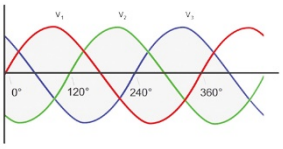
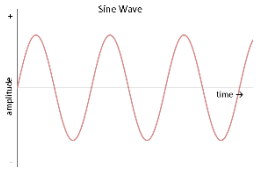
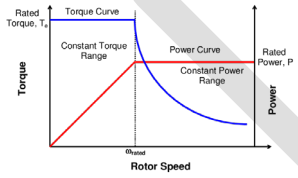
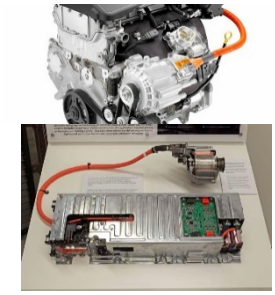
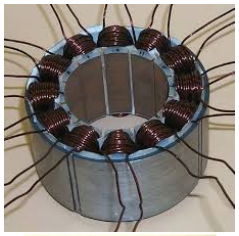
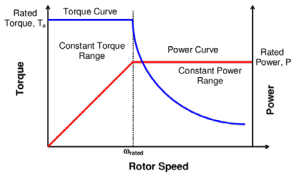
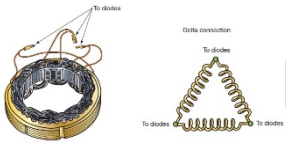
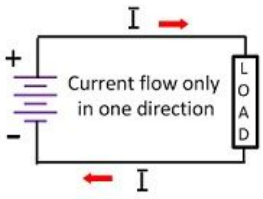
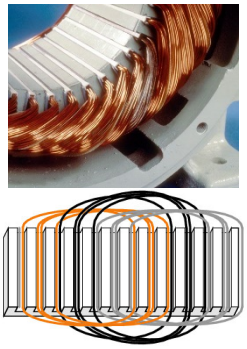
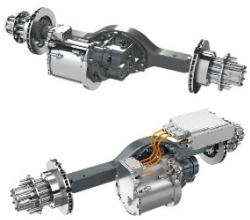
Vehicle Electrification System Standards

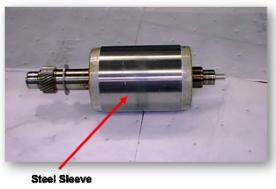
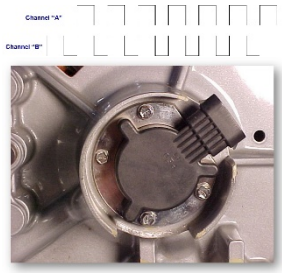
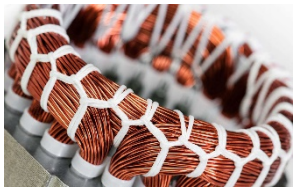
V. Phase Drive Motors and Generators

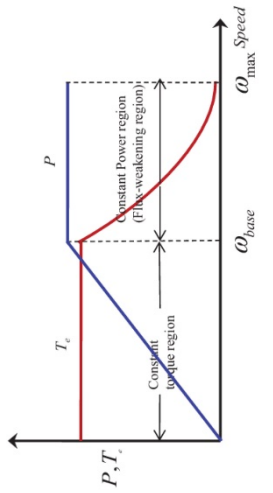
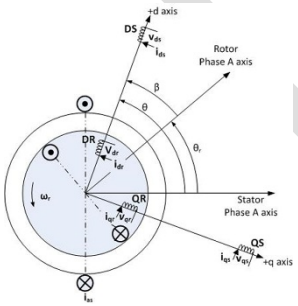
V.a Acronyms and Definitions

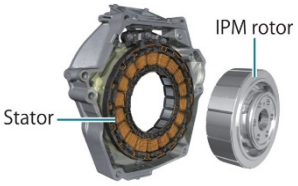
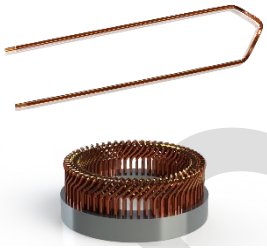
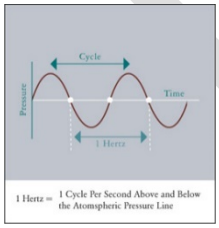
Image	Name	Acronym	Definition
	3-Phase Alternating Current		Three-phase electricity consists of three AC voltages of identical frequency and similar amplitude. Each of the three AC voltage phases is separated by 120°.
	Alternating Current	AC	A type of electrical current in which, the direction of the flow of electrons switches back and forth at specified intervals or cycles. The cycles per second (Hz) can be variable or fixed.
	Back Electromotive Force	BEMF	Back Electromotive Force (Counter-electromotive force or CEMF), also known as back electromotive force (EMF), is the electromotive force or "voltage" that opposes the change in current which induced it. CEMF is the EMF caused by magnetic induction
	Base Speed		It is the maximum speed at which motor can operate under constant torque characteristics or the minimum speed to operate at rated power.
	Belted Alternator Starter	BAS	A configuration of HEV that places the electric machine on the front of the engine where it drives or is driven by a serpentine drive belt to provide/receive torque, through the engine vibration damper. The BAS system provides torque in parallel with the engine

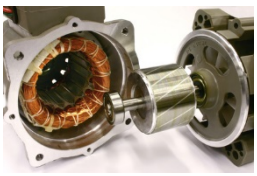
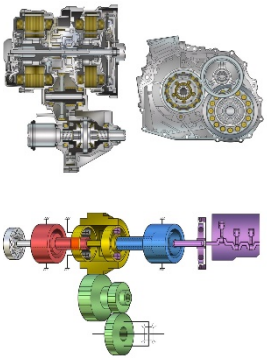
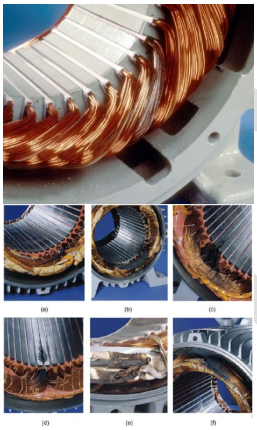
 	Concentrated Winding		A singular winding that is wound around an iron (ferrite) that concentrates a magnetic field within a confined area. Concentrated winding provide a very high torque/amp.
	Coil Turns (i.e., 4 Turn Coil)		The number of times a group of wires in hand is turned (wound into a loop) and then inserted into a stator slot
	Constant Power		The region on a graph that indicates that an electric machine is no longer in the rpm region for constant torque and indicates the rpm region where the electric machine is controlled with constant power (V x A). The constant power rpm region succeeds the constant torque rpm region.
	Constant Torque		The region on a graph that indicates that an electric machine is in the rpm region where it will provide constant torque irrespective of the rpm. The constant torque region precedes the constant power rpm region on a graph.
	Counter Electromotive Force	CEMF	See BEMF
	Delta Wound Stator		A 3-Phase stator design in which all 3 phases are connected in a Delta (triangle) shape that electrically connects them in parallel.
	Direct Current		An electrical current which flows consistently in one direction. The current that flows in a flashlight or another battery powered appliance is direct current.

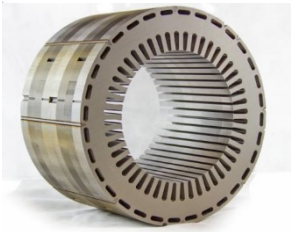
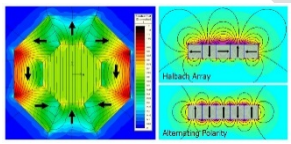
	Distributed Winding		A stator winding configuration that, places round wire windings in the stator slots that are spanned (Distributed) to a specific number of slots between each winding bundle, to widen the magnetic field that will interact with the rotor magnetic fields for smooth rotation.
	Drive Unit	DU	A gear reduction unit used to house an electric vehicle electric machine that typically does not include hydraulic clutches.
	Diagnostic Trouble Code	DTC	A specific hexadecimal code assigned to a specific vehicle system and component that identifies when an abnormal operating condition is occurring.
	eAxle		A drive axle that is designed with the electric machine integrated as part of the axle assembly
	Electric Axle		See eAxle
	Electric Machine	EM	A generic term that describes a unit that can provide both motoring and generating electrical power.
	Electromotive Force	EMF	See BEMF

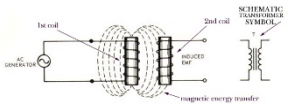
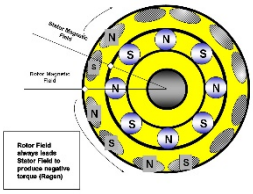
	Encapsulated Rotor		An manufacturing process for Induction Machines that has rotor bars covered (encapsulated) by a sleeve so no further diameter machining processes need to be performed after the rotor is cast.
	Encoder		A digital sensor that senses the position and speed of an electric machine rotor but, does not provide absolute position of the rotor
	End Turn		End turns are the area of electric machine windings which extend out from the slots at either end of a motor and appear a wire bundles that are held in place by dipping the stator in a varnish or poly material and wrapping the end turns in a Nomex-Mylar string to reduce the movement caused by the Lorentz Force

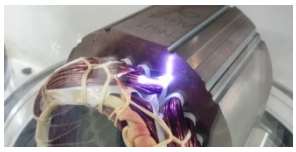
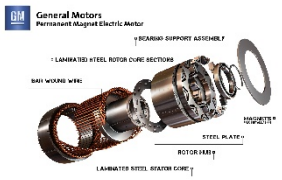
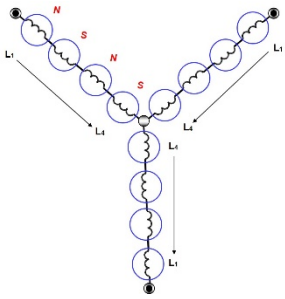
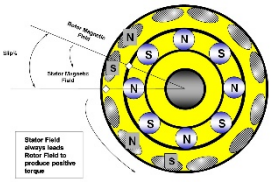
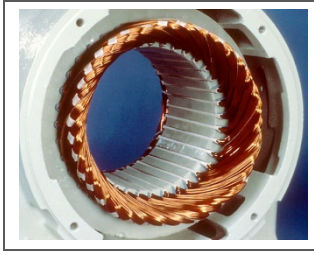
	Field Weakening	As a motor rotates, it creates a back-EMF voltage across its coils proportional to the speed of rotation. In order to force current into the coils, the applied voltage must exceed this voltage. The limitation comes when the speed of rotation is such that the required applied voltage is greater than the voltage available from the inverter electronics. At this point, the inverter can no longer supply current to the stator coils and the motor will not generate any torque. If the rotor is externally forced to rotate faster, the back-EMF voltage will exceed the power supply voltage, and current will attempt to flow from the coils into the power supply, producing a torque counter to the direction of rotation. In practical terms, this means that for a given power supply voltage, and a required coil current, there is a maximum speed of rotation obtainable before inverter saturation occurs preventing more coil current from flowing into the coil. This speed is referred to as the base speed. In order to exceed the base speed, the back-EMF voltage must be reduced. Since the back-EMF is also a function of the magnetic flux between rotor permanent magnets and stator coils, reducing this magnetic flux will reduce the back EMF voltage. The inverter then does not enter saturation, current can flow into the stator coils, and the motor can rotate faster, although at the expense of reduced maximum torque. The basic principle of field weakening, as its name suggests, is to weaken the magnetic field strength of the rotor magnets, by applying an opposing magnetic field on the stator coils in phase with the rotor field. This is the direct axis (d-axis) in field-oriented control, and acts to reduce the back EMF generated by the motor as it rotates. Without field weakening, a motor drive can only operate the machine up to base speed in the plot below. That's the constant torque region, you can achieve full torque in all that speed region, and then torque suddenly drops to zero.
	Flux Vector	Vector control, also called field-oriented control (FOC), is a variable-frequency drive (VFD) control method in which the stator currents of a three-phase AC electric motor are identified as two orthogonal components that can be visualized with a vector. One component defines the magnetic flux of the motor, the other the torque. The control system of the drive calculates the corresponding current component references from the flux and torque references given by the drive's speed control.

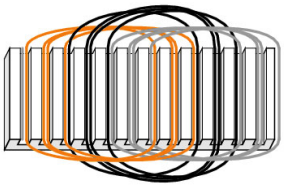
	Faraday Shield		A container comprised of copper or other alloy material that will block magnetic fields from exiting or entering the container
 	Flywheel Alternator Starter	FAS	A configuration of HEV that places the electric machine in series between the engine and transmission but, the torque is supplied in parallel with the powertrain driveline
	Fractional Slip		The relative rpm speed difference between an Induction Machine rotor and stator given in a percentage unit.
	Hairpin (Bar) Wound Stator Winding		A stator winding comprised of square or rectangular wire that, provides much higher slot copper fill than traditional round wire, and results in higher electric machine torque.
	Hertz	Hz	The SI unit of frequency, equal to one cycle per second.
	Horsepower	hp	A unit of measurement of power (equal to 550 foot-pounds per second or 745.7 watts), or the rate at which work is done, usually in reference to the output of engines or motors. ... The term was adopted in the late 18th century by Scottish engineer James Watt to compare the output of steam engines with the power of draft horses. 1 hp = 746W

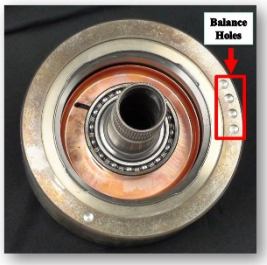
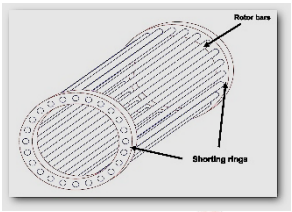
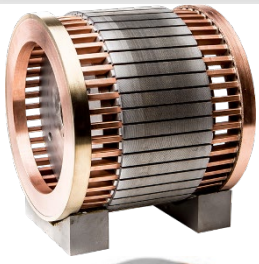
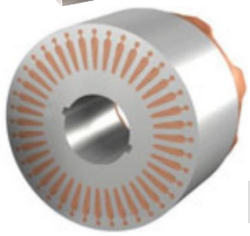
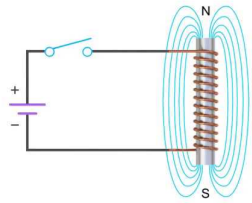
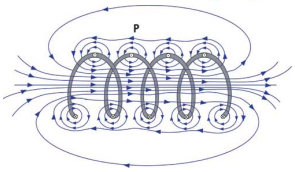
	Induction Machine	IM	An brushless 3-Phase electric machine used in electric vehicles that uses mutual induction to magnetize the rotor using the magnetic field from the stator field that results in electric machine rotor rotation. It does not use permanent magnets.
	Integrated (Electric Machine) Architecture		A powertrain design that places the electric machines inside design of a transmission, transaxle, or eAxle with all other transmission internal components
	Interior Permanent Magnet Machine	IPM	A brushless 3-Phase electric machine used in electric vehicles that uses permanent magnets mounted below the surface of the rotor to interact with the stator magnetic field that results in rotor rotation. The magnets can be single or double row
	Inter-turn Winding Short		The short circuit occurs between the same phase winding wires or when the fault occurs between the same winding turns. This results in the total current circulation in the number of turns (ampere turns) become reduces. It affects the total flux produced in winding depending upon the fault location of the winding). This type of failure is also known as an in turn short.
	Intra-turn Winding Short		The short circuit occurs between two different phases, such as two different phase coils of wire within one slot of a stator. This results in the total current circulation in the number of turns (ampere turns) to increase. It affects the total flux produced in the winding depending upon the fault location of the winding. This type of failure is also known as an in turn short.

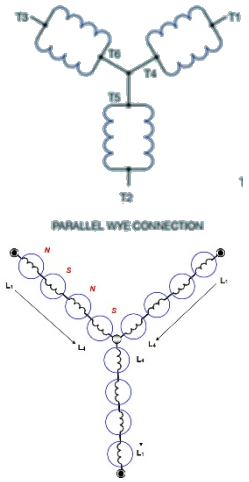
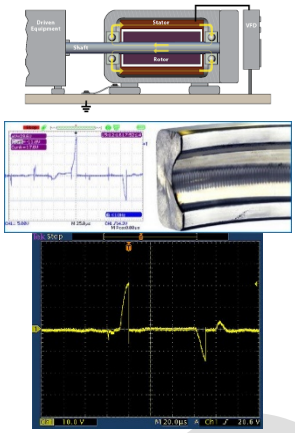
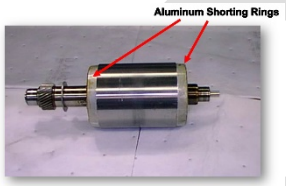
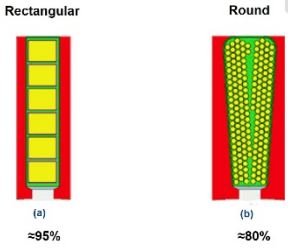
	Kilowatts	kW	1kW = 1,000 Watts; 1kW = 1.34hp; 103kW/0.746 = 138hp; (138hp)(0..746) = 103kW
 	Laminations		Thin wafers (0.015" - 0.030") of electrical grade silicon steel used in the rotor and stator (also known as the lamination stack). Stator laminations reduce eddy current by insulating the core. Thin silicon steel plates are stacked on top of one another around the center, preventing eddy current flow. With the eddy current reduced, the stator core can maintain higher efficiency. Silicon steel has the advantage of high saturation flux density
	Lead and Lag (i.e., Vector Lead and Lag)		Lead is the number of sine wave degrees (up to +80°) electrical that the stator magnetic field will lead the rotor magnets speed (rpm) to provide propulsion positive torque. +80° provides the maximum torque. Lag is the number of sine wave degrees (up to -80°) electrical that the stator magnetic field will lag the rotor magnet speed (rpm) to provide regenerative breaking torque. -80° provides the maximum negative torque.
	Magnet "V" Shape		Rotor interior magnets that are configured in the shape of the alphabetical letter "V" that permits a smoother BEMF sine wave
	Magnet Halbach Array		A concept or reorienting magnets to optimize magnetic field strength that exceeds traditional magnet North & South orientation

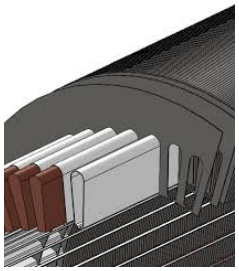
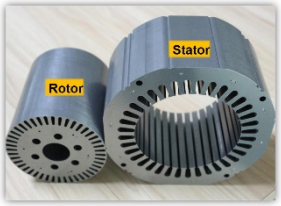
	Magnet Wire		Wire used in electric machines, transformers, relays, etc. that is a copper alloy core and covered by a coating so the windings are electrically isolated but, not magnetically isolated from each other
	Motor Circuit Analysis	MCA	An electric machine testing process in which DC Resistance, Inductance, Impedance, Capacitance, Phase Angle, Current to Hz Ratio, Dissipation Factor, and insulation Resistance metrics are used to determine electric machine state of health
	Mutual Induction		The concept of placing two separate winding groups within close proximity (or winding one group over the top of another). The result is if one (primary) winding has an expansion or collapsing of its magnetic fields, induced voltages and currents will be generated the adjacent (secondary) winding but, will be out of phase with the primary winding.
	Negative Slip%		Slip% is an alternative term for Torque. The percent of speed (Hertz) that the stator field is being switched slower than the rotational rpm of the rotor. When the stator field Hz is slower than rotor rotational speed, the Slip% is Negative (vehicle being driven in reverse or during regenerative braking mode). Example: If the stator frequency speed is an equivalent of 90rpm and the rotor is rotating at 100rpm then, the Slip is -10%. Maximum Negative Slip% for an Induction Machine is -15% before torque breakdown occurs
	Open Slot Rotor		An manufacturing process for Induction Machines where the rotor bars are not covered by a sleeve but, would require machining processes to be performed after the rotor is cast to acquire the correct rotor diameter

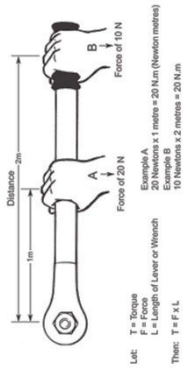
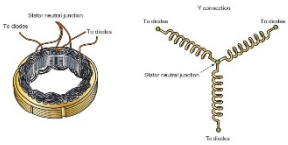
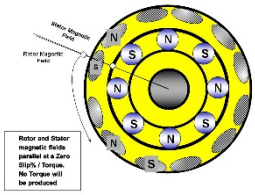
	Partial Discharge	PD	A partial discharge (PD) is an electrical discharge or spark that bridges a small portion of the insulation between two conducting electrodes. Partial Discharge can happen at any point in the insulation system, where the electric field strength exceeds the breakdown strength of that portion of the insulating material.
	Permanent Magnet Machine	PM	An Electric machine that, utilizes permanent magnets that are located on the surface or interior of the rotor, for coupling the magnetic field of the rotor magnets to the magnetic field of the stator causing the rotor to rotate
	Poles Per Phase	Poles/ϕ	The number of stator winding for each phase of an electric machine. If each phase of an electric machine has 4 windings for each phase of a 3-Phase electric machine then, it is considered to be a 3-Phase - 4 pole machine (or a total of 12 poles for the entire machine)
	Positive Slip%		Slip% is an alternative term for Torque. The percent of speed (Hertz) that the stator field is being switched faster than the rotational rpm of the rotor. When the stator field Hz is faster than rotor rotational speed, the Slip% is Positive (or, vehicle traveling in the forward direction in propulsion mode). Example: If the stator frequency speed is an equivalent of 100rpm and the rotor is rotating at 90rpm then, the Slip is 10%. Maximum Positive Slip% for an Induction Machine is 15% before torque breakdown occurs
	Power Density		The maximum kW of horsepower and/or torque that can be produced within a specific volumetric package (i.e., size of the electric machine or generator)
	Random Wound Stator Winding		A stator manufacturing process in which magnet wire is placed in each stator slot by a winding machine that will place each wire of a coil is placed in the slot in a random position

			
	Rare Earth Magnet		The rare earth magnet family is derived from what is called rare earth which is an ore from which both Neodymium & Samarium are extracted. These 2 elements listed as lanthanides on the periodic table are the namesakes of the 2 most powerful permanent (can't turn them on and off like electromagnets) magnets on the planet. Neodymium is the strongest with Samarium cobalt is a very close 2nd place in terms of strength. Neodymium the strongest and most affordable type of rare-earth magnet. Invented in the 1980s, it's made of a combination of neodymium, iron and boron
	Reluctance Torque		A secondary Electric machine rotor torque that is generated by specifically shaping the stator magnetic field around the rotor magnets in such a way that there is a secondary torque developed from stator magnetic fields that are curved by the magnets on the rotor
 	Resolver		An electric machine rpm (speed) and position sensor that is connected to the shaft of an electric machine rotor that measures absolute speed and position changes in finite rotational degree increments to ensure that a controller can trigger phase coils at the correct time
	Revolutions Per Minute	rpm	Revolutions per minute is the number of turns in one minute. It is a unit of rotational speed or the frequency of rotation around a fixed axis

	Rotor Balancing		High speed balancing of an electric machine rotor by removing rotor material (i.e., drill holes) to ensure that the rotor balance is achieved to ensure low noise and vibration operation
  	Rotor Bar		A copper or aluminum alloy bar within the structure of an electric machine rotor (i.e., one of 40, 50, 60, etc. bars) that are analogous to the secondary windings of a transformer that, serve to circulate currents to generate magnetic fields to interact with stator magnetic fields to cause the rotor to rotate
 	Self-Induction		The property of the coil due to which it opposes the change of current flowing through it. Inductance is attained by a coil due to the self-induced emf produced in the coil itself by changing the current flowing through it.

	Series and Parallel Connected Stator Windings		Series coils are stator coil windings that are connected in series while Parallel coils are stator coil windings that are connected in parallel.
	Shaft Currents		Shaft circulating currents are caused from "dissymmetry's" in the magnetic paths through the stator and rotor iron. As the rotor rotates within the stator and as the stators magnetic field rotates, small differences in the magnetic "reluctance" of the core parts generate small voltages between the ends of the shaft.
	Shorting Ring		Induction machine rotors have two rings cast at each end of the rotor that connect and hold all of the rotor bars that, serve as the collection point to carry current from each of the rotor bars
	Slot Fill		The percentage of materials that fill the stator winding slots

	Slot Liner		Typically is a Nomex-Mylar material that is placed in each stator slot to physically and electrically insulate the stator windings from the
	Speed (rpm) Sensor		See Resolver and Encoder
	Spin Loss		The loss of rotational energy that is lost/wasted with an electrical machine is freely spinning without being electrically powered in in propulsion or regenerative braking modes
	State of Health	SOH	Comparing the current operational metrics of a system or component to when the component or system was new. Example: If a battery cell stores 100% of its possible capacity when its new, its state of charge is 100%. During its service life, testing and performance metrics can be applied by the battery controller to track how well the cell performs. The battery controller can measure changes in cell temperatures, voltage, and current. The controller can gauge cell performance (SOH) during the service life to determine the overall degradation and generate a composite performance number or SOH. The SOH value is an indicator to the battery controller as where the cell is performing within it service life and this SOH value is an overall diagnostic indicator. The SOH metrics can also be developed and generated for electric machines or any system or component.
	Stator Core		A stack of laminations that is typically welded together that comprises the material that will permit a magnetic field core to be highly concentrated when electrical current is transmitted through each stator coil that will magnetize the windings and core (laminations)
	Stator Frequency	Stator Hz	The frequency in which the electric machine stator phases are switched (triggered) to determine the rpm of the rotor

	Torque		A mechanical system that produces or tends to produce torsion or rotation. The newton-meter (also newton meter; symbol N·m or N m) is a unit of torque (also called moment) in the SI system. One newton-meter is equal to the torque resulting from a force of one newton applied perpendicularly to the end of a moment arm that is one meter long. One newton is the force needed to accelerate one kilogram of mass at the rate of one meter per second squared in direction of the applied force. Pound-Feet is the English unit of torque measurement. As a unit of energy, one foot-pound is the energy it takes to push with one pound-force one pound for a distance of one foot
	Wires in Hand		The number of wires (conductors) that will be used to make a coil turn. The Wires (conductors) in Hand, combined with the Coil Turns, determine the magnetic field strength within the span of a distributed winding electric machine. Example: If 6 conductors of 18-gauge wires are used to wrap a stator coil then, this would be 6 wires in hand
	Wye Wound Stator		A 3-Phase stator design in which all 3 phases are connected at a central point in the configuration of the alphabet letter "Y" that electrically connects them in parallel.
	Zero Slip%		Slip% is an alternative term for Torque. The percent of speed (Hertz) that the stator field is being switched at the same speed as the rotational rpm of the rotor. When the stator field Hz is the same as the rotor rotational speed, the Slip% is Zero. Zero slip speed is used for vehicle coasting or Traction Control. Example: If the stator frequency speed is an equivalent of 100rpm and the rotor is rotating at 100rpm then, the Slip is 0% and no Negative or Positive torque is produced

To comment or offer suggestions on this standard, contact Ken Mays:

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