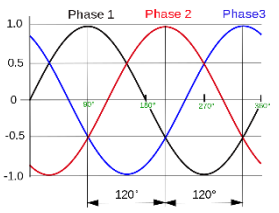
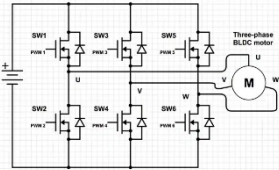
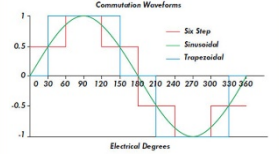
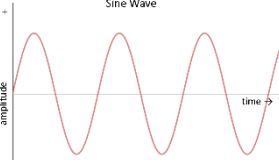
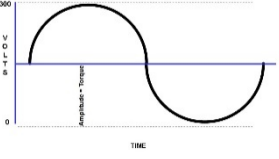
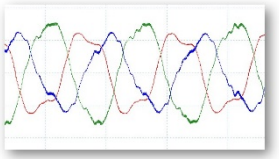
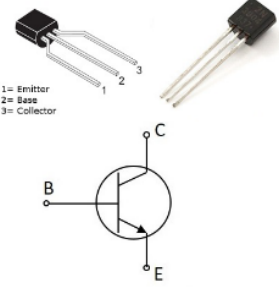



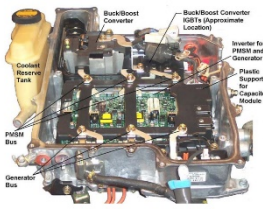
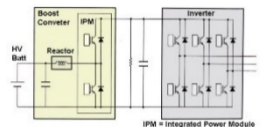
Vehicle Electrification System Standards



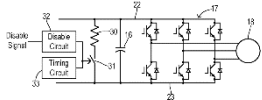
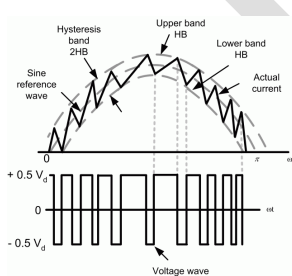
VII. 3-Phase Power Inverter Systems and Controls

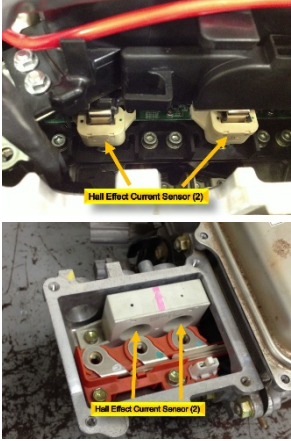
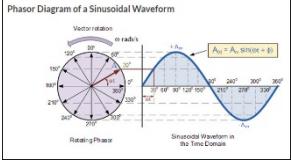
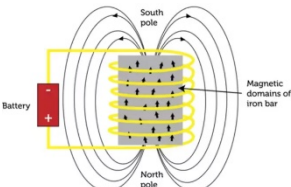
VII.a Acronyms and Definitions


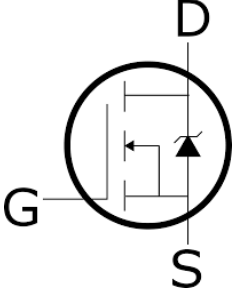
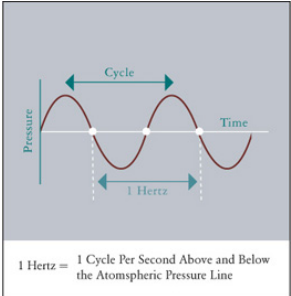
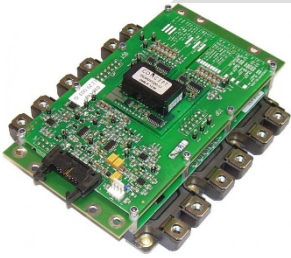

Image	Name	Acronym	Definition
	3-Phase		Three Phases are the number of conductor circuits within a motor or generator that are connected in a Wye or Delta configuration.
	6-Pack Motor Drive		A 6-Pack motor drive circuit contains 6 transistor (typically IGBT) circuits that connect to a source (battery pack) and a 3-Phase electric machine. The 6-Pack drive circuit will be controlled with a sine or 6-step waveform strategy to control the torque and speed of the electric machine
	6-Step		The 6-Step (overmodulated) waveform is a derivative of a sine waveform that is used in electric machine control to provide conditions that will permit higher speed operation
	Alternating Current	AC	Alternating current is an electric current which periodically reverses direction, in contrast to direct current which flows only in one direction

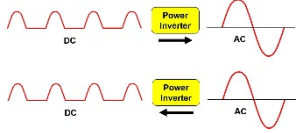
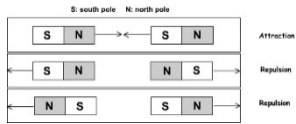
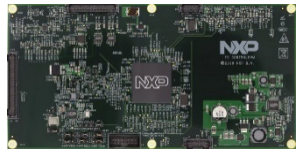
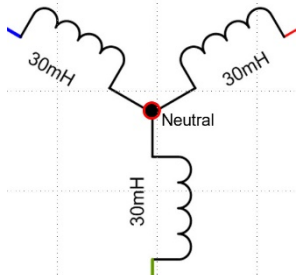
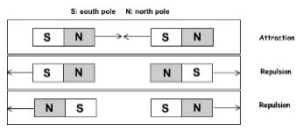
	<p>Amplitude</p>		<p>Amplitude of a waveform is a direction indication of how much voltage or current is being supplied from a Power Inverter to an electric motor (whether single phase or 3-Phase electric machines). Amplitude of Voltage or Current correlates, in a linear sense, to how much torque can be developed within an electric machine</p>
	<p>Asymmetrical Waveform</p>		<p>Having parts or aspects that are not equal or equivalent; unequal in some respect. Example: 3-Phase sine waves that are not equal in shape, height, width, etc.</p>
	<p>BiPolar Transistor</p>	<p>NPN; PNP</p>	<p>A bipolar junction transistor is a type of transistor that uses both electrons (negative) and holes (positive) charge carriers. Unipolar transistors, such as field-effect transistors, use only one kind of charge carrier</p>
	<p>Buck/Boost Converter (Boost Reactor)</p>		<p>An inductor that uses self-induction to boost battery voltage to a higher level for the purpose of increasing electric machine rpm, torque, and horsepower. The inductor is also used to buck (reduce) electric machine voltage that is transmitted to the battery pack during Regenerative Braking</p>

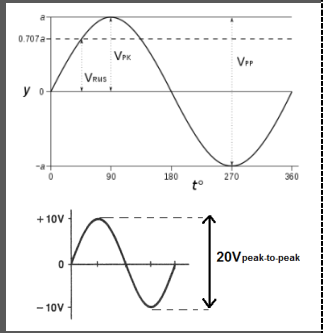
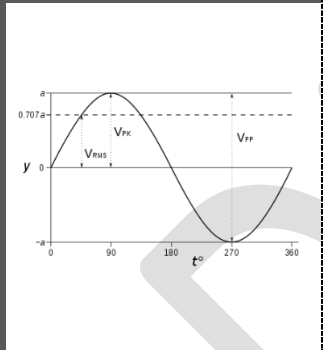
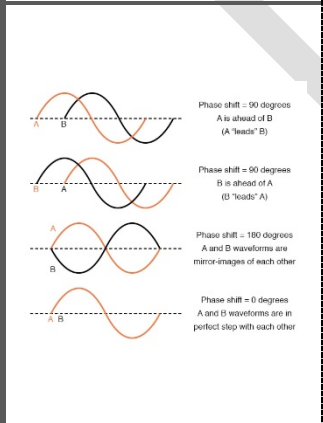


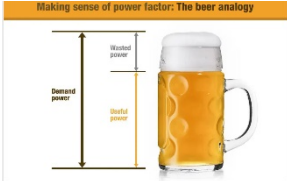
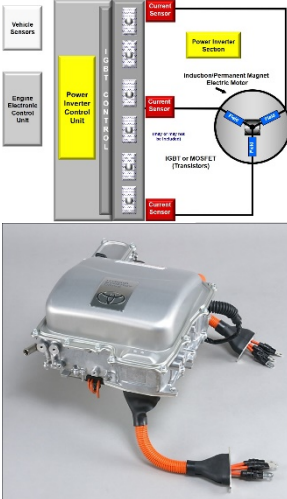
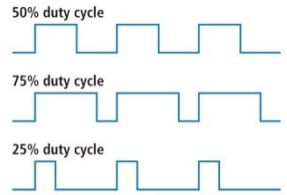
	<p>Bus Bar</p>		<p>A copper or copper alloy bar, with a specified thickness and width that, is bent into a form that will serve as a medium to transfer electrical current from one device/circuit to another</p>
	<p>Bus Capacitor</p>		<p>The dc bus capacitor is the most important passive component in a traction motor drive. Conventional designs have been using a set of electrolytic bulk capacitors to smooth dc bus voltage, reduce waveform harmonics, and increase power factor</p>
	<p>Bus Discharge Circuit</p>		<p>An electronic circuit that discharges the energy stored in the Bus Capacitors each time the power inverter system is powered OFF (i.e., each time vehicle powered OFF, collision detection or, the opening of the safety interlock circuit when the vehicle is powered ON</p>
	<p>Current Regulation</p>		<p>3-Phase current from the Power Inverter to an electric machine is regulated within the 3-Phase sine waves delivered or received from the electric machine to ensure that current does not exceed the current commanded by the electric machine controller</p>

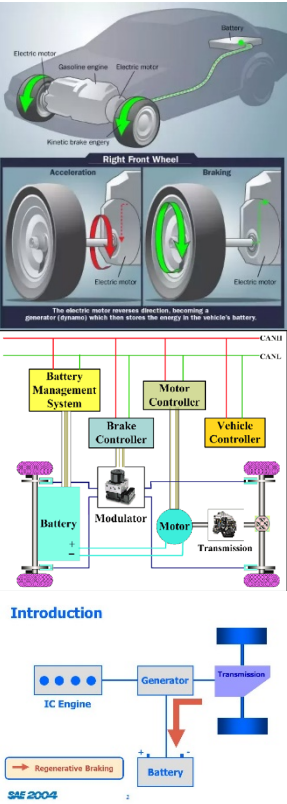
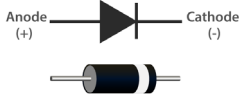
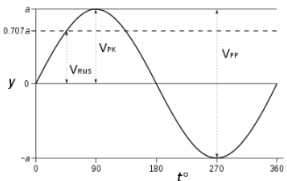
	<p>(Power Inverter) Current Sensor</p>		<p>A current sensor is a device that detects electric current in a wire (typically Hall Effect design) and generates a signal proportional to that current. The generated output signal could be analog voltage, analog current or digital</p>
	<p>Direct Current</p>	<p>DC</p>	<p>Direct current is the unidirectional flow of an electric charge. An vehicle 12V is a prime example of DC power. Direct current may flow through a conductor such as a wire, but can also flow through semiconductors, insulators, or even through a vacuum as in electron or ion beams</p>
	<p>Electrical Degrees</p>		<p>Vector (rotational) and sinusoidal (sine) wave cycles are constructed of 360° increments that comprise 1 cycle</p>
	<p>Electromagnetic Interference (Gasket)</p>	<p>EMI</p>	<p>Electromagnetic shielding is the practice of reducing the electromagnetic field in a space by blocking the field with barriers made of conductive or magnetic materials. EMI shielding is utilized in power electronics gaskets, connectors, wires or, cables</p>
	<p>Electromagnetic Pole</p>		<p>Each of the two points or regions of an artificial or natural magnet to and from which the lines of magnetic force are directed.</p>

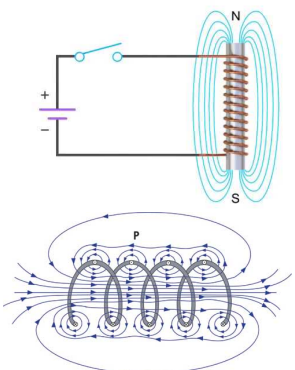
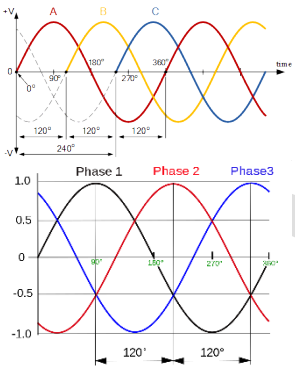
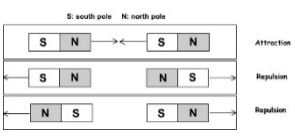
	<p>Enclosure (Case)</p>		<p>An electrical enclosure is a cabinet for electrical or electronic components to mount internal parts and to prevent electrical shock to equipment users and protect the contents from the environment. The enclosure is the only part of the equipment which is seen by users</p>
	<p>Field Effect Transistor</p>	<p>FET</p>	<p>The field-effect transistor is a type of transistor which uses an electric field to control the flow of current. FETs are devices with three terminals: source, gate, and drain</p>
	<p>Frequency (Hertz)</p>	<p>Hz</p>	<p>The SI unit of frequency, equal to one cycle per second.</p>
	<p>Gate Driver</p>		<p>A gate driver is a power amplifier that accepts a low-power input from a controller IC and produces a high-current drive input for the gate of a high-power transistor such as an IGBT or power MOSFET. Gate drivers can be provided either on-chip or as a discrete module</p>
	<p>Insulation Gate Bipolar Transistor</p>	<p>IGBT</p>	<p>Insulated Gate Bipolar Transistor is a power transistor that has characteristics of both MOSFET and bipolar junction transistors (BJTs). Introduced in the 1980s, the IGBT handles high current, a characteristic of BJTs, but enables fast switching with greater ease of</p>

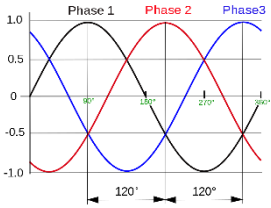

			control. IGBTs are found in home appliances, electric cars and digital stereo power amplifiers. Modules with multiple IGBTs can support very high voltage and amperage.
	Invert (an electrical signal)		The inverting of a signal means that it can be changed from one type of signal to another. Example: An AC signal can be inverted from AC to DC or, DC to AC. A Power Inverter changes AC to DC or DC to AC by the use of IGBTs and Rectifier Diodes.
	Magnet Pole		Each of the two points or regions of an artificial or natural magnet to and from which the lines of magnetic force are directed.
	Microcontroller Motor Controller	MC	A microprocessor-based system (mounted on a printed circuit board with signal conditioning) that controls the torque and speed of an electric machine in HEV, PHEV, BEV, and FCEV Microcontroller Article
	Neutral (electric machine)		The common point at which the 3-Phases of an electric machine are connected within a Wye or Delta wound stator
	North Pole (Magnet or Electromagnet)		1. A permanent magnet is a piece of iron (or an ore, alloy, or other material) that has its component atoms so ordered that the material exhibits properties of magnetism, such as attracting other iron-containing objects or aligning itself in an external magnetic field. A

			<p>magnet consists of a North and South Pole that can be used to cause electrical or mechanical movement within a component.</p> <p>2. An electromagnet is a soft metal core made into a magnet by the passage of electric current through a coil surrounding it and will act as a permanent magnet but, it does need electrical current to activate the magnetic fields</p>
 <p>The top graph shows a sine wave with peak voltage V_{pk} and peak-to-peak voltage V_{pp} indicated. The bottom graph shows a sine wave with a peak-to-peak voltage of 20V, ranging from +10V to -10V.</p>	<p>Peak (Sinusoidal Waveform)</p>	<p>Pk</p>	<p>One half (180°) of a full 360° alternating current sine wave</p>
 <p>The graph shows a sine wave with peak voltage V_{pk} and peak-to-peak voltage V_{pp} indicated. The peak-to-peak voltage is shown as the total vertical distance between the highest and lowest points of the wave.</p>	<p>Peak-to-Peak (Sinusoidal Waveform)</p>	<p>Pk-Pk</p>	<p>Peak-to-peak (pk-pk) is the difference between the maximum positive and the maximum negative amplitudes of a waveform, as shown below. If there is no direct current (DC) component in an alternating current (AC) wave, then the pk-pk amplitude is twice the peak amplitude.</p>
 <p>The diagrams show four cases of phase shift between waveforms A and B:</p> <ul style="list-style-type: none"> Phase shift = 90 degrees: A is ahead of B (A "leads" B) Phase shift = 90 degrees: B is ahead of A (B "leads" A) Phase shift = 180 degrees: A and B waveforms are mirror-images of each other Phase shift = 0 degrees: A and B waveforms are in perfect step with each other 	<p>Phase Angle (Phase Shift)</p>		<p>Describes the phase shift between total voltage and total electric current. In the voltage triangle this matches the phase shift between total voltage and active voltage. For the resistance triangle the phase shift lies between the impedance and effective resistance vector. When voltage and current waveforms are superimposed Power Factor is Unity (perfect)</p>

 <p>Making sense of power factor: The beer analogy</p> <p>Beer is active power (Watts) used to power up the froth (useless energy). This is the total you want.</p> <p>Foam is reactive power (VARs)—the foam is wasted power or lost power. It's the energy being unloaded, not for doing any work, such as the production of heat or motion.</p> <p>The mug is apparent power (kVA). The mug is the correct power, or the power being collected by the utility.</p> <p>If a circuit uses 100% efficient, demand would be equal to the power available. When demand is greater than the power available, a circuit is placed on the utility system. Many utilities add a demand charge to the bill of large customers to offset different load factors and demand during supply or power line demand. For most utility use, demand is calculated based on the average load power (rather than 30 minutes). For some equipment, such as hospitals, the utility may have more restrictive regulatory guidelines than (and may be more expensive) power sources.</p> <p>Power Factor Article</p>	<p>Power Factor Correction</p>	<p>PF</p>	<p>Power factor (PF) is the ratio of working power, measured in kilowatts (kW), to apparent power, measured in kilovolt amperes (kVA). Apparent power, also known as demand, is the measure of the amount of power used to run machinery and equipment during a certain period. It is found by multiplying ($kVA = V \times A$). The result is expressed as kVA units. PF expresses the ratio of true power used in a circuit to the apparent power delivered to the circuit. A 96% power factor demonstrates more efficiency than a 75% power factor. PF below 95% is considered inefficient in many regions."</p>
	<p>Power Inverter</p> <p>Power Inverter Module</p>		<p>A power electronic unit that converts dc electrical power to ac electrical power in single or multi-phase systems</p>
	<p>Pulse Width Modulation</p>	<p>PWM</p>	<p>Pulse-width modulation (PWM) is a modulation process or technique used in most control systems for encoding the amplitude of a signal right into a pulse width or duration of another signal, usually a carrier signal, for transmission. The purpose of PWM is to control the</p>

			<p>power that is supplied to various types of electrical devices, most especially to inertial loads such as AC/DC motors. PWM is also known as duty cycle</p>
 <p>The electric motor reverses direction, becoming a generator (dynamo) which then stores the energy in the vehicle's battery.</p> <p>SAE 2004</p>	<p>Regenerative Braking</p>	<p>Regen</p>	<p>Regenerative braking uses an electric vehicle's motor as a generator to convert much of the vehicle kinetic energy lost when decelerating back into stored energy in the vehicle's battery. The generation of electrical power results in negative torque on the vehicle axle causing its speed to slow (braking effect). The rate of vehicle speed reduction is determined by a significant number of factors in the powertrain and battery pack system. The next time the car accelerates, it uses much of the energy previously stored from regenerative braking instead of tapping in further to its own energy reserves.</p>
	<p>Rectifier Diode</p>		<p>"A diode allows current in only one direction. It can be used to "rectify" AC current into a DC current (i.e., an alternator operates with positive and ground or 0V negative to charge a 12V vehicle battery). Such a diode can also be used to prevent current from flowing in the "wrong" direction in a circuit."</p>
	<p>Root-Mean-Square</p>	<p>RMS</p>	<p>A calculation of an average used in statistics and engineering, abbreviated as RMS. To find the root mean square of a set of numbers, square all the numbers in</p>

			<p>the set and then find the arithmetic Mean of the squares. Take the square root of the result. This is the root mean square. It is also amount of AC power that produces the same heating effect as an equivalent (or useable) DC power. RMS is calculated as $RMS = (P-P)(.3535)$ or $RMS = (P)(0.707)$</p>
	<p>Self-Induction</p>		<p>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.</p>
	<p>Sine Wave (3-Phase) Sinusoidal Waveform</p>		<p>A circuit, system, or device that magnetically energizes or is energized by three electromotive forces that are separated by 120° sine wave cycles.</p>
	<p>South Pole (Magnet or Electromagnet)</p>		<p>1. A permanent magnet is a piece of iron (or an ore, alloy, or other material) that has its component atoms so ordered that the material exhibits properties of magnetism, such as attracting other iron-containing objects or aligning itself in an external magnetic field. A magnet consists of a North and South Pole that can be used to cause electrical or mechanical</p>

		<p>movement within a component. 2. An electromagnet is a soft metal core made into a magnet by the passage of electric current through a coil surrounding it and will act as a permanent magnet but, it does need electrical current to activate the magnetic fields</p>
	<p>Symmetrical (Waveform)</p>	<p>Similarity or exact correspondence between different things. With respect to 3-Phase AC waveforms, symmetry would indicate that all 3 waveforms within one cycle would be identical (symmetrical shape)</p>
	<p>Thermal Grease</p>	<p>Thermal grease is printed onto the IGBT or, other power modules or the cooling fin, and the force exerted by tightening the screws that secure the IGBT module to the cooling fin causes the thermal grease to spread out and fill the gap between the IGBT module and cooling fin. The thermal grease will transfer heat from a power electronic device to the mounting surface. The heat sink system is either a mounting surface utilizes heat sink fins or liquid coolant routed through an enclosure to remove high temperatures from the power electronic device</p>

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

Ken Mays	NEVTEX
541-383-7753	kmays@cocc.edu

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