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THE SIMPLE TRUTH (PART 1)

BOTTOM LINE UP FRONT

Electric motor manufacturers seemingly suggest that their exceptional electric motor performance was the result of new invention, instead of the empirical selection of port voltage, frequency of excitation, and available packaging techniques that would always result in the similar performance gain, if equally applied between contestants.

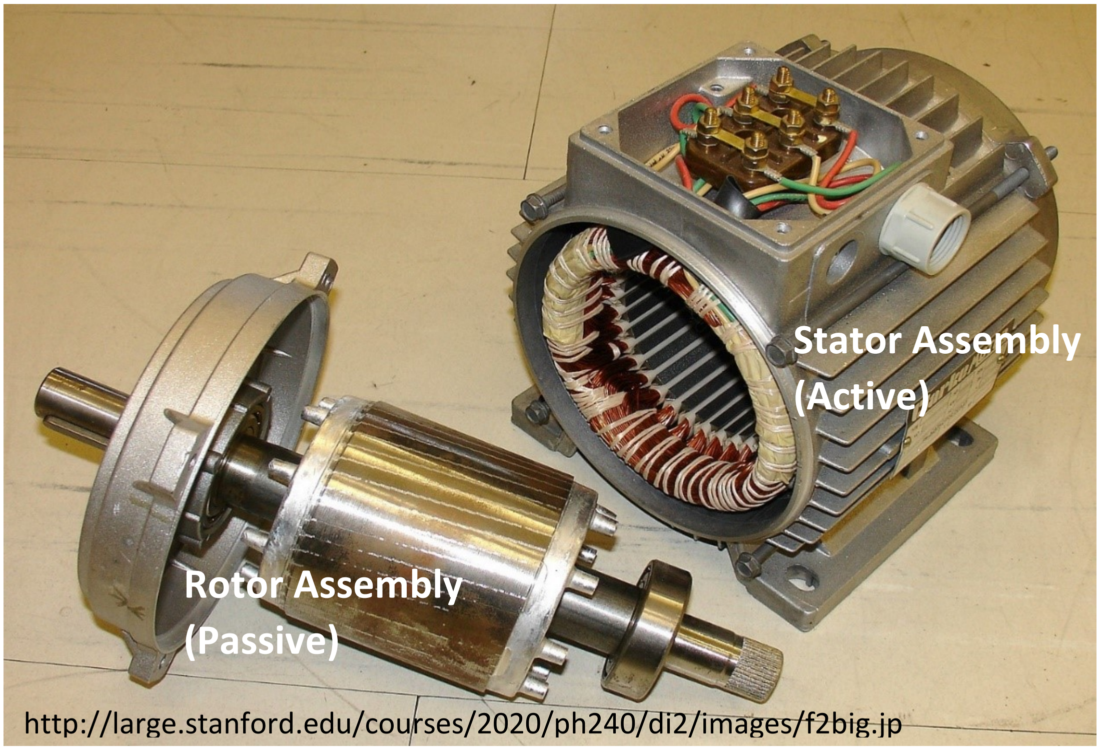
This white paper will show that only BEM with the invention of brushless real time emulation control (BRTEC) implements the brushless, permanent magnet free, symmetric multiphase wound-rotor “synchronous” doubly-fed electric motor system, which at least a half century of classic electric motor study, research, and publication proved to provide double the power density and octuple the peak torque at half the cost and half the loss per unit of continuous power rating of any other electric motor system with the same port voltage, frequency of excitation, torque, maximum load speed, flux density, and packaging design.

https://www.clarketooling.co.uk/product/clarke-1-5hp-single-

Figure 1

DESCRIPTION

Figure 1 shows a typical electric motor with the fan assembly. For high power density electric motors, such as for electric vehicles (EV), the fan assembly is replaced with a cooling fluid mechanism with hydraulic pumps and radiators.



http://large.stanford.edu/courses/2020/ph240/di2/images/f2big.jp

Figure 2

Figure 2 shows the disassembled electric motor of Figure 1 with the rotor and stator assemblies exposed. Without component deviation, all electric motors have basically the same packaging of materials, such as structural material, electrical steel, copper windings, rare-earth permanent magnets (**RE-PM**), etc.

The Stator Assembly (Active) comprises: 1) the "Stator Active Winding Set," which is a directly-excited multiphase winding set that determines the torque (or active current) rating of the electric motor and the power rating of the electric motor with a given voltage and frequency of excitation applied at the winding terminals, 2) the "Motor Chassis," and 3) the "3-Phase Terminal Box" for electrical connection to the active winding set. Note: Only a directly-excited multiphase winding set *independently* produces a rotating magnetic field that pulls or pushes on the rotor assembly and as a result, produces working power to the electric to mechanical energy conversion process. In contrast, the Rotor Assembly (Passive) comprises: 1) a "Passive" Slip-Induction Winding Set (*i.e., asynchronous or induction electric motors*), RE-PMs (*i.e., synchronous permanent magnet*), Reluctance Saliencies (*i.e., synchronous or asynchronous reluctance electric* *motors depending on control*), or a DC Field Winding (*i.e., synchronous field wound motors, such as field wound superconducting motors of today*), 2) the "Bearings," 3) the "End Shields" (with only one showing), 4) the "Axle," and 5) the "Cooling Fan" (not shown).

The size of the rotor assembly is similar to the size of the stator assembly by including all of the unshown rotor components, such as the fan and both end shields. The operational loss of the rotor assembly is similar to the loss of the stator assembly by including frictional losses, such as the fan and bearing losses. The cost of the rotor and stator are similar, since cost is a function of the amount (*i.e., size*) and types of material, such as electrical steel, copper, or RE-PMs. Noticeably without a directly excited multiphase windings set (or active winding set), the passive rotor effectively *wastes* half of the electric motor real estate, cost, and loss by not contributing an additional increment of "working power" to the electromechanical energy conversion process along with the active stator assembly. Higher Efficiency means "more" electrical (and structural) steel and "more" copper. "More" means larger size, higher cost, and shallower air-gap.

The motor shown is the customary "radial flux" electric motor, which has a cylinder (rotor) inside a cylinder (stator) form factor and a flux path that flows radially (*i.e., perpendicular*) to the axle across the air-gap between the rotor and stator. In contrast, the flux path of an "axial-flux" electric motor, which has an adjacent rotor and stator disk form factor, flows axially (*i.e., parallel*) to the axle. With similar adjacent rotor and stator disks, the "axial-flux" electric motor gives a better visual understanding that the rotor or stator assembly reasonably consumes half of the electric motor size. The axial flux electric motor has other attractive cost, loss, and size attributes, which are making these motors attractive for electric vehicles once the manufacturing complexities are resolved, such as with MOTORPRINTER.

Performance electric motor systems, such as for an electric vehicle, include a universal electronic controller component that applies a load-tuned, variable excitation frequency and voltage to the stator winding terminals of the electric motor component for optimized performance or for practical operation. Customarily, the electronic controller and electric motor are from different manufacturers but this concept is beginning to change with the advent of the so-called smart motor that distinctly mounts the electronic controller component onto the motor chassis with additional fine control tuning. Without considering the optimized performance, the electronic motor controller *compounds* the loss, cost, and size of the electric motor "system." For instance, if the motor is 95% efficient and the controller is 95% efficient, the operational system efficiency of the electric motor system is actually 90.25% (95% x 95%) and as a result, the electronic controller should always be equitably included in the motor system size, loss, and cost calculations. Also, RE-PM electric machine systems are operating at high speeds to reduce its size and amount of expensive RE-PM materials but must include a speed reduction gearbox, which compounds the loss, cost, size, and reliability of the propulsion electric motor system and likewise, should be included in the motor system size, loss, and cost calculations. For instance, if the motor system is 90.25% efficient and the gearbox is 98% efficient, the operational efficiency of the propulsion electric motor system is a sobering 88.45% (90.25% x 98%).

The classic 101 study of electric machines (*i.e., electric motors, generators, and transformers*) begins with the optimized synchronous, symmetric multiphase wound-rotor circuit and control architecture by postulating the invention of a brushless real time emulation control (BRTEC) means to guarantee stable, contiguous, and synchronous operation from sub-synchronous to super synchronous speeds, regardless of random rotor axle and line perturbations, of two directly-excited multiphase winding sets or active winding sets (*i.e., doubly-fed*) on the rotor and stator assemblies, respectively, which conveniently preserves the same packaging of size, loss, and cost as any other electric motor system. The classic 101 study of the synchronous symmetric electric machine becomes the follow-on study for the synchronous or asynchronous asymmetric electric machines by deoptimizing the electromagnetically *symmetry* of an active rotor and active stator assembly under precision BRTEC with the electromagnetically *asymmetry* of an active stator assembly (*i.e., singly-fed*) but a passive rotor assembly of slip-induction windings, rare-earth permanent magnets, reluctance saliencies, or DC field windings under an *estimating* control derivative of flux-oriented control (FOC), such as direct-torque control (DTC). Stable, contiguous, and synchronous operation from sub-synchronous to super-synchronous speeds calculates to twice the constant torque speed range (*i.e., maximum load speed or MLS*) or twice the power within the electric motor packaging with a given torque, excitation frequency, and voltage of operation (*i.e., 7200 RPM for 60 Hz and two pole for the symmetric electric machine versus 3600 RPM for the asymmetric electric machines*). As a result, BEM forgoes the customary multiplicity of electric motor categories and instead, correctly categorizes all electric motor systems as either the synchronous symmetric electric machine system, as only provided by SYNCHRO-SYM, or the asynchronous or synchronous asymmetric electric machine systems.

In conclusion, by simply retrofitting the "passive rotor assembly" of the "me-too" asymmetric circuit and control architecture of *all other* electric motor or generator systems with the "active rotor assembly" of the *symmetric* circuit and control architecture of SYNCHRO-SYM, which includes replacing FOC with the compact BRTEC for synchronous operation, a century of classic electric motor and generator study, research, and publication, which were reimagined to practical reality by a regiment of BEM prototyping and invention, have proven the power density of the *original* asymmetric electric machine "system" package would double, the loss would halve, the cost would halve, and the peak torque would octuple (*per unit of continuous power rating*) by magnifying the performance with two active winding sets instead of the single active winding set of all other asymmetric electric motor systems. With octuple peak torque potential of all others and without RE-PMs, only SYNCHRO-SYM is the direct-drive (*i.e., gearless*) electric motor propulsion system candidate, which would provide a big increase in an electric vehicle range. For instance, with a typical gearless electric motor propulsion system efficiency of 97% *(See Koenigsegg Alternative)*, SYNCHRO-SYM reasonably provides a 10% (*i.e., 1 – 97.00% ÷ 88.45%*) increase in EV battery range over the typical geared RE_PM electric motor propulsion system.[i]

- SIMPLE TRUTH (PART 2) -

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[i] Assuming a fully regenerative EV and continuous driving speed, the only EV drag is reasonably assumed to be vehicle friction, such as road friction, wind resistance, accessories, etc., and continuous electric motor propulsion system Loss and as a result, Battery Charge (KWH) minus [Friction (KW/H) minus (1 minus (Efficiency * Electric Motor Propulsion System Continuous Power) (KW/H))] * Time (H) = 0. Assuming the same vehicle with the same battery and continuous driving speed but with two different electric motor propulsion systems of highest efficiency, X, and lowest efficiency, Y, the improvement in battery range, while including all EV losses, calculates to (1 -X) minus (1 – Y) * 100, or every incremental percentage point increase in electric motor propulsion system efficiency provides approximately an incremental percentage point increase in battery range.