Reference Guide

Low Voltage Motors
Basics of IEC Motors

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As North American manufacturers increase export activities, power transmission designers should should also increase their understanding of IEC motor parameters. This publication serves as a primer on the most common IEC designations and how they relate to NEMA Standards.

In the world of electric motors, there are basically two languages: NEMA in North America, and IEC in much of the rest of the world. Until recent years, there was little need to be aware of the differences, both subtle and obvious. However, that changed as the motor market has become increasingly global. This trend gained additional fuel in 1990s when the economies of the European Common Market countries became one.

Today, the industrial economy connects multinational companies with engineering and production in many countries around the world. Alongside the economic opportunities, globalization has also created a mounting challenge in motor specification, as more and more companies want to standardize their component purchases around the world. Once specified and put into use, production equipment may need to move from one country to another. More requently than ever, global OEMs are specfying international standards and the regional divisions of NEMA vs IEC have become more blurred.

What is IEC?

The National Electrical Manufacturers Association goes by its acronym, "NEMA." The International Electrotechnical Commission goes by the acronym "IEC." Like NEMA, IEC establishes and publishes mechanical and electrical standards for motors. Many IEC standards have been somewhat nationalized. For example, Germany has its VDE 0530 standard, Great Britain has its BS 2613 standard and France has NF CS1-100. But they parallel IEC 34-1 standards. The same can be said with minor exceptions for standards worldwide. They're likely to be IEC clones or close derivatives.

Though NEMA and IEC standards use different terms, they are essentially similar in ratings and, in most cases, are interchangeable. NEMA standards tend to be more moderate - allowing more room for "design interpretation." IEC standards on the other hand, tend to be more specific and more categorized.

▲ Left: An ABB NEMA frame motor. Right: An ABB IEC frame motor ▲

Frame Relationships

Both IEC and NEMA standards use letter codes to indicate specific mechanical dimensions, plus codes for general frame size. The letters can get especially tricky because, for example, a “D” in NEMA is really an “H” in IEC - while an “H” in NEMA is a “K” in IEC.

Frame relationships are a bit easier; in onlv one case. NEMA and IEC use the same nomenclature for the 56 frame, but actually has different meanings. IEC’s 56 frame is what we’d call a subfractional motor, while NEMA’s 56 frame is our most common, covering about 1/4 to 1-1/2 HP.

Table A (on page 4) provides a translation guide for most common mechanical parameters, with dimensions solely in millimeters. By the way, as long as we’re talking “IEC,” we should talk a little metric, too. What you’ll notice is that the dimensions are not identical, but they’re pretty close. The dimension least in similarity is NEMA “N-W” (IEC “E”). That dimension is the shaft shoulder-to-shaft end measurement. Most often, the NEMA measurement is much greater.

To convert from millimeters to inches, multiply by 0.03937

To convert from inches to millimeters, multiply by 25.4

To obtain equivalent HP, multiply the KW Rating by 1.358

To obtain equivalent KW, multiply the HP Rating by 0.7457

Kilowatts & HP

A dictionary will tell you a watt is a unit of electrical power measurement based on amperes and volts (an input unit), while a HP is a power measurement based on mechanical work (an output unit). By definition, a horsepower equals the power to lift 33,000 lbs, 1 ft in 1 minute. In electric motors, watts and HP compare because watts are also used as output units.

IEC uses kilowatts, NEMA uses horsepower. And like NEMA, IEC assigns comparable power ratings to standard frame sizes. IEC and NEMA, KW/HP comparisons flow smoothly in smaller ratings. However, in larger sizes, they can vary enough to cause concern in some design applications. An example is the IEC 225S / NEMA 364T areas for 4-pole motors. (See Table A footnote.)

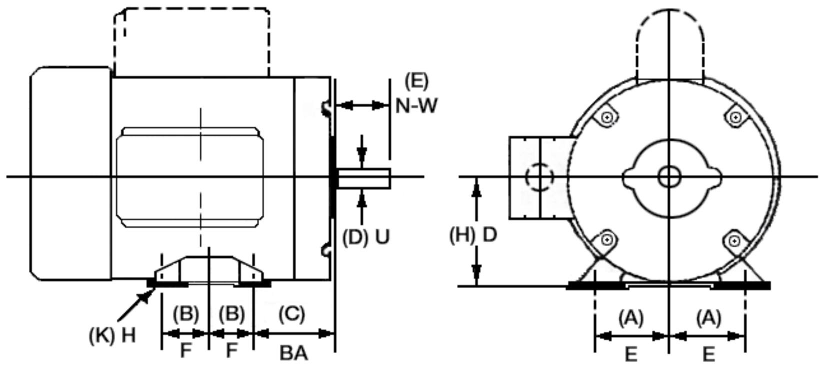
In this case, NEMA calls for 75 HP in the frame size in which IEC calls for 50 HP. Dropping to a NEMA 326T frame provides the 50 HP needed, if the dimension differences are acceptable. If you need the 364T dimensions, be sure not to damage the drive train or load if using the higher-power motor.

Table A: Dimensions and Frame Comparisons, IEC and NEMA

	IEC and NEMA dimensions in mm							KW and HP Ratings 3 Phase TEFC Motors		
IEC	(H)	(A)	(B)	(K)	(D)	(C)	(E)	2 Pole	4 Pole	6 Pole
NEMA	D	E	F	H	U	BA	N-W			
56	56	45	35.5	5.8	9	36	20	---	---	---
NA	---	---	---	---	---	---	--	---	---	---
63	63	50	40	7	11	40	23	.25 KW	.18KW	---
42	66.7	44.5	21.4	7.1	9.5	52.4	28.6	1/3 HP	1/4 HP	---
71	71	56	45	7	14	45	30	0.55	0.37	---
48	76.2	54	34.9	8.7	12.7	63.5	38.1	3/4	1/2	---
80	80	62.5	50	10	19	50	40	1.1	0.75	0.55
56	88.9	61.9	38.1	8.7	15.9	69.9	47.6	1-1/2	1	3/4
90S	90	70	50	10	24	56	50	1.5	1.1	0.75
143T	88.9	69.8	50.8	8.7	22.2	57.2	57.2	2	1-1/2	1
90L	90	70	62.5	10	24	56	50	2.2	1.5	1.1
145T	88.9	69.8	63.5	8.7	22.2	57.2	57.2	3	2	1-1/2
100L	100	80	70	12	28	63	60	3	2.2	1.5
NA	---	---	---	---	---	---	---	4	3	2
112S	112	95	57	12	28	70	60	3.7	2.2	1.5
182T	114.3	95.2	57.2	10.7	28	70	69.9	5	3	2
112M	112	95	70	12	28	70	60	3.7	4	2.2
184T	114.3	95.2	68.2	10.7	28	70	69.9	5	5.4	---
132S	132	108	70	12	38	89	80	7.5	5.5	3
213T	133.4	108	69.8	10.7	34.9	89	85.7	10	7-1/2	---
132M	132	108	89	12	38	89	80	---	7.5	5.5
215T	133.4	108	88.8	10.7	34.9	89	85.7	---	10	7-1/2
160M*	160	127	105	15	42	108	110	15	11	7.5
254T	158.8	127	104.8	13.5	41.3	108	101.6	20	15	10
160L*	160	127	127	15	42	108	110	18.5	15	11
256T	158.8	127	127	13.5	41.3	108	101.6	25	20	15
180M*	180	139.5	120.5	15	48	121	110	22	18.5	---
284T	177.8	139.8	120.2	13.5	47.6	121	117.5	---	25	---
180L*	180	139.5	139.5	15	48	121	110	22	22	15
286T	177.8	139.5	139.8	13.5	47.6	121	117.5	30	30	20
200M*	180	159	133.5	19	55	133	110	30	30	---
324T	203.3	158.8	133.4	16.7	54	133	133.4	40	40	---
200L*	200	159	152.5	19	55	133	110	37	37	22
326T	203.2	158.8	152.4	16.7	54	133	133.4	50	50	30
225S*	225	178	143	19	60	149	140	---	37	30
364T	228.6	117.8	142.8	16.7	60.3	149	149.2	---	50/75**	40
225M*	225	178	155.5	19	60	149	140	45	45	37
365T	228.6	177.8	155.6	16.7	60.3	149	149.2	60/75**	60/75**	50
250M*	250	203	174.5	24	65	168	140	55	55	---
405T	254	203.2	174.6	20.6	73	168	184.2	75/100**	75/100**	---
280S*	280	228.5	184	24	75	190	140	---	---	45
444T	279.4	228.6	184.2	20.6	85.7	190	215.9	---	---	60/100**
280M*	280	228.5	209.5	24	75	190	140	---	---	55
445T	279.4	228.6	209.6	20.6	85.7	190	215.9	---	---	75/125**

* Shaft dimensions of these motors may vary among manufacturers.

** HP listed is the closest comparable rating with similar mounting dimensions. In some cases, this results in greater HP than required (i.e. 37KW 4 pole converts to 50 HP. However, the nearest NEMA HP rating having comparable dimensions is 75 HP). The HP printed first is the direct conversion and the HP printed second is that of a NEMA frame of comparable dimensions (Conversions formulas are on page 3.)



▲ **Figure 1: Motor Dimension Designations**

Enclosures

This is the area where IEC standards get very specific. "Open drip-proof" and "totally enclosed" are the descriptive words NEMA uses. However, IEC uses numbers to describe enclosures, and there are a lot of them.

It all makes sense when you think about it. IEC refers to its enclosure designations as "degrees of protection," and gives ratings based on a two-digit numbering scheme. The numbers follow the letters "IP." A simple way to think of it would be to use the term "Ingress Protection."

The first digit indicates how well-protected the motor is against entry of solid objects such as dust, wire, tools, or fingers. Here's what the first digit means:

0 - No protection.
1 - Protection against objects larger than 50 mm (about 2 in.) in diameter, like hands.
2 - Protection against objects larger than 12 mm (about 1/2 in.) in diameter, like fingers.
4 - Protection against objects larger than 1 mm (about 0.04 in.) in diameter, like small tools and wires.
5 - Complete protection, including dust-tightness.
6 - IP 66 does not apply to motors

The second digit signifies protection against water entry. These ratings are:

0 - No protection.
I - Protected from water falling straight down.
2 - Protected from water falling as much as 15 degrees from vertical.
3 - Protected from spraying water as much as 60 degrees from the vertical.
4 - Protected from splashing water coming from any direction.
5 - Protected from water sprayed from a nozzle in any direction.
6 - Protected from heavy seas.
7 - Protected against immersion for a given time.
8 - Protected against immersion indefinitely.

For most industrial applications, IP 22 relates to open drip-proof motors, IP 44 or IP 54 to totally enclosed (like NEMA 12), IP 45 to weatherproof, and IP 55 to washdown -duty motors.

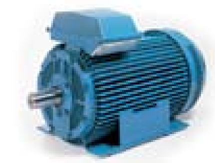
If you're dealing with explosion-proof motors, pay special attention. The hazardous atmospheres defined by our National Electrical Code (NEC) parallel those of IEC "flameproof" motors.

Cooling Designations

As with enclosures, IEC uses a letter-and-number code to designate how a motor is cooled. The code covers nearly every known cooling method, including those for very large liquid-cooled motors. It can extend all the way, to a four letter, four number code. For most of our common applications, the following "short-code" designations should be sufficient:

IC 01

The first digit means there is free exchange of coolant into and out of the motor. The second digit means the exchange takes place because of "self-circulation," or a fan mounted on the motor shaft. This is most likely a standard open motor, because of the internal-fan action.



IC 410

The first digit means the frame surface is cooled; the second digit means that cooling is by convection only with no fanning action. The motor is totally enclosed, non-ventilated (TENV).

IC 411

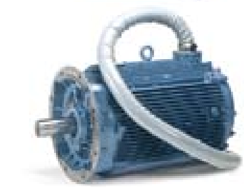
The first digit again indicates frame-surface cooling, but the second digit shows fanning. This is a fan-cooled motor (TEFC).

IC 416

This motor features an external blower motor on back and therefore is it is totally enclosed blower cooled motor (TEBC).

IC 418

The first digit again indicates frame-surface cooling. The second digit says the coolant and motor move relative to each other. Translation: a totally enclosed airover motor. This relates to uses where the motor is in the airstream of the fan or blower it drives, and is thus cooled by fan action.



Example

IC 4 (A) 1 (A) 6

International Cooling — IC

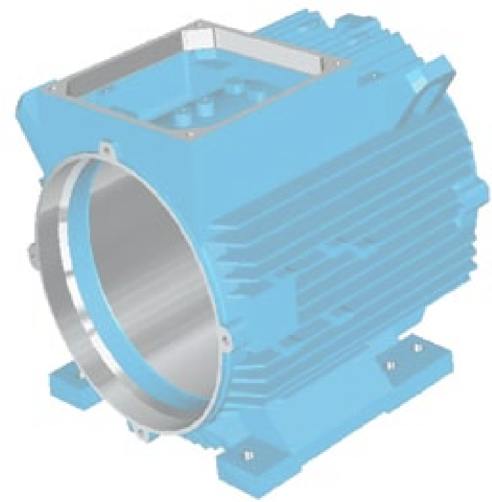
Circuit arrangement — 4
0: Free circulation (open circuit)
4: Frame surface cooled

Primary coolant — (A)
A for air (omitted for simplified designation)

Method of movement of primary coolant — 1
0: Free convection
1: Self-circulation
6: Machine-mounted independent component

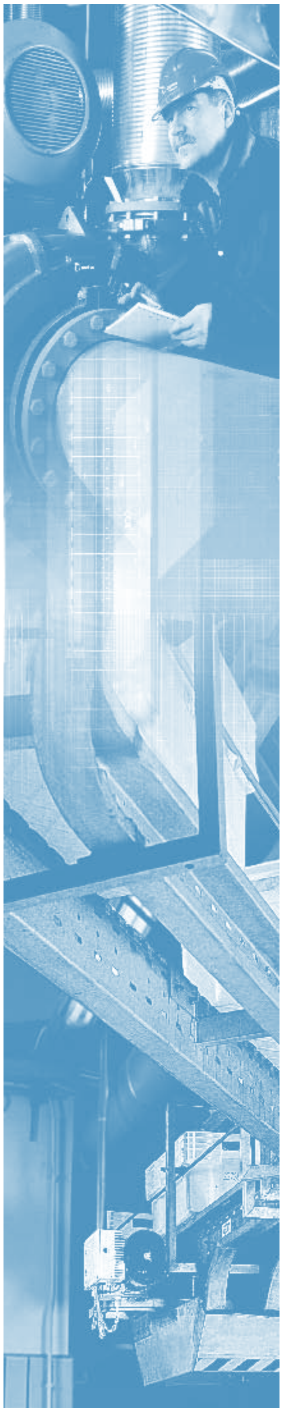
Secondary coolant — (A)
A for air (omitted for simplified designation)
W for water

Method of movement of secondary coolant — 6
0: Free convection
1: Self-circulation
6: Machine-mounted independent component
8: Relative displacement



Duty Cycle

In the NEMA world, typically "duty cycle" is referred to in one of two terms: continuous or intermittent. IEC breaks it into ten ratings:



SI - Continuous duty
The motor works at constant load for enough time to reach temperature equilibrium.

S2 - Short-time duty
The motor works at constant load, but not long enough to reach temperature equilibrium, and rest periods are long enough for the motor to reach ambient temperature.

S3 - Intermittent periodic duty
Sequential, identical run and rest cycles with constant load. Temperature equilibrium is never reached. Starting current has little effect on temperature rise.

S4 - Intermittent periodic duty with starting
Sequential, identical start, run, and rest cycles with constant load. Temperature equilibrium is not reached, but starting current affects temperature rise.

S5 - Intermittent periodic duty with electric braking
Sequential, identical cycles of starting, running at constant load, electric braking, and rest. Temperature equilibrium is not reached.

S6 - Continuous operation with intermittent load
Sequential, identical cycles of running with constant load and running with no load. No rest period.

S7 - Continuous operation with electric braking
Sequential, identical cycles of starting, running at constant load, and electric braking. No rest period.

S8 - Continuous operation with periodic changes in load and speed
Sequential, identical duty cycles of start, run at constant load and given speed, then run at other constant loads and speeds. No rest.

Insulation Designations

Amid all the differences, there is a one are of common ground - insulation classes. IEC and NEMA use the same classification system for winding insulation. It is based on the highest temperature the material can withstand continuously without degrading or reducing motor life. (Note: NEMA does not have a Class E.)

Temperature Classes are:
Class A - 105° C (221° F).
Class E - 120° C (248° F).
Class B - 130° C (266° F).
Class F - 155° C (311° F).
Class H - 180° C (356° F).

Most industrial-duty motors use Class B or Class F insulation, depending on the application. Table B compares temperature rises allowed under IEC and NEMA standards.

Table B: IEC vs. NEMA Temperature Rise Degrees C

Insulation Class	IEC 1.0 Service Factor	NEMA 1.0 Service Factor	NEMA 1.5 Service Factor*
A	60	60	70
E	75	-	-
B	80	80	90
F	100	105	115
H	125	125	-

* The term "Service Factor" is not defined in IEC. However, an IEC motor with Class F insulation meets the NEMA MG-1 definition of 1.15 Service Factor.

Torque Requirements

ABB motor designs mirror those of a NEMA Design A motor. This design offers higher starting torque and current (compared to a NEMA Design B). This stronger design from ABB results in higher efficiencies and lower noise than traditional NEMA B Designs. It should be noted that a NEMA Design B is the most common industrial motor type. Another similarity is the torque of the IEC Design H (think of it as "high" torque). Torques of the IEC "H" are nearly identical to those of NEMA Design C.

Table C shows the torque standards for IEC vs NEMA. Wherever NEMA's torque requirements differ, they are usually slightly higher, especially for 4-pole motors.

In most cases, actual values are significantly greater than those listed here. For ABB motors, this is always the case.

Table C: IEC/NEMA standards for Locked-Rotor Torque (LRT), Pull-Up Torque (PUT), and Breakdown Torque (BDT) as percent of full-load torque

HP	LRT	2 Pole PUT	BDT	LRT	4 Pole PUT	BDT
3	170/160	110/110	200/230	180/215	120/150	200/250
5	160/150	110/105	200/215	170/185	120/130	200/225
7.5	150/140	100/100	200/200	160/175	110/120	200/215
10	150/135	100/100	200/200	160/165	110/115	200/200
15 to 20	140/130	100/100	200/200	150/150	110/105	200/200

IEC Controls

As with motor ratings, IEC ratings for motor starters and contactors tend to be more numerous and application-oriented. NEMA controls are designed to fit broad ranges of needs. Therefore, by nature they will be over-designed for all but the highest ratings within a given range. IEC controls can be much more closely matched to the task at hand. There are roughly two-thirds more IEC ratings compared to NEMA.

IEC-style controls have already become common in this country, even among domestic control manufacturers. This is because of the greater rating variety and the flexibility this offers designers. Similarly, IEC motors are becoming more commonly used and purchasd in this country.

Using 50 Hz Motors at 60 Hz

In Europe and much of the world, the power grid furnishes 50 Hz power rather than 60 Hz power of North America. A common question might be. "Can you safely connect a 50 Hz design motor on a 60 Hz supply? The answer is "Yes, you can."

Three Phase Motors

A 50Hz, 3-Phase motor will operate satisfactorily (at the nameplate KW) on a 60-Hz supply if the voltage is increased by the same ratio as the frequency. For example, a 380V, 50-Hz motor can satisfactorily operate on a 460V, 60Hz input supply. The motor will perform acceptably at full nameplate KW, though shaft speed would be 1/6th higher than the nameplate speed. The available output KW of the motor will actually increase by the ratio of the frequencies (i.e. about 20%).

50 Hz, 3 phase motors operated at 230 Volts, 60 Hz may not operate satisfactorily without derating. A typical derate of KW might be by a factor of 0.80 to 0.85. This all relates to keeping motor heating in check on the 230 Volt, 60-Hz load. Most manufacturers indicate in their literature whether a given motor is satisfactory for 60-Hz input and at what KW rating. Some manufacturers will provide this information upon request.

A specially wound motor will be required in most cases when the V/Hz does not remain relatively constant (i.e. 380 / 3 / 60 or 575 / 3/ 60). Table D indicates the effects of operating the same 50-Hz, general-purpose, 3 Phase motor on various other voltage supplies. Note that the only disadvantage is the effects of heating when operated on the 230 Volt / 60 Hz supply.

Table D Operation of a Standard AC Induction Motor at Various Voltages and Frequencies

Volts	HZ	Output KW **		Speed **		Temp Rise **		Locked Rotor Amps **		Full Load Amps **		Locked Rotor Torque **		Breakdown Torque **		Full Load Torque **	
380	50	75	0%	1482	-0.1%	72	10.8%	641	-9.7%	140	5.3%	207	-10.0%	252	-10.0%	352	0.0%
400	**50**	**75**	**0%**	**1484**	**0.0%**	**65**	**0.0%**	**710**	**0.0%**	**133**	**0.0%**	**230**	**0.0%**	**280**	**0.0%**	**352**	**0.0%**
415	50	75	0%	1485	0.1%	63	-3.1%	751	5.8%	130	-2.3%	248	7.8%	302	7.9%	352	0.0%
230	60	75	0%	1777	19.7%	77	18.5%	501	-29.4%	288	116.5%	162	-29.6%	197	-29.6%	293	-16.7%
230	60	90	20%	1773	19.5%	109	67.7%	421	-40.7%	344	158.6%	135	-41.3%	164	-41.4%	352	0.0%
440	60	75	0%	1784	20.2%	56	-13.8%	699	-1.5%	123	-7.5%	232	0.9%	283	1.1%	293	-16.7%
440	60	90	20%	1781	20.0%	77	18.5%	597	-15.9%	145	9.0%	193	-16.1%	235	-16.1%	352	0.0%
460	60	75	0%	1786	20.4%	51	-21.5%	770	8.5%	117	-12.0%	254	10.4%	309	10.4%	293	-16.7%
460	60	90	20%	1783	20.1%	70	7.7%	657	-7.5%	137	3.0%	211	-8.3%	257	-8.2%	352	0.0%
480	60	75	0%	1787	20.4%	47	-27.7%	832	17.2%	113	-15.0%	277	20.4%	337	20.4%	293	-16.7%
480	60	90	20%	1784	20.2%	65	0.0%	710	0.0%	133	0.0%	230	0.0%	281	0.4%	352	0.0%

** Indicates % Change compared to a standard nameplate IEC output of 75 KW, 4 Pole, IP-55 Motor at 400V, 50 Hz

Single Phase Motors

For general-purpose, single-phase motors, the answer to the 60-Hz / 50-Hz application question is: Don't do it!

Here's the reason. Most single-phase motors require a speed-sensitive starting method. It must be sized differently to account for the lower operating speed of motors on 50-Hz supplies (i.e. The operating speed of a 50 Hz motor would be 5/6 of a 60 Hz motor). For specific applications, a motor manufacturer may be able to design a single-phase motor suitable for both 50-Hz and 60-Hz operation.

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