
Vehicle Electrification System Standards

XII Regenerative Braking Systems

XII.a Acronyms and Definitions

Description:

Vehicle Electrification acronyms that are typically found in OEM, online, or special technical documents that can be accessed by technicians and instructors. Industry and OEM terminology and acronyms for hybrid, plug-in, and electric vehicles

Outcome (Goal):

Students shall be able to use industry terminology and acronym standards when documenting and communicating with others with respect to Regenerative (Regen) Braking Systems.

Objective:

When documenting Regenerative (Regen) braking systems information students shall be able to use proper vehicle electrification terminology and acronyms.

Task:

Utilize proper terminology and acronyms when documenting information on Regenerative (Regen) Braking Systems



Name	Acronym	Definition
Air Flow Sensor	AFS	Sensor that measures the flow of air entering or within a component
Air Temperature Sensor	ATS	Sensor that measures the temperature of incoming or ambient air of a component
Amp-Hour	A-h	The amperage that can be delivered by energy storage device (i.e. battery) for a period of 1 hour
Apparent Capacity Loss	ACL	A failure mode of NiMH battery technology that places portions of the battery cell in a dormant state and causes capacity loss. ACL is reversible by cycling the cell.
Battery Control Module	BCM	The electronic controller that controls the operation of a high voltage battery pack
Battery Electric Vehicle	BEV	A battery electric vehicle (BEV) is an electric vehicle that utilizes chemical energy that is stored in a rechargeable battery pack. Electric vehicles use electric motors instead of an engine system to propel the vehicle.
Battery Management System	BMS	A control system software/firmware within the BCM that manages the control and balancing of a battery pack
Capacity Rate	"C" Rate	The rate that an energy storage device is charged or discharged within a one-hour period
Coulomb	C	SI unit of electric charge, equal to the quantity of electricity transferred in one second by a current of one ampere.
Electromagnetic Compatibility	EMC	A method of ensuring that electronic components that produce electrical (magnetic) noise are operationally compatible when the components are within a close or moderate proximity
Electromagnetic Interference	EMI	Electrical signal noise generated from components that produce magnetic fields that can interfere with the operation of other electronic components in the immediate area



Energy Density (Watt-Hours/Liter)	Wh/L	The watt-hours of energy stored within a specified volume area.
Energy Storage System	ESS	A system that stores energy and is non-rechargeable (i.e., an onboard hydrogen storage tank for an FCEV)
Fuel Cell Electric Vehicle	FCEV	A vehicle containing a fuel cell using stored hydrogen gas and oxygen pumped into the fuel cell to create electricity that is transferred to an electric propulsion system for propelling a vehicle
Heating-Ventilation-Air Conditioning	HVAC	A vehicle system that provides heating or cooling to the cabin or high voltage battery pack
High Voltage	HV	Per the SAE, high voltage is defined as a DC voltage that is $\geq 60V$ or 30VACRMS
Hybrid Electric Vehicle	HEV	A vehicle that uses a combination of an engine and electric propulsion system to propel a vehicle
Joule	J	One joule is the equivalent of one watt of power radiated or dissipated for one second
Kilowatt-Hour	kW-h	A measure of electrical energy equivalent to a power consumption of 1,000 watts for 1 hour.
Kilowatts/Kilogram	kW/kg	A unit of specific energy commonly used to measure the density of energy in batteries and capacitors (i.e., the mass of battery and the number of watts that it can deliver)
Accumulator		Accumulators are used as energy storage devices to provide pressurized fluid to a hydraulic brake system of a to permit operation of the brake for speed control of a machine. Brake Actuators in HEV/PHEV/BEV systems can apply pressure to the braking system without the application of the brake pedal when required.



Accumulator Pressure Sensor		A sensor, placed in the braking circuit that, senses Accumulator hydraulic pressure and converts it to a Voltage. Sensor voltage ranges are typically 0V - 5V.
ABS Braking Event		A braking event that will cause the ABS system to override other braking system controls to apply the hydraulic braking system with ABS control strategies. The controls may also negate the use of Regenerative braking during a panic or highly aggressive braking event.
State of Charge	SOC	The state of charge is a measurement of the amount of energy available in a battery at a specific point in time expressed as a percentage (100% energy is full or 0% energy empty). The SOC provides the user with information of how much longer the battery can perform before it needs to be charged or replaced or need to be recharged.
Battery Pack Temperature Sensors		Sensors within the battery pack that will sense the temperature of specified battery modules/cells and the air within the battery pack. The battery pack will render adjustments in the control system based on these temperature inputs such as charging rates, regenerative braking requirements, propulsion torque, etc.
Blended Braking		A braking control strategy in which both electric and friction braking are blended to reduce vehicle speed. Typically, this method is used when electric braking (by itself) may not produce enough braking force to stop the vehicle quickly
Brake Actuator Assembly		A brake actuator assembly contains components such as, an accumulator, solenoids, electromechanical valves, pressure relief, and dump valves to control the levels of contribution from the regenerative and hydraulic/friction braking systems



<p>Brake Stroke Sensor</p>		<p>A brake stroke sensor detects the stroke (application of pressure from a vehicle operator's foot) of a brake pedal by detecting an electric signal (from the stroke sensor) that varies in response to the stroke (physical travel) of the brake pedal. A deceleration value that calculates a target value, which is correlated with a target deceleration of a vehicle to ensure braking integrity.</p>
<p>Brake Pedal Stroke Simulator</p>		<p>A brake pedal stroke simulator is a key component of the Regenerative Braking System. The function of the brake pedal stroke simulator is to separate the operator foot pedal pressure during a braking event from applying hydraulic pressure to the braking system. This permits the electric propulsion system to be utilized as an electric braking function that will capture vehicle kinetic energy and transfer it to the battery pack to be stored as electrical energy in the form of electro-chemistry. The stroke simulator utilizes springs and hydraulic pressure within the stroke sensor system to provide brake pedal feel feedback to the driver. The stroke simulator function, combined with electric braking, is transparent to the vehicle operator, as electric braking provides the same feel as hydraulic braking while capturing energy during a braking event.</p>
<p>Electric Creep System</p>		<p>Electric creep provides a means of low speed electric propulsion system that simulates the operation of an automatic transmission, permitting the brake to be applied while the vehicle maintains a very slow speed (e.g., <5mph). This type of function permits the electric propulsion to be transparent to the vehicle operator, so the operator can utilize existing driving habits and not be required to learn new driving skills.</p>



Cut Valve		The cut-valve provides the control of brake pedal feel (provided by the stroke simulator) by permitting brake master cylinder fluid to be transmitted to the stroke sensor. The cut valve opening/closing is controlled by a solenoid, and when the solenoid is commanded ON, will permit hydraulic fluid pressure to apply pressure to the stroke simulator springs. This results in providing pressure feel feedback to the vehicle operator and simulate brake pedal pressure while slowing the vehicle through negative torque from the electric drive motor.
Dump Valve Solenoid		A solenoid within the braking system that will very quickly relieve (dump) hydraulic pressure in the braking system to bring brake caliper and/or brake drum hydraulic pressure to zero in the event the brake controller requires braking pressure to be terminated.
Regenerative Braking Current		The electrical current that is generated by an electric machine. Electric machine current can be varied infinitely by its controller, thereby determining the level of current and negative torque developed by the electric machine.
Electric Machine Regenerative Braking (Regen)		The electrical current that is consumed or generated by an electric machine. Electric machine current can be varied infinitely by its controller, thereby determining positive or negative torque developed by the electric machine.
Brake Fluid Reservoir		The brake fluid reservoir is a small container that stores brake fluid and permits the volume of brake fluid in the braking system to fluctuate, based on brake system operating mode. There are some braking modes that require more or less brake fluid and the reservoir ensures that there is a site to store the fluid as it changes levels.



Flyback Diode		A flyback diode is a diode connected across an inductor used to eliminate flyback, which is the sudden voltage spike seen across an inductive load when its supply current is suddenly reduced or interrupted.
Base Braking		A braking mode in a BEV/FCEV/HEV/PHEV vehicle braking system in which only hydraulic-mechanical braking is utilized, and electric braking is inhibited. A panic/aggressive braking event is one example of where friction only braking is applied.
Hill Hold		Hill-hold is a related behavior where a vehicle on an uphill slope will not roll backwards when the driver removes his or her foot from the pedals. To inhibit the vehicle from rolling back on the hill (gravity), the electric drive motor controls will command (increase) the correct level of electrical current that will result in the drive motor rotor to stop rotation and hold its position. This function is similar to a vehicle with an automatic transmission that will hold its position on a hill, due to the transmission torque converter applying torque that holds the vehicle at zero speed.
Insulated Gate BiPolar Transistor	IGBT	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 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.



Lag Angle		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 braking torque. -80° provides the maximum negative torque.
Linear Valves or Actuators		An electromagnetic device that converts an electrical signal into a magnetic field producing a linear motion. The linear motion can be used to control mechanical systems, hydraulic fluids or, other devices. When utilized in a hydraulic system, linear solenoids are typically controlled with a PWM signal that, will control the position of the solenoid. By controlling the position of the solenoid, the flow and pressure of the fluid in a circuit can be controlled.
Isolation Valves		A solenoid valve that controls whether or not Master Cylinder hydraulic pressure is transferred to vehicle front or rear braking components
Master Cylinder Pressure Sensors		Pressure sensors that monitor Master Cylinder pressures and report the pressure, through a sensor (typically a 0-5 Volts) to the Brake System Controller
Modulation		A method of controlling the electrical power of an electric machine to apply braking (negative) torque when utilizing a 3/6/9 phase power inverter to modulate (turning ON/OFF) the electrical power with IGBT semiconductors (or equivalent) to the battery pack to control negative torque on the drive axles(s) and the amount of electrical current transferred to the high voltage battery pack to increase the state-of-charge level.
Powertrain Torque Control		When regenerative brakes are initiated, negative torque is applied to the drive wheels. Therefore, in a two-wheel- drive vehicle, negative torque is applied to the drive wheels with brakes while the wheels with no brakes can spin freely.



Slip Control		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
Brake Pedal Apply vs. Regen Braking		Friction braking is always used in conjunction with regenerative braking when the brake pedal is pressed. An example, 2000 - 2012 Honda hybrid systems utilized Parallel braking systems.
Power Inverter Module	PIM	A power electronic unit that converts dc electrical power to AC electrical power in automotive electric propulsion systems
Pulse Width Modulation	PWM	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 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



Energy Capture (or Recapture)		<p>With Conventional braking systems, vehicle kinetic energy is lost to heat energy that results from the friction between the brake pads and wheels. Regenerative braking permits the heat energy to be converted to electrical energy that increases the range of an EV. However, the efficiency of capturing this energy is reported to vary from 16% to 70% (Boretti, 2013). Ford (2019) has intimated that, the Fusion Energi regenerative braking conserves up to 94%, when braking is redirected to the battery where it's stored for future use.</p>
Regenerative Braking (Regen)		<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>
Regen Inhibit (Vehicle Coasting)		<p>Inhibiting Regenerative Braking by using a switch, gear selection, or instrumentation control that will permit the vehicle to coast without generating electrical power that would be transferred to the battery pack or assist with vehicle braking.</p>



<p>Vehicle Kinetic Energy Recovery</p>		<p>Regenerative braking is an energy recovery mechanism that slows down a moving vehicle or object by converting its kinetic energy into a form that can be either used immediately or stored until needed. In this mechanism, the electric traction motor uses the vehicle's momentum to recover energy that would otherwise be lost to the brake discs as heat. This contrasts with conventional braking systems, where the excess kinetic energy is converted to unwanted and wasted heat due to friction in the brakes.</p>
<p>Rotor</p>		<p>The rotor is a moving component of an electromagnetic system in the electric motor, electric generator, or alternator. Its rotation is due to the interaction between the stator windings and magnetic fields created in rotor bars by the stator (induction machine) or magnets mounted in the rotor (permanent magnet machine) which produces a torque around the rotor's axis</p>
<p>Stator</p>		<p>In an electric motor, the stator is an electro-magnet that provides a rotating magnetic field that couples with the magnetic field of the rotor and the result is the rotor rotating in the clockwise or counter-clockwise direction. In Regenerative Braking, the Stator Frequency is triggered at a slower speed than the Rotor rpm to generate magnetic energy that is converted to electrical energy and used to provide negative axle torque and recharge the vehicle battery pack.</p>



<p>Vehicle or Wheel Speed Sensor</p>	<p>WPS or VSS</p>	<p>The wheel speed sensor, also known as the vehicle speed sensor (VSS), is a sensor used to measure the rotational speed of the car wheels. Technology choices for magnetic speed sensors include magneto-resistive, inductive, variable reluctance, Hall Effect and Optical. Magneto-resistive sensors incorporate the resistance of the sensing element as a function of the direction and magnitude (proximity) of an applied magnetic field.</p> <p>For modern vehicles, wheel speed information is essential. Vehicle dynamic control system (VDC), automotive electronic stabilization program (ESP), anti-lock braking system (ABS), automatic transmission control system, etc., all require wheel speed information. Therefore, the wheel speed sensor is one of the most important sensors in the vehicle control system</p>
<p>Anti-Lock Braking System</p>	<p>ABS</p>	<p>Anti-Lock Braking System is a braking functionality that will permit the vehicle wheels to continue to rotate, while hydraulic pressure is applied to the brakes (via pulsed cyclic operation) during a panic/aggressive braking event, to provide the vehicle operator with directional stability to maintain steering control during the braking event.</p>



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