EXECUTIVE SUMMARY of BEST ELECTRIC MACHINE

Bottom Line Up Front:

- As the backbone of the electricity infrastructure, electric motors consume at least 45% of the entire global supply of electricity, which has a compounded annual growth of 4%, electric generators produce virtually the entire global supply of electricity, which includes electricity generated from renewable energy, and electric motors and generators (i.e., electric machines) will virtually produce and consume the entire 70% of additional expected growth in the global supply of electricity for providing electric propulsion as the likely primary means of transportation by circa 2035:
  - More efficient electric machines (i.e., electric motors or generators) would save considerable amounts of electricity, associated cost, and resulting environmental pollution, such as CO2. For instance, a reasonable 2% incremental improvement in electric motor system efficiency (e.g., from 90% efficiency to 92%) could save nearly 1% (e.g., 45% x (2% ÷ 100%)) of electricity consumption of today’s entire global supply of electricity; or by reasonably assuming 45% of all electric vehicle (EV) loss is associated with the propulsion electric machine system of a fully regenerative EV, which does not consume work in a round trip (against gravity) and with wind and rolling resistance as the remaining loss, the 2% out of a possible 10% improvement could increase the EV range by a healthy 9% (e.g., 45% x (2% ÷ (100%-90%))).
  - Always essential for decarbonization applications, such as renewable energy (e.g., wind, hydro, tidal, hydrogen, etc.), electric transportation (e.g., ships, EV, electric airplanes, trains, etc.), and industry (e.g., fans, pumps, machinery, etc.), the very competitive electric machine market (including electronic control) is well over $300B annually, all of which use the same century old asymmetric electric machine circuit and control architecture with a “passive rotor assembly” of permanent magnets, slip-induction dependent windings, reluctance saliencies, or DC field windings.
  - In response, professional articles are being published almost daily that effectively focus on optimizing the efficiency, cost, and size of the century old me-too electric machine circuit and control architecture by strategically applying readily available and conveniently appliable performance enhancing material, winding, thermal, packaging, manufacturing, and control techniques (with similar results) but with the majority of articles blindly focused on the expensive neodymium-dysprosium rare-earth permanent magnet (RE-PM) electric machine system, which are notionally considered to be the best performing but with its supply chain controlled by a global adversary, the Chinese Communist Party (CCP), with critical environmental, free enterprise innovation, and geopolitical consequences.

- While “innovating for our clean and sustainable energy future,” Best Electric Machine (BEM) provides at least the only practical solution to the CCP RE-PM electric machine system with the patented invention of a new symmetric electric machine circuit and control architecture, called SYNCHRO-SYM, which uniquely comprises the symmetry of a contiguously stable “active rotor assembly” that contributes additional active power rating to the electro-mechanical conversion process from sub-synchronous to super-synchronous speeds and as a result, immediately magnifies the performance of the century old me-too asymmetric electric machine circuit and control architecture while reducing its cost and improving its efficiency by effectively eliminating the entire “passive rotor assembly,” where reasonably half of the electric machine cost, size, and...
loss per unit of active power rating occur but without contributing additional active power rating to the electro-mechanical conversion process.

**General Electric Motor or Generator Comparative Design Criteria:**

- Using the following electric machine design basics from *Electric Machine Design Distinctions and Constraints*, any electric machine system, including RE-PM electric machine systems, equitably designed with similar performance enhancing material, winding, packaging, manufacturing, thermal, and high speed control techniques will show similar effective air-gap area (and associated size or volume) for a given continuously rated torque at a “synchronous speed” determined by a given voltage and frequency of excitation. Instead, true cost-performance differentiators between electric machine systems with the same thermal considerations that go beyond the century old me-too electric machine system circuit and control architecture are: 1) continuous constant torque speed range (*at the synchronous speed design torque*), 2) associated loss or efficiency, and 3) peak torque capability:
  - All electric machine systems produce moving force or rotating torque with synchronized interaction between two orthogonal magnetic flux or current vector components in accordance with Lorentz Law, which are: 1) winding magnetizing current or magnetizing flux (or instead permanent magnet coercivity) for “passively” establishing the flux density in the air-gap between the rotating and stationary bodies (*i.e.*, static energy) and 2) winding torque current or torque flux for “actively” establishing force at speed (*i.e.*, kinetic energy or work).
  - Only a directly excited multiphase winding set at its terminals (*i.e.*, active winding set) produces a working or moving magnetic field for average torque production and electromechanical energy conversion but only if the synchronous speed relation is satisfied (*i.e.*, ±rotor winding excitation frequency ±stator winding excitation frequency ±angular mechanical speed = 0 with “synchronous speed” at rotor winding excitation frequency = 0).
  -Therefore, all electric machines have at least one active winding set (*i.e.*, singly-fed) and at most two active winding sets (*i.e.*, doubly-fed), after which the basic electric machine circuit topology repeats.
  - Mechanical power is the product of torque (or active winding current) and speed (or active winding voltage and excitation frequency), while electrical power is the product of active winding current (or torque) and voltage (or speed) with conversion loss or efficiency as the difference between the active and passive electrical power converted to mechanical power.
  - Since electric machine design performance is tightly coupled to Ampere’s Circuital Law, Faraday Law, and Lorentz Force Law, all of which have a flux density component, the largest air-gap flux density calculates to the smallest effective air-gap area and winding magnetizing MMF or RE-PM coercivity and the largest continuous torque for a given voltage, excitation frequency, and synchronous speed (or pole-pairs).
  - Therefore, the first steady-state design criteria for any electric machine is to establish the largest possible airgap flux density, which is determined by the same flux saturation limit of the electrical steel core and not by the flux density limits of RE-PMs (with potential demagnetization and reduced life expectancy) or by the boundless flux density of electromagnets (limited by winding resistance, which makes superconductor electric machine systems the exception).
  - The electrical and core loss of the “magnetizing component” of magneto-motive-force (MMF), which is the product of winding-turns and winding current, for establishing air-gap
flux density can be eliminated by replacing the electrical provisioning and volume of a passive winding (or electromagnet) with a proportionally related volume of passive permanent magnets but only with the MMF competitive performance of expensive cartel-controlled RE-PM with high coercivity, high energy product, and practical persistent magnetizing life (see “The Important Role of Dysprosium In Modern Permanent Magnets”).

- The coercivity and volume of RE-PMs cannot achieve the air-gap flux density provided by the magnetizing MMF of an electromagnet because unlike the BH product curve of an electromagnet with flux density directly proportional to magnetizing MMF, the highly temperature sensitive BH product curve of RE-PMs shows flux density inversely proportional to coercivity, which calculates to ever larger amounts of expensive RE-PM materials to achieve the flux saturation limit of the electrical steel core at operating temperature (e.g., 1.25T at 100°C).

- Any material research to improve the BH product of RE-PM material would most likely improve the flux density saturation limit of core material, which would neutralize any electromagnet versus RE-PM distinction due to material science, because after all, it takes an electromagnet to magnetize a RE-PM.

- It follows that all optimally designed electric machine cores show similar size based on similar size of the active winding set with similar air-gap flux density (e.g., 1 to 1.25T) because the effective air-gap area is chiefly determined by the necessary “active winding set” with a given continuous torque and power rating at a given air-gap flux density, synchronous speed, voltage, and frequency of excitation.

- A slip-induction electric machine relies (or depends) on the slip (or asynchronism) between the rotating magnetic field of the stator active winding set and the speed of the rotor for current induction onto the rotor multiphase winding set (in accordance to the synchronous speed relation) in order to establish the rotor orthogonal flux vector. It follows that a slip-induction electric machine functionally relies (or depends) on slip-induction between rotor and stator. Traditionally, a synchronous electric machine depends on synchronism between the rotating magnetic field of the stator active winding set and the speed of a rotor with the traditional rotor permanent magnets or DC electromagnet establishing the rotor orthogonal flux vector instead of a slip-induction dependent multiphase winding set. However, the classic textbook study of all electric machines begins with the symmetric (or multiphase wound-rotor) “synchronous” doubly-fed electric machine comprising balanced directly excited multiphase winding sets (i.e., active winding sets) on the rotor and stator, respectively, but only with the postulation of a brushless, sensor-less and automatic (i.e., emulation), and instantaneous (i.e., real-time) control means providing balanced multiphase excitation directly to the terminals of the rotor multiphase winding set automatically and without delay in order to guarantee the stator and rotor magnetic fields never lose synchronism (regardless of winding position) for continuously stable operation from sub-synchronous to super-synchronous speed, including about synchronous speed, by “not relying or depending” on indirect slip-induction excitation with the elusive torque angle shifting by external line voltage or rotor perturbations, particularly about synchronous speed where slip-induction ceases to exist. The symmetric multiphase wound-rotor synchronous doubly-fed electric machine study becomes the classic study for all other electric machines by deoptimizing its symmetry with the asymmetry of a “passive rotor assembly” of permanent magnets, slip-induction dependent windings, reluctance saliencies, or DC field windings. Although always confused with the traditionally unstable asymmetric wound-rotor [asynchronous or slip-induction] doubly-fed electric machine system that comprises “a passive rotor assembly” of reluctance saliencies or an
indirectly excited (or slip-induction dependent) multiphase winding set with the common quasi-direct multiphase slip-ring-brush assembly, a practical and contiguously stable symmetric “synchronous” doubly-fed electric machine has never materialized (until SYNCHRO-SYM) because of the formidable technical challenges of the necessary brushless real time emulation control means that eliminates the unstable “reliance or dependency” on indirect slip-induction excitation. As a result, its research was conveniently redirected to asymmetric electric machines, including the asymmetric wound-rotor asynchronous doubly-fed electric machine. But to at least include the classic textbook study of electric machines, which is the symmetric multiphase wound-rotor “synchronous” doubly-fed electric machine, a universally accurate definition, which is different from the traditional technologically constrained definition, should be, “A synchronous electric machine does not functionally rely (or depend) on slip-induction between the rotor and stator.”

• Virtually all of today’s high-performance electric machines are electronically controlled (or electric machine “systems”) for: 1) practical operation, such as for a functional RE-PM or reluctance electric machine system, 2) optimum application balancing, such as by adjusting excitation frequency for variable speed or by adjusting torque current, for torque and active power control, and 3) higher operating speeds (e.g., extended constant horsepower speed range) and electronic reliability control, such as by adjusting magnetizing MMF, commonly known as field weakening:
  o Control is adjusting the magnitude and phase of the port voltage and current excitations, such as the magnetizing current control (for field weakening) and torque current control, while keeping the excitation frequency synchronized to the speed of the shaft in accordance to the synchronous speed relation.

The Challenging Electric Motor or Generator Problem:

• The RE-PM was originally discovered (circa 1980) with mostly USA subsidized or funded research and development (R+D) but now with controlling ownership over the abundance of minable rare-earth deposits and disregard for human labor and environmental considerations during its extraction and production, the global affiliates and shell companies of the CCP have become the de facto manufacturer and supplier of virtually all RE-PM electric machine systems, components, and materials with critical environmental, free enterprise innovation, and geopolitical consequences:
  o Because of the prodigious amounts of at least inherited USA taxpayer funded or subsidized R+D, CCP RE-PM electric machine systems are notionally considered the best and therefore, are becoming universal for at least electric vehicles and large wind turbines, which again allows the CCP to easily hijack other original pioneering work and investment, such as today’s prodigious amount of taxpayer subsidized R+D, manufacture, and installation investments in electric transportation and wind turbines.
• Without addressing past consequences of consistently offshoring taxpayer funded R+D and manufacture with blind disregard for repatriation, USA is belatedly funding electric machine system R+D that tries to decouple the CCP RE-PM influence: 1) by using proportionally less RE-PM material with the smaller footprint of a higher speed electric machine system but with the additional compounding cost, size, loss, complexity, and reliability of a speed reduction gearbox and sophisticated high frequency electronic control, 2) by using RE-PM material more efficiently with the practical application of better electromagnetically performance enhancing material,
winding, packaging, manufacturing, thermal, and control techniques, and 3) by completely eliminating the RE-PM materials with performance enhanced slip-induction dependent, DC field wound, reluctance, or futuristic superconducting electric machine systems:

- By the inherited momentum of offshoring USA taxpayer funded R+D investment that originally blindly disregarded the CCP geopolitical consequences of RE-PMs and now with the CCP stealthy penetration into every aspect of the electric machine materials, manufacture, and academic research, including superconductor electric machine systems, a dominant portion of any ongoing electric machine system R+D always reverts back to the CCP, such as the RE-PM electric machine system, but more importantly, effectively steals from alternative innovative electric machine research, such as symmetric electric machine system research.

- Equally affected by the CCP RE-PM debacle, at least Japan has proactively taken a more protective approach with the purchase of Metglas, which was the USA inventor of amorphous metal ribbon, to continue its empirical research in nanocrystalline derivatives and their practical, cost effective electric machine manufacturing method, such as Nanomet and Finomet, which reduce the amount of RE-PM material in electric machines by increasing core permeability; but unlike the USA, Japan protects the intellectual property of taxpayer funded research by forbidding offshore manufacture, which has returned Japan to an electric machine system competitor with the CCP (and may have renewed the CCP hostility towards Japan).

- Ironically, the superior performance fixation on RE-PM asymmetric electric machine systems is more notional:
  - An “optimally” designed “asymmetric slip-induction dependent” electric machine may show up to 9% (e.g., 0.09) more electrical loss (and size) than an “optimally” designed RE-PM electric machine because of passive magnetizing MMF. For instance, if a RE-PM electric machine shows 10 watts of electrical loss (e.g., 90% efficiency for a 100 watt rated motor), a magnetizing MMF electric machine with similar optimization, such as a slip-induction electric machine, would show a tolerable 10.9 watts of loss (e.g., 89.1% efficiency) but without the expense, limited magnetizing life, and geopolitical consequences of RE-PMs or without including the compounding neutralizing effect of the additional loss, cost, and size of the necessary “system” gearbox and high speed electronic controller of the RE-PM electric machine “system.”

- The relatively recent spawning of the RE-PM recycling industry obviously shows the limited operating life expectancy of RE-PMs, which again increases consumption of RE-PMs through waste, but more importantly, shows the lack of enough global mineable RE-PM materials to support the growth in its major consumer, the RE-PM electric machine system.

- The coercivity and volume of RE-PMs cannot reach the high air-gap flux density provided by the MMF of an electromagnet, such as the core saturation flux density for the highest electric machine power density and efficiency.

- Although the original reason for migrating to the asymmetric RE-PM electric machine system was the elimination of electrical loss, cost, size, and electrical provisioning associated with the magnetizing MMF of slip-induction, DC Field wound, or reluctance electric machine systems, RE-PM electric machine systems are ironically re-introducing magnetizing MMF back into their asymmetric circuit and control architecture (with similar associated electrical loss, cost, and size) to regain the coveted benefit of field weakening, which provides better speed bandwidth, flux control, and reliability of electronic control as already and inexpensively provided by magnetizing MMF electric machine systems, such as the slip-induction electric machine system.
Exemplifying the blind fixation on the notion that RE-PM persistent magnetism provides superior performance to similarly optimized magnetizing MMF electric machine systems, recent research is ironically trying to eliminate the cartel controlled RE-PMs by substituting inexpensive Ferrite PMs with very low BH product and short persistent magnetizing life that is not even cost-performance competitive with the field weakening capable slip-induction electric machine system being replaced.

With the notion that asymmetric RE-PM electric machine systems have superior performance, original equipment manufacturers (OEMs) of EVs are acquiescing to the CCP geopolitical consequences by effectively branding the same optimized CCP RE-PM electric machine system with only marketing suggesting discernable performance differences:

- In retrospect, all OEMs would be better served by dropping the marketing ploy to at least provide the “economy of scale” from the cooperative high volume manufacture of an industry generic electric machine system without the nuances of branding, particularly if that OEM component manufacturer and supplier has the best product under the best manufacturing method, such as Best Electric Machine (BEM).

The Only Electric Motor or Generator Solution:

To provide a straightforward electric machine system comparison with at least simple quantitative observations, Best Electric Machine (BEM) classifies all singly-fed or doubly-fed electric machine systems into two categories: 1) the century old me-too asymmetric electric machine system circuit and control architecture that always comprises: a) an active stator assembly with a directly excited multiphase winding set (i.e., active winding set), which establishes the total torque and active power rating, b) a “passive rotor assembly” with the asymmetry (and associated loss, cost, and size) of slip-induction dependent (i.e., indirectly excited) multiphase windings (i.e., asynchronous), saliencies (i.e., reluctance), conventional or superconducting DC field windings (i.e., traditional synchronous), or RE-PMs (i.e., traditional synchronous), which establishes the static airgap magnetic field without contributing active power (i.e., work) to the electromechanical conversion process, and c) a derivative of field oriented control (FOC), or 2) the symmetric electric machine system circuit and control architecture (i.e., symmetric multiphase wound-rotor [synchronous] doubly-fed electric machine system) that always comprises: a) an active stator assembly, which establishes the torque rating and a portion of the air-gap magnetic field, b) an operationally stable “active rotor assembly” with the symmetry of another active (i.e., directly excited multiphase) winding set, which in synchronous combination with the active stator assembly, contributes additional active power to the electromechanical energy conversion process while also establishing the other portion of the air-gap magnetic field to halve the magnetizing MMF I²R loss, and c) the instrumental brushless real-time emulation controller (BRTEC):

- Only the symmetric electric machine system circuit and control architecture stably provides twice the constant torque speed range for a given rated synchronous speed torque, frequency and voltage of excitation (i.e., 7200 RPM with 2 poles and 60 Hz excitation versus 3600 RPM for the asymmetric electric machine system), which is equivalent to doubling cost-performance per unit of active power.

- While “innovating for our clean and sustainable energy future,” Best Electric Machine (BEM) provides the only practical solution to the CCP RE-PM electric machine system (even with the same contemporary electric machine system fabrication methods and materials) by leveraging the
patents of 1) the only *symmetric electric machine system circuit and control architecture*, called SYNCHRO-SYM, as only possible with the patented invention of brushless real time emulation control (BRTEC), and 2) the only high speed method of 3D Printing axial-flux electric machines, called MOTORPRINTER. Together, BEM, SYNCHRO-SYM, and MOTORPRINTER *uniquely* provide the following improvements if retrofitted to any electric machine system, including the RE-PM electric machine system:

- R+D by the tried and true old fashion way with private sweat equity and investment in innovative free enterprising solutions that did not acquiesce to government funding, which continually directs R+D and manufacturing towards me-too CCP RE-PM electric machine systems with careless disregard to the serious geopolitical, free enterprise, and electric machine innovation consequences of CCP control.
- Validated by the only computer-aided-design (CAD) tool, called BEM-CAD, that guarantees equitable comparative results between the asymmetric circuit and control architecture of an axial-flux slip-induction or RE-PM electric machine system and the symmetric electric machine circuit and control architecture of an axial-flux SYNCHRO-SYM by tightly holding design to the same electromechanical parameters with the same performance enhancing material, winding, packaging, thermal, construction, manufacturing (such as using MOTORPRINTER), and control techniques (*see Table 1 for a scalable but non-optimized example*).
- Innovation that brings the very “best” electric machine system technology and manufacturing (i.e., SYNCHRO-SYM and MOTORPRINTER) to the free enterprise market with a better cost-performance choice to the CCP cartel-controlled RE-PM electric machine system.
- As a solid-state transformer with active components of high frequency electronics, compact position dependent transformer, and inherent parasitic neutralizing resonant soft-switching, BRTEC provides the only symmetric electric machine system with a unique bi-directional high power **gyrator** and real time emulation computer for simple direct multiphase control of speed, torque magnitude, and leading, lagging, or unity power factor while automatically, immediately, and sensorlessly neutralizing stochastic kinetic energy and multiphase excitation perturbations, which is very different from the detrimentally unstable reaction delays and imprecisions that are characteristic of offline processing control with sensor measurement, estimation, compensation calculation, and excitation synthesis of today’s state-of-art controllers of the century old me-too asymmetric electric machine systems, such as Field Oriented Control (FOC), which are incapable of realizing a stable symmetric synchronous electric machine system because of processing delays and estimations that introduce unstable slip-induction components.
- By the additional power rating of an “active rotor assembly” (in concert with the active stator assembly), simple comparative observation easily shows the **power density** of the century old me-too asymmetric electric machine system *is immediately twice magnified with its cost and electrical loss halved (per unit of active power)* by effectively eliminating the entire “passive rotor assembly” of slip-induction windings, DC field windings, reluctance saliencies, or RE-PMs, where reasonably half of the cost, size, and loss per unit of active power rating of any electric machine system occurs but without contributing additional active power to the electromechanical power conversion process, particularly in an axial-flux form electric machine system (i.e., adjacent rotor and stator disks of equal size) or a slip-induction electric machine system.
Immediately twice magnifies the performance improvement (per unit of active power) expected from the same performance enhancing material, winding, packaging, thermal, manufacturing, and control techniques that all century old, me-too asymmetric circuit and control architectures use for their performance enhancement or so-called invention.

At least octuple the peak torque (per unit of active power) of the century old, me-too asymmetric electric machine system nominal frame size continuous torque by the physics of a dual-ported transformer circuit topology (i.e., symmetric multiphase wound-rotor synchronous doubly-fed electric machine) that avoids core saturation by uniquely holding airgap flux density and port voltage constant with increasing torque current (and resulting torque). High peak torque potential is essential for eliminating the compounding size, loss, cost, maintenance, and reliability issues of an electric vehicle gearbox.

Steady state air-gap flux density can be designed closer to the saturation limits of electrical steel cores for another level of power density and efficiency, which is impractical with RE-PM electric machine systems.

Saves precious CCP RE-PM materials for more strategic applications by replacing its major consumer, the RE-PM electric machine system, with a higher performance, more reliability, lower cost, and environmentally friendlier alternative.

Inherently provides distributed adjustable leading, lagging, or unity power factor correction for dynamic VAR compensation at the electric machine installation to dramatically improve electric distribution resiliency and overall electricity cost.

Democratizes the manufacture of high performance amorphous or nanocrystalline axial-flux electric machines with portable, high-speed, universally programmable, additive manufacturing (i.e., 3D Printer) to at least provide distributed, high speed, non-smokestack manufacturing of electric machines with similar “economy of scale” as the high-volume manufacture of a generic me-too product.

Brings superconductor electric machine systems of today closer to practical reality by brushlessly relocating the superconductor winding and cryogenics to the stator assembly for improved logistics while eliminating electronic control harmonic heating.

When AC superconductors become available by on-going research, the performance of the fully electromagnetic superconductor slip-induction electric machine system will be far superior to the RE-PM electric machine system; but more importantly, the fully electromagnetic superconductor SYNCHRO-SYM will be the electric machine system of choice by far surpassing the performance of the superconductor slip-induction electric machine system.

Conveniently leverages the full performance opportunities expected from WBG semiconductors, such as high temperature tolerant Silicon Carbide (SiC) semiconductors, and additive manufacturing of integrated high and low frequency axial flux cores, such as MOTORPRINTER, which are driving the next electric machine evolution of completely integrating the motor and drive (IMD), as recently revealed in Combining Motors and Drives, Incredible Shrinking Motor Drive and Performance Comparison of State-of-Art 300A/1700V Si IGBT and SiC Power Modules, with a brushless solid-state high frequency electronic transformer and real time emulation computer (BRTEC) inherently integrated and tightly paired to the symmetric electric machine entity instead of today’s afterthought of integrating distinctly different components, such as the FOC with the asymmetric electric machine entity.

In Conclusion:
• With the majority of the so-called Rare Earth (RE) material supply chain owned and controlled by a formidable global adversary with critical environmental, free enterprise innovation, and geopolitical consequences, the Chinese Communist Party (CCP), at least the United States is belatedly trying to seek supply chain alternatives for the major consumer of CCP controlled neodymium and dysprosium rare-earth materials, which is the rare-earth permanent magnet (RE-PM) electric motor or generator system that is rapidly being applied in the efficient production and consumption of electrical energy, such as the so-called green technologies of electric transportation and wind turbines:
  o Originally spawned during early times of low RE pricing by ignoring the CCP disregard for human labor, safety, and environment abuse during RE extraction and production, the CCP has stealthily become the de facto supplier, researcher, designer, and manufacturer of virtually all products comprising RE materials, such as RE-PM electric motors and generators. As a result, much of the alternative supply chain research ironically reverts back to the CCP, including subsidized or funded electric machine research to at least reduce the amount of RE material in the RE-PM electric motor or generator system, which is notionally considered to be the most efficient electric machine by the momentum of vast amounts of inherited R+D. Now, overall control of the rapid expansion and production of so-called green technology, such as RE-PM electric machine systems, falls into the hands of the CCP but even more sinister, attempts to stabilize control eventually falls back into the hands of the CCP, which is devoting much of the revenue to military build-up that if unleashed as was COVID-19, would cause far more environmental devastation and climate change than what the notional efficiency of RE-PM electric machine systems are expected to reduce.

• With its founder as an original pioneer of green technology since late 1970 with previous experience as an international oil exploration consultant and in accordance with our mission statement, “Innovate for our clean, efficient, and sustainable energy future,” Best Electric Machine acquired at least two patent protected products, SYNCHRO-SYM, which is the only symmetric synchronous electric machine system circuit and control architecture, and MOTORPRINTER, which is the only practical 3D Printer for the high speed fabrication of high and low frequency axial-flux electric machines with at least high performing nanocrystalline or amorphous metal ribbon. By completely eliminating the loss, cost, and size of the passive rotor assembly of RE-PMs, while twice magnifying the power density with half the cost and better system efficiency, SYNCHRO-SYM provides the only cost-performance solution to the RE-PM electric machine system. Like all electric machine systems, SYNCHRO-SYM does comprise copper (windings) and electrical steel (fully electromagnetic core) with their material demand expected to rise dramatically with the embracement of green electric technology but unlike RE materials, copper and steel are abundantly available without CCP control. More importantly, simple quantitative observation shows that only SYNCHRO-SYM effectively halves the amount of these materials per unit of electric machine power rating and when AC superconductors become a practical reality, copper and steel will again be reduced, if not eliminated, which will elevate the totally adaptable (i.e., fully electromagnetic) SYNCHRO-SYM as the electric machine of choice without rival.
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<tr>
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<th>SYNCHRO-SYM</th>
<th>RE-PM Electric Machine</th>
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<tr>
<td><strong>Rated Continuous Design Torque</strong></td>
<td>100 N-M</td>
<td>100 N-M</td>
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<tr>
<td><strong>Continuous Constant Torque Speed Range</strong></td>
<td>0-1200 RPM</td>
<td>0-600 RPM</td>
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<tr>
<td><strong>Continuous Constant Horsepower Range</strong></td>
<td>&gt;1200 RPM</td>
<td>&gt; 600RPM</td>
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<tr>
<td><strong>Continuous Rated Power</strong></td>
<td><strong>12.5 KW @1200 RPM</strong> (doubly-fed or two active winding sets)</td>
<td><strong>6.25 KW @ 600 RPM</strong> (singly-fed or one active winding set)</td>
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<tr>
<td><strong>Continuously Power Density</strong></td>
<td>3.12 KW/L (BRTEC included)</td>
<td>1.56 KW/L (Electronic controller not included)</td>
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<tr>
<td><strong>Peak Efficiency (system)</strong></td>
<td>92.2%</td>
<td>91.7%</td>
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<tr>
<td><strong>Weight</strong></td>
<td>34 kg (@12.5 KW) (BRTEC included)</td>
<td>29 kg (@6.25 KW) (Electronic controller not included)</td>
</tr>
<tr>
<td><strong>Diameter</strong></td>
<td>328mm (@12.5 KW) (BRTEC included)</td>
<td>328 mm (@6.25 KW) (Electronic controller not included)</td>
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<tr>
<td><strong>Length</strong></td>
<td>100mm (@12.5 KW) (BRTEC included)</td>
<td>146mm (@6.25 KW) (Electronic controller not included)</td>
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<tr>
<td><strong>System Cost</strong></td>
<td>$85/KW (dual converter BRTEC for interfacing with any power, such as DC or single and multiphase AC)</td>
<td>$121/KW</td>
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<tr>
<td><strong>Peak Torque</strong></td>
<td>Up to 800 N-M For 12 seconds with no cooling</td>
<td>250 N-M For 45 seconds with no cooling</td>
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<tr>
<td><strong>Peak Power</strong></td>
<td>100KW @1200 RPM</td>
<td>16 KW @ 600 RPM</td>
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<tr>
<td><strong>Peak Power Density</strong></td>
<td>25 KW/L @1200 RPM</td>
<td>4 KW/L @ 600 RPM</td>
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<td><strong>2x stack (system)</strong></td>
<td>200mm/50Kg/25KW (1600 N-M peak torque) (BRTEC included)</td>
<td>300mm/60Kg/12.5 KW (500 N-M peak torque) (Electronic controller not included)</td>
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