VOGELSANG & BENNING

Test Systems
Automation Solutions
Quality Control Systems

Determination of the efficiency factor

of electric motors according to IEC 60034

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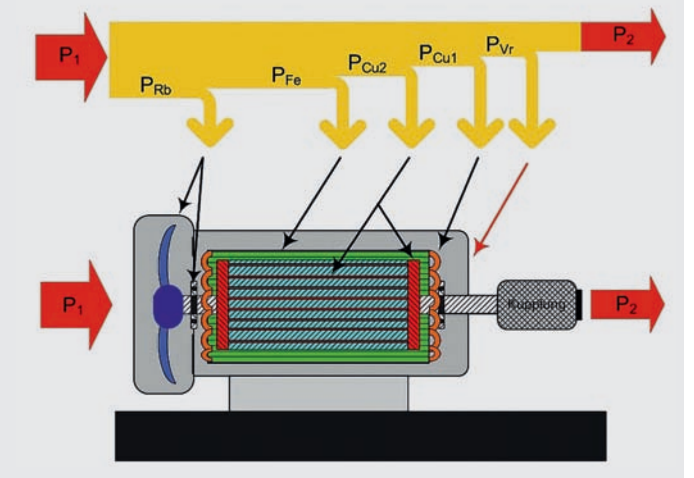
Electrically driven systems account for around 70 % of the power consumption of industry and the manufacturing sector. With consideration to cost aspects and not least due to ambitious climate protection targets, it is necessary to increase the effectiveness and efficiency factor of electric drives, and thereby achieve savings in industrial power consumption.

A classification of electric motors according to their efficiency factor already existed: EFF1, EFF2 and EFF3, with corresponding limit curves. This classification encompassed three-phase motors with a power range of 1.1 to 90 kW (only 2- and 4-pole machines).

Now the standard IEC 60034-30-1, in the version released in 2014, stipulates the minimum efficiency factor for three-phase asynchronous motors with cage rotor. The motors are divided up into the classes IE1, IE2, IE3 and IE4 with corresponding requirements regarding the nominal minimum efficiency rating.

These new globally harmonised classes apply to almost all low voltage three-phase motors within a power range of 0.75 to 375 kW.

In order to perform this classification, it is necessary to determine the efficiency factor as precisely as possible and such that it is reproducible. The preferred methods for determining the efficiency factor are specified in IEC 60034-2-1.



Efficiency factor electric motors

For motors up to 1 kW the direct efficiency factor is determined. For motors with nominal capacities up to 2 MW, direct measurement of the shaft output is required with subsequent calculation of the single losses (according to method B). By adhering to the specifications of the standard, the following test sequence is obtained for determining the efficiency factor:

Test method for determining of efficiency factor

1. Measurement of the winding resistance
of the cold motor.

2. Endurance measurement
Execution of a heat run with the nominal load until the steady-state temperature is reached.

3. Measurement of winding resistance
Directly after switching the motor off one measurement is optionally taken, if the measurement takes place sufficiently quickly within 90s, or a complete cooling curve is implemented with extrapolation (back calculation) to the switch-off time point.

4. Measuring the operating characteristic curve
Load measurement with 25 %, 50 %, 75 %, 100 %, 125 % of the nominal load. Directly before and after the measurement it is necessary to measure the winding resistances.

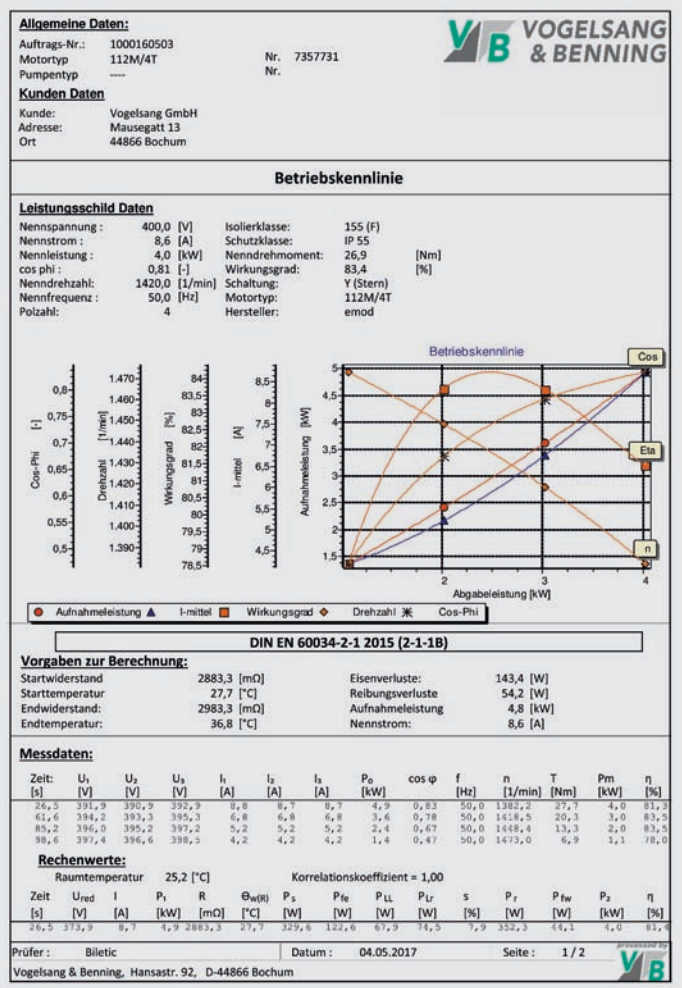
5. Measuring the idle characteristic curve
with a motor at operating temperature. Directly before and after the measurement it is necessary to measure the winding resistances.

Using the results of these measurements and evaluations it is possible to assign the motor to the efficiency factor class IE1, IE2, IE3 or IE4. Based on the example of a 2 pole motor with 110 kW nominal output, this means the following for the efficiency factor:

IE1 ≥ 93,3 %
IE2 ≥ 94,3 %
IE3 ≥ 95,2 %
IE4 ≥ 96,0 %

It is clearly apparent here how small the difference is in the efficiency factor between the efficiency factor classes.

Expressed in power, a power consumption of just 1250 Watt lies between the classification of 110 kW motors in the efficiency class IE1 and IE2, whilst 1103 Watt lies between efficiency classes IE2 and IE3 and 963 Watt between IE3 and IE4. With an assumed nominal speed of 2950 rpm, this 110 kW motor has a nominal moment of 356 Nm in S1 operation.



Allgemeine Daten:

Auftrags-Nr.: 1000160503
Motortyp 112M/4T — Nr. 7357731
Pumpentyp ---- — Nr.

Kunden Daten

Kunde: Vogelsang GmbH
Adresse: Mausegatt 13
Ort 44866 Bochum

Betriebskennlinie

Leistungsschild Daten

Nennspannung :	400,0	[V]	Isolierklasse:	155 (F)	
Nennstrom :	8,6	[A]	Schutzklasse:	IP 55	
Nennleistung :	4,0	[kW]	Nenndrehmoment:	26,9	[Nm]
cos phi :	0,81	[-]	Wirkungsgrad:	83,4	[%]
Nenndrehzahl:	1420,0	[1/min]	Schaltung:	Y (Stern)	
Nennfrequenz :	50,0	[Hz]	Motortyp:	112M/4T	
Polzahl:	4		Hersteller:	emod	

DIN EN 60034-2-1 2015 (2-1-1B)

Vorgaben zur Berechnung:

Startwiderstand	2883,3	[mΩ]	Eisenverluste:	143,4	[W]
Starttemperatur	27,7	[°C]	Reibungsverluste	54,2	[W]
Endwiderstand:	2983,3	[mΩ]	Aufnahmeleistung	4,8	[kW]
Endtemperatur:	36,8	[°C]	Nennstrom:	8,6	[A]

Messdaten:

Zeit: [s]	U_1 [V]	U_2 [V]	U_3 [V]	I_1 [A]	I_2 [A]	I_3 [A]	P_0 [kW]	cos φ	f [Hz]	n [1/min]	T [Nm]	Pm [kW]	η [%]
26,5	391,9	390,9	392,9	8,8	8,7	8,7	4,9	0,83	50,0	1382,2	27,7	4,0	81,3
61,6	394,2	393,3	395,3	6,8	6,8	6,8	3,6	0,78	50,0	1418,5	20,3	3,0	83,5
85,2	396,0	395,2	397,2	5,2	5,2	5,2	2,4	0,67	50,0	1448,4	13,3	2,0	83,5
98,6	397,4	396,6	398,5	4,2	4,2	4,2	1,4	0,47	50,0	1473,0	6,9	1,1	78,0

Rechenwerte:

Raumtemperatur 25,2 [°C] — Korrelationskoeffizient = 1,00

Zeit [s]	U_{red} [V]	I [A]	P_1 [kW]	R [mΩ]	$\Theta_{w(R)}$ [°C]	P_s [W]	P_{fe} [W]	P_{LL} [W]	P_{Lr} [W]	s [%]	P_r [W]	P_{fw} [W]	P_2 [kW]	η [%]
26,5	373,9	8,7	4,9	2883,3	27,7	329,6	122,6	67,9	74,5	7,9	352,3	44,1	4,0	81,[illegible]

Prüfer : Biletic — Datum : 04.05.2017 — Seite : 1 / 2

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Example: Operating characteristic curve (option)

If one assumes a permissible measuring error of 0.2 % (per IEC 60034-2-1) during the torque measurement then this means a measuring error of roughly 220 Watt, i.e. approx. 25 % of the difference between the two efficiency classes.

Influence of the mechanical test stand configuration

Three-phase asynchronous motors with regenerative frequency converters are used as load equipment in the test. The torque and speed between the specimen and load equipment are acquired via torque measurement shafts with a high degree of measuring accuracy.

When coupling the specimens it is necessary to achieve optimum alignment of the shaft connection between the specimen and torque measurement shaft.

All losses in the clutch, e.g. an increased flexing due to incorrect alignment, cannot be logged or separated and lead to an error in the determination of the efficiency factor.

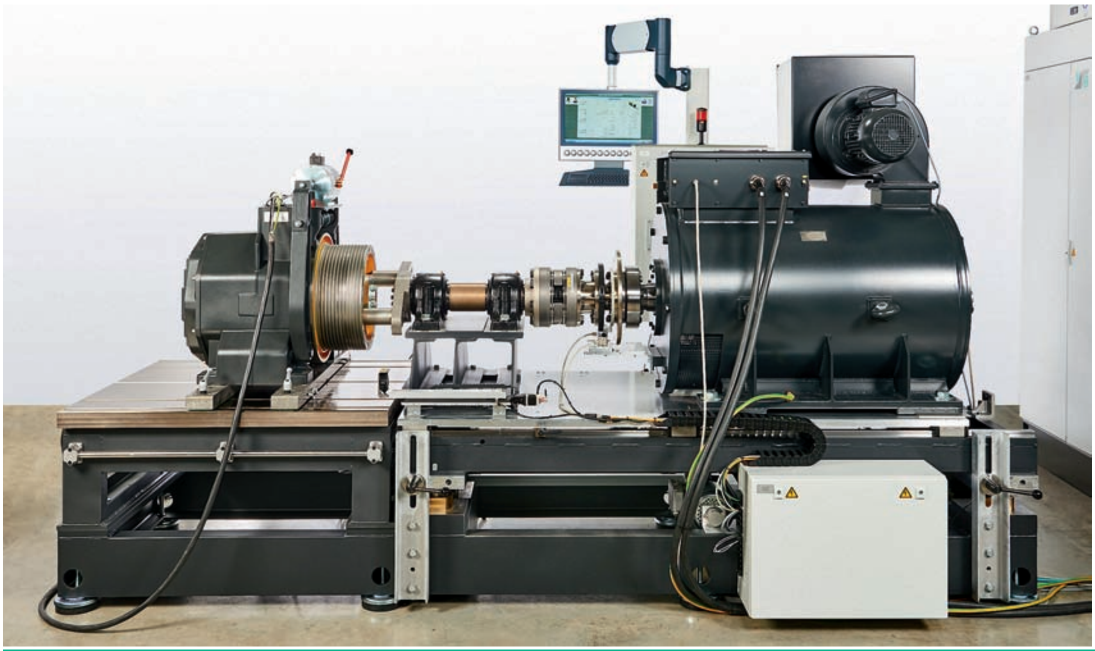
This error distorts the actual efficiency factor or the test results. The mechanical concept for the alignment of the shaft connection must be simple and reproducible.

Long-term experience

The long-term experience of Vogelsang & Benning in the field of electric motor testing accounts for all of these requirements.

A refined software concept with the necessary evaluations and protocols means that manufacturers of electric motors have high performance test equipment at hand.

In this way it is possible to obtain reliable and reproducible measurement results with motors undergoing test, and perform the classification of electric motors.



Test stand with 600 kW load equipment; test specimen adaptation takes place by means of height-adjustable lift table with clamping plate.

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