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Determination of motor efficiency on the basis of IEC60034-2-1

Round-Robin testing for the improvement of the standard

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Round-Robin Test for the Improvement of IEC 60034-2-1

Overview

- Where do we come from? - Changes at the Introduction of IEC60034-2-1
- The Round-Robin Test - Targets and Test-Setup
- Test Results of the Round-Robin for Parts 1 to 3
- Conclusions and Consequences for the Next Edition of IEC 60034-2-1

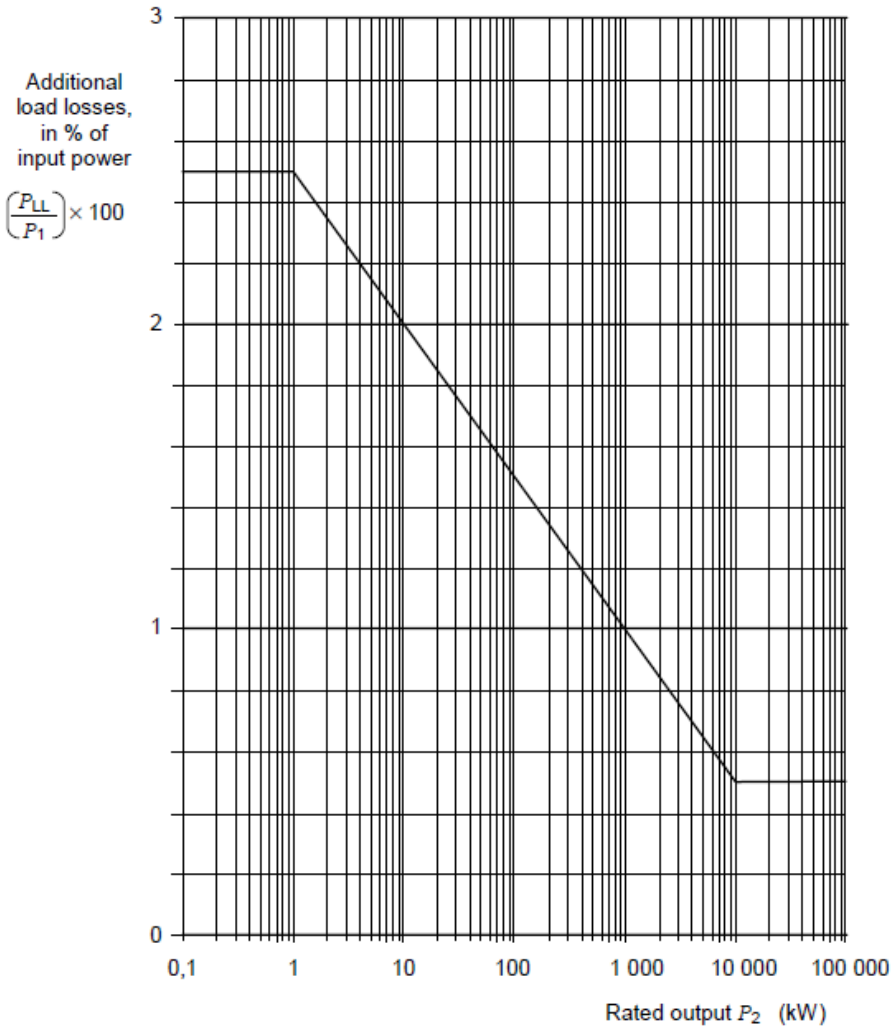
Round-Robin Test for the Improvement of IEC 60034-2-1

Where do we come from? - Changes at the introduction of IEC 60034-2-1

- Introduction of efficiency classification for induction motors according to IEC60034-30 caused the necessity to update IEC60034-2
- Main objective was to increase the reliability of the efficiency values determined on the basis of this standard
- The well-know figure of 0,5 % of PN as assigned value for the additional load loss was replaced by a curve, giving the upper value of the additional load loss of a large population of motors in dependence of machine rating
- Introduction of new test procedures for measuring the additional load loss instead of using the assigned value
- Determination of additional load losses from direct testing (residual losses) similar to IEEE 112 and introduction of Eh-star method

Round-Robin Test for the Improvement of IEC 60034-2-1

Where do we come from? - Changes at the introduction of IEC 60034-2-1



Assigned value for additional load loss vs. rated power - standardised factor of 0,5 % has been abolished

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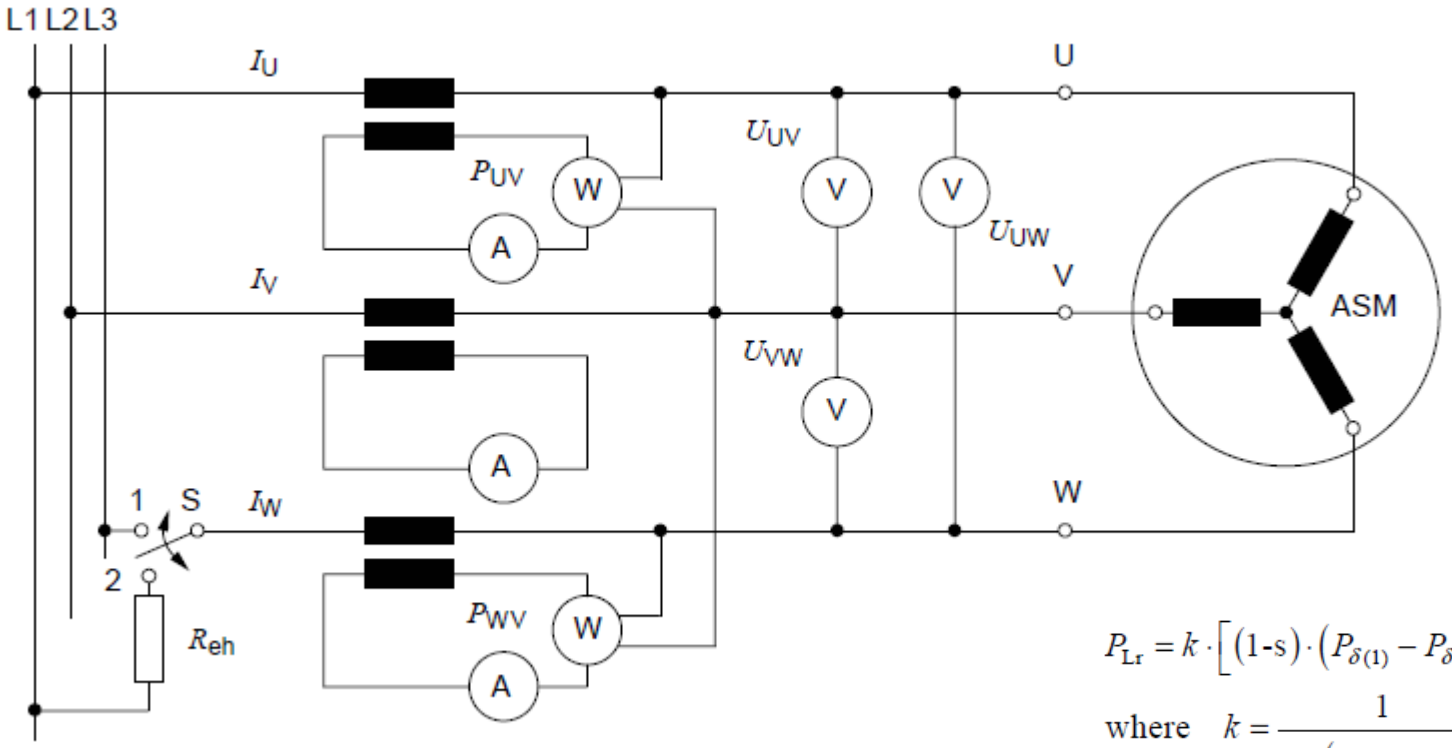
Where do we come from? - Changes at the Introduction of IEC 60034-2-1



$$P_{Lr} = k \cdot \left[(1\text{-s}) \cdot \left(P_{\delta(1)} - P_{\delta(2)} \right) - P_{fw} \right]$$

$$\text{where} \quad k = \frac{1}{1 + \left(I_{i(1)} / I_{i(2)} \right)^2}$$

Test-Setup for the Eh-star test

Round-Robin Test for the Improvement of IEC 60034-2-1

The Round-Robin Test - Targets and Test-Setup

Part 1: A series of tests in the same laboratory on a single motor

- Quantification of differences between different test methods
- Determination of the influence of testing tolerances, i.e. impact of operator errors and test equipment
- Both methods to be used for determining additional-load losses
- Minimum of five tests, each on the same motor

Part 2: A series of tests in the same laboratory on motors of the same design, from different manufacturing cycles, using the same test method

- Determination of uncertainty caused by variations in material properties and manufacturing processes
- Minimum of five test results for the same motor design of five different manufacturing cycles

Round-Robin Test for the Improvement of IEC 60034-2-1

The Round-Robin Test - Targets and Test-Setup

Part 3: A series of tests by different laboratories on the same motor

- Identification of uncertainties due to different interpretations of the test procedures, differences in instrumentation and laboratory equipment and personnel variations
- Each of the motors under test of different manufactures was sent to at least five different test laboratories

Test-Setup

- Test sequence covered four motor power ranges:
  1 - 10 kW / 11 - 50 kW / 51 – 200 kW / above 200 kW
- In total 17 laboratories of 11 countries submitted reports
- 75 motors were involved, 194 individual tests were evaluated

Round-Robin Test for the Improvement of IEC 60034-2-1

Results for Part 1 - A series of tests in the same laboratory on a single motor

		Additional-load (residual loss)		Additional-load (Eh-star)	
Test report	Rating	Min	Max	Min	Max
1A	1,5 kW	28,3 W	38,5 W	34,1 W	39,8 W
1B	5,5 kW	47,1 W	58,2 W	48,7 W	60,7 W
1C	6,8 kW	118 W	163 W	96,6 W	117 W
1D	11,2 kW	105 W	118 W	n.a.	n.a.
1E	15 kW	257 W	273 W	277 W	311 W
1F	11,2 kW	56 W	69 W	40 W	66 W
1G	18,5 kW	250 W	320 W	207 W	310 W
1H	18,5 kW	179 W	431 W	252 W	276 W
1J	20 kW	431 W	464 W	313 W	332 W
1K	37 kW	383 W	497 W	451 W	552 W
1L	40 kW	792 W	1025 W	690 W	761 W
1M	110 kW	1084 W	1357 W	952 W	1071 W
1N	132 kW	1105 W	1271 W	551 W	625 W
1P	200 kW	1583 W	1847 W	1318 W	1435 W
1Q	3 kW	20,8 W	31,5 W	24,3 W	31,8 W
1R	18,4 kW	81,8 W	175,6 W	200 W	224 W
1S	55 kW	446 W	491 W	313 W	332 W
1T	250 kW	1760 W	2465 W	1001 W	1094 W

- Good correlation between Eh-star and Residual Loss for machine ratings up to approximately 150 kW
- Increased deviation between methods for higher ratings - reasons not yet clear

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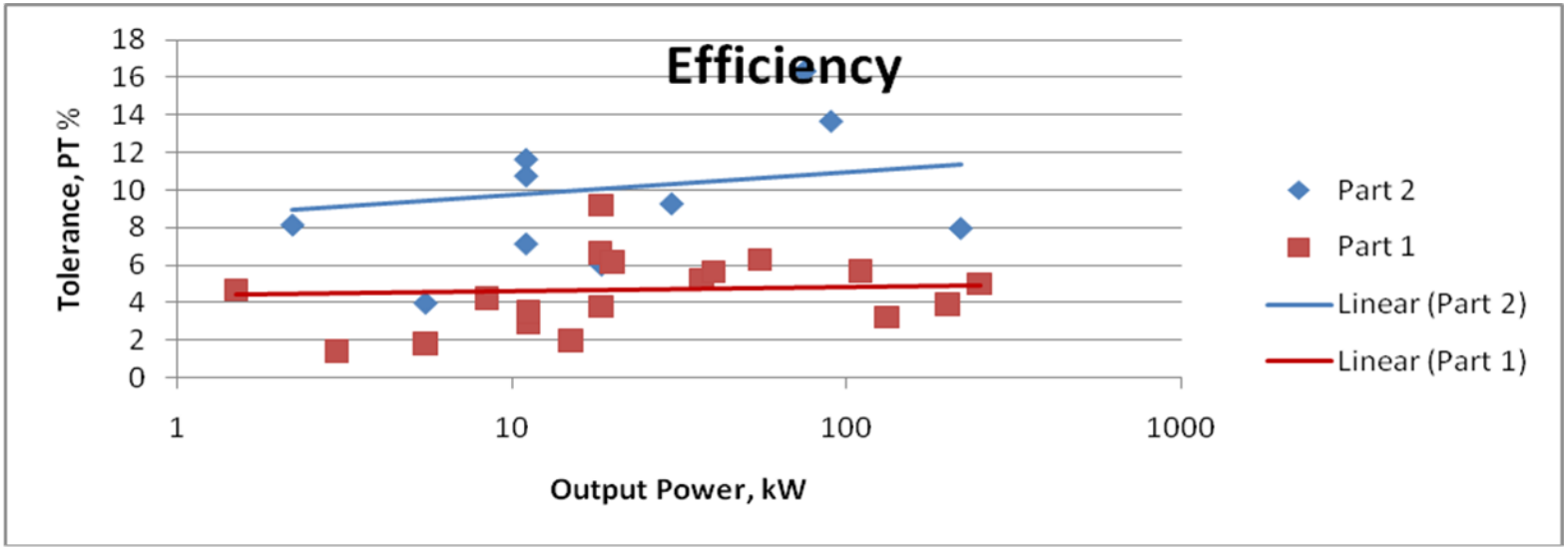
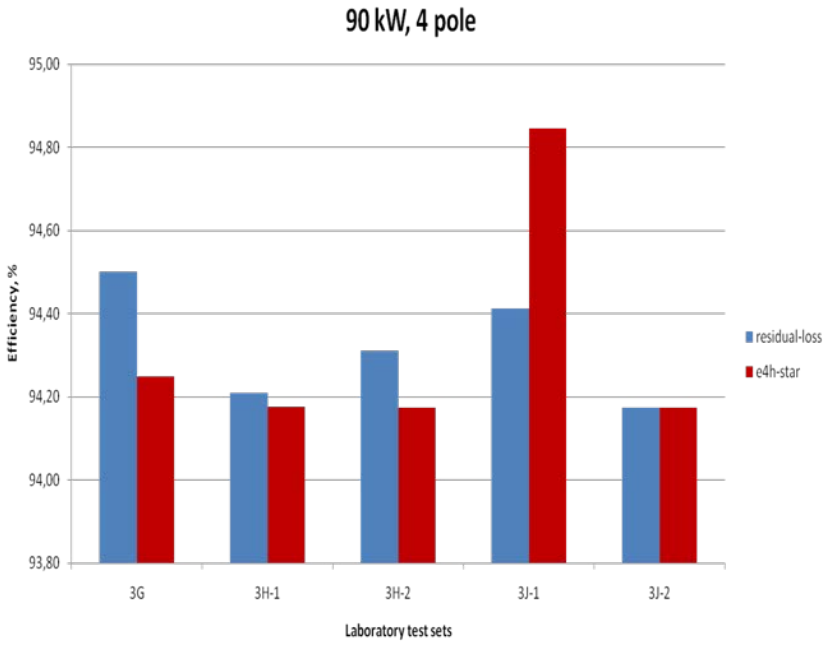
Results for Part 2 - A series of tests in the same laboratory on motors of the same design, from different manufacturing cycles, using the same test method

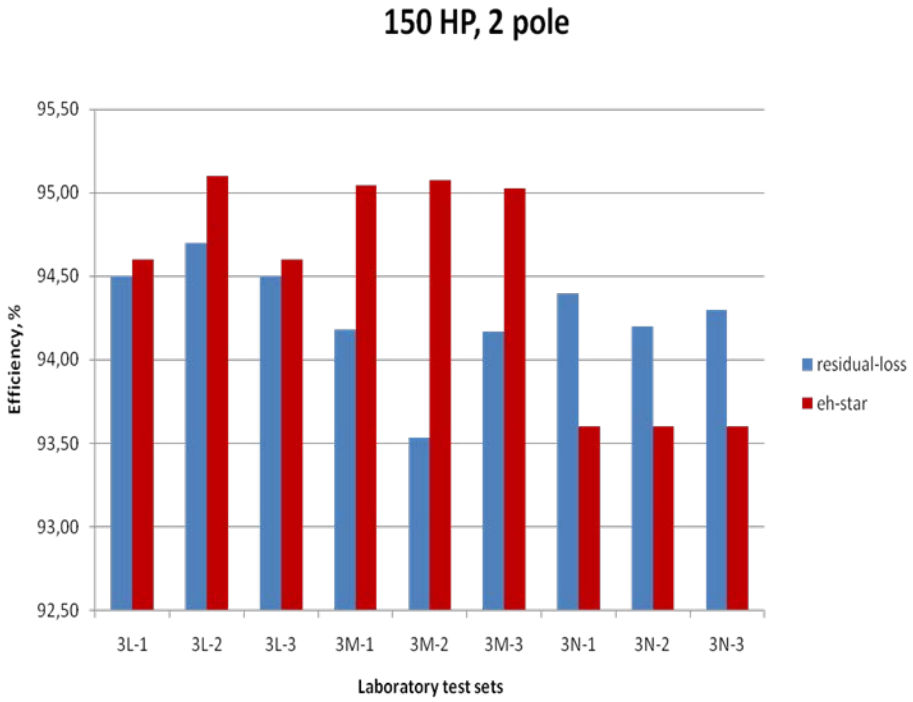


- Test data of this part mainly based on the method of residual loss
- Results show a significant variation of losses determined for the same motor design at different points of time
- Approx. 5% of the variation of total losses seems to be caused by material and manufacturing tolerances

Round-Robin Test for the Improvement of IEC 60034-2-1

Results for Part 3 - A series of tests by different laboratories on the same motor





- Unfortunately results of this part are the most unclear
- Part of the laboratories determined higher losses by the Eh-star method, while the other part did this for residual loss, even though the same machine was tested

Round-Robin Test for the Improvement of IEC 60034-2-1

Conclusions and Consequences for the Next Edition of IEC 60034-2-1

- Also with respect to practical reasons the method of residual loss will be introduced as preferred method to determine the additional load loss for compliance checks with national energy efficiency regulations for all 3-phase machines with ratings up to 1 MW
- All other methods, including Eh-star, will be kept in the standard for field- or routine testing
- Description of the procedures will be detailed with respect to instrumentation and sequence of testing
- Even though the results of the Round Robin test did not fully met the expectations, the test series proved that the loss tolerance of 15%, which is currently mentioned in IEC60034-2-1, is reasonable: None of the test results showed variations above 15%, nevertheless tolerances of 10% to 12% appeared regularly

Round-Robin Test for the Improvement of IEC 60034-2-1

Conclusions and Consequences for the Next Edition of IEC 60034-2-1

Method	Clause	Preferred method	Required facilities	Uncertainty
Direct				
Torque measurement	8.1.1	All single phase and polyphase ≤ 1 kW	Torquemeter/dynamometer for full-load	Low
Calibrated machine test	Annex D		Calibrated machine	See Note 4
Dual-supply, back-to-back test	8.1.2		Machine set for full-load Two identical units	Low
Total losses				
Calorimetric method	Annex D		Special thermal enclosure	See Note 4
Single supply back-to-back test	8.2.1		Two identical units (wound rotor)	Low
Summation of losses, with and without load test				
P_{LL} determined from residual loss	8.2.2.5.1	Three phase > 1 kW up to 150 kW	Torquemeter/dynamometer for ≥ 1,25 × full-load	Low
P_{LL} from assigned value	8.2.2.5.3			Medium to high
P_{LL} from removed rotor and reverse rotation test	8.2.2.5.2		Auxiliary motor with rated power ≤ 5 × total losses P_T	High
P_{LL} from Eh-star test	8.2.2.5.4	(see Note 3)	Resistor for 150 % rated phase current	Medium
Summation of losses, without load test				
Currents, powers and slip from the equivalent circuit method P_{LL} from assigned value	8.2.2.4.3		If test equipment for other tests is not available (no possibility of applying rated load, no duplicate machine)	Medium/high

NOTE 1 Due to measurement inaccuracies, the determination of P_{LL} from residual losses is limited to correlation coefficients (see 8.2.2.5.1.2) greater than 0,95 and may have uncertainties of the determined efficiency exceeding ±0,5 %.

NOTE 2 In the "Uncertainty" column, "Low" indicates a procedure determining all loss-components from tests; "Medium" indicates a procedure which is based on a simplified physical model of the machine; "High" indicates a procedure that does not determine all loss-components by tests.

NOTE 3 The method for P_{LL} from Eh-star test is suitable for motors between 1 kW and 150 kW; larger ratings are under consideration. The method requires that the winding can be connected in star.

NOTE 4 Uncertainty to be determined.

Current edition of IEC60034-2-1:

Overview of preferred methods for determination of efficiency classification

Round-Robin Test for the Improvement of IEC 60034-2-1

Conclusions and Consequences for the Next Edition of IEC 60034-2-1

Ref	Method	Description	Clause	Preferred application	Required facility
A	**Input-Output**	Direct torque measurement	8.1.1	Single phase machines	Torquemeter/dynamometer for full-load
B	**Residual losses**	Summation of losses; P_{LL} determined from residual loss	8.2.2.5.1	Three phase machines with rated output power up to 1 MW	Torquemeter/dynamometer for 1,25 x full-load
C	**Assigned value**	Summation of losses; P_{LL} from assigned value	8.2.2.5.3	Three phase machines with rated output power 1 MW and greater	

Proposal for the next revision of IEC60034-2-1