

## Comparison of DC Brushed Motors vs. AC Induction Motors for Electric Vehicle Drive

Of all the components in an electric drive conversion, the motor is probably the most important. The motor has the most influence on the performance (speed, acceleration, efficiency) of the converted vehicle. Also, the motor influences the selection of other major components of the vehicle (controller, batteries, and indirectly the charger and DC/DC converter). The motor is a primary factor in the cost of the conversion.

There are several motor types and many sizes (power) and form factors (physical shapes) of these motor types. For reasons of practicality and commercial availability in the sizes required for electric vehicle conversions, the choice of motor types is reduced to just two types: series wound DC brushed machines and three-phase AC induction machines. The advantages and disadvantages for these two motor types are listed in Table 1 on page 2.

The overwhelming disadvantage to DC brushed machines (both series wound and other types) are the brushes themselves. Brushes ride on the commutator of the motor's armature (the part of the motor that turns) and form a rotary switch that switches high currents to various sections of the armature coils. The mechanical nature of this rotary switching of high power produces considerable electrical arcing and also mechanical wear of the carbon brushes and the copper segments of the commutator. This arcing can ignite flammable vapors if they are present around the motor. Although this condition is generally unlikely, the possibility of such ignition usually excludes brushed motors from commercially manufactured vehicles. In contrast, an AC induction motor, which has no brushes, completely eliminates this risk.

Besides the ignition risk, brushes produce electrical noise (EMI/RFI) that can interfere with cell phones, computers, and other electronics. Because brushes are subject to mechanical wear they should be checked annually (increased maintenance) and may have to be replaced every few years. Carbon dust is produced as they wear. The dust is conductive and can cause unintended connections between high voltage and the vehicle chassis. Such connection paths can electrically shock those who service the vehicle.

An induction AC motor avoids these problems. They are generally of higher efficiency; virtually maintenance-free operation, sealed or splash resistant, and the controllers generally provide regenerative braking. But, the controllers (each motor type requires a specific type of controller) are more complicated and more expensive for AC. So AC motor systems are typically more expensive than comparable DC brushed motor systems.

Most AC induction motors are used in industrial applications. They are designed to operate at 240 volts AC or higher. As a result, using AC motors in electric vehicles generally requires higher voltage battery packs, thus a greater quantity of batteries to obtain the higher voltage. The greater number of batteries also adds cost in more battery cables and a higher voltage charger than for a lower voltage system.

Industrial motors can be rewound to operate on lower voltages, but that would be a "custom" motor and more expensive than a standard motor. The cost of the custom rewinding will be comparable to the cost of extra batteries. Higher voltage AC motors run faster than lower voltage motors (or DC motors) and are more efficient. Rewinding

for lower voltage operation will increase the electrical current requirements, which means thicker cables and also a drop in efficiency.

**Table 1: Series DC Brushed Machine to 3-phase AC Induction Machine Comparison**

<b>Series DC: Advantage</b>	<b>Importance to application</b>
1. Commonly available	Multiple vendors
2. High peak torque for a given hp size	Faster acceleration of vehicle.
3. Available in lower voltage windings	Less batteries in series required.
<b>Series DC: Disadvantage</b>	
1. Brushes (arching, wear, carbon dust)	Possible to ignite flammable environments, radio interference, increased maintenance, electrical shock
2. "Open" motor	Susceptible to damage from water spray
3. Generally lower maximum speed	Uses a smaller gear ratio so tends to negate advantage #2
<b>Induction AC: Advantage</b>	
1. "Brushless" motor	More reliable, virtually maintenance free, no arching, no carbon dust.
2. Sealed motors	Water or cleaning spray not a problem.
3. Generally higher efficiency	Longer run time on a given battery charge.
4. Most AC controllers offer regenerative braking	Returns some energy for slightly longer driving range.
<b>Induction AC: Disadvantages</b>	
1. Generally 240V or higher voltage	Requires more batteries in series.
2. Controller more expensive than DC	More expensive conversion.