

Technical Report

**Tesla's Battery
Management System
Developments**

1. Adaptive Battery Management for Longevity

1.1. Electric Vehicle Battery Management Mode with Adjustable Charging, Discharging, and Temperature Parameters

Number US8970173B2

Filed on 2012-02-28

Summary An operational mode for electric vehicles that extends the life of the vehicle's battery pack. The mode involves adjusting charging, discharging, and temperature limits when the vehicle is parked for extended periods. When selected, the mode allows the battery to self-discharge deeper before charging, limits charging rates, and maintains a higher minimum charge level. This reduces cycling and stress on the battery when left connected to a charger. The mode also sets temperature limits and balancing during discharge.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8970173B2>

1.2. Battery Pack Charging Method with Adaptive State-of-Charge Window Management for Capacity Degradation Compensation

Number US8629657B2

Filed on 2010-11-19

Summary Battery pack charging method and management system that improves cycle lifetimes for automotive lithium-ion batteries by adapting to capacity degradation with age. It involves charging to specific state-of-charge (SOC) windows based on the expected driving range needs. By charging to smaller SOC ranges as the pack ages to compensate for capacity loss, it extends overall pack life. The system determines the optimal SOC range based on past usage and user input.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8629657B2>

1.3. System and Method for Operating Stationary Rechargeable Batteries with Mode-Dependent State-of-Charge Management

Number US20120046795A1

Filed on 2010-08-18

Summary Flexible management system and method for efficiently operating stationary rechargeable batteries to extend lifetime and decrease costs. The method involves operating the battery in a usage mode during active energy consumption periods and a storage mode during inactive periods. In the usage mode, the battery is charged to a higher state-of-charge (SOC) for higher power, while in the storage mode, it is charged to a lower SOC to minimize degradation.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20120046795A1>

1.4. Battery Pack Management System with Dynamic Charge Profile Adjustment Based on Anticipated Usage

Number US8536825B2

Filed on 2009-12-31

Summary Improving cycle life of lithium-ion battery packs in electric vehicles by dynamically adjusting charge profiles based on anticipated usage. The battery pack management system determines optimal charging parameters to enhance pack performance and cycle life while meeting desired range requirements. It calculates target charge levels based on anticipated driving distances and weights user inputs versus actual usage. This allows balancing range and cycle life by tailoring charge profiles to individual user needs.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8536825B2>

1.5. Context-Aware Adaptive Battery Charging System for Electric Vehicles

Number US7782021B2

Filed on 2007-07-18

Summary Adaptive battery charging for electric vehicles to reduce cost and extend battery life. It involves charging the battery based on context like electricity rates and vehicle usage patterns. The charging algorithm adapts the charge level and capacity based on factors like cheaper off-peak electricity, battery aging, and driving habits. This allows users to charge to lower levels during off-peak times to save cost, charge to higher levels before long trips, and maintain battery health by not overcharging. The system can also automatically switch to hybrid charging curves to extend range as battery degrades. Users can also select ranges to drive and have the charging adapt accordingly.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7782021B2>

2. Detecting and Mitigating Internal Short Circuits

2.1. Battery Pack Short Circuit Detection via Voltage Pattern Analysis with Cooling Activation Mechanism

Number US8618775B2

Filed on 2012-01-05

Summary Detecting and responding to internal short circuits in electric vehicle battery packs to prevent excessive heating and thermal runaway. The detection method involves monitoring voltage patterns across series-connected battery cells to identify imbalances that indicate internal shorts. If contiguous cells uniformly drop voltage consistent with overcurrent, it indicates an internal short. This allows detecting shorts between cells without fuses, as they are below the fusing threshold. The response is activating maximum cooling to prevent heating until the short clears. This allows discharging the affected cells to prevent thermal runaway.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8618775B2>

2.2. Battery Pack Electrolysis Detection and Remediation System with Integrated Sensor Array

Number US20130073233A1

Filed on 2011-09-21

Summary Detecting and responding to low voltage electrolysis in electric vehicle battery packs to prevent hazardous hydrogen gas buildup. The system uses sensors like hydrogen, voltage, current, and immersion sensors inside the battery pack to detect conditions indicative of low voltage electrolysis. If electrolysis is suspected, the system can activate remediation measures like stopping the battery charge/discharge, purging flammable gases, and adding inert gas to displace oxygen. This mitigates the risk of hydrogen accumulation from coolant leaks or other conductive fluid ingress.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20130073233A1>

2.3. Method for Detecting Internal Short Circuits in Battery Packs via Parameter Monitoring and Profile Comparison During Charging

Number US8866444B2

Filed on 2010-12-16

Summary Method to detect internal short circuits in battery packs containing multiple interconnected cells. The method involves monitoring specific data parameters during charging, comparing them against profiles indicative of internal shorts, and establishing an internal short state if the comparison meets certain conditions. This allows identifying short circuits within cells during charging, which is important to prevent hazardous conditions and performance degradation.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8866444B2>

2.4. Electric Vehicle Battery Pack with Cell-Level Fault Isolation Using Embedded Processors and Series Switches

Number US7683575B2

Filed on 2007-07-18

Summary Intelligent architecture for electric vehicle battery packs that can selectively disconnect faulty cells with weak shorts. The architecture involves connecting an electronically controlled switch in series with each cell and using embedded processors to monitor the cells. By tracking the balancing time for each cell group, weak shorts can be identified. The processor then opens the switch for the faulty cell to isolate it from the pack. This allows bad cells to be selectively removed without disassembling the pack.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7683575B2>

2.5. Battery Module with Internal Optical Pyrometer for Early Thermal Event Detection

Number US7939192B2

Filed on 2007-06-20

Summary Early detection of thermal events in individual battery cells to prevent propagation of thermal runaway in battery modules. An optical pyrometer inside the battery module detects short wave radiation density increases indicative of a cell becoming too hot. This allows mitigation measures like full cooling or power reduction to be initiated before widespread thermal runaway. The pyrometer can be placed anywhere in the module since radiation from all cells reflects internally.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7939192B2>

3. Detecting and Responding to Exceptional Charge Events

3.1. Battery Pack with Charge State Detection and Remediation for Series-Connected Elements

Number US20160197501A1

Filed on 2016-03-16

Summary Detecting and remediating exceptional charge states in individual battery elements of a series-connected battery pack. The technique involves monitoring charge-dependent parameters during operation to establish characterizations for each element. If a selected element's characterization shows an exceptional charge pattern during operation, it indicates an imbalance. This detects charge anomalies that voltage monitoring misses. Responses to exceptional charge events include preventing charging, increasing cooling, and limiting charging cycles.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20160197501A1>

3.2. Battery Pack System with Dual-Mode Charge Event Detection and Remediation Mechanism for Series-Connected Cells

Number US9153990B2

Filed on 2012-11-30

Summary Detection and remediation of exceptional charge states in battery packs with series-connected cells. The system detects excessive overcharge or overdischarge of individual cells in a pack beyond normal limits. It uses two types of charge event detection: one for steady state charging and one for transient charging. For steady state, statistical analysis of cell parameters is used. For transient, deviations in cell impedance during discharge are monitored. If an exceptional charge event is detected, responses like preventing charging, reduced cooling, or service are taken to mitigate risks like thermal runaway.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9153990B2>

3.3. Series-Connected Battery Pack System with Dual-Mode Exceptional Charge Event Detection and Response Mechanism

Number US9529048B2

Filed on 2012-11-30

Summary Detecting and responding to exceptional charge events in series-connected battery packs to prevent overcharge and overdischarge. The system uses two detection modalities: steady-state analysis of charge-dependent parameters like voltage and impedance, and transient analysis during charging and discharging to detect deviations from normal behavior. If an exceptional charge event is detected, responses like preventing further charging, increasing cooling, or service intervention are triggered to mitigate potential hazards.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US9529048B2>

3.4. Series-Connected Battery Pack with Dual-Mode Charge Imbalance Detection and Remediation System

Number US20140152259A1

Filed on 2012-11-30

Summary Detecting and responding to exceptional charge events in series-connected battery packs to prevent overcharge and overdischarge of individual cells. The system uses two charge imbalance detection methods, one for steady-state and one for transient operations. If a cell imbalance is detected, steps are taken to reduce it. If an exceptional charge event is detected in a cell, different remediation actions are initiated to mitigate the risk. These include preventing further charging, increasing cooling, and limiting charging until servicing.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20140152259A1>

3.5. System for Monitoring and Reporting Electric Vehicle Charging Disruptions with Differentiation of Authorized and Unauthorized Interruptions

Number US20130015814A1

Filed on 2011-07-13

Summary Monitoring and reporting electric vehicle (EV) charging disruptions to notify users when charging is unexpectedly interrupted. The system detects charging initiation, monitors charging operation, and issues a command to a notification system if charging disruption is detected. The notification instructions specify conditions for authorized disruptions like user proximity, full charge, or safe zone. This allows differentiating between planned and unplanned disruptions. The system notifies users of unplanned disruptions to enable prompt remediation.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20130015814A1>

4. Efficient Charging and Preconditioning

4.1. Multi-Stage Charging Protocol for Lithium-Ion Batteries with Dynamic Voltage and Current Adjustments Based on State-of-Charge, Temperature, and Internal Resistance

Number US9419450B2

Filed on 2015-01-15

Summary Fast charging lithium-ion batteries to reduce charging time without degrading cycle life. The charging process involves multiple stages with adjustable voltages and currents based on factors like cell state-of-charge, temperature, and internal resistance. This allows fast charging without excessive voltage or current levels that can damage the battery. The stages are: 1) initial constant current with increasing voltage, 2) intermediate stages like constant voltage, constant current, or decreasing current, 3) final constant voltage with decreasing current. The intermediate stages are selected based on resistance, SOC, and temperature to prevent overcharging or plating. The adjustable profile compensates for resistance changes and reduces degradation compared to fixed two-step CC-CV charging.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US9419450B2>

4.2. Automated System for Dynamic Charging Rate Adjustment of Lithium-Ion Batteries Based on Critical Parameter Monitoring

Number US9694699B2

Filed on 2014-11-21

Summary Automated method and apparatus for low temperature fast charging of lithium-ion battery packs to enable fast charging at cold temperatures without risk of lithium plating. The method involves periodically monitoring critical parameters like cell temperature, state of charge, and current to determine if fast charging is safe. If conditions allow, fast charging is used. Otherwise, slower charging is used. This allows fast charging at low temperatures without disabling it completely. The charging rate scales dynamically based on the critical parameters.

Owner(s) Tesla, Inc.

Source <https://patents.google.com/patent/US9694699B2>

4.3. External Thermal Conditioning System with Adaptive Thermal Interface for Electric Vehicle Battery Management During Charging

Number US9527403B2

Filed on 2014-04-29

Summary External thermal conditioning system for electric vehicles that provides active cooling or heating of the vehicle's battery pack during charging to maintain optimal operating temperatures. The charging station detects the battery's thermal information and provides customized thermal conditioning through connections like fluid loops, air intakes, or contact pads. This allows external cooling during fast charging when internal systems can't keep up, or heating to bring the battery up to a required temperature. It enables more efficient and flexible charging by supplementing the onboard cooling system.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9527403B2>

4.4. Battery Cell Preconditioning System with Predictive Charge Type Identification and Temperature Adjustment Mechanism

Number US9728990B2

Filed on 2012-10-31

Summary Efficiently fast charging electric vehicle batteries by preconditioning the battery cells before charging to improve charging efficiency. The method involves predicting if an upcoming charge will be fast or slow, and if fast, adjusting the battery cell temperature above the standard operating temperature. This is done by identifying an impending fast charge opportunity and using that information to prepare the battery cells for the fast charge by raising their temperature above the normal operating temperature. This improves fast charging efficiency compared to trying to cool the cells during fast charging. The technique involves a charge prediction system that identifies upcoming fast or slow charges, and an environment control system that adjusts the battery cell temperature based on the prediction.

Owner(s) TESLA, INC.

Source <https://patents.google.com/patent/US9728990B2>

4.5. Electric Vehicle Battery Charging System with Real-Time AC Power Sensing and DC Current Adjustment

Number US8638063B2

Filed on 2010-10-13

Summary Charging system for electric vehicle batteries that improves utilization of available AC power during onboard charging. The system uses AC current sensing and control to maximize charging efficiency by adjusting the DC charging current based on real-time AC power availability. It establishes a maximum DC charging current based on AC power and controls the charger to provide the actual DC current. This allows full use of the AC power versus conservatively assuming DC efficiency.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8638063B2>

4.6. Lithium-Ion Battery Charging Method with Temperature-Dependent Adjustable Voltage Profile

Number US8552693B2

Filed on 2009-09-30

Summary Charging lithium-ion batteries at low temperatures to enable charging electric vehicles in cold weather without degrading battery life. The charging method involves using an adjustable voltage profile that reduces charging current at low temperatures to prevent capacity loss. The profile has stages for normal and low temperature charging. The low temperature stage decreases current as cell temperature falls below zero Celsius. This prevents lithium plating and cycle degradation. The adjustment is based on an imaginary resistance in the cell model that increases at low temperatures.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8552693B2>

4.7. Battery Temperature Management System with Preconditioning and Mode-Responsive Thermal Control

Number US7741816B2

Filed on 2008-03-28

Summary An intelligent battery preconditioning system for electric vehicles that optimizes performance and battery lifespan by actively managing battery temperature. The system monitors the battery temperature and preheats/precools it to an optimal level based on the driving mode selected by the user. It also has a storage mode to maintain the battery at an optimal temperature when parked to prevent degradation. The system provides flexibility for performance driving without compromising battery life by preconditioning the battery to a lower impedance temperature. It also alerts the user if the selected driving mode could reduce battery life due to higher temperatures.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7741816B2>

4.8. Battery Charger with Series-Connected Heating Element and Voltage Comparator for Temperature-Dependent Charging

Number US7683570B2

Filed on 2007-07-18

Summary Battery charger for electric vehicles that heats the battery during charging to improve charging efficiency, especially in cold weather. The charger has a comparator that compares the battery voltage to the line voltage. If the battery voltage is less than a line voltage offset value, calculated based on a voltage level above the line voltage, it connects a heating element in series between the charger and the battery pack. This heats the fluid circulating through the battery cells to accelerate charging. If the battery voltage is already above the offset, the heating element is bypassed to avoid unnecessary heating.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7683570B2>

5. Enhancing Battery Safety Mechanisms

5.1. Battery Cell Cap with Ejectment Structure for Controlled Gas and Debris Release During Thermal Runaway

Number US9692025B2

Filed on 2015-12-17

Summary Battery cell design to prevent cell rupture during thermal runaway by efficiently releasing hot gas and debris through the cell cap. The design involves creating a specialized ejectment structure in the cell cap that responds to specific combustion properties of the electrode materials. This structure provides an aperture to direct combustion gases and debris out of the cell in a controlled manner, reducing the likelihood of side wall perforation compared to conventional cells. The ejectment aperture is created by responding to preselected combustion properties like temperature and pressure. This allows hot gases to escape the cell through the cap rather than penetrating the side walls.

Owner(s) TESLA, INC.

Source <https://patents.google.com/patent/US9692025B2>

5.2. Battery Pack with Rigid Substrates for Force Distribution and Integrated Cooling System

Number US9065103B2

Filed on 2014-02-27

Summary Battery pack design to improve reliability, durability, and cooling for applications like electric vehicles. The pack sandwiches batteries between rigid substrates that distribute force to prevent crushing. Conductors draw power and connect parallel/series between the batteries. Holes in the substrates prevent shorting. Cooling is via air blown through the pack and interconnected cooling tubes. The pack shape closely fits space, reducing wasted area.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9065103B2>

5.3. Battery Pack Enclosure with Shape Memory Alloy Actuated Exhaust Nozzles for Thermal Runaway Gas Venting

Number US8663824B1

Filed on 2013-01-26

Summary Battery pack thermal management system to mitigate risks and damages from battery thermal runaway. The system uses a sealed battery pack enclosure with exhaust nozzles that open during thermal runaway to direct hot gases out. An SMA seal retainer captures the sealing element in the nozzle. During normal operation, the SMA retainer is shaped to hold the seal. But when heated past its transformation temperature during a runaway, it changes shape to release the seal and eject it through the nozzle. This controlled exhaust pathway lowers temperatures and prevents spontaneous combustion of released gases.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8663824B1>

5.4. Electric Vehicle Battery Disconnection System with Pyrotechnic Switch for Collision Response

Number US9221343B2

Filed on 2012-10-10

Summary A system for safely disconnecting the high voltage battery of an electric vehicle in the event of a crash. It uses a pyrotechnic switch instead of an inertial switch to decouple the battery. The pyrotechnic switch has a pre-activated state allowing normal battery operation. But upon receiving a collision signal from the airbag system, it activates to sever the battery connection. This prevents unnecessary battery decoupling for minor collisions while ensuring decoupling for severe crashes.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9221343B2>

5.5. Battery Pack with Integrated Venting and Fault Isolation System Featuring Interruptible Electrical Connector

Number US8389139B2

Filed on 2012-06-27

Summary Battery pack design with integrated venting and isolation for improved safety and reliability. The battery pack has a unique interconnect system that allows the pack to isolate a faulty battery cell when the cell pressure exceeds normal operating range. The battery terminal has a vent that ruptures at high pressure, which breaks an interruptible electrical connector between the terminal and pack. This isolates the faulty cell while venting gas. The connector is covered in non-conductive coating and may have thinning or scored regions to facilitate breaking at vent rupture. A potting material covers the vent area. The connector is separated from the cell by a non-conductive support substrate.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8389139B2>

5.6. Battery Pack Thermal Event Detection via Pressure Data Anomaly Analysis with Exponential Decay Curve Fitting

Number US9083064B2

Filed on 2012-03-29

Summary Detecting thermal events like thermal runaway in battery packs using pressure data analysis. The method involves dividing pressure data into sets, detecting anomalies, fitting curves to trailing edges, and checking time constants. If an anomaly's trailing curve fits an exponential decay with a certain time constant range, it indicates a thermal event. This helps distinguish true thermal events from false positives caused by vibrations or noise. The system also checks curve goodness of fit. If a thermal event is detected, it triggers an appropriate response.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9083064B2>

5.7. Battery Pack Monitoring System with Electrical Isolation Resistance Detection and Failure Containment Mechanism

Number US9046580B2

Filed on 2011-08-23

Summary Early detection of thermal events in batteries to prevent propagation and mitigate damage. The system monitors the electrical isolation resistance of a battery pack. If the resistance drops below a threshold, indicating cell failure, the system responds to contain the failure. The response can be a warning, reducing load, increasing cooling, or activating fire containment. The system also tracks the isolation resistance fall and recovery to distinguish between initial venting and subsequent runaway.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9046580B2>

5.8. Overcharge Protection Device with Terminal Shorting Mechanism for Battery Packs

Number US8659270B2

Filed on 2010-10-29

Summary An overcharge protection device for battery packs that provides an additional layer of protection against overcharging beyond conventional charging systems. The device shorts the battery terminals if the charging voltage exceeds a threshold, blowing the battery pack fuse to prevent overcharging. It is interposed between the battery pack terminals and can use components like IGBTs, crowbar circuits, or relays. The shorting threshold is set high enough to allow other overcharge protection systems to trigger first but low enough to prevent dangerous self-heating in the batteries.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8659270B2>

5.9. Battery Thermal Event Detection System with Conductive Member Resistance Monitoring

Number US8059007B2

Filed on 2009-05-28

Summary A system for detecting thermal events in batteries to provide early warning of overheating and potential thermal runaway. The system uses conductive members in contact with the battery surfaces that are connected to resistance measuring devices. When the battery temperature is within normal operating range, the resistance is within a first range. If the battery temperature exceeds a predetermined threshold, the resistance increases into a second range. The resistance change is monitored to detect thermal events before they escalate into runaway.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8059007B2>

6. Improving Thermal Management Systems

6.1. Lithium-Ion Cell Manufacturing with Liquid-Based Thermal System for Accelerated Reaction and Testing

Number US20160233559A1

Filed on 2016-01-21

Summary Improving the manufacturing process of lithium-ion cells by using a liquid-based thermal system for accelerating chemical reactions, capacity testing, and OCV measurement during cell assembly and formation. The cells are stored in contact with circulating liquid at elevated temperatures to initiate and accelerate chemical reactions. After initial charging/discharging, open circuit voltage (OCV) testing is done at high and low temperatures. Cells are then cooled and tested again. Finally, capacity testing is performed. This sequence allows accurate detection of defects using OCV and capacity tests. The liquid thermal system provides even temperature distribution, faster reaction times, and more accurate capacity measurement.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20160233559A1>

6.2. Electric Vehicle Thermal Management System with Coolant Loop Bypass Valve for Independent Flow Regulation

Number US10522845B2

Filed on 2013-07-22

Summary Thermal management system for electric vehicles that allows continuous and optimized control of battery cooling and passenger cabin cooling. The system uses a bypass valve in the coolant loop that allows splitting the coolant flow between going through the heat exchanger and bypassing it. This allows independent regulation of the amount of coolant going through the heat exchanger versus bypassing it. By adjusting the bypass valve, the system can fine-tune the cooling of the battery pack and passenger cabin to maintain desired temperatures within preset ranges. It also provides flexibility to balance cooling demands when the compressor output of the refrigeration system cannot be increased further. The bypass valve also allows bypassing the heat exchanger entirely for very low battery pack temperatures, further optimizing cooling.

Owner(s) Tesla, Inc.

Source <https://patents.google.com/patent/US10522845B2>

6.3. Underfloor Battery Pack Base Plate with Thermally Coupled Decoupling Heat Exchanger

Number US10476051B2

Filed on 2013-01-08

Summary Integrating a heat exchanger into the base plate of an underfloor battery pack in an electric vehicle. The heat exchanger is thermally coupled to the batteries when the pack is in operation. When the pack is not in use, the heat exchanger is decoupled from the batteries. This allows optimal heat transfer from the pack to the ambient air flowing over the exposed base plate during vehicle motion. An integrated heat exchanger like this provides efficient cooling without stacking multiple heat exchangers, reducing power losses and improving performance.

Owner(s) Tesla, Inc.

Source <https://patents.google.com/patent/US10476051B2>

6.4. Dual Mode Thermal Management System with Configurable Parallel and Serial Coolant Loops for Electric Vehicles

Number US8402776B2

Filed on 2012-03-23

Summary Dual mode thermal management system for electric vehicles that allows optimized cooling and heating of the battery pack and drive train components while simplifying the overall system complexity. The system has two separate coolant loops, one for the battery pack and one for the drive train components. A valve allows switching between parallel operation (circulating coolant in each loop separately) and serial operation (circulating coolant through both loops in series). This enables efficient cooling of the battery pack without requiring a separate coolant loop for it. The reservoir is always connected to the drive train loop. The serial mode allows shared cooling between battery and drive train when both need it. The valve can also isolate the battery loop for independent cooling when needed.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8402776B2>

6.5. Battery Pack Temperature Control System with Ambient-Dependent Coolant Circulation

Number US8555659B2

Filed on 2011-11-01

Summary Efficiently controlling the temperature of an electric vehicle battery pack after the vehicle is turned off to extend battery lifetime without incurring excessive additional costs. The method involves circulating coolant through the battery pack cooling system if the ambient temperature is lower than the battery temperature, but suspending coolant circulation if the ambient temperature is higher. This prevents overcooling the battery in cold environments while avoiding overheating in warm environments. The ambient temperature is monitored and compared to the battery temperature to determine if coolant circulation is needed.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8555659B2>

6.6. Battery Pack Temperature Control System with Post-Shutdown Active Cooling Mechanism

Number US8899492B2

Filed on 2011-10-03

Summary Efficiently controlling the temperature of an electric vehicle battery pack to extend battery life without excessive cost. After the vehicle is turned off, a method actively cools the battery pack using techniques like pumping coolant through loops or operating refrigeration systems. Temperature thresholds and SOC ranges are used to select the cooling implementation. This prevents overheating when the vehicle is idle.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8899492B2>

6.7. Cooling Manifold Assembly with Flexible Interface Layer and Contoured Coolant Tube for Battery Packs

Number US8758924B2

Filed on 2011-05-06

Summary Cooling manifold assembly for battery packs that improves manufacturability and performance compared to conventional cooling systems. The assembly uses a flexible thermal interface layer with deflectable fingers between adjacent cell rows and a contoured coolant tube. This allows easier assembly compared to rigid spacers and prevents shorting. The fingers conform to the cell shapes, providing better heat transfer while avoiding electrical contact. The flexible interface layer also prevents damage during cell insertion/removal. The contoured tube matches cell curvature.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8758924B2>

6.8. Cooling Tubes with Scalloped Outer Surfaces for Enhanced Thermal Contact in Battery Packs

Number US20080311468A1

Filed on 2007-06-18

Summary Optimized cooling tube geometry for battery packs in electric vehicles to improve thermal management and battery life. The cooling tubes have scalloped outer surfaces that contour around the battery cells. This provides maximum thermal contact with the cells for efficient heat removal. The tubes are filled with a thermally conductive medium to further enhance heat transfer. The scalloped shape allows a two-dimensional patch of minimum separation around each cell on both sides of the tube.

Owner(s) Weston Arthur Hermann, Scott Kohn, Gene Berdichevsky

Source <https://patents.google.com/patent/US20080311468A1>

6.9. Thermal Management System with Shared Heat Exchanger and Integrated Coolant Loops for Electric Vehicles

Number US7789176B2

Filed on 2007-04-11

Summary A thermal management system for electric vehicles that uses a single heat exchanger to efficiently cool the battery, HVAC, and motor components. The system has three coolant loops: a battery loop, an HVAC loop, and a motor loop. The loops share the heat exchanger. The refrigeration system cools the heat exchanger, and the battery loop circulates through it. The motor loop can also connect to the HVAC loop to provide heat if needed. This simplified, integrated thermal management system avoids multiple subsystems and provides efficient cooling and heating for all components using a shared heat exchanger.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7789176B2>

7. Optimizing Power Source Utilization

7.1. Electric Vehicle Charging System with Adaptive Rate Control Based on State of Charge and Time Constraints

Number US8963494B2

Filed on 2012-05-18

Summary Optimizing electric vehicle (EV) charging rate based on user needs to balance fast charging speed with battery life and cost. The charging system determines optimal charging profile based on factors like state of charge (SOC) and time constraints. If fast charging is not required to meet SOC and completion time targets, it slows down charging rate to improve battery life and cost. This allows users to prioritize convenience vs longevity when charging.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8963494B2>

7.2. Electric Motor Controller with Dual Modes for Efficiency and Heat Dissipation

Number US8970147B2

Filed on 2011-06-29

Summary Intentionally inefficient operation of an electric motor in cold weather to enhance vehicle performance by generating excess heat. The motor controller has two modes: an optimal efficiency mode and a dissipation mode. In the optimal mode, the motor operates at maximum efficiency to conserve energy. But in cold weather, when battery power is limited, the dissipation mode is selected. This involves operating the motor at lower efficiency to intentionally dissipate excess power as heat. The extra heat warms the vehicle's electronics and battery, mitigating cold weather performance degradation.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8970147B2>

7.3. Metal-Air Battery Pack with Oxygen Recycling via Compressed Exhaust Management System

Number US8298692B2

Filed on 2011-01-26

Summary System for optimizing metal-air battery packs by capturing and reusing the oxygen-rich exhaust during charging to supplement air intake during discharging. The system has a compressor between the battery pack outlet and a gas tank inlet. During charging, the compressor compresses the oxygen-rich exhaust and stores it in the tank. During discharging, the compressed oxygen is fed back into the battery pack. This recycles the oxygen and reduces the need for external air, avoiding excessive oxygen levels during charging. The system also has valves to isolate the battery pack from external air during charging/discharging.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8298692B2>

7.4. Electric Vehicle Power Source System with Dual Battery Type Optimization Based on State of Charge and Efficiency Parameters

Number US8180512B2

Filed on 2010-12-10

Summary Optimizing the power source of an electric vehicle with two different types of batteries, one metal-air and one non-metal-air, to balance efficiency and range. The optimization involves determining optimal split between the battery packs to minimize use of the less efficient metal-air pack while providing enough power for the expected distance. It also sets acceleration limits based on battery SOC and vehicle efficiency. The optimization considers factors like SOC, efficiency, distance, environment, weather, driver, and itinerary.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8180512B2>

8. Preventing Thermal Runaway Propagation

8.1. Battery Pack with Venting Assembly and Angled Duct for Controlled Gas and Debris Expulsion

Number US8557416B2

Filed on 2012-05-19

Summary Battery pack design to mitigate thermal runaway hazards by guiding hot gases and debris away from the pack and vehicle during runaway events. The pack has a venting assembly with valves covering exhaust ports. During normal operation, the valves seal. But if pressure rises due to battery runaway, the valves unseal and gas escapes through the ports. An angled duct inside the pack guides the escaping gases away from the pack and vehicle. This prevents gas and debris from spreading inside the pack or vehicle, reducing collateral damage and propagation risks.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8557416B2>

8.2. Battery Pack with Thermally Isolated Cell Featuring Elevated Temperature Safety Mechanism

Number US8932739B2

Filed on 2011-04-18

Summary Battery pack design to mitigate thermal runaway propagation in case of internal short circuits. It involves selecting one cell in the pack to be the last one to short circuit by using a higher temperature safety mechanism in that cell. This cell is then thermally isolated from the others using a barrier like ceramic enclosure, coating, or filler. This prevents excessive heating and collateral damage if the isolated cell shorts, as the barrier insulates it from the rest of the pack. The other cells still have their regular short circuit safety mechanisms.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8932739B2>

8.3. Battery Cell Heat Dispersion System with Thermally Conductive Material and Offset Row Cooling Tubes

Number US20110091760A1

Filed on 2010-12-30

Summary Dispersing heat from battery cells to prevent chain reactions and failures. The method involves surrounding and contacting a portion of the cell cases and the cooling tubes with a thermally conductive material. This allows heat from a thermal event in one cell to be transferred to adjacent cells and the cooling liquid, preventing a chain reaction. The cells are arranged with offset rows and the cooling tubes between them. The thermally conductive material solidifies around the cells after application.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20110091760A1>

8.4. Battery Assembly with Intumescent Coating for Thermal Runaway Containment

Number US8263254B2

Filed on 2010-04-29

Summary Battery design to prevent thermal runaway propagation in battery packs. The battery assembly has a layer of intumescent material coating the cell casing sidewalls and bottom, excluding contact regions near the cap and bottom. The intumescent material absorbs heat, expands and hardens to contain thermal events and prevent cascading failures. It provides thermal insulation, contains gases and flames, and directs heat away from adjacent cells. The intumescent material is biologically inert, electrically non-conductive and has a set temperature above typical cell operating temps.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8263254B2>

8.5. Battery Pack with Fluid-Filled Conduits for Thermal Runaway Mitigation Through Temperature-Triggered Breach Mechanism

Number US9093726B2

Filed on 2009-09-12

Summary Mitigating thermal runaway in battery packs to prevent cascading cell failures and contain the thermal energy release. The system uses fluid-filled conduits around the cells that breach at lower temperatures than the cell materials. When a cell enters thermal runaway, the breach allows fluid to discharge onto the overheating cell, cooling it and nearby cells. This helps prevent propagation of thermal runaway. The fluid can be pumped or from a source, and sensors monitor pressure, temperature, and fluid level.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US9093726B2>

8.6. Lithium-Ion Battery with Thermal Runaway Isolation and Cooling Structures

Number US20100151308A1

Filed on 2008-12-12

Summary Battery design to prevent thermal runaway propagation in lithium-ion batteries. It uses insulation and cooling strategies to isolate cells in thermal runaway (TR) and prevent neighboring cells from also going into TR. The battery has air gaps between cells to reduce conduction, high capacity heat conductors to absorb TR cell heat, and shielding materials with high heat capacitance between cells. This slows TR cell heat transfer to neighbors while enabling efficient heat removal through the conductors. It aims to prevent cascading TR events by isolating and cooling TR cells.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20100151308A1>

9. Others

9.1. System for Monitoring and Mitigating High Voltage Electrolysis in Electric Vehicle Battery Packs

Number US10714735B2

Filed on 2018-05-03

Summary Detecting and mitigating high voltage electrolysis within electric vehicle battery packs to prevent thermal runaway and hydrogen buildup. The system uses sensors to monitor for conditions like coolant leaks and bridged terminals that can lead to electrolysis. If electrolysis is detected, the system responds by cutting power to prevent further energy input, and actively cooling the electrolyzing area to prevent boiling and temperature rise. This prevents chain reactions and thermal runaway that can occur from electrolysis.

Owner(s) Tesla, Inc.

Source <https://patents.google.com/patent/US10714735B2>

9.2. Battery Pack Enclosure with Emergency Coolant Ingress and Controlled Breach Mechanism

Number US11081739B2

Filed on 2018-03-26

Summary A system for allowing controlled cooling of electric vehicle battery packs during internal thermal events. The system provides a way to ingress coolant like water into the sealed battery enclosure during thermal runaway conditions. This allows direct contact with the affected cells to remove heat and mitigate chain reactions. A specialized fill port is used for normal coolant refilling. But in emergency situations, a perforation tool can breach the enclosure wall to allow coolant ingress through a specific hole. The tool has features to prevent unintended breaches. The hole location is also designed to minimize damage and contamination. The breach-and-fill method provides a controlled way for first responders to cool a battery pack in an urgent situation where normal coolant access is unavailable.

Owner(s) Tesla, Inc.

Source <https://patents.google.com/patent/US11081739B2>

9.3. Multi-Port Valve with Single Actuator and Stemshell Component for Selective Fluid Flow Control

Number US10344877B2

Filed on 2016-11-30

Summary A multi-port, multi-mode valve with multiple inlets and outlets for fluid like coolant. It has a single actuator that can selectively open or close fluid flow between pairs of ports while simultaneously not affecting flow between other pairs. The valve uses a stemshell component as the actuated valve to regulate operational modes.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US10344877B2>

9.4. Modular Energy Storage System with Galvanic Isolation and Independent Power Electronics for Parallelization of Dissimilar Battery Blocks

Number US20170093157A1

Filed on 2016-09-30

Summary Scalable, modular energy storage system that allows parallelization of multiple battery blocks with different cell types, ages, and voltages without requiring exact voltage matching. The system uses galvanic isolation and power electronics converters for each battery block to provide a common DC interface. This allows failure independence, scalability, and parallelization of dissimilar batteries without propagation or system-wide voltage balancing.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20170093157A1>

9.5. Data Communication System with Redundant Single Conductor Paths and Break Detection for Electric Vehicles

Number US9568534B2

Filed on 2015-10-02

Summary Low-cost, fault tolerant, EMI robust data communications system for high performance electric vehicles. The system uses redundant signal and power paths to improve reliability and mitigate EMI. It has dual single conductors for data and power between devices, with break detection loops to immediately detect and signal faults. This allows redundant paths to prevent complete failure when one breaks. The break detection also provides early warning before both paths fail simultaneously. The redundant paths are implemented using single wires and connectors to reduce cost and improve reliability compared to using multiple wires.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US9568534B2>

9.6. Vortex Separator with Chimney and Catch Basin for Particle-Gas Separation in Electrochemical Cell Systems

Number US20160380248A1

Filed on 2015-06-25

Summary Vortex separator for energy storage systems with electrochemical cells to mitigate thermal runaway events. The separator has an inlet, a chimney, and a catch basin. The cells exhaust gas into the chimney during thermal runaway. The separator has a vortex flow design with an inlet at the chimney top and outlets at both the catch basin and outside. The vortex flow separates particles from the gas as it exits the chimney and sends particles to the catch basin while allowing the gas to escape. This prevents ignition by confining particles while allowing gas to disperse.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20160380248A1>

9.7. Energy Storage System Nodes with Redundant Communication Devices on Looped Medium Using Passive Frequency Division Multiplexing

Number US20170177048A1

Filed on 2015-04-02

Summary Redundant function performance in the communications and data transmissions of energy storage systems using a looped communications medium. The looped medium connects nodes in the energy storage system. Each node has redundant devices for communication and data transmission using the looped medium. The devices can operate simultaneously on the same medium segment without interference. The looped medium allows redundant communication even if segments are disrupted. Passive frequency division multiplexing allows simultaneous operation without interference. The looped medium termination allows indeterminate reception detection. The redundant devices mitigate failure impacts on each other.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20170177048A1>

9.8. Battery Pack Service System with External Charging and Discharging Capability

Number US9466992B2

Filed on 2013-03-04

Summary A system and method for charging and discharging high voltage battery packs outside of the vehicle they are normally installed in. The system allows maintenance and management of battery packs when the vehicle is not operational or the pack is compromised. It uses a separate battery service unit with access to the pack's ports. The unit can charge/discharge the pack directly or simulate the vehicle environment to trigger the pack's BMS. This enables setting pack SOC levels without needing a functional vehicle. It also provides charging/discharging for storage, transport, recycling, and servicing scenarios.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US9466992B2>

9.9. High-Voltage Battery Pack with Flexible Printed Circuit Matrix and Mechanical Joints

Number US20140212695A1

Filed on 2013-01-30

Summary High-voltage battery pack design using flexible printed circuits to improve reliability, manufacturability, and resource efficiency compared to conventional wire bonding. The battery pack uses a matrix of energy storage elements connected using flexible printed circuits with mechanical joints. The circuits have thin insulating layers and conductive patterns with parallel bulk conductor regions for series connections and terminal contacts for parallel connections. This allows dense packaging, reduced weight, and eliminates susceptible wire bonds. The circuits also provide onboard electronics integration.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20140212695A1>

9.10. Reconfigurable Overcurrent Protection Device with Adaptive Current Demand Adjustment for High-Voltage Battery Packs

Number US8867180B2

Filed on 2012-11-30

Summary Dynamic overcurrent protection for high-voltage battery packs in electric vehicles that adapts the protection level based on the current demand to prevent false trips and improve performance. The system uses an actively reconfigurable overcurrent protection device that dynamically adjusts the protection rating based on the current level. It applies a lower protection rating during normal operation and a higher rating during peak demand to avoid false trips during normal use while still protecting against overcurrent during high demand.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8867180B2>

9.11. Electric Vehicle Battery Charging System with Dual-Mode Generator Control and User Interface

Number US8463481B2

Filed on 2012-11-13

Summary Controlling battery charging in electric vehicles to reduce engine usage and improve efficiency. The system has a user interface to select between two operational modes for the onboard generator. In the first mode, the engine starts charging when battery SoC drops below 50% and stops at 70%. In the second mode, the engine starts at 10% SoC and stops at 70%. After reaching 10% once, it starts charging at 50% SoC. This prevents frequent engine starts and stops while maintaining an average SoC above 68%.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8463481B2>

9.12. High Voltage Electrical Interface with Cable-Dependent Interlock Lever Mechanism

Number US20130228431A1

Filed on 2012-10-19

Summary High voltage electrical interface with interlock mechanism to prevent unsafe conditions when high voltage cables are not installed. The interface has levers inside the housing that detect if the high voltage cables are connected. If the cables are not connected, the levers prevent the cover from closing the interlock switch. This prevents power from being applied to the high voltage circuit. If the cables are properly connected, the levers retract allowing the cover to close the switch and apply power.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20130228431A1>

9.13. Battery Pack Humidity Control System with Regenerable Desiccant Enclosure

Number US8247097B1

Filed on 2012-01-28

Summary A system to extend the life of battery packs in devices like electric vehicles by controlling humidity inside the pack. The system uses a separate desiccant enclosure connected to the battery pack enclosure. It removes moisture from the pack through the desiccant, then periodically heats the desiccant to reactivate it. This prevents saturation and ensures ongoing moisture absorption. The heater is controlled based on time or humidity levels. This avoids desiccant replacement while maintaining dehumidification effectiveness throughout pack life.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8247097B1>

9.14. Electric Vehicle Charging Port with Multi-Color Visual Status Indicator System

Number US8125324B2

Filed on 2011-10-05

Summary Battery charging monitoring and status indication system for electric vehicles that provides visual feedback to users about the charging status and any issues. The system uses colored lights around the charging port to indicate the connection, charge level, and faults. When the charging connector is plugged in but not charging, the light is blue. If the battery is fully charged, the light is green. If there's a charging fault, the light flashes red. If there's a vehicle fault, the light is solid red. If the connector is plugged in and charging, the light pulsates. The light color and pulsing frequency changes based on charge level.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8125324B2>

9.15. Electric Vehicle Battery Pack System with Electrolysis Detection and Gas Management Mechanism

Number US20130073234A1

Filed on 2011-09-21

Summary Detecting and remediating low voltage electrolysis in electric vehicle battery packs to mitigate hydrogen gas buildup and explosion hazards. The system uses sensors to monitor battery pack parameters like voltage, current, flow rate, and immersion to detect low voltage electrolysis. If electrolysis is likely, the system responds by stopping the battery discharge, purging flammable gas, and adding inert gas to displace oxygen. This prevents explosive hydrogen accumulation. It also provides safe service procedures like purging before opening the pack.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20130073234A1>

9.16. Metal-Air Battery Charging System with Oxygen Effluent Collection and Controlled Exhaust Mechanism

Number US8557414B2

Filed on 2011-02-25

Summary System to safely charge metal-air batteries in confined spaces like garages without increasing oxygen levels to hazardous levels. The system collects and stores the oxygen-rich effluent generated during charging, compresses it, and stores it in a tank. If the oxygen level drops, it exhausts the stored oxygen through an external exhaust. If the oxygen level rises, it stores the effluent. This prevents oxygen buildup during charging while allowing oxygen depletion during discharging.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8557414B2>

9.17. Power Inverter with Dynamic Negative Rail Voltage Adjustment for Overshoot Control

Number US8760898B2

Filed on 2011-01-31

Summary Dynamic control of the negative rail voltage in a power inverter to efficiently and economically reduce excessive voltage overshoot during device turnoff. The control adjusts the negative rail voltage dynamically based on monitored parameters to reduce risk of overshoot while maximizing bus voltage usage. It leverages the fact that device turnoff time varies with rail voltage. If overshoot is excessive, the rail voltage is decreased during that high current state to limit overshoot without increasing losses.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8760898B2>

9.18. Dynamic Negative Gate Voltage Rail Control for Voltage Overshoot Mitigation in High-Voltage Power Inverters

Number US20120195085A1

Filed on 2011-01-31

Summary Dynamic control of a negative gate voltage rail in high-voltage power inverters to efficiently and economically reduce excessive voltage overshoot during fast switching of semiconductor power devices. The control dynamically adjusts the negative bias voltage to limit voltage overshoot during device turn-off based on monitored parameters. This allows maximizing use of the DC bus voltage while minimizing switching losses and preventing device breakdown. The negative voltage rail is decreased during higher drive current states when overshoot is excessive. This reduces risks of voltage overshoot without increasing device size.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20120195085A1>

9.19. Battery Pack Charging System with Thermal Energy Transfer Between Metal-Air and Non-Metal-Air Cells

Number US7940028B1

Filed on 2010-11-20

Summary Maximizing charging efficiency of battery packs containing different types of cells by using thermal energy from one pack to heat the other pack during charging. This prevents undercharging due to lower temperatures and allows faster charging. A system with metal-air and non-metal-air battery packs is connected to an external power source. Charging starts with the metal-air pack. If the non-metal-air pack is too cold, thermal energy is transferred from the metal-air pack via a heat exchanger. This prevents undercharging due to low temperatures. The charging rate can also be controlled based on pack temperatures. The metal-air pack can be heated if too cold. This ensures both packs charge efficiently.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7940028B1>

9.20. Electric Vehicle Battery Pack Enclosure with Controlled Water Ingress System and Selectively Permeable Fill Port

Number US20120111444A1

Filed on 2010-11-09

Summary A system to allow controlled water ingress into an electric vehicle battery pack enclosure to cool overheating batteries during internal thermal events. The system has a normally closed fill port on the enclosure with a selectively permeable obstruction. This allows water ingress while inhibiting gas egress. The port is positioned clear of hot gases. This enables an operator to fill the enclosure with water to cool overheating batteries during internal thermal events, while preventing gas leakage. The enclosure wall reinforces battery protection when installed in the vehicle.

Owner(s) TESLA MOTORS, INC.

Source <https://patents.google.com/patent/US20120111444A1>

9.21. System for Maintaining Lead-Acid Battery Charge within Specified Range Using SOC Detection

Number US20120098501A1

Filed on 2010-10-26

Summary Method and apparatus to improve the efficiency of lead-acid batteries like those used in vehicles, backup power systems, and load leveling applications without risk of sulfation. The method involves maintaining a specific charge range of 70-85% instead of fully charging the battery. An SOC detector measures the battery charge and a charger keeps it within the optimal range. This prevents deep discharges and prolongs battery life by avoiding sulfation.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20120098501A1>

9.22. Electric Vehicle Charging System with Common Mode Voltage Alignment and Switching Assembly

Number US20120019194A1

Filed on 2010-07-20

Summary Charging system and method for electric vehicles that reduces residual currents and prevents ground fault interrupters (GFIs) from tripping when charging an isolated battery pack. The charging system uses a switching assembly to decouple the AC line voltage from the battery chargers when initially connecting. A sensing circuit measures the battery and line common mode voltages. Then a common mode voltage driver aligns them. Once within a threshold, the switching assembly connects the line voltage to charge the battery. This balances the common mode voltages before charging to avoid triggering GFIs.

Owner(s) Tesla Motors Inc.

Source <https://patents.google.com/patent/US20120019194A1>

9.23. Voltage Converter with Dual Stage Configuration and Adaptive Control for Line-to-Battery Voltage Management

Number US8324863B2

Filed on 2010-04-19

Summary Voltage converter for charging rechargeable energy storage systems (like batteries) from an AC power source that efficiently and safely handles cases where the line voltage is higher than the battery voltage due to low state-of-charge. The converter has a main charging stage to boost the line voltage to battery level and a switchable auxiliary stage that down-converts the line voltage to a lower level. The auxiliary stage is used when line voltage exceeds battery voltage to charge at a reduced current through the main stage's inductor. A controller switches between main and auxiliary stages based on line/battery voltage relationship.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8324863B2>

9.24. Intelligent Control of Auxiliary Loads for Adaptive Electric Vehicle Battery Charging

Number US7755329B2

Filed on 2009-11-05

Summary Optimizing battery charging time for electric vehicles by intelligently controlling auxiliary loads during charging. The method involves delaying activation of auxiliary systems like cooling systems until surplus power is available. This allows charging at the optimal rate limited only by the available power. If the battery temperature is below a threshold, charging can proceed at optimal rate. If above, it's suboptimal due to cooling load. Once surplus power is available, cooling can be enabled. This balances charging and cooling needs versus available power.

Owner(s) Telsa Motors, Inc.

Source <https://patents.google.com/patent/US7755329B2>

9.25. Battery Pack with Position-Based Dynamic Module Identifier Assignment

Number US20110003183A1

Filed on 2009-07-06

Summary Simplifying manufacturing and detection of battery pack condition during operation by dynamically assigning unique module identifiers based on their physical positions in the pack. When the pack is assembled, each module's position is determined and used to assign a unique identifier. This eliminates the need for manual mapping of positions and potential errors. During operation, comparing a module's current position to its assigned reference position can flag issues if they mismatch.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20110003183A1>

9.26. Battery Thermal Event Detection via Optical Fiber Light Attenuation Monitoring

Number US8092081B2

Filed on 2009-05-28

Summary Detecting thermal events in batteries to mitigate damage and fires. An optical fiber is placed near the battery surface and light is transmitted through it. When the battery heats up during thermal runaway, the light is attenuated, shifted, or interrupted. This change is detected by the fiber optic system to indicate a thermal event. The fiber optics allows monitoring battery health without contact and provides early warning of thermal runaway to enable preventative action.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8092081B2>

9.27. Sealed Battery Enclosure with Impermeable Housing, Pressure Management, and Hermetically Sealed Interfaces

Number US20100136402A1

Filed on 2009-04-22

Summary Sealed battery enclosure for extending the life of batteries in applications where repeated charging and discharging is required. The sealed enclosure prevents contamination from water, gases, and other liquids that can degrade battery performance over time. It uses impermeable housing members, an impermeable sealing gasket, a pressure management system, and a desiccant to maintain a low humidity internal environment. The enclosure also has hermetically sealed electrical connectors, coolant lines, and conduit couplers to prevent ingress of contaminants. Two-way pressure relief valves limit pressure differential between the enclosure and external environment.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US20100136402A1>

9.28. Battery Charging System with Adaptive Cut-off Voltage Based on Dynamic Usage Prediction

Number US8054038B2

Filed on 2009-01-29

Summary Optimizing the cut-off voltage used during battery charging to minimize cell degradation by tailoring the charge level based on expected usage. A system that calculates the total travel distance based on a user's planned route, then sets the optimal charge level for the battery pack accordingly. This prevents overcharging and reduces cell wear compared to fixed charge algorithms. Factors like departure time, road conditions, weather, driving style, and mid-journey charging needs are considered.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8054038B2>

9.29. Electric Vehicle Battery Management System with User-Selectable Charging and Cooling Modes

Number US7671567B2

Filed on 2009-01-16

Summary A system for optimizing the performance and life of electric vehicle batteries by allowing the user to select charging and cooling modes based on their specific needs. The system provides multiple charging/operational modes with different cutoff voltages and temperature ranges. The user can choose between modes like Standard, Storage, and Extended Range. This allows customization for scenarios like daily driving vs long trips. The system remembers the user's preference unless they manually switch. It also prompts for mode selection after turning off the car. The default mode can be set by the user.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7671567B2>

9.30. Redundant Battery Monitoring Circuits for Voltage and Charge State Detection

Number US8044786B2

Filed on 2008-06-19

Summary Accurately monitoring battery voltage and charge state in electric vehicles to prevent issues like loss in efficiency, overcharging, and fires. The technique involves using redundant battery monitoring circuits to provide backup if one circuit fails, which mitigates the risk of misreporting battery parameters that can lead to issues like overcharging and fires.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US8044786B2>

9.31. Electric Vehicle Communication Interface with Network-Connected Remote Battery Management and Location-Based Preset Storage

Number US7698078B2

Filed on 2007-07-18

Summary Communication interface for electric vehicles that allows remote charging, monitoring, and controlling of the battery. It uses a device in the vehicle to connect to networks and communicate with a user interface. This allows features like initiating charging, delaying charging, and minimizing current draw from the grid. It also notifies the user of battery issues and can prompt choices for second homes. The interface can store presets for multiple locations using a GPS.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7698078B2>

9.32. Battery Management System with Autonomous Module Voltage Balancing and Target Voltage Communication

Number US7602145B2

Filed on 2006-07-18

Summary Self-balancing battery management system for electric vehicles that enables balancing of battery modules without external equipment. The system balances voltages between modules as soon as they connect or disconnect. It initiates balancing based on target voltages derived from individual module voltages. Modules announce their target voltages to other modules, which replace their targets if appropriate. Modules then adjust voltages based on their targets. This allows balanced voltage distribution throughout the battery pack without external intervention.

Owner(s) Tesla Motors, Inc.

Source <https://patents.google.com/patent/US7602145B2>

Disclaimer

This patent report is meant and provided for informational purposes only. Although we have quality check procedures in place to ensure reliability of the information provided in this report, we cannot guarantee its accuracy or completeness. The report does not cover all the patents related to its topic. GreyB shall not be responsible for any losses or legal issues arising from using the information provided in this report. We recommend consulting a qualified patent attorney or expert for legal advice and guidance before taking any decision based on the information provided herein.