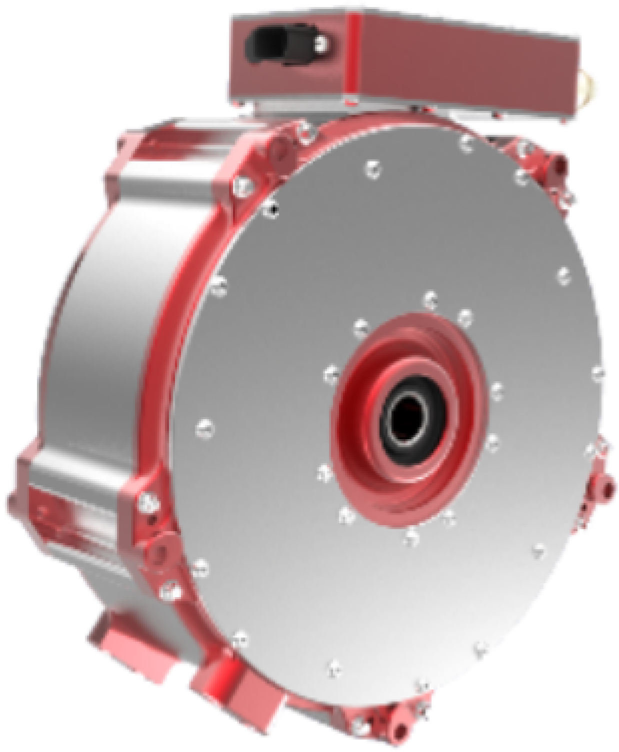
One Hundred and Thirty-Six Years of Practical Electric Motor/Generator Evolution and Study:



SYNCHRO-SYM Technologies

– One Hundred and Thirty Six Years of Practical Electric

Motor/Generator Evolution and Study –

Our Mission:

Innovate For Our Clean, Efficient, and Sustainable Energy Future!

One Hundred and Thirty-Six Years of Practical Electric Motor/Generator Evolution and Study:

Electric Motor/Generator Beginnings (circa 1740):

In accordance with an electric motor timeline, the idea of electromechanical conversion was only a novelty as early as the 1740s. Michael Faraday devised the first continuous rotation machine (circa 1821), which culminated into the first quasi-practical electric motor (circa 1831) that was an axial-flux electric motor, called Faraday’s disk. After Faraday, electromechanical conversion was on its way.

DC Electric Motor/Generator (circa 1886):

The electromechanically commuted, direct current (**DC**) motor/generator (or more appropriately, the [redacted]), which still has venerable application today, was the first evolution of electric motor/generator technology due to the availability of DC electrical power sources at the time, such as batteries, and the ability to self-start from standstill. The traditional DC motor comprised at least two sliding contacts that would phase energize connected rotor winding sets in synchronism with the speed of the rotor and as a result, effectively produce the essential moving air-gap flux wave in accordance with Lorentz Force Law. Until the first so-called "practical" DC motor/generator was invented in 1886 by Frank Sprague, the DC electric motor/generator was only a scientific curiosity since perhaps 1740. Thomas Edison was a proponent of DC distribution and DC motor/generators (see [redacted]).

AC Induction Motor (circa 1887):

The alternating current (**AC**) induction motor/generator was the next evolution of electric motor/generator technology with the advent of multiphase AC distribution and the ability to self-start from standstill. The AC induction motor/generator eliminated the archaic, unreliable, noisy, inefficient, and sparking sliding electromechanical contacts of the traditional DC motor by inducing speed-synchronized multiphase AC onto the rotor winding set by the asynchronous movement (*i.e., slip*) between the rotor winding set and the energized multiphase AC stator winding set (*i.e., slip-induction*). The AC induction motor/generator was invented by Tesla in 1887 and adapted to practical 3-phase operation in 1891. Westinghouse was a proponent of multiphase AC distribution and Tesla's AC Induction Motor (see War of the Currents).

Motor/Generator Control (circa 1960):

Control of electric motors was electromechanical, which consisted of gearboxes, rheostats, g[redacted] (*in rare cases*), etc., to match the single steady-state motor speed to the speed of the load, until practical electronic motor control was invented (circa 1960) to vary the speed of the motor to match the speed of the load.

*Rare-Earth Permanent Magnet (**RE-PM**) electric motor/generator (circa 1980s):*

The permanent magnet electric motor was an obvious improvement in the electromechanically commutated DC motor by simply replacing the DC field winding on the stator with permanent magnets. In fact, the first experimental electric motor by Michael Faraday (circa 1821) has been reported to have permanent magnets in axial-flux form; however, it wasn't until the advent of high energy product neodymium/dysprosium permanent magnets or RE-PM (circa 1980's) and practical electronic control for self-start instead of an electromechanical commutator that made RE-PM motors *viable* in most applications (*within thermal tolerance*) but recently, the geopolitical, cartel-controlled expensive, exploited labor, and environmental consequences of producing RE-PMs by a global adversary seeking world dominance has become critically obvious. Even today, the RE-PM *solution* is to mate a gearbox to a high speed (and therefore smaller) RE-PM motor to *only reduce* the amount of expensive and delicate RE-PMs but ironically, without considering the overall *compounding* complexity, size, loss, cost, noise, maintenance, and reliability consequences of the gearbox to the entire system of systems or instead, without simply optimizing the induction electric motor system, which the RE-PM electric motor system is quickly replacing in at least electric vehicle (**EV**) applications. Also, the size, loss, and cost of magnetizing MMF, which was the basic reason for migrating to RE-PM motor systems, is ironically being re-introduced into high performance RE-PM motor systems to leverage the coveted attribute of field weakening, which is already inherently and optimally available in induction electric motor systems.

Reluctance Electric Motor/Generator (circa 2020):

Like the permanent magnet electric motor/generator, the reluctance electric motor/generator has been studied in the very early days of electric motor evolution. However, it was not until the advent of practical sophisticated electronic control that the reluctance electric machine system with a simple solid rotor of saliencies became a practical reality. Today, reluctance electric machine principles are being applied to at least enhance today's RE-PM electric motor system in electric vehicles. Otherwise, a viable stand-alone RE-PM free reluctance electric motor alternative to the RE-PM electric machine system for at least propulsion applications is still a rarity because of seemingly unsolvable noise and pulsating torque issues.

The Symmetric Multiphase Wound-Rotor "Synchronous" Doubly-Fed Electric Motor/Generator (circa 2022):

The classic study of electric motors (circa 1889) begins with the symmetric multiphase wound-rotor "synchronous" doubly-fed electric motor/generator with the *optimal symmetry* of an "active" rotor and stator of directly excited multiphase winding sets but only by *hypothesizing the invention* of a brushless real-time emulation controller means (**BRTEC**) for stable "synchronous" operation from sub-synchronous to super-synchronous speeds, including at (or about) synchronous speed where slip-induction ceases to exist. As a result, the symmetric multiphase wound-rotor "synchronous" doubly-fed electric motor/generator does not rely on slip-induction for functional operation. The classic study becomes the follow-on study for all other electric motors/generators by deoptimizing the symmetry of an active rotor and stator, respectively, with the *non-optimal asymmetry* of a "passive" rotor with RE-PMs, slip-induction dependent windings, reluctance saliencies, or DC field windings, which cannot *independently* contribute additional active power to the electromechanical energy conversion process as does a *directly-excited* multiphase winding set (*or active winding set*). With continuously stable synchronous torque control from zero speed to twice synchronous speed or twice the constant-torque speed range (*i.e., Maximum Load Speed*) for a given continuous torque, air-gap flux density, port voltage, and frequency of excitation (*as only provided by BRTEC*), the classic study (from circa 1960) verified that the symmetric synchronous electric motor/generator provides twice the power density and octuple the peak torque at half the cost and half the loss (*per unit of power rating*) within the same packaging of the asymmetric electric machine system. However, the invention of a *practical* BRTEC has been a formidable challenge until the patented invention of Frederick Klatt beginning in 1984, who is the sole keeper of the knowledge base with follow-on patents and trade secrets reaching today.

Timeline Comments:

Just the idea of a practical brushless symmetric multiphase wound-rotor “synchronous” doubly-fed electric machine with an active rotor and stator, as only provided by SYNCHRO-SYM, which historically influenced the development of *all* (e.g., asymmetric) electric machine study, material, winding, and packaging techniques, has been effectively abandoned because: a) the essential invention of a practical brushless BRTEC from academia or industry for a symmetric wound-rotor doubly-fed electric motor was never realized, 2) the optimal symmetric multiphase wound-rotor “synchronous” doubly-fed electric machine is always subconsciously confused with the archaic and non-optimal “asymmetric” multiphase wound-rotor “slip-induction or asynchronous” doubly-fed electric machine system with an active stator, a passive rotor, and a multiphase slip-ring assembly, 3) the massive investment inertia in the asymmetric RE-PM electric motor/generator system industry has insidiously led to the cartel-control of RE-PM production and subsequently, to electric motor manufacture, academia research, and innovation *acceptance* by a global adversary seeking world dominance, and 4) the unconventional wisdom of a highly integral electronic controlled motor system, as only provided by SYNCHRO-SYM with BRTEC, challenges the established conventional wisdom of the componentized electronic controller and motor/generator system.

Timeline Results:

Electric motor/generator (i.e., electric machine) experts [redacted] but in reality, there are only two clearly distinct categories of electric motor *circuit and control* architectures, 1) the "symmetric synchronous" electric motor circuit and control architecture, as only provided by SYNCHRO-SYM, with an "active rotor that comprises a *directly-excited* multiphase winding set (i.e., active winding set), which contributes additional active power to the electromechanical energy conversion process along with the active stator, and of course BRTEC and 2) the "asymmetric asynchronous or synchronous" electric motor circuit and control architecture with a "passive rotor" that comprises either permanent magnets (i.e., synchronous), DC field windings (i.e., synchronous), reluctance saliencies (i.e., asynchronous or synchronous), or slip-induction windings (i.e., asynchronous), which waste precious electric motor real-estate, cost, and loss by not contributing additional active power to the electromechanical energy conversion process along with the active stator, and an estimating control derivative of flux-vector or direct torque control for optimized or practical operation.