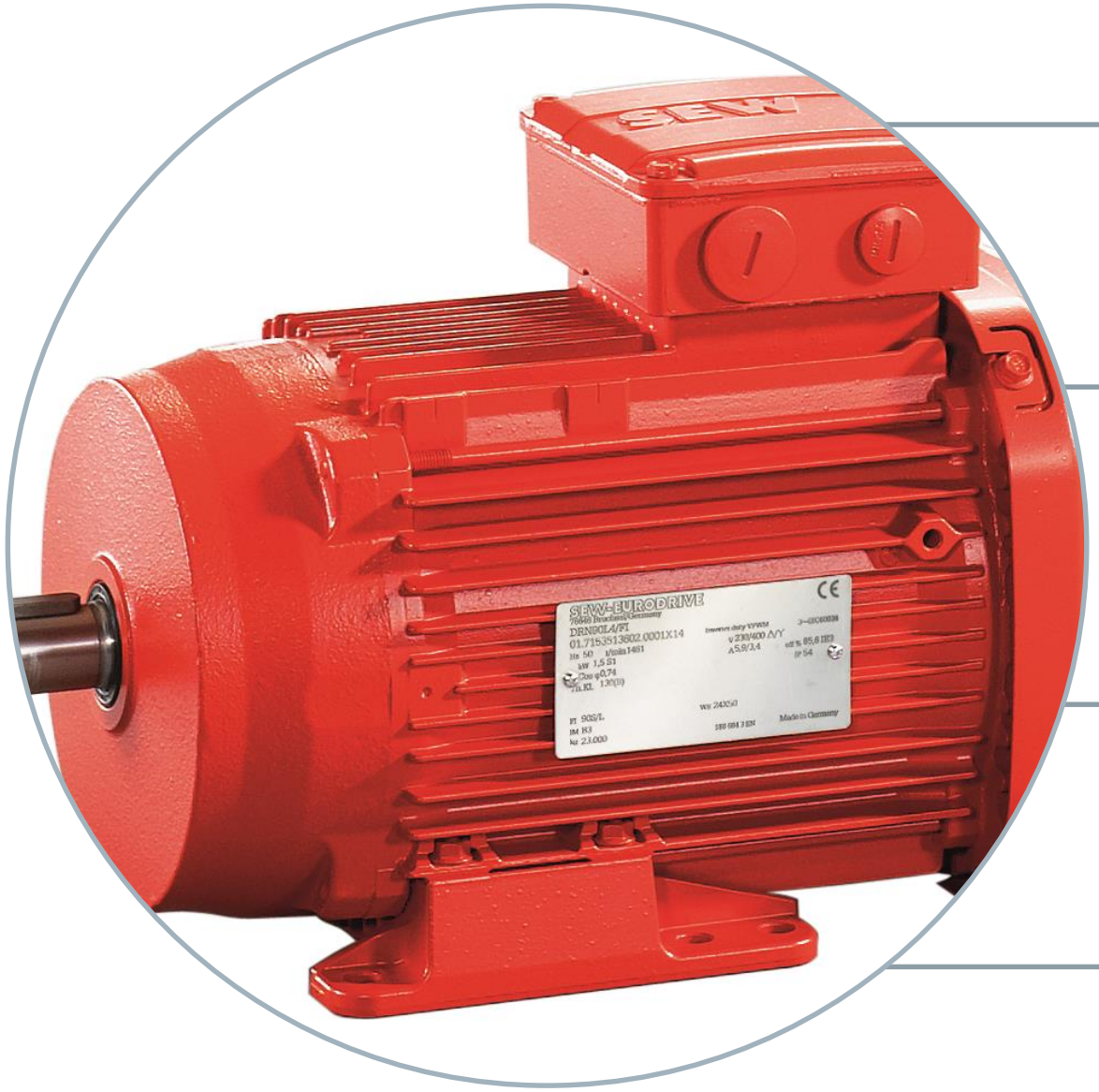
INNOVATIVE
EFFICIENT
RELIABLE
POWERFUL

Induction Motor Computation

Design criteria for induction motors

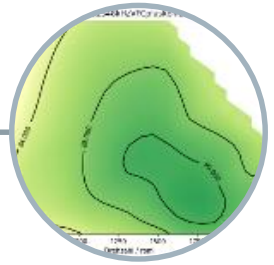


Standardization

- Efficiency (IEC 60034-30)
- Sizing (IEC 60072-1)
- Measurement methods (IEC 60034-2-1)

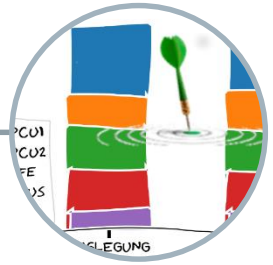
Variety / Customization

- Behaviour under grid restrictions (IEC 60034-1)
- Winding variants
- Cooling methods (IEC 60034-6)



Inverter controlled drives

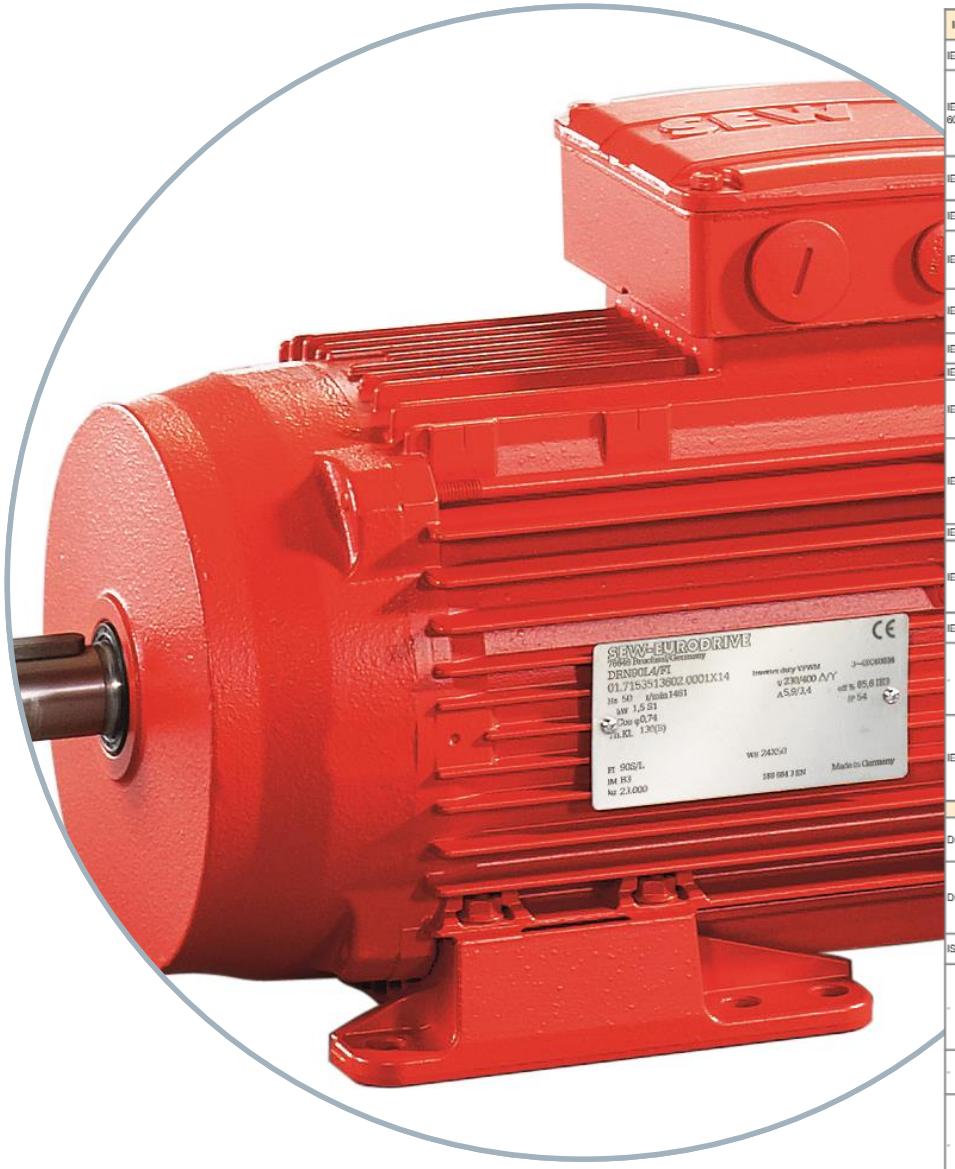
- Behaviour at different setpoints (IEC 61800-9-2)
- Possible Basis: Equivalent circuit data (IEC 60034-28)



Design criteria

- Comply with all given constraints
- Minimize resources / costs

Design criteria for induction motors



International Standard IEC	Harmonized European Standard	Description
IEC 60034-1 +A1 and A2	EN 60034-1+A1, A2 and All	Rotating electric motors. Part 1: Rating and design
IEC 60034-2+A1, A2 and IEC 60034-2A	EN 60034-2 + A1 and A2	Rotating electric motors. Part 2: Measuring methods to determine the loss and the efficiency of electric motors (except machines for traction vehicles)
IEC 60034-5	EN 60034-5	Rotating electric motors. Part 5: Enclosure class for rotating electric motors.
IEC 60034-6	EN 60034-6	Rotating electric motors. Part 6: Cooling (IC code)
IEC 60034-7+A1	EN 60034-7+A1	Rotating electric motors. Part 7: Classification of types of construction and mounting (IM code)
IEC 60034-8	EN 60034-8	Rotating electric motors. Part 8: Terminal marking and direction of rotation
IEC 60034-9	EN 60034-9	Rotating electric motors. Part 9: Noise limits
IEC 60034-11	-	Thermal protection
IEC 60034-12	EN 60034-12	Rotating electric motors. Part 12: Start capacity of three-phase induction motors.
IEC 60034-14	EN 60034-14	Rotating electric motors. Part 14: Mechanic vibration for machines with drive shaft heights of 56mm or more. Measuring, estimate and vibration limits
IEC 60038	-	IEC Standard Voltages.
IEC 60072-1	EN 50347	Dimensions and output power for rotating electric motors. Part 1: Frame size 56 to 400 and flange size 55 to 1080.
IEC 62114	-	Electrical insulation systems
-	EN 50102	Degrees of protection for enclosures for electrical equipment against external mechanic strokes. (IK-code)
IEC 60072-1	EN 50347	Three-phase induction motors for standard use with standard dimensions and output power. Frame size 56 to 315 and flange size 65 to 740.
Other Standards		
DIN 51825		Lubricant; lubricating grease K; classification and requirement (1990-08)
DIN 44082		Thermistors; PTC sensors; thermal protection of machines; climate categorization HFF (1985 -08)
ISO 2409	EN ISO 2409	Paints and enamels. Grid cut value.
-	EN ISO 3743-2	Definition of sound power level. Minor removable sources of noise. Engineering method. Part 2: Rooms with sound control
-	EN ISO 4871	Declaration and verification of noise from machines and equipment.
-	EN ISO 11203	Noise from machines and equipment. Measurement of sound pressure by the operator's ear (noise emission). Calculation on the basis of sound power level.

Standardization

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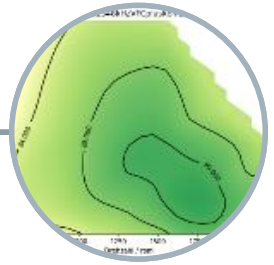

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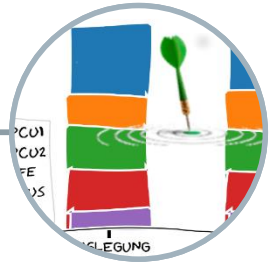

Design criteria

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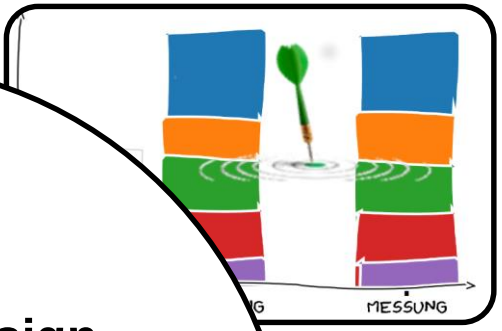
Design cycle for induction motors

- Customized Design



Analytical motor model

Design

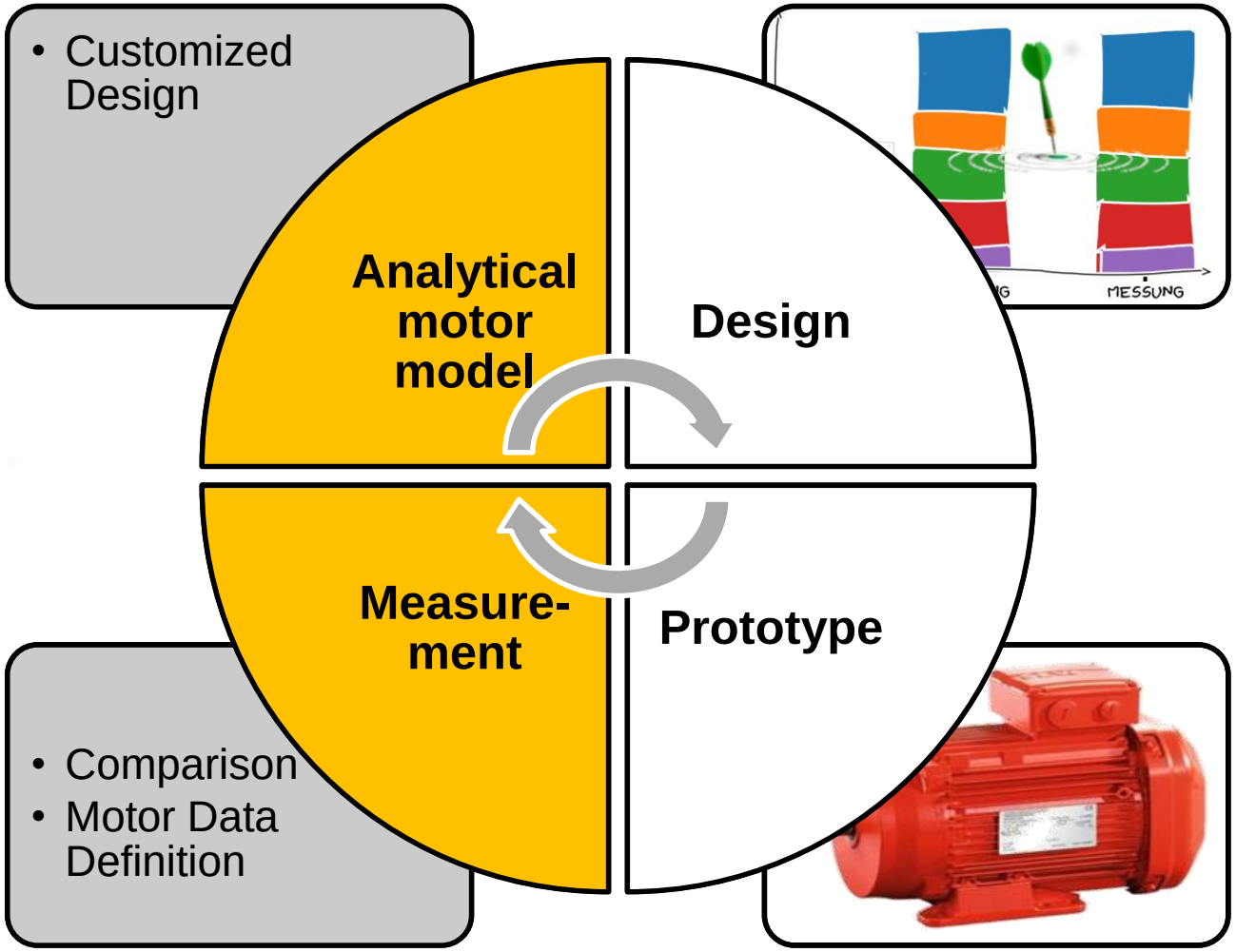
Measure-ment

Prototype

- Comparison
- Motor Data Definition

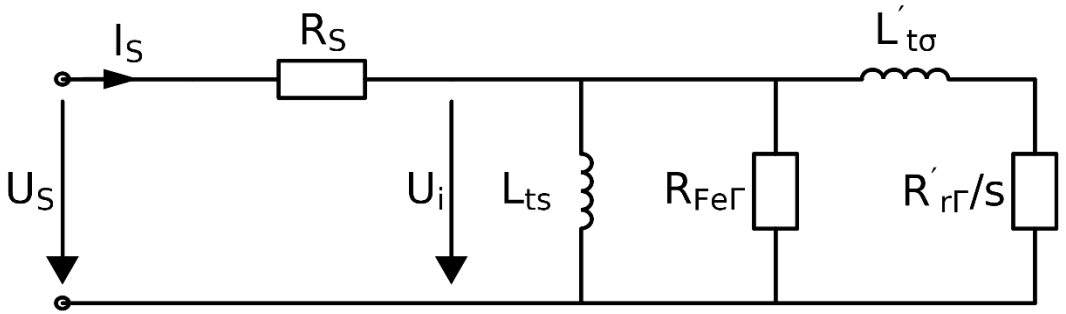
Which came first: Prototype or model?

Design cycle for induction motors



Which came first: Prototype or model?

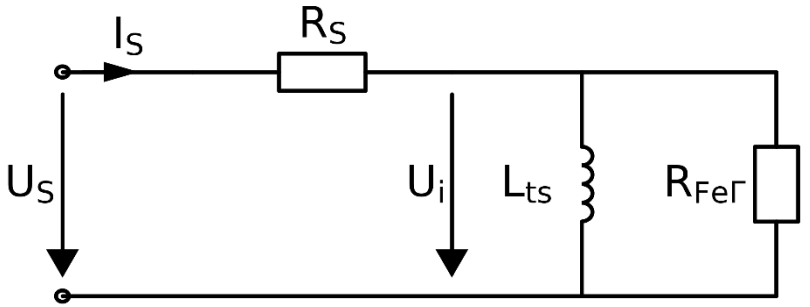
Modeling example: based on IEC 60034-28



Γ-equivalent circuit

Modeling example: based on IEC 60034-28

- No-load test, i.e. $s = 0$
- Measurements of Current and Power for varying Voltage at 60Hz



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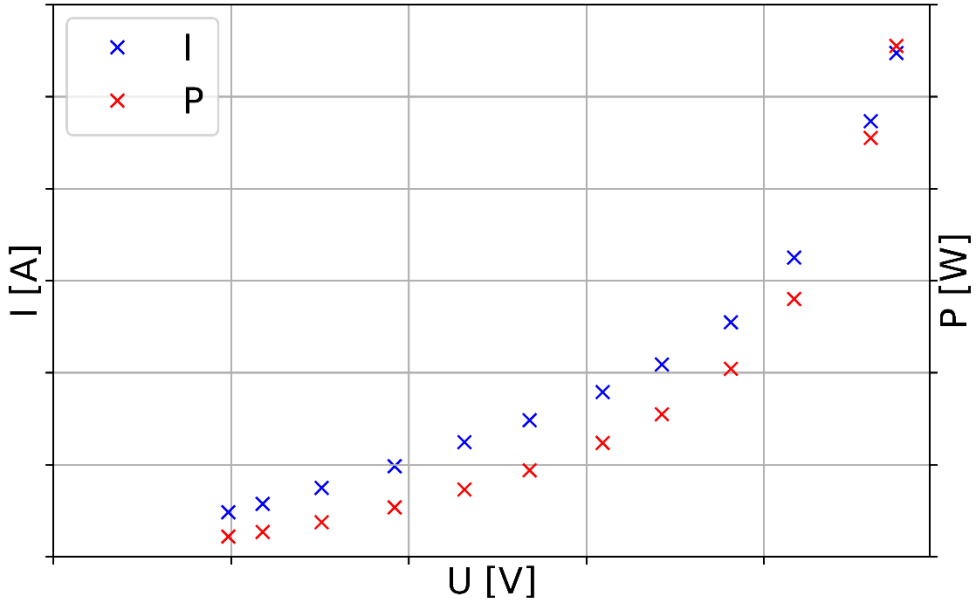

Measurement: no-load test

Modeling example: based on IEC 60034-28

- No-load test, i.e. $s = 0$
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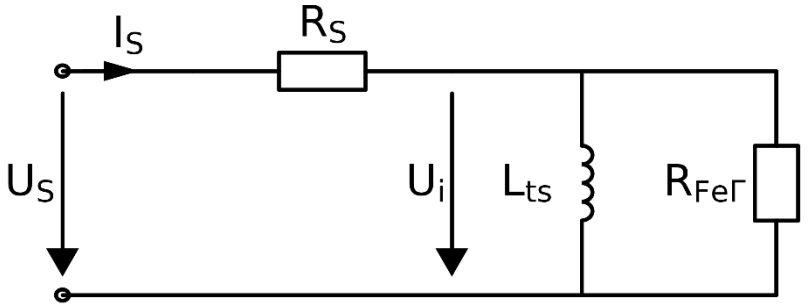
- Get machine data by IEC Standard



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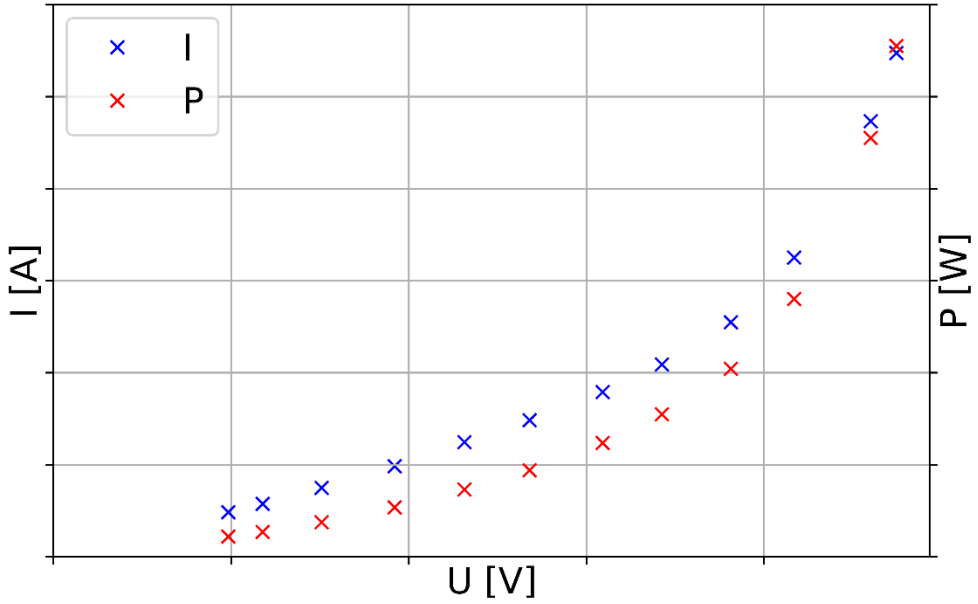

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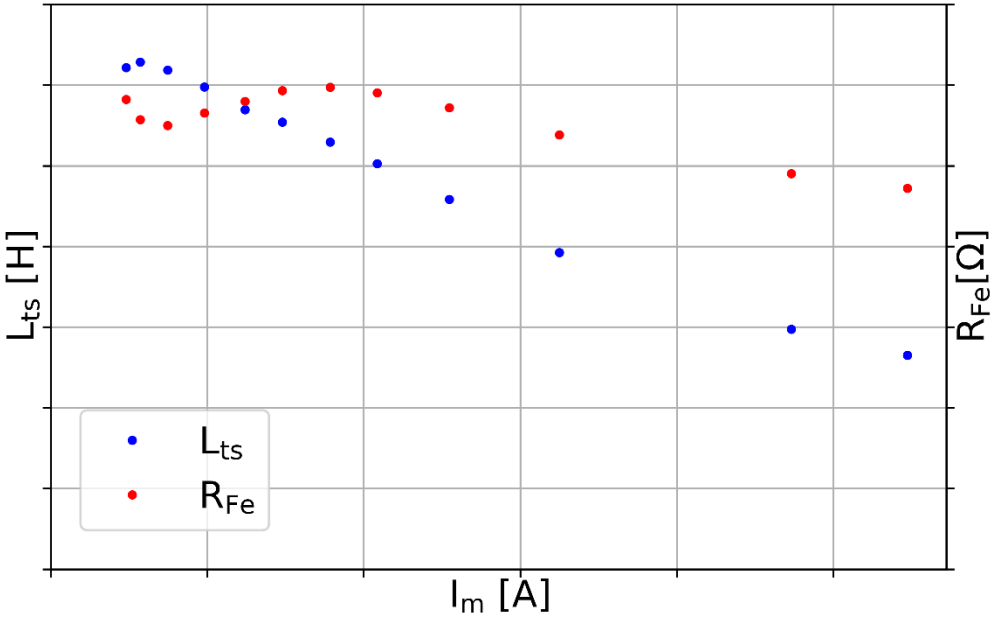

Model data derived from no-load test

Modeling example: based on IEC 60034-28

- No-load test, i.e. $s = 0$
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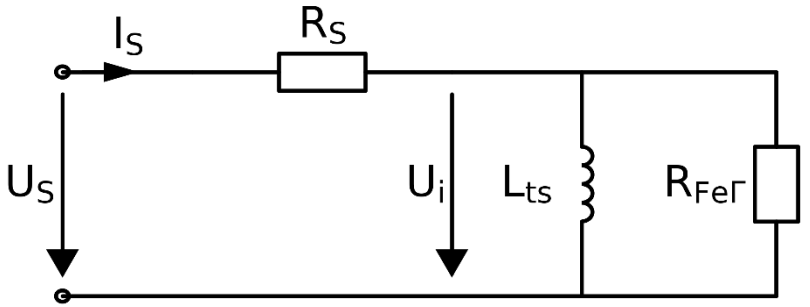
- Get machine data by IEC Standard
- Fit Data to get applicable model



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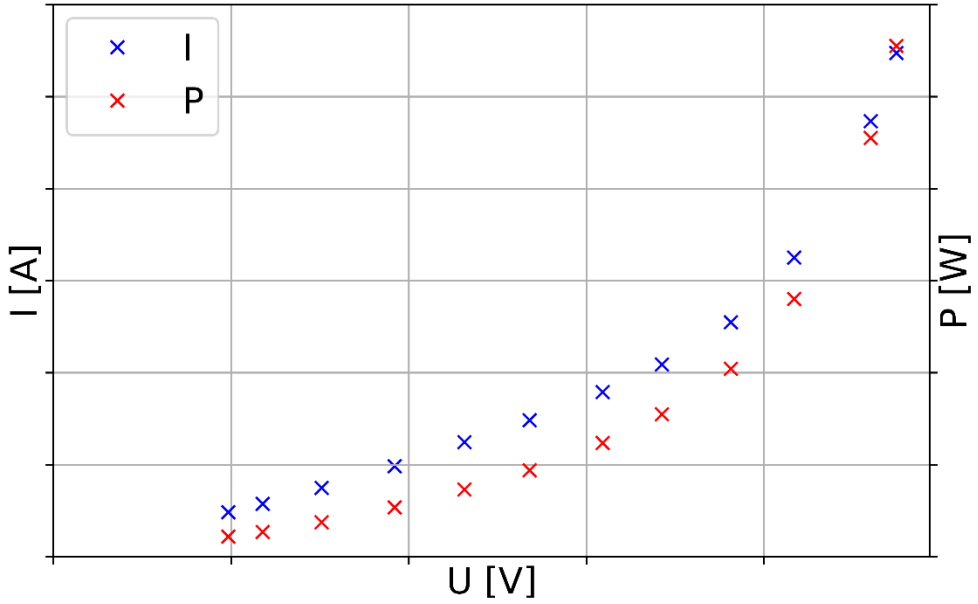

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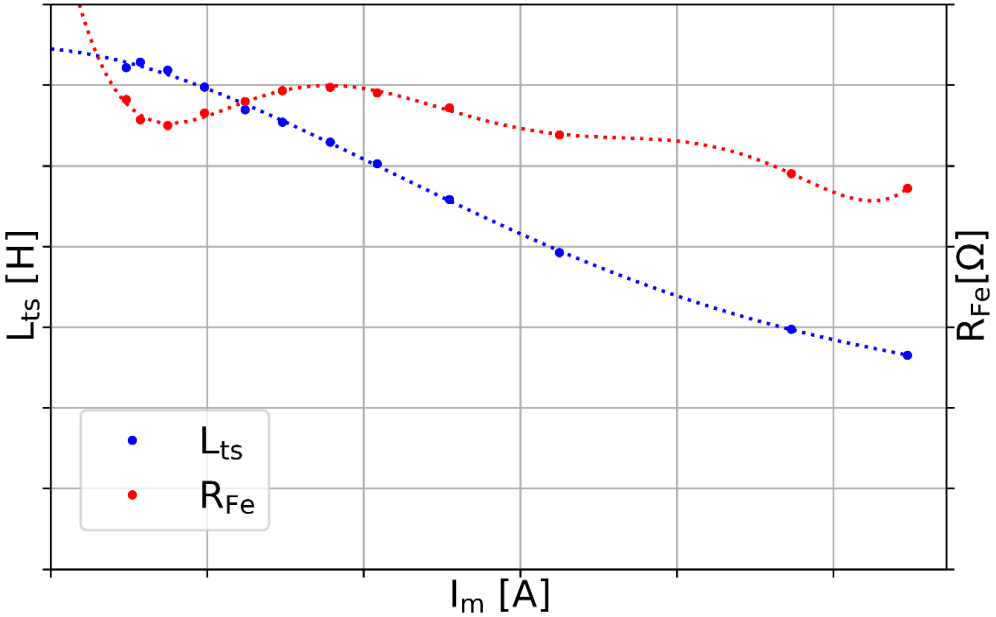
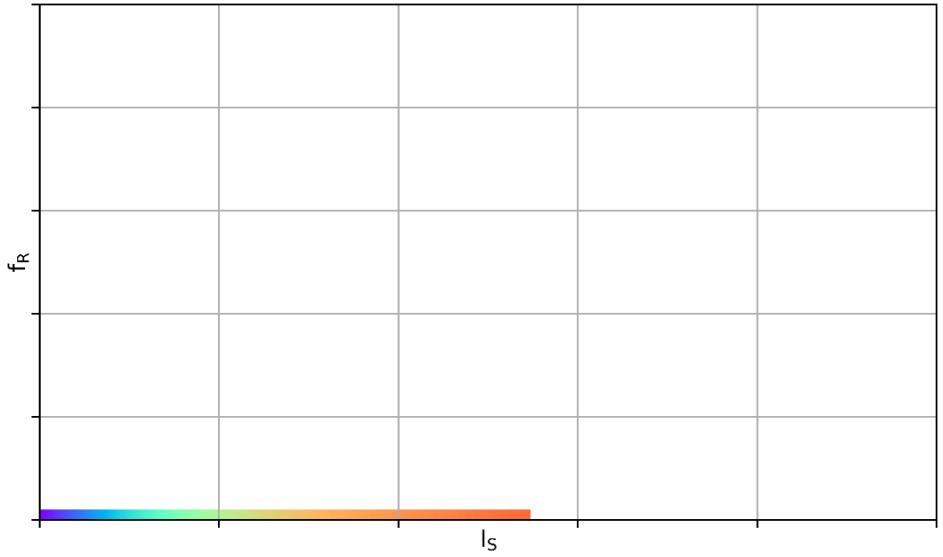


Model data derived from no-load test

Analytical motor models – the big picture

- Induction machine can be described in f_R/I_S-plane (analogy to I_d/I_q-plane for PM) (see e.g. Winzer/Doppelbauer 2013)
- No-load results are for $f_R = 0$



Stator flux (absolute value) from measurement-based model in f_R/I_S-plane

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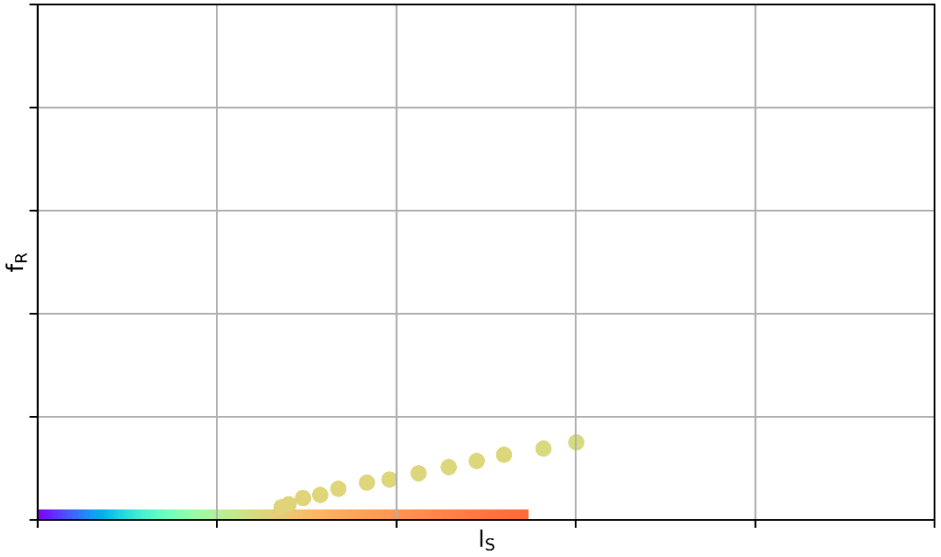

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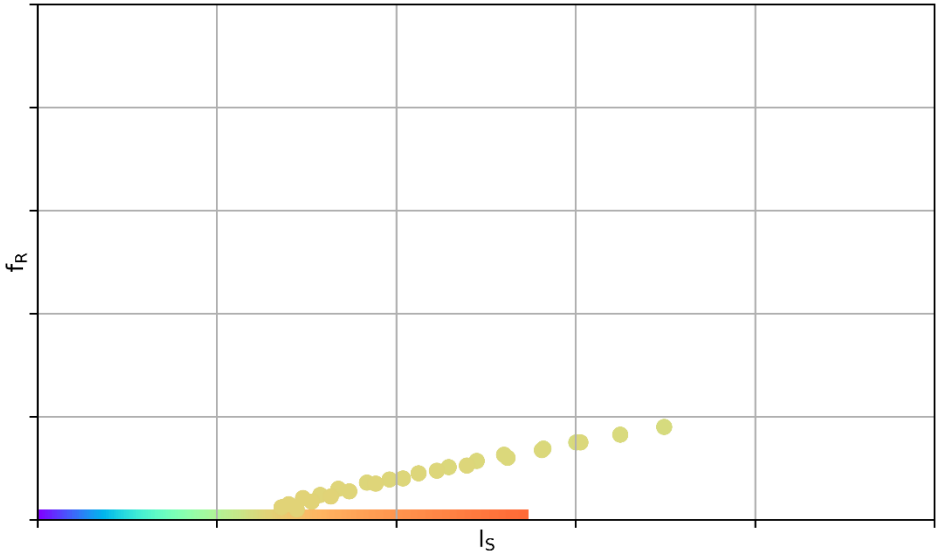

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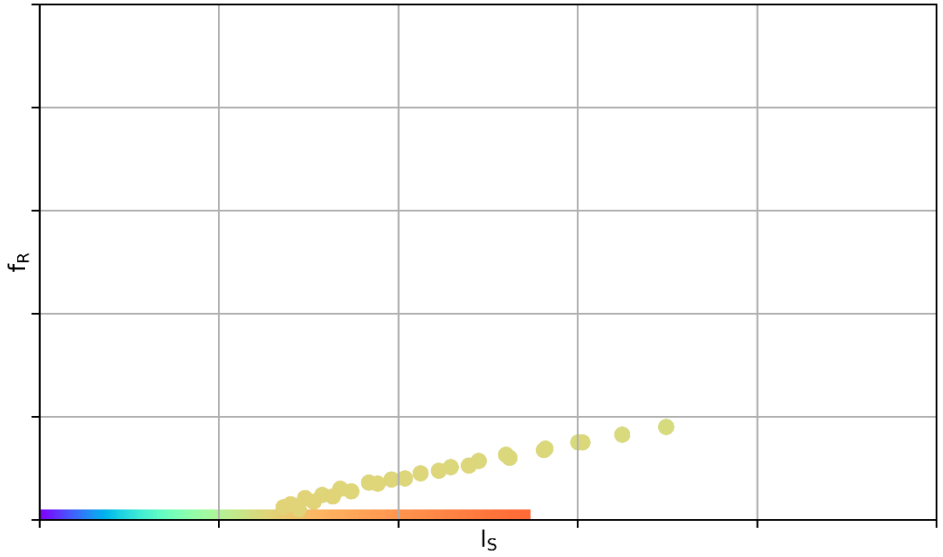
- Inverter-fed motor requires to fill the plane. How to? More Measurements?
- Computation needed
- **Need for Accuracy!** A model must be tunable to meet the measurement results !



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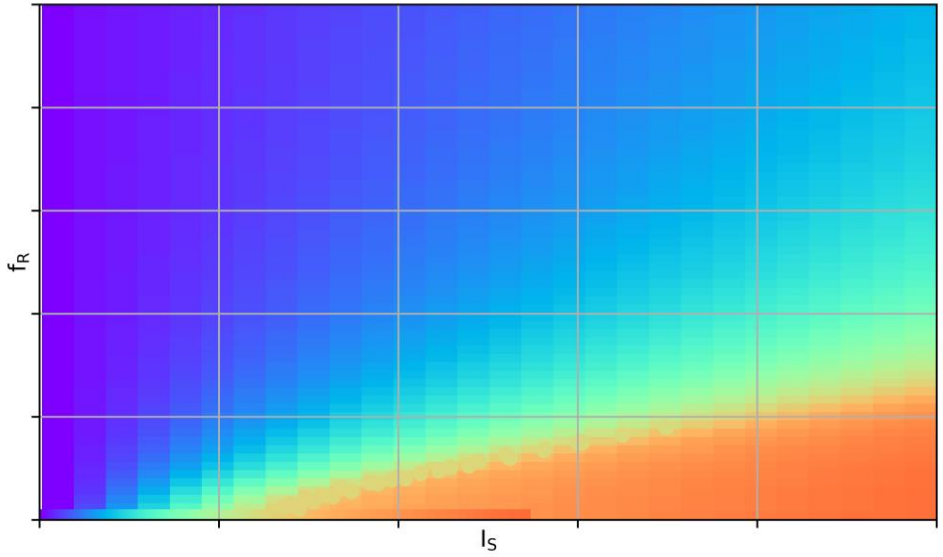
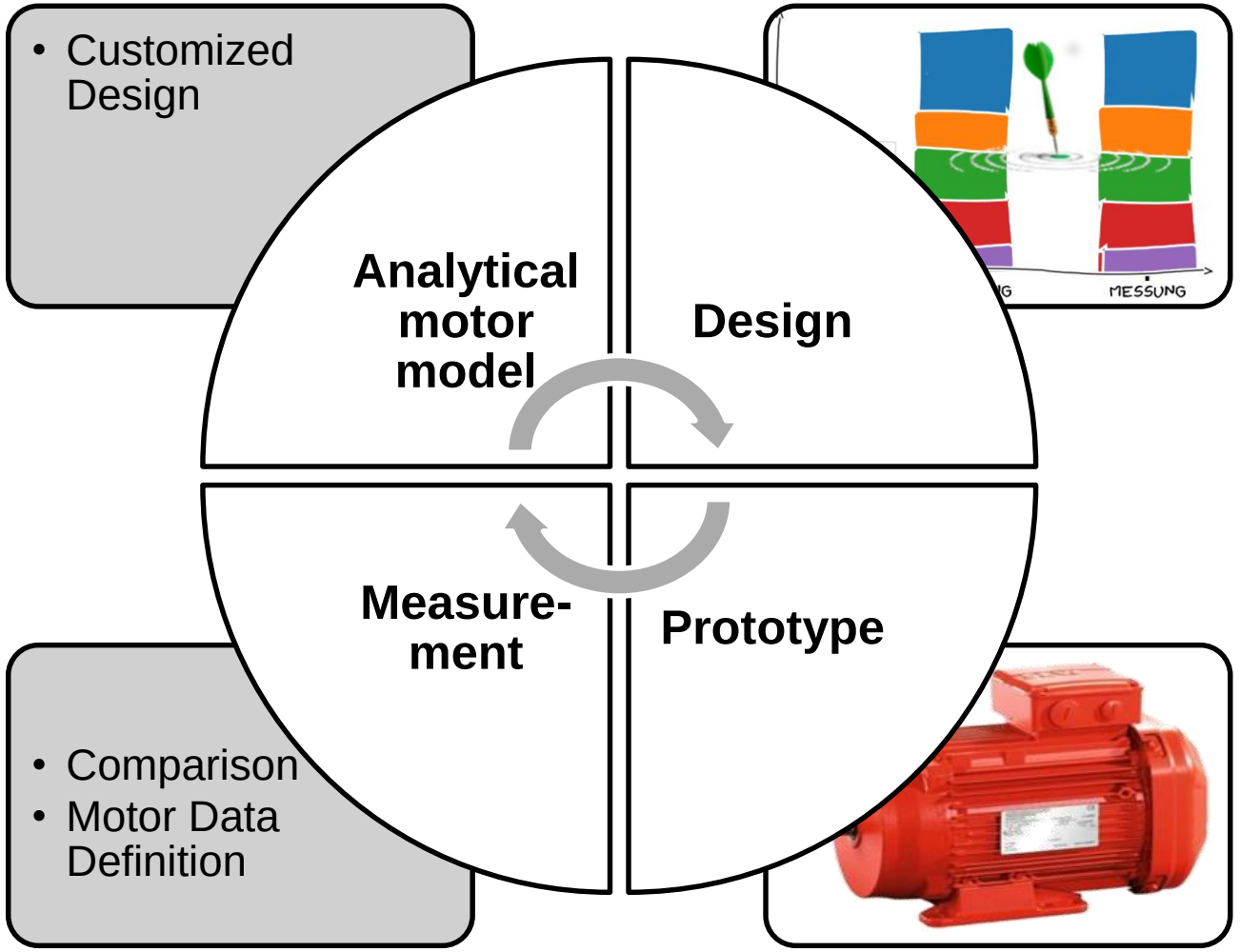


Stator flux (absolute value) from computation-based model in f_R/I_S-plane

Conclusion: Requirements for motor design software for induction motors



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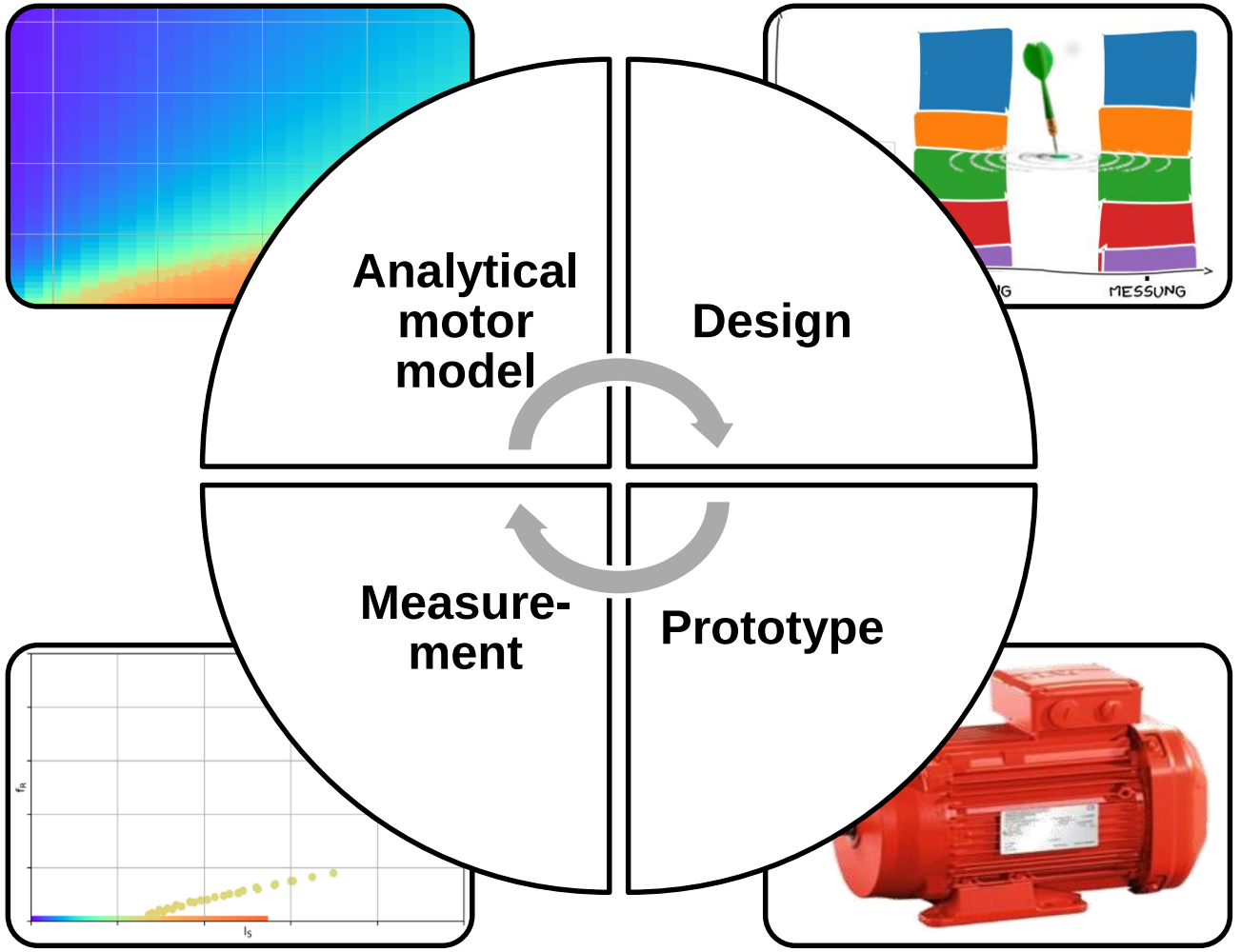
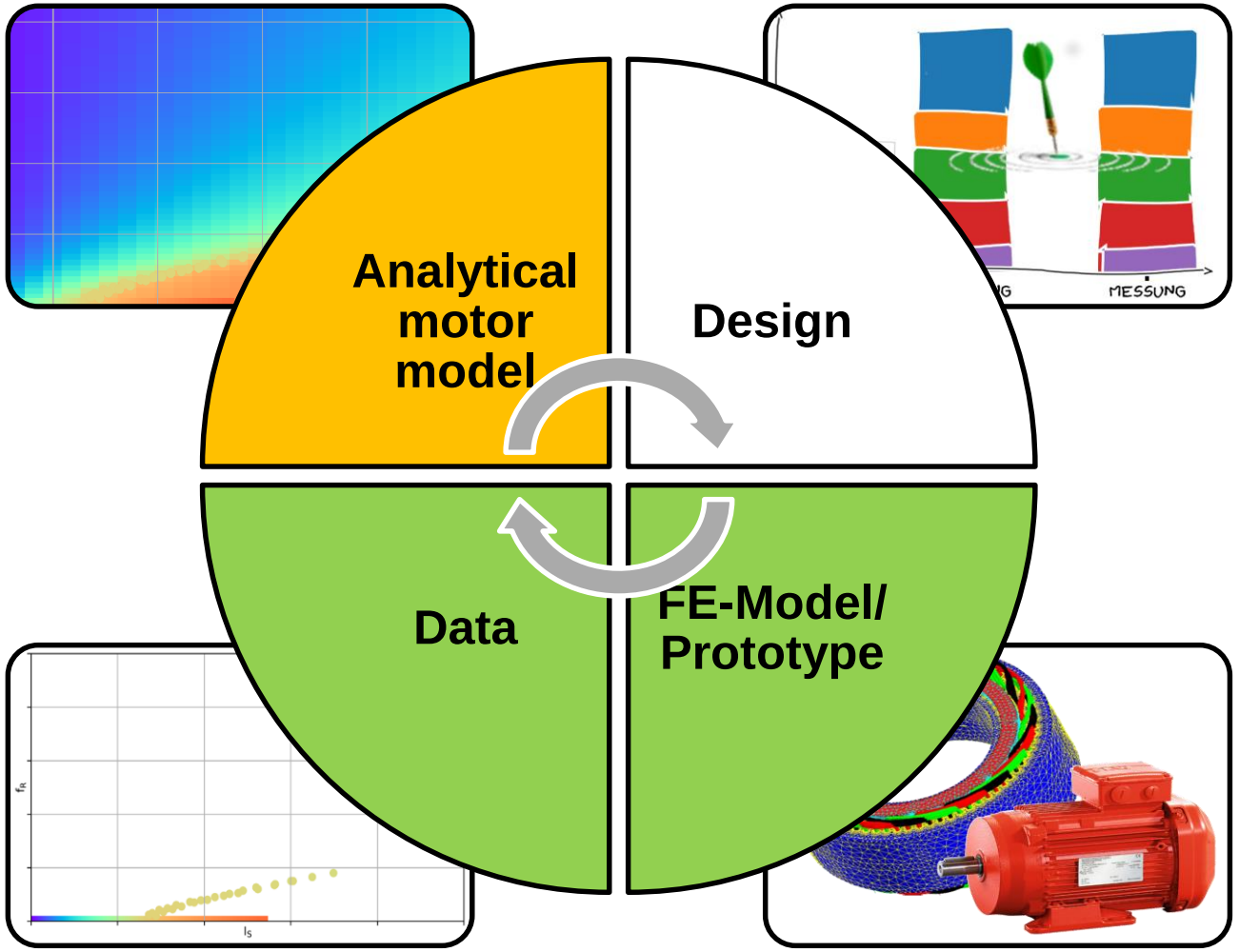


Conclusion: Requirements for motor design software for induction motors

1) **Reproduction**:

   Accurate reproduction of (standardized) measurements



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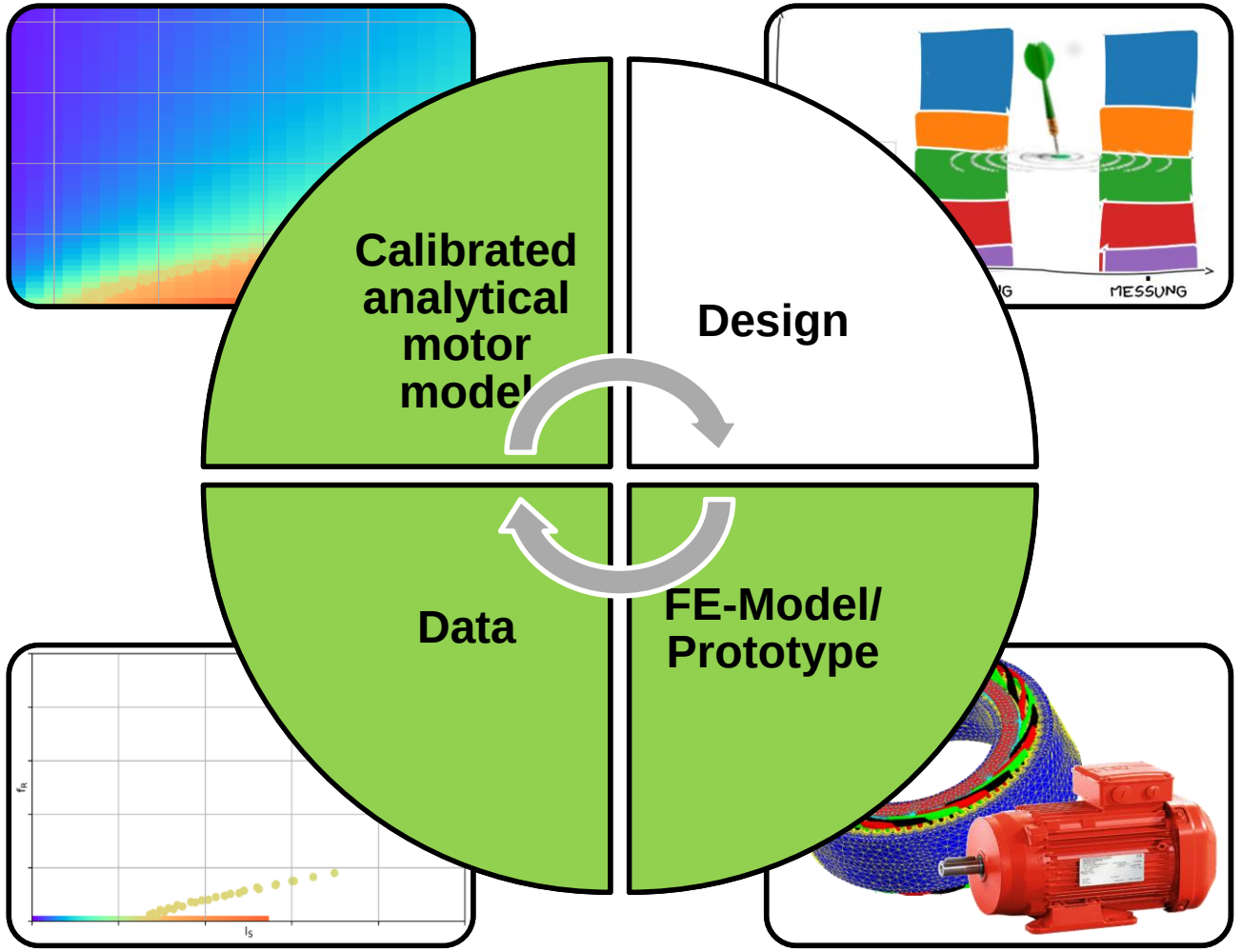
   Accurate computation of load-points or cooling conditions that have not been measured (AEDM)



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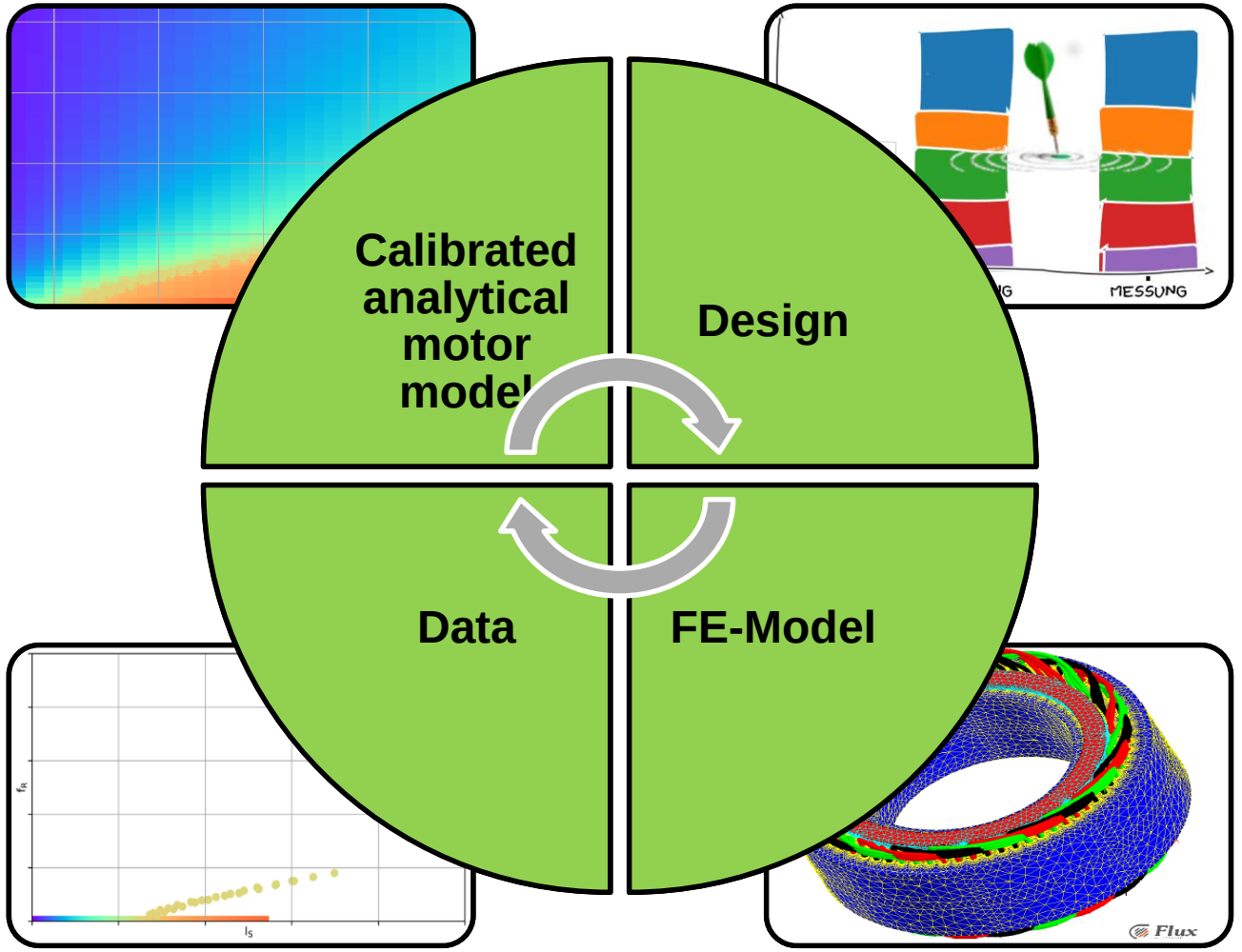
3) **Extrapolation**:

   For Predesign: compute results under *small design changes* with FEM only



Reference: Calculation of Efficiency Maps of Induction Motors Using Finite Element Method - Winzer, Doppelbauer 2013