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Technical safety in electric and hybrid vehicles: service, isolation, and incident response guidelines for independent workshops.

Technical safety in electric and hybrid vehicles: service, isolation, and incident response guidelines for independent workshops

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Summary

The advancement of electric and hybrid vehicles has transformed the routine of independent workshops, shifting the focus from specific diagnostic skills to the systematic management of electrical risk. This article organizes a minimal map of normative references and best practices—articulating Brazilian electrical safety legislation with international standards for occupational protection, vehicle charging, and incident response—and translates this set into concrete operational procedures for workshops that service battery-electric and hybrid vehicles. Based on this foundation, guidelines are proposed for high-voltage bay layout, signage, PPE management and dedicated tools, installation and safe use of charging infrastructure, as well as a standard procedure for servicing, isolating, and verifying the absence of voltage, based on lockout/tagout practices and the "Stop–Isolate–Test" sequence. The challenges of implementing this system in independent workshops are also discussed, including barriers to training, cost, and safety culture. It concludes that safety in electric and hybrid vehicles in the workshop is not limited to the adoption of PPE: it depends on a management system that aligns standards, procedures, training, and documented evidence, raising the level of occupational protection and the reliability of the service provided.

Keywords: electric vehicles; hybrid vehicles; high-voltage safety; independent workshops; electrical risk management; technical standards.

Abstract

The growing presence of battery electric vehicles (BEVs) and hybrid electric vehicles (HEVs) in independent repair shops has shifted the focus from isolated diagnostic skills to systematic electrical risk management. This article consolidates a minimum set of regulations and best practices —
combining Brazilian electrical safety rules with international standards on occupational protection, charging infrastructure and incident response — and translates these frameworks into concrete operational procedures for workshops servicing electrified vehicles. Based on this foundation, it proposes guidelines for high-voltage bay layout, signage, dedicated PPE and tool management, safe installation and use of charging equipment, as well as a standard procedure for service intake, electrical isolation and verification of absence of voltage grounded in lockout/tagout practices and the “Stop–Isolate–Test” sequence. The discussion barriers addresses for small independent shops, including training gaps, cost constraints and safety culture. It concludes that safety in servicing electric and hybrid vehicles cannot be reduced to PPE selection alone; it depends on a management system that aligns regulations, procedures, training and documented evidence, thereby improving occupational protection and the reliability of workshop operations.
Keywords: electric vehicles; hybrid vehicles; high-voltage safety; independent repair shops; electrical risk management; technical standards.

1. Introduction

Over the past fifteen years, electric propulsion systems have gone from being "exotic" to...

To make up the day-to-day operations of the independent workshop. Mild hybrids, full hybrids, plug-ins and electric vehicles.

The battery is now appearing regularly in both neighborhood workshops and larger establishments.

The key difference compared to the purely thermal model is not just technological; it's about risk.

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In an electrified vehicle, the high-voltage assembly — consisting of the traction battery, converters, inverters and orange harnesses — operates in voltage and current ranges capable of causing Shock, severe burns, and electric arc can occur if the work is not organized. The international standard which deals with protection against shock and thermal incidents in electrified vehicles makes it clear that the The vehicle offers inherent protections to the end user, but it does not replace the need for Safe work procedures in maintenance. In other words, the vehicle design is a A starting point, not an absolute shield.

For the independent workshop, this means migrating from a model based on “skills”. individual with multimeter” for an electrical risk management model, in which areas are defined, workflows, access permissions, lockout and tagging routines, selection of PPE and EPC, records of Service and periodic retraining. Electrical risk is now treated as a process. not as an exception.

In the Brazilian context, the legal basis for this movement is primarily provided by two Regulatory Standards: NR-10, which deals with safety in installations and services in electricity, and NR-06, which regulates the selection and management of Personal Protective Equipment. (PPEs). These local references are linked to national and international technical standards. Occupational safety, vehicle recharging, insulated tools and incident response, broadly. used in countries that already have a large-scale electrified fleet. Instead of tracking each While the acronym is used individually, this article takes this normative block as a backdrop and focuses on how This can be translated into clear routines for the workshop.

The charging environment is also part of the problem. In countries where electrification is already... More consolidated, national electrical codes define requirements for circuits and equipment. Recharging, emergency disconnection points, and protection criteria. In Brazil, recharging standards. Conductive and connector standardization serve a similar function. For the workshop, this translates to... In simple terms: dedicated circuit, adequate protection, accessible disconnection, routine inspection. cables and connectors and procedures for handling damaged vehicles.

Finally, there is the risk of incidents (smoke, anomalous heating, collision, immersion, “remaining energy” in the pack) which require specific isolation, quarantine and protocols. Coordination with fire departments, insurance companies, and towing services. Recent technical reports on Fires involving lithium-ion batteries highlight risks such as reignition hours after the fire is extinguished. apparent, as well as additional risks to responders.

This article is therefore a study of applied technical synthesis. It is part of a set of It uses recognized standards and guidelines and organizes them into a minimum operational roadmap for workshops. Independent service centers that cater to electric and hybrid vehicles. The goal is not to replace manuals. manufacturer, but offer a practical basis for workshops, training centers and other stakeholders in the

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so that the chain can structure a security system compatible with the massive arrival of electrification.

2. Normative foundations and equivalences: a roadmap for working correctly

2.1. Occupational electrical safety and lockout

In Brazil, NR-10 is the document that structures safety in installations and services with... electricity. It requires risk analysis, control measures, written procedures, training, documentation and delimitation of work zones. For the workshop, this means that one should not open high-voltage compartments or intervening in electrified systems without a work plan, lockouts defined and formal verification of absence of voltage.

NR-06, in turn, defines responsibilities in the selection, supply, registration, and maintenance of PPE with a Certificate of Approval. It is this standard that forms the basis for the management of insulating gloves. Face shields, thermal protective clothing, and other PPE used in the high-voltage bay.

In countries where the culture of electrical safety is more established, specific standards They detail methods for controlling hazardous energies, such as the well-known practice of lockout and... Labeling (lockout/tagout). These references describe the steps to isolate circuits, prevent the Avoid inadvertent reconnection and check for the absence of voltage before starting any work.

In practice, we can view NR-10 and NR-06 as the legal minimum and best practices. International electrical lockout and safety protocols, such as a more detailed operational manual. This article combines these two approaches: it adheres to Brazilian legislation and relies on... Methods already validated in other contexts.

2.2. Charging and vehicle-installation interface

The internal charging infrastructure, when it exists, is part of the electrical installation itself. The company needs to be treated with the same degree of care: this applies to circuit sizing, choice of protections, presence of emergency disconnection and physical positioning of the station. recharging in the warehouse. Conductive charging standards describe how energy is transferred, what What power levels are acceptable, how does communication between vehicle and station occur, and what are the... Basic safety requirements. Connector standards, on the other hand, define formats, capabilities, etc. Current and voltage, and the operating conditions of the components that the technician handles every day — Vehicle plugs, cables and sockets.

In practice, for the workshop, all of this translates into a few very clear precautions: Use a dedicated and properly protected circuit for the charging station, maintain a device with a visible and easily accessible emergency shutdown switch, inspect cables and connectors with Regularly check for damage, overheating, or cracks, and finally, only authorize recharges. inside the vehicle after a quick check of its safety conditions.

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2.3. Tools, PPE and tests

The regulations concerning tools for electrical work define how they should be used.
to design and test wrenches, pliers, sockets, torque wrenches and other items intended for use
near energized parts. They establish voltage classes, insulation criteria and the
The need for periodic testing to ensure that the level of protection is maintained throughout the process.
time. In the case of insulating gloves, international specifications determine the types and classes of
in accordance with the supported voltage range, in addition to guiding factory tests and routine tests.
NR-06 itself reinforces that these PPEs need to be registered, inspected, and kept within the
The expiration date applies and they should be replaced whenever they are damaged or expired.

In practical terms, this means that the workshop must maintain a dedicated kit for the job.
high voltage, and not just “grab any tool off the workbench”. This kit includes tools
insulated handpieces, clearly identified and regularly inspected; insulating gloves
Compatible with the operating voltage, always used in conjunction with mechanical protection gloves;
Facial protection and clothing with thermal properties appropriate to the risk; in addition to footwear.
appropriate to the environment and type of activity. When this set is organized and under
With responsibility defined, safety no longer depends solely on the technician's memory and becomes...
to be part of the workshop routine.

2.4. Incident response, towing and quarantine

Recent standards and technical reports on accidents involving electrified vehicles offer
Specific recommendations for first and second responders. These documents address, therefore...
For example, how to safely isolate an accident scene involving electrified vehicles, of
What criteria should guide the removal and storage of vehicles after a collision or fire and of
What are the particular risks of lithium-ion batteries, including the possibility of energy loss?
remaining and restarting fire hours after the initial event. They also bring models
standardized emergency information sheets, with pictograms, battery locations, cut-off points and
Essential instructions for those who need to intervene quickly.

These references are valuable not only for firefighters and rescue teams, but also for
Workshops, insurance company yards, and towing services. They offer a common language base.
and procedure, helping the repair sector to stop acting in an improvised manner and to integrate
to a more mature and coordinated response chain.

3. Workshop preparation: layout, signage, and isolation kit.

This section translates the normative map into concrete elements. The idea is that any technician...
The trained individual should be able to intuitively recognize where the high-voltage zone begins and what PPE is required.

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mandatory, where the locking devices are located, and how each step of the work should be performed.
documented.

3.1. High-voltage bay as a controlled zone

The high-voltage bay is the heart of the safety system and needs to be understood as a...
A true controlled zone. This begins with physical and visual delimitation: markings on the floor, barriers.
Non-conductive furniture and signs with clear messages, such as "High Voltage Zone — Accessible Area".
"Restricted" helps to make it clear that the space has its own rules. **Access** must be
controlled, allowing entry only to authorized professionals trained in electrical risk.
avoiding unnecessary circulation of people in a sensitive area.

When recharging occurs within the bay itself, it is essential that the sectioning point of
The emergency exit at the charging station is clearly identified and within reach of the staff, so that
Any technician can quickly shut off the power supply in case of an anomaly. The bay
It also needs adequate ventilation and unobstructed escape routes, taking into account the risk of
smoke, anomalous heating, or recurrence of thermal events in batteries that have already undergone
some kind of stress. This arrangement is completed by an emergency kit with materials for containment of
electrolytes, an infrared thermometer to monitor the temperature of suspected modules, and PPEs
Additional resources for initial incident response.

More than just a layout detail, the high-voltage bay serves as a permanent physical reminder that working
with electrified vehicles requires visual and behavioral discipline. It is
She is the one who distinguishes between "ordinary workshop work" and work in a high-risk environment.

3.2. Dedicated tools and PPE

Another key aspect of preparation is the clear separation between high-voltage tooling and the rest.
of the workshop tools. The tools intended for interventions in electrified systems must
meet the insulation requirements defined in the standard, be easily identifiable, and pass through
Periodic inspections. Insulating gloves, in turn, need to be chosen according to the class.
appropriate to the working voltage, always used in conjunction with mechanical protection gloves and
Visually inspected before each use. Face protection, clothing with thermal properties.
Suitable clothing and appropriate footwear complete the minimum set of PPE expected for the high-pressure bay.
voltage.

From a management perspective, high-voltage tools and PPE should not be mixed with...
remaining. They remain in a dedicated location, under defined responsibility, with control of
Use, integrity, and validity. When this set is organized and under someone clearly
Responsible security ceases to depend solely on individual goodwill and becomes part of the overall responsibility.
structured workshop routine.

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3.3. EVSE in the workshop: installation and safe use

Indoor charging infrastructure adds an extra layer of risk and therefore needs

The charging station must be treated with the same rigor applied to other parts of the electrical installation.

It must be connected to a dedicated circuit, with adequately sized protection and with

possibility of quick shutdown in case of emergency. The cables and connectors associated with

Refills need to be inspected regularly for mechanical damage and overheating.

Abnormal, cracks, or obvious signs of aging.

Before loading a vehicle that is undergoing maintenance, it is essential to carry out an inspection.

A quick safety check, observing for significant structural damage, immersion history, presence

smoke, unusual noises, or any indication of instability. In suspicious situations, the path

The correct procedure is not to take the vehicle to the charging bay, but rather to activate the isolation protocol and...

quarantine, keeping the vehicle in a secure area under observation until the risks are eliminated.

properly assessed.

4. Standard procedure for handling and isolating: from LOTO to absence of voltage.

4.1. Reception and risk assessment

Upon arrival, before any detailed diagnosis, the first step is to ensure that...

the vehicle should be parked in a safe area, preferably within the high-voltage bay itself or in

A designated screening area, with barriers and signage already in place. Then, the team

Performs a quick safety check, looking for obvious signs of risk: electrolyte odor,

presence of smoke, abnormal ventilation noises, significant structural damage or information of

that the vehicle has been submerged in water or recently involved in a collision. Whenever any further indication arises

In critical cases, the incident must be immediately referred to the incident protocol, with isolation.

reinforced and eventual quarantine of the vehicle.

When available, the model-specific emergency information sheet should also be consulted.

In this initial stage, to identify the location of the traction battery, the shutdown devices

Emergency routes and points considered safe for cutting or access. Finally, it is important

Communicate the plan to the customer transparently, explaining that the vehicle will be undergoing a period of maintenance.

initial security measures that may involve lockout, more prolonged observation and, in situations

extreme cases, even refusal of service. This seemingly simple screening process significantly reduces the risk.

The risk of surprises during the intervention is significant.

4.2. Electrical isolation — consolidated sequence

Electrical insulation is the backbone of safety in electrified vehicles.

In summary, the recommended sequence begins with preparing the work: the technician reviews the

specific procedure for the model, consult the technical manual and the emergency information sheet and identify

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all relevant power sources, including high voltage, auxiliary battery, and any circuits.
pneumatic and hydraulic systems. Then, the vehicle is switched off according to the instructions of the manufacturer, whether through a maintenance or service mode, or through general switches and specific shutdown devices for that project.

The next step is to disconnect and lock out the auxiliary battery. Instead of just removing it... A cable uses a physical locking device on the terminal or harness, along with a A label with the technician's name, date, and reason for the block. The idea is to prevent someone from... authorized to reconnect the circuit by mistake. After that, it is mandatory to respect the waiting time. Recommended by the manufacturer for discharging capacitors and inverters, preventing premature opening. high-voltage connections or access to internal components that are still energized.

When the vehicle has a specific service plug or interlocks, these Resources are also activated or removed according to the recommended procedure, adding Layers of safety insulation are added. Only then does one proceed to the stage of verifying the absence of voltage. In this verification, an instrument suitable for the measurement category and the maximum voltage is used. as expected, following the "test-measure-test" routine: first, the instrument is tested on a source. known; then measurements are taken at the points defined by the manufacturer; and finally, the The instrument is tested again on the same reference source to confirm that it was... functioning correctly. The measured values, the date, the time, and the name of the responsible technician. They must be recorded clearly.

Finally, the entire isolation process is documented. Whenever possible, photographs are taken. If there are locks, tags, and measurement screens, these records are attached to the service file. Intervention on high-voltage components should only begin after formal confirmation of absence. voltage, recorded and traceable.

4.3. Approach limits and PPEs

Inspired by international best practices, the approach to energized parts or potentially energized materials do not operate in an improvised manner. The workshop defines limits of The approach is linked to minimum protection requirements. No one crosses the high-level bay barrier. Voltage without the correct combination of PPE, training, and authorization. Insulating gloves, chosen from Depending on the appropriate class and when used in conjunction with mechanical protective gloves, they become mandatory whenever there is any possibility of contact with living parts. Similarly, Ordinary tools are not allowed in the high-voltage zone: only insulated, identified tools and Vehicles in good condition are authorized for this type of intervention.

4.4. Practical pocket checklist

For everyday use, this entire sequence can be condensed into a simple checklist that...

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The technician should carry it in their memory or on a pocket card: have the specific procedure for the model at hand. (Technical manual and emergency information sheet), turn off the vehicle according to the manufacturer's instructions, Disconnect and lock the auxiliary battery with a physical device and label, wait for the time to Recommended discharge: perform the test-measure-test sequence at the indicated points with the PPE. complete, record any blockages, readings, and the technician's signature, and only then authorize the intervention. under high tension. When this script becomes a habit, the workshop reduces the reliance on improvisation and It consistently increases the level of safety in every interaction.

5. Incident response and interface with fire departments, insurance companies, and towing services.

Not every vehicle that arrives at the repair shop is in a stable condition. In cases of collision, immersion In the event of water damage, a previous fire, or signs of abnormal heating, the workshop will occupy a designated space. A delicate part of the incident response chain.

Based on technical recommendations for first and second responders, it is possible to outline some principles:

Isolation and quarantine

Potentially unstable vehicles or packs should be kept outdoors or dedicated compartment, preferably with a non-combustible floor, safely distanced from buildings and periodic thermal monitoring for a minimum interval defined in the procedure. internal.

Structured communication with firefighters and insurance companies.

The workshop should have pre-established contact information for each type of incident. Concise reports, including photos, timestamps, measures taken, and monitoring results, help to... To reduce conflicts and speed up decisions by insurers and authorities.

Integration with towing and yard services

Tow trucks and impound lots need to be instructed on how to handle electrified vehicles. damaged components, avoiding procedures such as improper dragging and pulling on high-pressure components. tension or parking in locations without adequate ventilation.

By adopting these principles, the workshop ceases to be just "another point in the chain" and becomes... to be a qualified link in the risk response, contributing to reducing material damage and risks to life.

6. Discussion — challenges and implications for independent workshops

The proposal for a comprehensive safety system for electric and hybrid vehicles may This may seem far removed from the reality of many independent workshops, especially smaller ones. Some Recurring challenges emerge from practice and technical literature.

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The first concerns training and learning time. The requirement of
Formal training in electrical hazards, reading regulations, and interpreting emergency information sheets can...
to be perceived as a barrier by teams accustomed to learning "on the job". On the other hand, the
Adopting clear protocols reduces rework, communication failures, and exposure to serious accidents.
which tends to offset the initial investment.

The second challenge is the cost of adaptation. Isolated tools, specific PPE and
Layout adjustments require financial investment and implementation time. A strategy
Realistically, adoption should be phased in: starting with a basic high-voltage bay, a minimum set of
PPE and tools, and evolving into a more comprehensive system as the volume of vehicles increases.
Electrified areas are growing.

The third point is the culture of security and documentation. The transition from one culture
The shift from "intuitive" to a culture based on procedures and records is perhaps the most difficult change.
Documenting checklists, photos, and readings is not a mere formality: it creates evidence in case of litigation.
It improves communication with clients and insurance companies and strengthens the professional image of the workshop.

Finally, there is the challenge of connecting with training centers and manufacturers. Workshops
Independent companies rarely have direct access to the entire technical archive of automakers. Partnerships with
Technical training centers, sectoral associations, and qualification programs can mitigate this.
This gap reinforces both access to up-to-date content and the training of internal instructors.

From an academic point of view, the article shows how a scattered set of norms and guidelines
This can be "translated" into a coherent arrangement for the reality of the workshop. Future studies may...
to advance the empirical evaluation of this model, measuring, for example, its impact on incident rates,
Productivity and perception of safety on the part of the technicians.

7. Final Considerations

The arrival of electric and hybrid vehicles at independent workshops shifts the focus of
Technical competence with a focus on specific diagnostic skills for the systematic management of
Electrical hazard. Throughout the article, a minimum map of standards and best practices was organized, and it was...
translated into a set of operational guidelines that range from the creation of a bay to
High voltage, with proper layout and signage, and the use of dedicated tools and PPE, under management.
formal, going through the definition of a standard procedure for care, isolation and verification.
absence of tension and the construction of incident response protocols articulated with
Firefighters, insurance companies, and towing services.

More than just an inventory of acronyms and obligations, the proposal presented here is a
of a safety management system for electrified vehicles, designed to be scalable
depending on the size and reality of each workshop. The progressive adoption of this system tends to increase the

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level of occupational protection, reduce the risk of property damage and litigation, strengthen employee confidence.

customers, insurers and partners, and prepare the workshop for a market where electrification will be...

Less and less of an exception and more and more the norm.

By aligning the language with the everyday norms of the independent workshop, the article seeks to...

to contribute to a more mature debate on the role of automotive repair in the transition

Energy. Ultimately, high-voltage safety is not just a matter of equipment.

sophisticated, but above all, organizational skills, clear procedures, and a culture of...

prevention.

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