for other applications (see case study).

Simple Measurement Chain - Electric & Mechanical Measurements





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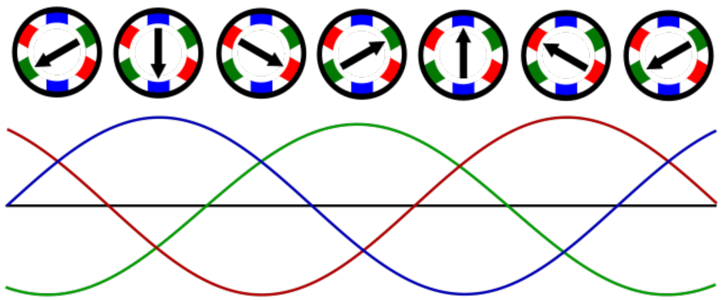
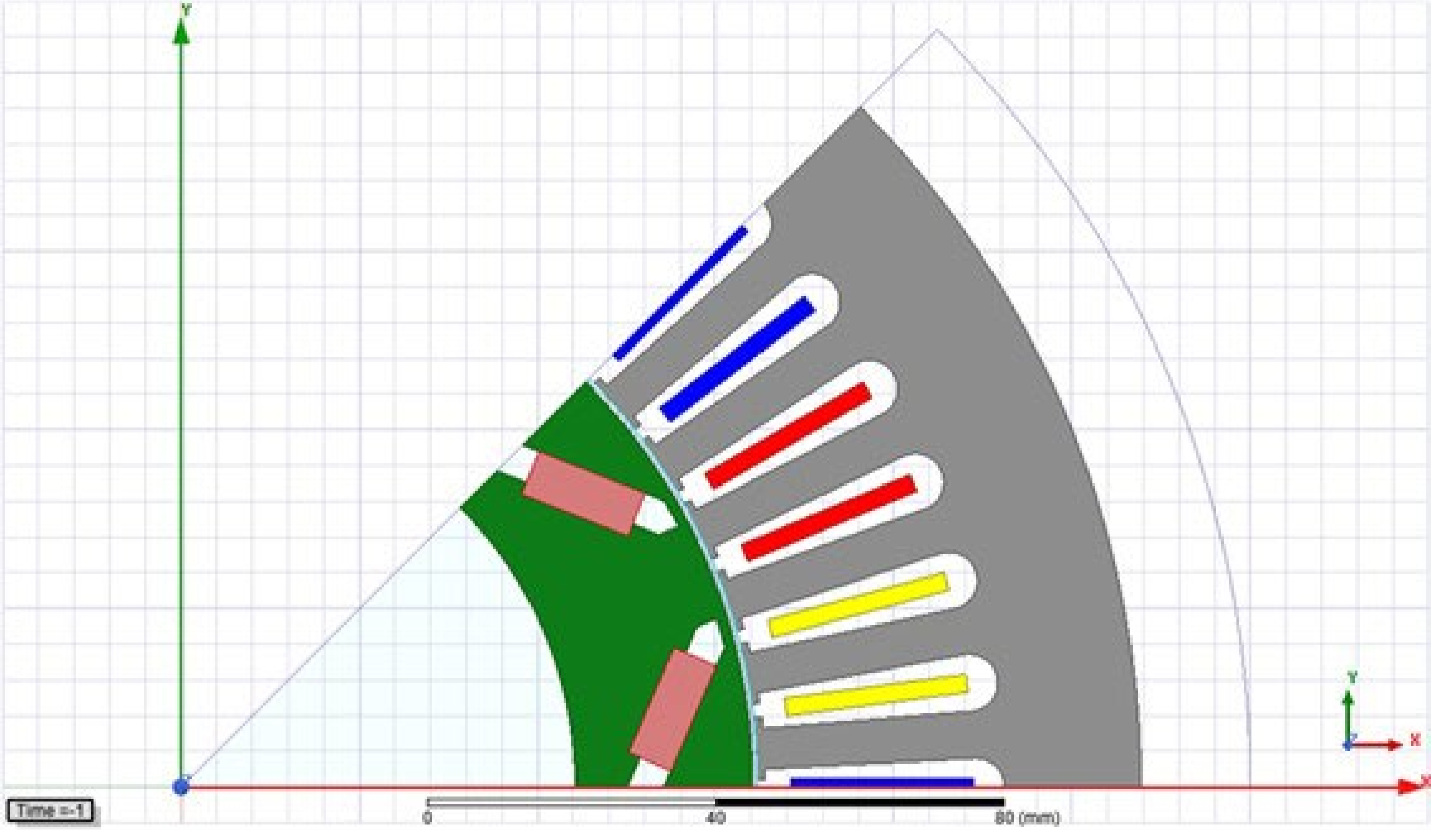
Motor construction – Sources of vibration



- Torque follows the envelope of AC excitation
  - Slow speed ripple proportional to electrical frequency
  - Function of winding distribution
- Permanent magnets interact with slot teeth
  - Magnets want to stick to iron
  - Function of magnets
  - Function of slots
- Also applies for induction machines and reluctance machines
  - The rotor is magnetized



Single motor pole for a PM machine highlighting iron slots and widnings

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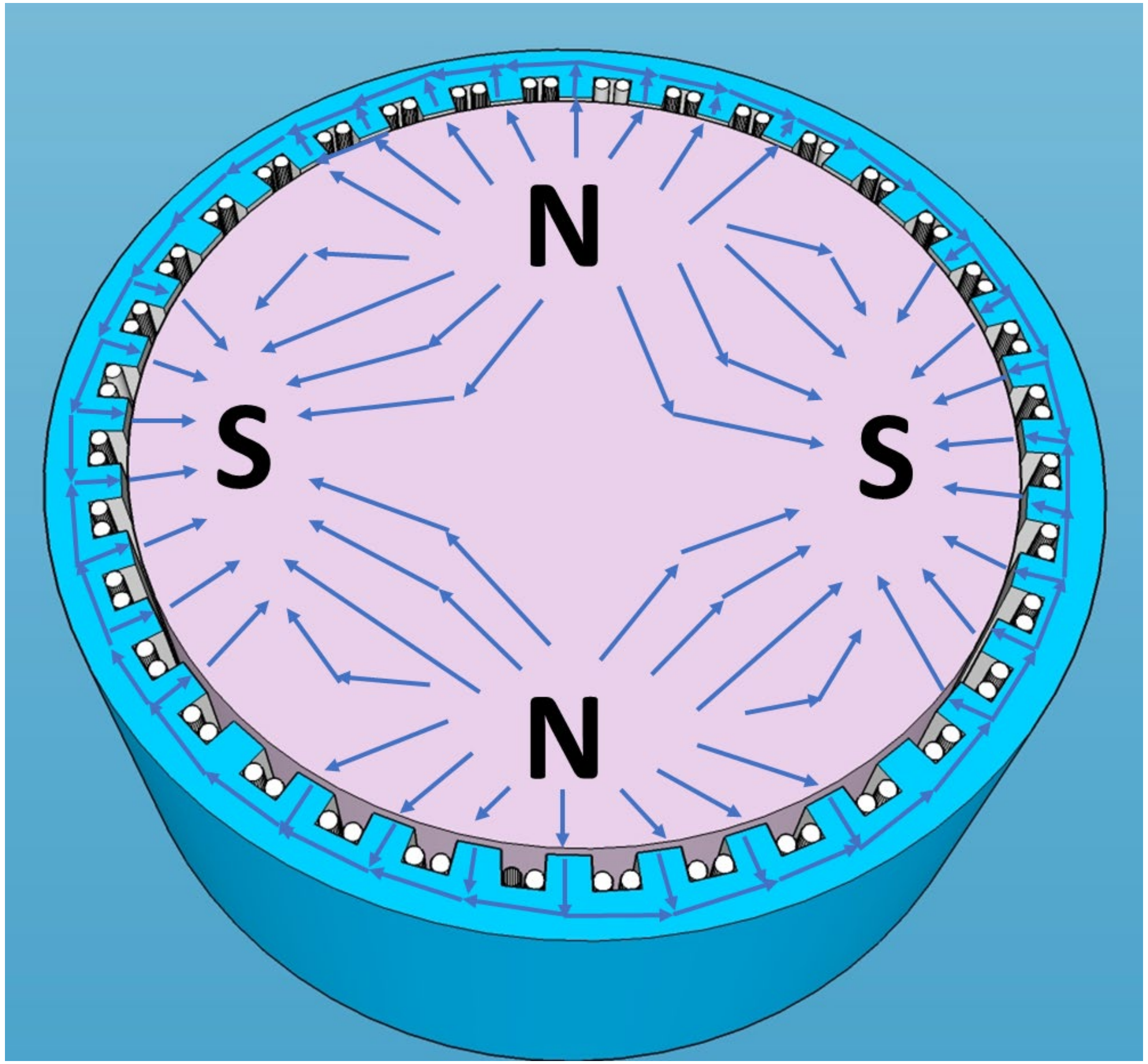
Motor construction – Sources of vibration



- Consider the simple synchronous motor. The rotor is a powerful magnet, the stator is iron, and they are separated by as small of a gap as possible
- Thus, huge radial forces are exerted on the stator, and these forces move as the rotor moves
- Tangential forces produce motor torque (and torque ripple), but **strong radial forces are produced that radially load the stator housing and produce noise**
- The **fundamental excitation frequency** is:

$$f_{ex}(Hz) = \frac{pN}{60}$$

p is number of poles
N is the rpm

- Also, noise corresponding to number of slots

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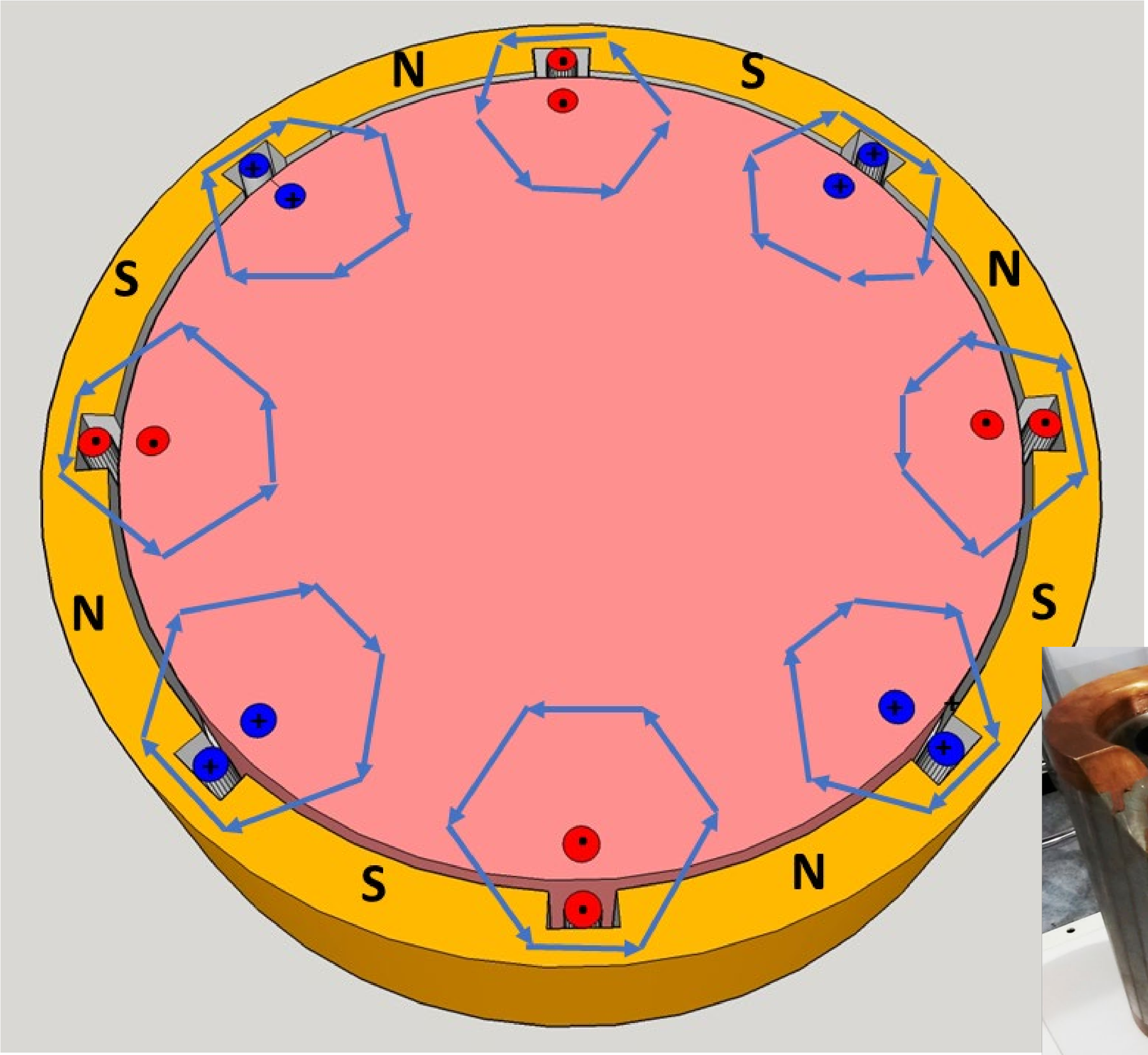
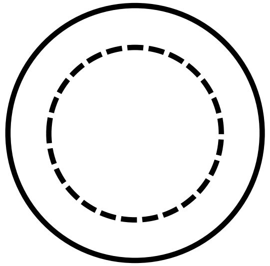
Motor construction – Sources of vibration

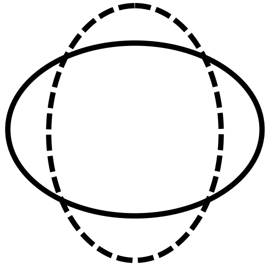


- Induction motor (IM) is shown
- **Current from the stator coils induces current in the cage (rotor conductors)** which produces a magnetic field in the rotor – like a transformer!
- Slip is the percent difference between rotor speed and energizing speed
- Unlike a synchronous motor, the rotor speed must be slower than the excitation of the stator.
- **Fundamental excitation frequencies corresponding to both the number of poles and the excitation frequency**

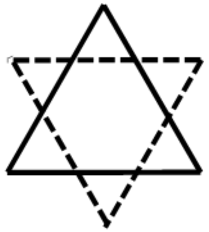
Motor construction – Sources of vibration



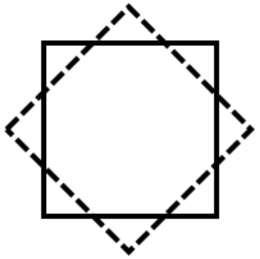
Breathing Mode



First Cylindrical Bending Mode



Second Cylindrical Bending Mode



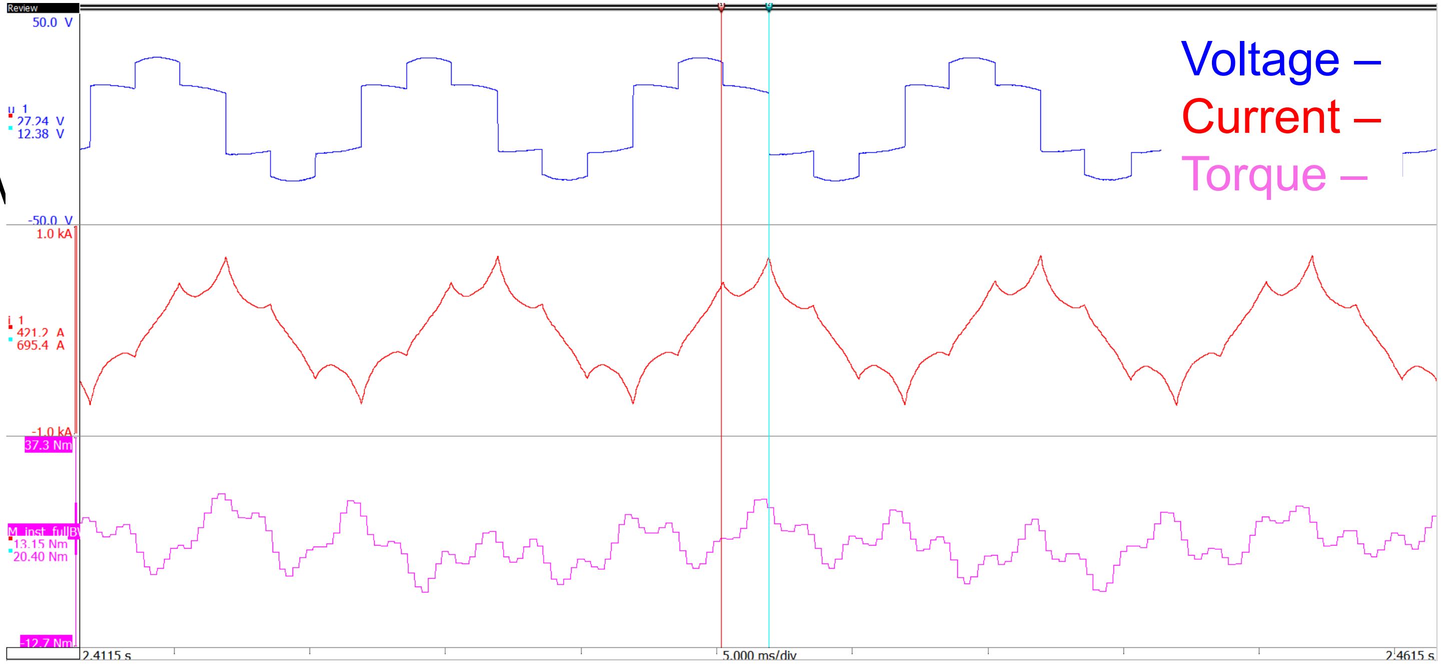
Third Cylindrical Bending Mode, etc.

- The stator is approximately a cylindrical shell that has natural frequencies
- These are excited by the radial forces
- Degree of excitation depends on participation factor (spatial and temporal matching of force and mode shape)
- Generally requires software (such as EOMYS Manatee) to determine the level of excitation
- Best designs preferentially excite higher modes, have more poles, have many slots, and are multi-phase
- Skewing and pole shaping to smooth excitation from on to off – analogous to using helical gears rather than spur gears

Inverter operation

- Inverter often creates AC with a Pulse Width Modulated voltage
  - Pulses of different length create a sine wave
  - Unequally timed pulses result in multiple frequencies of NV
- PWM voltage → PWM current → PWM Magnet → PWM torque → PWM NV
  - Noise and vibration at switching rate
- Many more controls than PWM

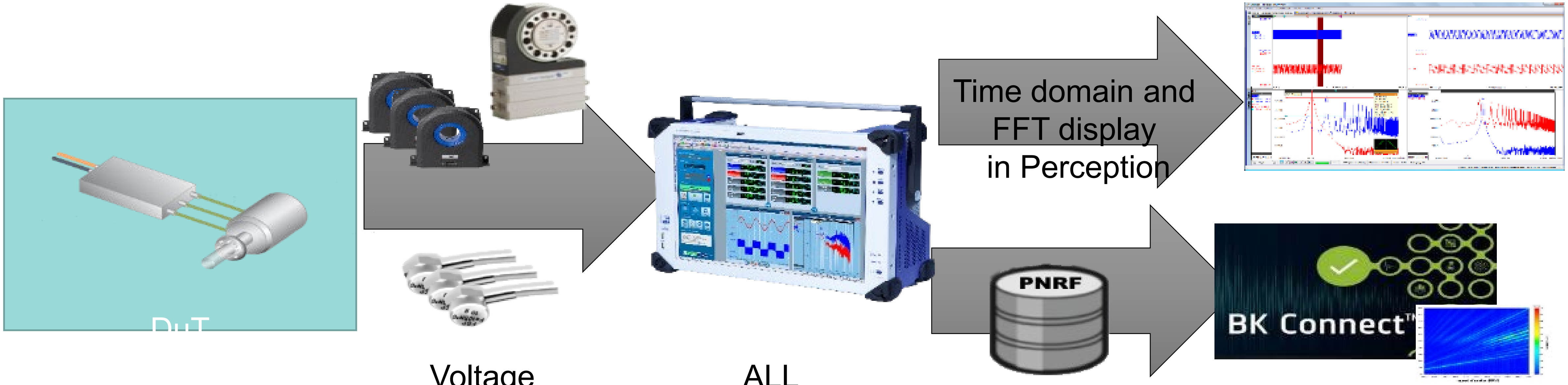
PWM to Synthesize Sinusoidal Output



Voltage, current, and torque highlighting the correlation between the 3 values

Electric Powertrain and NVH Testing

- Genesis eDrive to record data - safe measurement of high voltage and acquisition speeds up to 1 GHz
- Data analyzed using BKConnect - fast and powerful NVH analysis



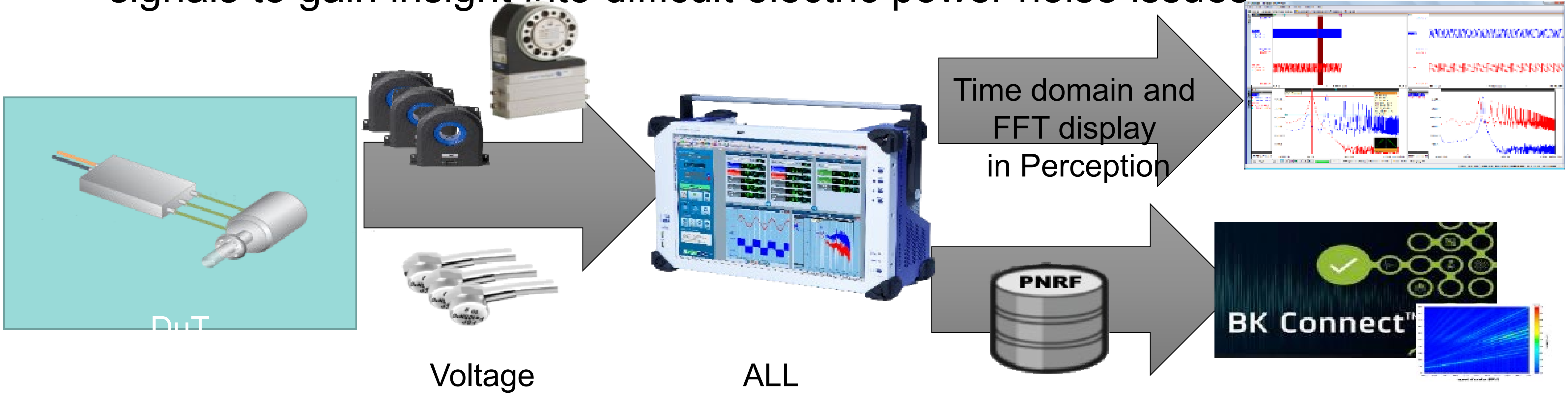
Voltage
Current
AND
Acceleration

ALL synchronously and continuously recorded with eDrive

Post process analysis in BKconnect

Recording Data with Genesis eDrive

- Put another way, for the N&V engineer Genesis eDrive is used as a high-speed, high-voltage data recorder!
- This allows side-by-side recording of current, voltage, sound, and vibration signals to gain insight into difficult electric power noise issues



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Genesis High Speed

- Genesis High Speed with Perception Software
  - Sample rates up to 250 MHz, 64 bit
  - Measurement of voltage up to 1000 V
  - Microphone/accelerometer/torque meter compatibility
  - Output compatible with traditional N&V system inputs (UFF and prnf)

- Perception/BKConnect compatibility
  - **Traditional N&V analysis (colormaps, sound quality, ODS, etc.) with simultaneous current and high-voltage measurement**


Case Study: Background

Motor Measurements to Identify Erratic Performance

- Our customer provides 75+ motorized units that all run simultaneously for a cooling application. They had experienced erratic performance on a select group of motors, and needed to collect data to identify abnormal operation that could help root cause analysis.

- Customer did not have resources or experience to deploy such a measurement system. It would need to be in place for an extended period of time to record data during normal use.

- The objective was to monitor motor parameters simultaneously to identify anomalies in specific motors.

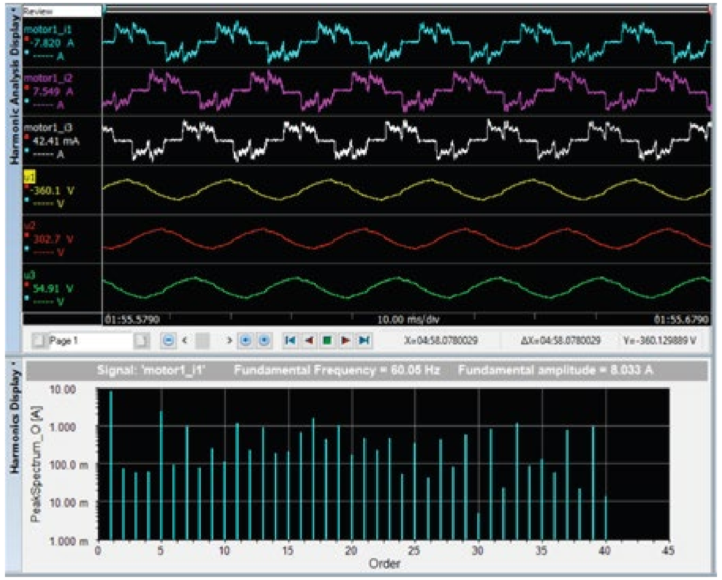
Case Study: Solution

Motor Measurements to Identify Erratic Performance

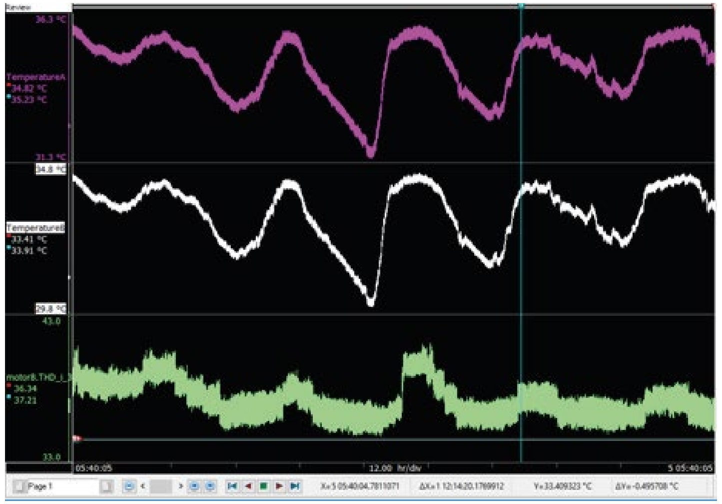
- Where/What did we instrument?
  - Genesis High Speed Data Acquisition System GEN7tA: 30 channels
  - 3Φ Voltage at common point of couple
  - Current at 8 motors, 3Φ each
  - Operating temp

- Software - Perception Data Analysis Software version V8.14
  - Formulas added to trigger based on total harmonic distortion (THD) level
    - 1 second total triggered acquisition, 0.4 second pretrigger
  - Untriggered data stored at 1 kHz sample rate
  - Triggered data stored at 200 kHz sample rate

- Several parameters were measured/calculated:
  - RMS
  - Power (V & I)
  - Efficiency
  - Total Harmonic Distortion
  - Individual harmonic



Various harmonic waveforms



THD & Temp

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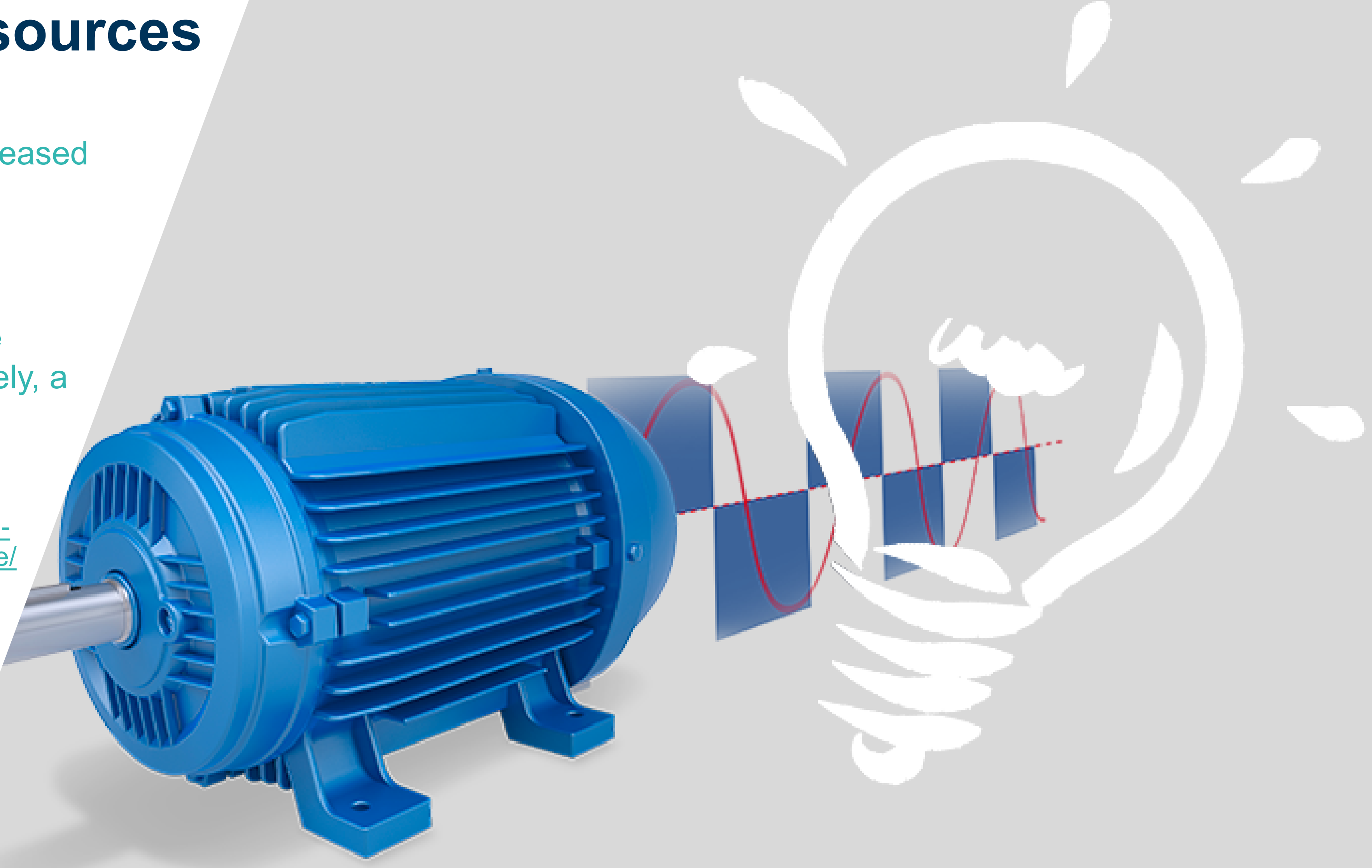
Conclusions & Resources

Analysis identified motors with increased temperature and Total Harmonic Distortion.

This identification led to root cause analysis of the failures and ultimately, a more robust system.

https://www.hbm.com/en/10673/monitoring-electric-power-for-extended-periods-of-time/



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