

ELECTRIC MOTORS

Electric motors, both ac motors and dc motors, come in many shapes and sizes. Some are standardized electric motors for general-purpose applications. Other electric motors are intended for specific tasks. In any case, electric motors should be selected to satisfy the dynamic requirements of the machines on which they are applied without exceeding rated electric motor temperature. Thus, the first and most important step in electric motor selection is determining load characteristics -- torque and speed versus time. Electric motor selection is also based on mission goals, power available, and cost.

Starting and running torque are the first parameters to consider when sizing electric motors. Starting torque requirements for electric motors can vary from a small percentage of full load to a value several times full-load torque. Starting torque varies because of a change in load conditions or the mechanical nature of the machine, which the electric motor is installed in. The latter could be caused by the lubricant, wear of moving parts, or other reasons.

Electric motors feature torque supplied to the driven machine, which must be more than that required from start to full speed. The greater the electric motor's reserve torque, the more rapid the acceleration.

Electric motor drive systems that use gear reducers have parts that rotate at different speeds. To calculate acceleration torque required for these electric motors, rotating components must be reduced to a common base. The part inertias are usually converted to their equivalent value at the drive shaft. Equivalent inertia $W_2K_2^2$ of the load only is found from:

$$W_2K_2^2 = (W_1K_1^2)(N_1/N_2)^2$$

where $W_1K_1^2$ = load inertia in lb-ft², N_1 = load speed in rpm, and N_2 = electric motor speed in rpm.

Electric motors have bodies, which have a straight-line motion are often connected to rotating driving units by rack-and-pinion, cable, or cam mechanisms. For these electric motor parts, the equivalent WK^2 is found from:

$$WK^2 = W(S/2\pi N)^2$$

where W = load weight, S = translation speed in fpm, π is pi, and N = rotational speed in rpm.

Electric Motors - Acceleration time:

Acceleration time for electric motors is directly proportional to total inertia and inversely proportional to the electric motor torque. For electric motors with constant acceleration torque, acceleration time is:

$$t = \frac{WK^2(N_2 - N_1)}{308 T_x}$$

where WK^2 = rotational inertia in lb-ft², $(N_2 - N_1)$ = the speed difference, and T_x = acceleration torque in lb-ft. For translating bodies, acceleration time is:

$$t = \frac{W(S_2 - S_1)}{1,932 F_x}$$

where W = weight of the load in lb, $(S_2 - S_1)$ = the translation speed difference, and F_x = translation force in lb.

An approximation method is necessary to find the electric motor's acceleration time if acceleration torque is not linear during speed increase. The quickest method is to break up the speed versus torque curves of the electric motor and the driven machine into segments and calculate acceleration time for each segment. Accurate electric motor acceleration times usually result.

Electric Motors - Power rating:

Electric motors offer the horsepower required to drive a machine, which is typically referred to as electric motor load. The most common equation for power based electric motors on torque and rotational speed is: hp = (torque X rpm)/5,250.

If the electric motor's load is not constant and follows a definite cycle, a horsepower versus time curve for the driven machine is helpful. From this curve both peak and rms the electric motor's horsepower can be determined. Rms load horsepower indicates the necessary continuous electric motor rating. Peak load

horsepower is not necessarily an indication of the required electric motor rating. However, when a peak load is maintained for a period of time, electric motors feature a rating, which usually should not be less than peak load horsepower.

Duty cycle - Electric Motors:

Continuous steady-running loads over long periods are demonstrated by fans and blowers. On the other hand, electric motors installed in machines with flywheels may have wide variations in running loads. Often, electric motors use flywheels to supply the energy to do the work, and the electric motor does nothing but restore lost energy to the flywheel. Therefore, choosing the proper electric motor also depends on whether the load is steady, varies, follows a repetitive cycle of variation, or has pulsating torque or shocks.

For example, electric motors that run continuously in fans and blowers for hours or days may be selected on the basis of continuous load. But electric motors located in devices like automatically controlled compressors and pumps start a number of times per hour. And electric motors in some machine tools start and stop many times per minute.

Duty cycle is a fixed repetitive load pattern over a given period of time which is expressed as the ratio of on-time to cycle period. When operating cycle is such that electric motors operate at idle or a reduced load for more than 25% of the time, duty cycle becomes a factor in sizing electric motors. Also, energy required to start electric motors (that is, accelerating the inertia of the electric motor as well as the driven load) is much higher than for steady-state operation, so frequent starting could overheat the electric motor.

For most electric motors (except squirrel-cage electric motors during acceleration and plugging) current is almost directly proportional to developed torque. At constant speed, torque is proportional to horsepower. For accelerating loads and overloads on electric motors that have considerable droop, equivalent horsepower is used as the load factor. The next step in sizing the electric motor is to examine the electric motor's performance curves to see if the electric motor has enough starting torque to overcome machine static friction, to accelerate the load to full running speed, and to handle maximum overload.

Duty cycle - Electric Motors:

Continuous steady-running loads over long periods are demonstrated by fans and blowers. On the other hand, electric motors installed in machines with flywheels may have wide variations in running loads. Often, electric motors use flywheels to supply the energy to do the work, and the electric motor does nothing but restore lost energy to the flywheel. Therefore, choosing the proper electric motor also depends on whether the load is steady, varies, follows a repetitive cycle of variation, or has pulsating torque or shocks.

For example, electric motors that run continuously in fans and blowers for hours or days may be selected on the basis of continuous load. But electric motors located in devices like automatically controlled compressors and pumps start a number of times per hour. And electric motors in some machine tools start and stop many times per minute.

Duty cycle is a fixed repetitive load pattern over a given period of time which is expressed as the ratio of on-time to cycle period. When operating cycle is such that electric motors operate at idle or a reduced load for more than 25% of the time, duty cycle becomes a factor in sizing electric motors. Also, energy required to start electric motors (that is, accelerating the inertia of the electric motor as well as the driven load) is much higher than for steady-state operation, so frequent starting could overheat the electric motor.

For most electric motors (except squirrel-cage electric motors during acceleration and plugging) current is almost directly proportional to developed torque. At constant speed, torque is proportional to horsepower. For accelerating loads and overloads on electric motors that have considerable droop, equivalent horsepower is used as the load factor. The next step in sizing the electric motor is to examine the electric motor's performance curves to see if the electric motor has enough starting torque to overcome machine static friction, to accelerate the load to full running speed, and to handle maximum overload.

Electric Motors - Service factors:

A change in NEMA standards for electric motor service factors and temperature rise has been brought about because of better insulation used on electric motors. For instance, a 1.15 service factor -- once standard for all open electric motors -- is no longer standard for electric motors above 200 hp.

Increases in electric motor temperature are measured by the resistance method in the temperature rise table. Electric motors feature a nameplate temperature rise, which is always expressed for the maximum allowable load. That is, if the electric motor has a service factor greater than unity, the nameplate

temperature rise is expressed for the overload. Two Class-B insulated electric motors having 1.15 and 1.25 service factors will, therefore, each be rated for a 90°C rise. But the second electric motor will have to be larger than the first in order to dissipate the additional heat it generates at 125% load.

Electric motors feature a service factor, which indicates how much over the nameplate rating any given electric motor can be driven without overheating. NEMA Standard MGI-143 defines service factor of an ac motor as "...a multiplier which, when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the service factor..." In other words, multiplying the electric motor's nameplate horsepower by the service factor tells how much electric motors can be overloaded without overheating. Generally, electric motor service factors:

- Handle a known overload, which is occasional.
- Provide a factor of safety where the environment or service condition is not well defined, especially for general-purpose electric motors.
- Obtain cooler-than-normal electric motor operation at rated load, thus lengthening insulation life.

Electric Motors - Efficiency:

Small universal electric motors have an efficiency of about 30%, while 95% efficiencies are common for three-phase machines. In less-efficient electric motors, the amount of power wasted can be reduced by more careful application and improved electric motor design.

Electric motor's feature an efficiency level, which also depends on actual electric motor load versus rated load, being greatest near rated load and falling off rapidly for under and overload conditions.

AC vs. DC motors

Although BLDC motors are practically identical to permanent magnet AC motors, the controller implementation is what makes them DC. While AC motors feed sinusoidal current simultaneously to each of the legs, (with an equal phase distribution), DC controllers only approximate this by feeding full positive and negative power to two of the legs at a time. The major advantage of this is that both the logic controllers and battery power sources operate on DC, such as in computers and electric cars.

Vector drives are DC controllers that take the extra step of converting back to AC for the motor. The DC-to-AC conversion circuitry is usually expensive and less efficient, but they have the advantage of being able to run smoothly at very low speeds or completely stop in a position not directly aligned with a pole. Motors used with a vector drive are typically called AC motors.

Electric Motor Comparison

<u>AC Motor</u>	<u>DC Motor</u>
Single-speed transmission	Multi-speed transmission
Light weight	Heavier at equivalent power
Less expensive	More expensive
95% Efficiency at full load	85-95% Efficiency at full load
More expensive controller	Simple controller
Motor/controller/inverter more expensive	Motor/controller less expensive

As shown in the comparison, an AC motor is less expensive than a DC motor, an AC system is more expensive due to the cost of the complex electronics associated with the AC inverter and motor controller. AC motors are the most commonly used motor in home appliances and machine tools. These motors are very reliable and because they contain a single moving part, they should last the life of the vehicle with little or no maintenance. Typical motor characteristics are listed in the table below.

DC Motors

Industrial applications use dc motors because the speed-torque relationship can be varied to almost any useful form -- for both dc motor and regeneration applications in either direction of rotation. Continuous

operation of dc motors is commonly available over a speed range of 8:1. Infinite range (smooth control down to zero speed) for short durations or reduced load is also common.

Dc motors are often applied where they momentarily deliver three or more times their rated torque. In emergency situations, dc motors can supply over five times rated torque without stalling (power supply permitting).

Dynamic braking (dc motor-generated energy is fed to a resistor grid) or regenerative braking (dc motor-generated energy is fed back into the dc motor supply) can be obtained with dc motors on applications requiring quick stops, thus eliminating the need for, or reducing the size of, a mechanical brake.

Dc motors feature a speed, which can be controlled smoothly down to zero, immediately followed by acceleration in the opposite direction -- without power circuit switching. And dc motors respond quickly to changes in control signals due to the dc motor's high ratio of torque to inertia.

DC Motor types: Wound-field dc motors are usually classified by shunt-wound, series-wound, and compound-wound. In addition to these, permanent-magnet and brushless dc motors are also available, normally as fractional-horsepower dc motors. Dc motors may be further classified for intermittent or continuous duty. Continuous-duty dc motors can run without an off period.

DC Motors - Speed control: There are two ways to adjust the speed of a wound-field dc motor. Combinations of the two are sometimes used to adjust the speed of a dc motor.

DC Motor - Shunt-field control: Reel drives require this kind of control. The dc motor's material is wound on a reel at constant linear speed and constant strip tension, regardless of diameter.

Control is obtained by weakening the shunt-field current of the dc motor to increase speed and to reduce output torque for a given armature current. Since the rating of a dc motor is determined by heating, the maximum permissible armature current is approximately constant over the speed range. This means that at rated current, the dc motor's output torque varies inversely with speed, and the dc motor has constant-horsepower capability over its speed range.

Dc motors offer a solution, which is good for only obtaining speeds greater than the base speed. A momentary speed reduction below the dc motor's base speed can be obtained by overexciting the field, but prolonged overexcitation overheats the dc motor. Also, magnetic saturation in the dc motor permits only a small reduction in speed for a substantial increase in field voltage.

Dc motors have a maximum standard speed range by field control is 3:1, and this occurs only at low base speeds. Special dc motors have greater speed ranges, but if the dc motor's speed range is much greater than 3:1, some other control method is used for at least part of the range.

Armature-voltage DC Motor Control: In this method, shunt-field current is maintained constant from a separate source while the voltage applied to the armature is varied. Dc motors feature a speed, which is proportional to the counter emf. This is equal to the applied voltage minus the armature circuit IR drop. At rated current, the torque remains constant regardless of the dc motor speed (since the magnetic flux is constant) and, therefore, the dc motor has constant torque capability over its speed range.

Armature-voltage DC Motor Control (cont.): Horsepower varies directly with speed. Actually, as the speed of a self-ventilated motor is lowered, it loses ventilation and cannot be loaded with quite as much armature current without exceeding the rated temperature rise.

DC Motors - Selection: Choosing a dc motor and associated equipment for a given application requires consideration of several factors.

DC Motors - Speed range: If field control is to be used, and a large speed range is required, the base speed must be proportionately lower and the motor size must be larger. If speed range is much over 3:1, armature voltage control should be considered for at least part of the range. Very wide dynamic speed range can be obtained with armature voltage control. However, below about 60% of base speed, the motor should be derated or used for only short periods.

DC Motors - Speed variation with torque: Applications requiring constant speed at all torque demands should use a shunt-wound dc motor. If speed change with load must be minimized, a dc motor regulator, such as one employing feedback from a tachometer, must be used.

When the dc motor speed must decrease as the load increases, compound or series-wound dc motors may be used. Or, a dc motor power supply with a drooping volt-ampere curve could be used with a shunt-wound dc motor.

DC Motors - Reversing: This operation affects power supply and control, and may affect the dc motor's brush adjustment, if the dc motor cannot be stopped for switching before reverse operation. In this case, compound and stabilizing dc motor windings should not be used, and a suitable armature-voltage control system should supply power to the dc motor.

DC Motors - Duty cycle: Direct current motors are seldom used on drives that run continuously at one speed and load. Motor size needed may be determined by either the peak torque requirement or heating.

DC Motors - Peak torque: The peak torque that a dc motor delivers is limited by that load at which damaging commutation begins. Dc motor brush and commutator damage depends on sparking severity and duration. Therefore, the dc motor's peak torque depends on the duration and frequency of occurrence of the overload. Dc motor peak torque is often limited by the maximum current that the power supply can deliver.

Dc motors can commutate greater loads at low speed without damage. NEMA standards specify that machines powered by dc motors must deliver at least 150% rated current for 1 min at any speed within rated range, but most dc motors do much better.

DC Motors - Heating: Dc motor temperature is a function of ventilation and electrical/mechanical losses in the machine. Some dc motors feature losses, such as core, shunt-field, and brush-friction losses, which are independent of load, but vary with speed and excitation.

The best method to predict a given dc motor's operating temperature is to use thermal capability curves available from the dc motor manufacturer. If curves are not available, dc motor temperature can be estimated by the power-loss method. This method requires a total losses versus load curve or an efficiency curve.

For each portion of the duty cycle, power loss is obtained and multiplied by the duration of that portion of the cycle. The summation of these products divided by the total cycle time gives the dc motor's average power loss. The ratio of this value to the power loss at the motor rating is multiplied by the dc motor's rated temperature rise to give the approximate temperature rise of the dc motor when operated on that duty cycle.

Brush less DC (BLDC) motors and Brushed DC (BDC) motors Comparison

A brushless DC motor (BLDC) is an AC synchronous electric motor that from a modeling perspective looks very similar to a DC motor.

In a conventional (brushed) DC-motor, the brushes make mechanical contact with a set of electrical contacts on the rotor (called the commutator), forming an electrical circuit between the DC electrical source and the armature coil-windings. As the armature rotates on axis, the stationary brushes come into contact with different sections of the rotating commutator. The commutator and brush-system form a set of electrical switches, each firing in sequence, such that electrical-power always flows through the armature-coil closest to the stationary stator (permanent magnet).

In a BLDC motor, the electromagnets do not move; instead, the permanent magnets rotate and the armature remains static. This gets around the problem of how to transfer current to a moving armature. In order to do this, the brush-system/commutator assembly is replaced by an intelligent electronic controller. The controller performs the same power-distribution found in a brushed DC-motor, but using a solid-state circuit rather than a commutator/brush system.

BLDC motors offer several advantages over brushed DC-motors, including higher efficiency and reliability, reduced noise, longer lifetime (no brush erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI.) The maximum power that can be applied to a BLDC motor is exceptionally high, limited almost exclusively by heat, which can damage the magnets. BLDC's main disadvantage is higher cost, which arises from two issues. First, BLDC motors require complex electronic

speed controls to run. Brushed DC-motors can be regulated by a comparatively trivial variable resistor (potentiometer or rheostat), which is inefficient but also satisfactory for cost-sensitive applications. Second, many practical uses have not been well developed in the commercial sector. For example, in the RC hobby scene, even commercial brushless motors are often hand-wound while brushed motors use armature coils which can be inexpensively machine-wound.

BLDC motors are considered more efficient than brushed DC-motors. This means for the same input power, a BLDC motor will convert more electrical power into mechanical power than a brushed motor, mostly due to absence of friction of brushes. The enhanced efficiency is greatest in the no-load and low-load region of the motor's performance curve. Under high mechanical loads, BLDC motors and high-quality brushed motors are comparable in efficiency.

BLDC motors can potentially be deployed in any field-application currently fulfilled by brushed DC motors. Cost and control complexity prevents BLDC motors from replacing brushed motors in most common areas of use. Nevertheless, BLDC motors have come to dominate many applications: Consumer devices such as computer hard drives, CD/DVD players, and PC cooling fans use BLDC motors almost exclusively. Low speed, low power brushless DC motors are used in direct-drive turntables. High power BLDC motors are found in electric vehicles and some industrial machinery. These motors are essentially AC synchronous motors with permanent magnet rotors.

The Honda Civic hybrid car uses a BLDC motor to supplement the output of the internal combustion engine when the extra power is needed. It is also used to start the engine versus a conventional starter and solenoid method.

Wheel Motor

Investigate wheelmotor...

Sample motors

<http://www.rotomag.com/permanentdcmotor.htm>

Battery Operated PMDC motors



[download PDF sheet >](#)

[Battery operated PMDC motors](#) feature large brushes, high current carrying capacity and can deliver high starting torque.

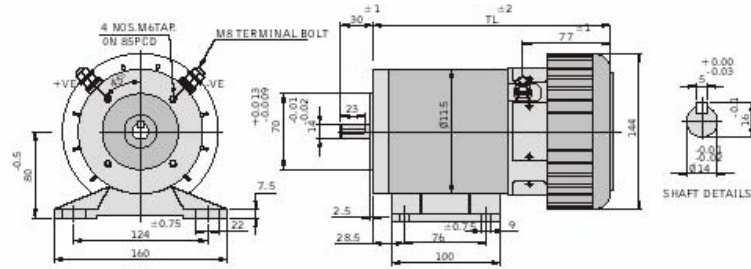
Voltage : 12,24,36,48

H.P. : 0.25 to 3.0

RPM : 1500-4000

Applications : Electric vehicles, Golf cars, Golf Caddies, Cleaning equipment

HK - SERIES (TEFC-4 POLE)

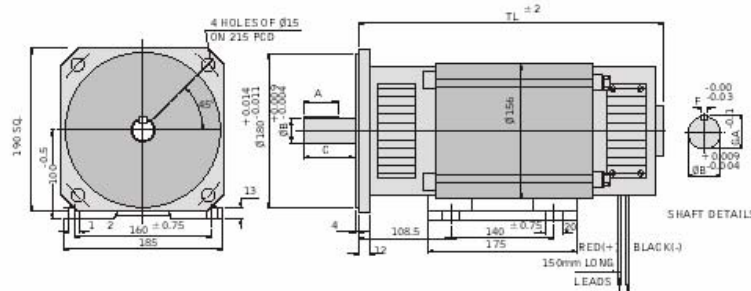


SPECIFICATIONS

H.P./Watts	Frame size	Volts				Current (Amps)				Torque (Kg.cm)	Mounting	Type	Ins. Class	Protection	Duty	TL	Wt. (kg)
		V1	V2	V3	V4	I1	I2	I3	I4								
1500 RPM MOTORS																	
0.25/180	HK-30	12	24	36	48	19.0	10.0	6.5	5.0	12	Foot/Face	TEFC	F	IP-44	S1	200	9
0.50/370	HK-3	12	24	36	48	39.0	19.5	13.0	10.0	24	Foot/Face	TEFC	F	IP-44	S1	220	11
0.75/560	HK-5	12	24	36	48	58.0	29.0	19.5	14.5	36	Foot/Face	TEFC	F	IP-44	S1	260	12
1.00/750	HK-7	-	24	36	48	-	39.0	26.0	19.5	48	Foot/Face	TEFC	F	IP-44	S1	300	14
3000 RPM MOTORS																	
0.50/370	HK-30	12	24	36	48	39.0	19.5	13.0	10.0	12	Foot/Face	TEFC	F	IP-44	S1	200	9
0.75/560	HK-3	12	24	36	48	58.0	29.0	19.5	14.5	18	Foot/Face	TEFC	F	IP-44	S1	220	11
1.00/750	HK-5	-	24	36	48	-	39.0	26.0	19.5	24	Foot/Face	TEFC	F	IP-44	S1	260	12
1.50/1120	HK-7	-	24	36	48	-	58.5	39.0	29.0	36	Foot/Face	TEFC	F	IP-44	S1	300	14

Choose Between Foot & Face Mounting. NEMA sizes also available.

V-SERIES (SPDP-4 POLE)



SPECIFICATIONS

HP/Watts	Frame Size	Volts				Current (Amps)				Torque (Kg.Cm)	Dimensions					Wt. (Kg.)	
		V1	V2	V3	V4	I1	I2	I3	I4		A	B	C	F	GA		TL
1500 RPM, F-CLASS, SPDP TYPE, S1 DUTY MOTOR, FOOT/FLANGE MOUNTING, WITH IP-21 PROTECTION																	
1.0/750	V1	12	24	36	48	78	39.0	26.0	19.5	48	34	19	37	6	21.5	310	16
2.0/1490	V2	-	24	36	48	-	78.0	52.0	39.0	95	40	24	50	8	27	385	23
3.0/2240	V3	-	-	36	48	-	-	78.0	62.0	144	40	28	60	8	31	460	30
3000 RPM, F-CLASS, SPDP TYPE, S1 DUTY MOTOR, FOOT/FLANGE MOUNTING, WITH IP-21 PROTECTION																	
1.0/750	V1	-	24	36	48	-	39.0	26.0	19.5	24	34	19	37	6	21.5	310	16
2.0/1490	V2	-	-	36	48	-	-	52.0	39.0	48	40	24	50	8	27	385	23
3.0/2240	V2	-	-	-	48	-	-	-	62.0	72	40	24	50	8	27	385	23

Choose between Foot & Flange Mounting. NEMA sizes also available.