International Journal of Engineering and Technical Research (IJETR)
ISSN: 2321-0869 (O) 2454-4698 (P), Volume-13, Issue-1, January-June 2023

Electric vehicle Traction Batteries Installation Guidelines for Bus Application

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ABSTRACT- As Lithium-ion battery (LIB) consumes significant amount of volume in commercial vehicles, it is very important to place them in locations considering weight distribution, structural rigidity, risk to accidents & vehicle dynamics point of view. As more lithium-ion battery (LIB) powered road vehicles become operational across the globe, their involvement in traffic accidents is also likely to rise. The performance of vehicles on road in case of overtaking, negotiating turns and driving in off-road conditions is very critical. While the risks associated with conventional vehicles are well defined and generally accepted by society, time and education are needed to achieve this comfort level for LIB powered road vehicles.

1. Introduction

The demand for battery electric vehicles (BEVs) continues to increase around the world. They have proven to reduce emissions and operate more efficiently than vehicles driven by fossil-fuels. In part this is made possible due to significant technological advances in energy storage systems, specifically those that are part of the lithium ion family. Their unmatched properties such as high cycle life, high energy density, and high efficiency makes them suitable for automotive applications The project this paper is Because the battery pack is the heaviest component in an electric vehicle, careful consideration must be given to its placement and weight distribution to ensure optimal vehicle performance and handling. Placing the battery pack low in the chassis can help improve stability and handling, while also optimizing weight distribution.

2. Research Methodology

This paper focuses on installation of lithium-ion batteries that significantly contributes to a vehicle's automotive force, namely the traction battery. The traction battery is of interest as it is one of the most challenging to install it on vehicle considering its exposure to various forces acting on it while the vehicle is in stationary and motion. In addition, their high voltage (300–1000 V) and large amount of energy stored (up to 200 kWh) can yield a significant safety hazard. They can be made up of many battery cells. The lithium-ion battery cell enclosure consists of one or several electrochemical cell units. Their voltage, which is usually around 4 V, varies depending on the cathode and anode material chosen. This is also true for other properties related *We have developed proficiency for battery installation and packaging and have worked out optimised proposals considering all the affecting variables. A set process has* based on aimed to alleviate such concerns and mitigate it in design phase

An increasing number of road vehicles is being electrified with the aid of lithium-ion traction batteries. They may either be a major source for the vehicle's traction force; hence they are referred to as traction batteries. Electrified road vehicles have proven to reduce emissions and operate more efficiently than vehicles driven by fossil-fuels. A major issue with conventional powertrains lies in their source of power, combustion of non-renewable fuels. This process is not very efficient. Even the most advanced internal combustion engines operate below 50% efficiency. Electric motors, however, operate at around 95% efficiency he most heavy component in electric vehicles is typically the battery pack. Electric vehicle batteries can weigh several hundred to over a thousand pounds, depending on the size and capacity of the battery.

Other heavy components in electric vehicles can include the electric motor, power electronics, and cooling systems. These components can also add significant weight to the vehicle, although they are typically lighter than the battery pack.

been derived following the established guidelines to their capacity, cost, and safety. The battery cells by themselves are not of much use for road vehicles. However, by connecting many cells in series and/or parallel, their final output can be scaled. The next scale in traction batteries for road vehicles is usually that of the battery module. The number of cells per module varies but generally adds up to less than 60 V of direct Theory and Calculation.

A detail study has been done considering all options of installation of traction batteries in various locations across the commercial vehicles so as to meet the space & safety requirements. Below **Fig.:-** 01 indicates a typical battery pack used especially on electric busses.

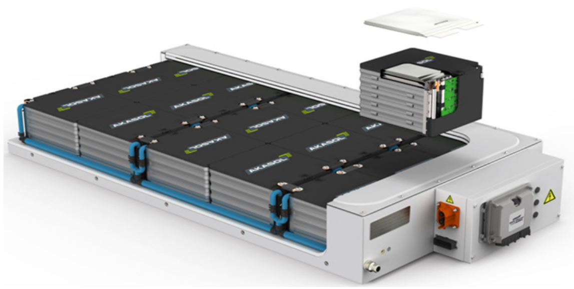

Fig.:- :- 1 Typical battery pack for electrical busses

3. Theory

The battery pack geometry, its position and the structural design of the vehicle are all relevant design parameters when integrating the battery pack in the vehicle. A common approach is to install the battery pack inside stiffened and reinforced compartments or areas less prone to be affected in crash. The latter is sometimes referred to as a vehicle's ‘‘safe zone’’. This zone refers to the area in the centre of the chassis, between the wheel shafts. For passenger cars there are three main configurations in which this space is used by the traction battery. Most common are the ‘‘T’’ and ‘‘Floor’’ configurations. Buses do not necessarily follow the configurations presented for passenger cars

When it comes to electric busses, long range & low kerb weight becomes a critical target to achieve considering the customer requirements. EV normally requires high energy storage capacity.

The fire safety of energy carriers is related to their fuel source. For conventional vehicles, a common fuel is gasoline for example. This fuel can be extremely dangerous if not handled or stored safely. The same principle applies to lithium-ion batteries, the fuel source for most EVs today. Burning LIBs have some distinct features, such as thermal runaway and ventilated flammable and toxic gases. This gives that although burning EVs pose a different risk, it may not be greater than that posed by the conventional vehicles we have gotten used to.

Here are some general guidelines for mounting the battery on a electric vehicle:-

Choose the right mounting materials: Use mounting materials that are appropriate for your vehicle model and battery type. OEM provides specific recommendations for the type of mounting materials to use.

Check for proper clearance: Make sure there is sufficient clearance between the battery and other components in the vehicle, such as the motor or chassis. Many OEM provide specific recommendations for the amount of clearance required.

Ensure proper ventilation: Proper ventilation is important to prevent overheating and potential fires. Make sure the battery compartment is well-ventilated according to specific recommendations.

Follow wiring guidelines: Follow wiring guidelines to properly connect the battery to the vehicle's electrical system. Use wiring that meets specifications and is rated for the amount of current your batteries will be carrying.

- **Test the battery:**

Test the battery before mounting it to ensure it is functioning properly. This can include checking voltage levels and performing load tests.

The ideal location for battery mounting on a bus may depend on several factors, including the type of bus, the battery technology used, and the desired performance and handling characteristics of the vehicle. Here are some general factors to consider when deciding on the location of the battery on a bus.

The ideal location for battery placement on an electric vehicle may vary depending on the specific vehicle design and its intended use. Here are some general factors to consider when deciding on the location of the battery:

Weight distribution: The location of the battery can affect the weight distribution of the vehicle, which can impact handling and stability. In general, placing the battery in the centre of the vehicle, between the front and rear axles, can help distribute the weight evenly.

Safety: The battery should be placed in a location that minimizes the risk of damage in the event of a collision. This can include placing the battery in a well-protected compartment, away from the vehicle's crumple zones.

Thermal management: Batteries generate heat when charging and discharging, and this heat can reduce battery performance and lifespan. The battery should be placed in a location that allows for proper thermal management, which can include incorporating cooling systems, placing the battery in a well-ventilated compartment, or placing it on the roof of the bus to take advantage of natural air flow.

- **Space consideration:**

The battery should be placed in a location that does not compromise interior space or cargo capacity. This may require creative placement solutions, such as mounting the battery beneath the vehicle or in the vehicle's floor. The battery should be placed in a location that maximizes the use of space inside the bus. This may require creative placement solutions such as mounting the battery beneath the bus or on the roof.

Accessibility and maintenance: The battery should be placed in a location that allows for easy accessibility for maintenance and replacement. For example, the battery compartment should be easily accessible for technicians to perform routine inspections, cleaning, or repairs.

Ultimately, the ideal location for battery mounting on a bus will depend on the specific design and intended use of the vehicle. Bus manufacturers will typically take these factors into account when designing and developing electric buses.

Commercial Busses

Following battery installation configurations are considered –

3.1 Chassis Rear configuration:-

Busses have a requirement of low floor height which makes it difficult to install traction batteries at the front and underfloor. In such cases the most widely used configuration is rear mounted traction batteries. Here the battery pack is in the rear of the vehicle stacked upwards one above the other (**Refer Fig.:- 02**). The traction motor is placed rear of rear axle below the battery stack. The major disadvantage being exposure to batteries in case of rear crash.

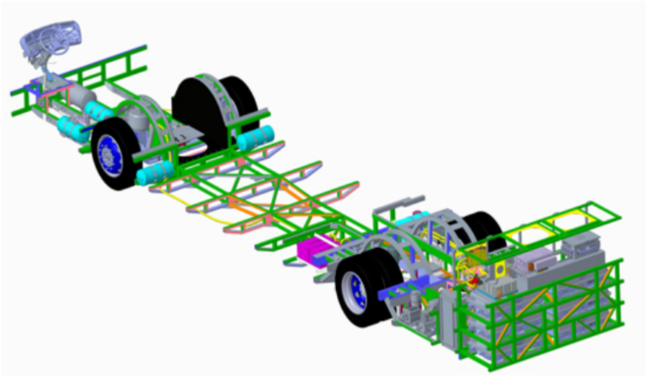

Fig.:- 02 Battery packaging at vehicle rear

Mounting the battery on the rear end of a bus can have some advantages and disadvantages. Here are some factors to consider regarding the ideal location of a battery on the rear end of a bus:

Advantages:

Better weight distribution: By mounting the battery on the rear end, the weight can be distributed evenly along the length of the bus. This can improve handling and stability, especially on turns.

More space inside the bus: Mounting the battery on the rear end can free up space inside the bus for passengers or cargo. This can be particularly advantageous for buses with limited interior space.

Improved accessibility for maintenance: Mounting the battery on the rear end can make it easier to access for maintenance, repairs, and replacement.

Improved thermal management: Heat generated by the battery during operation can be dissipated more easily when the battery is mounted on the rear end, where there is more airflow.

Disadvantages:

Higher centre of gravity: By mounting the battery on the rear end, the centre of gravity of the bus is raised, which can negatively impact stability and handling, especially in windy conditions or when turning.

Higher risk of damage: The battery on the rear end is more exposed to external elements such as wind, rain, and debris. This can increase the risk of damage to the battery and the bus.

Additional weight: Mounting the battery on the rear end adds weight to the bus, which can reduce fuel efficiency and increase energy consumption.

Additional cost: Mounting the battery on the rear end requires additional engineering and installation costs, which can increase the overall cost of the bus

3.2 Roof Top mounted –

Roof mounted battery top is a very popular option for city bus. The bus manufacturers such as Volvo Bus, Solaris, BYD and VDL opt for placing them on top of some of their vehicles, as seen in **Fig.:-** 03. Placing the battery on top of the vehicle namely requires fewer modifications to be made to existing buses. Other benefits include the fact that the batteries are easier exposed to air, allowing them to be cooled by the moving vehicle, along with them being more easily accessible for some charging systems, and that the maximum amount of space is made available to passengers. In addition there is lot of flexibility for packaging of EV aggregates like motor, invertor & power distribution using on chassis as battery which consumes lot of space is located on roof. However, it comes with few disadvantages like higher vehicle centre of gravity and longer length of high voltage cable lines connecting from the roof to the chassis.

Fig.:- 03 – Battery pack packaged on vehicle roof Courtesy - automacha.com

Mounting the battery on the roof of a bus can have some advantages and disadvantages. Here are some factors to consider regarding the ideal location of a battery on the roof of a bus:

Advantages:

Better weight distribution: By mounting the battery on the roof, the weight can be distributed evenly along the length of the bus. This can improve handling and stability, especially on turns.

More space inside the bus: Mounting the battery on the roof can free up space inside the bus for passengers or cargo. This can be particularly advantageous for buses with limited interior space.

Improved thermal management: Heat generated by the battery during operation can be dissipated more easily when the battery is mounted on the roof, where there is more airflow.

Easy accessibility for maintenance: Mounting the battery on the roof can make it easier to access for maintenance, repairs, and replacement.

Disadvantages:

Higher centre of gravity: By mounting the battery on the roof, the centre of gravity of the bus is raised, which can negatively impact stability and handling, especially in windy conditions or when turning.

Higher risk of damage: The battery on the roof is more exposed to external elements such as wind, rain, and debris. This can increase the risk of damage to the battery and the bus.

Increased weight and wind resistance: Mounting the battery on the roof adds weight and wind resistance to the bus,

which can reduce fuel efficiency and increase energy consumption.
Additional cost: Mounting the battery on the roof requires additional engineering and installation costs, which can increase the overall cost of the bus.
Ultimately, the ideal location of the battery in a bus roof will depend on the specific design and intended use of the vehicle, as well as factors such as cost, weight, and safety considerations.

3.3 Chassis Centre mounted

For Busses with higher floor height (900mm & above) & those who don't require luggage space at the bottom packaging batteries at the centre and side of chassis is a good option. The biggest advantage is low centre of gravity of vehicle, high stability, low roll & safety in case of frontal & rear crash. Refer **Fig.:-** 04

Fig.:- 04 – Battery packaging at chassis centre between front and rear axle

Mounting the battery on the chassis of a bus can have some advantages and disadvantages. Here are some factors to consider regarding the ideal location of a battery on the chassis of a bus:

Advantages:
Lower centre of gravity: By mounting the battery on the chassis, the centre of gravity of the bus is lower, which can improve stability and handling, especially in windy conditions or when turning.
Lower wind resistance: Mounting the battery on the chassis can reduce wind resistance and improve fuel efficiency.
Less risk of damage: The battery on the chassis is less exposed to external elements such as wind, rain, and debris. This can reduce the risk of damage to the battery and the bus.
Can be easily integrated into the existing design: Mounting the battery on the chassis can be easily integrated into the existing design of the bus, requiring less engineering and installation costs.

Disadvantages:
Less space inside the bus: Mounting the battery on the chassis can reduce the space inside the bus for passengers or cargo.
More difficult to access for maintenance: Mounting the battery on the chassis can make it more difficult to access for maintenance, repairs, and replacement.
Poorer thermal management: Heat generated by the battery during operation can be more difficult to dissipate when the battery is mounted on the chassis.
May require reinforcement of the chassis: Mounting the battery on the chassis may require reinforcement of the chassis to handle the additional weight.

4. Guidelines by Bus OEM (Original Equipment Manufacturer) regarding Battery installation

While the specific instructions for mounting the battery on an electric bus may vary depending on the model and configuration, here are some general guidelines for battery mounting.

- **Select a suitable location:** The battery should be mounted in a location that provides optimal weight distribution, stability, and accessibility for maintenance. Some OEM typically recommends mounting the battery in the middle of the bus, above the rear axle.
- **Prepare the chassis:** The chassis of the bus should be inspected and prepared for battery mounting, including the installation of mounting brackets and other hardware.
- **Install the battery:** The battery should be installed according to desired specifications, including the use of specific mounting brackets and bolts to secure the battery in place. The battery should be mounted in a horizontal position, with the terminals facing upwards.
- **Connect the battery:** All wiring and connections should be made according to desired specifications, to ensure proper function and safety. This includes connections to the vehicle's electrical system and the battery's cooling system.
- **Test and inspect:** Once the battery is mounted and connected, it should be thoroughly tested and inspected to ensure proper function and safety. This includes checking for leaks or other issues with the cooling system, and verifying that all electrical connections are secure.
- **Maintain and service:** OEM provides specific guidelines for maintenance and service of the battery system, including regular inspections, replacement of coolant and other components, and proper handling and disposal of batteries at the end of their life.

5. Results and Discussion

Below is pictorial comparison of merits and demerits of various battery installation options for EV bus platform. Rating has been decided based considering different vehicle parameters & guidelines for battery packaging. Higher the rating better is the performance against that criteria.

	Traction Battery Installations rating for Electric vehicle Bus		
Parameters	Chassis Mounted (Rear)	Bus Roof mounted	Chassis Mounted (Centre)
Weight Distribution	★★★☆☆	★★★☆☆	★★★★★
Vehicle Centre of Gravity	★★★☆☆	★★☆☆☆	★★★★★
Battery air draft	★★☆☆☆	★★★★★	★★★☆☆
Crash Safety	★★★☆☆	★★★★☆	★★★★★
Min vehilce level modifications	★★☆☆☆	★★★★☆	★★★☆☆
Accessibility and Maintenance	★★★☆☆	★★★★☆	★★☆☆☆
Low bus floor height	★★★★☆	★★★★★	★★☆☆☆
Water ingress	★★★☆☆	★★★★★	★★☆☆☆
High voltage cable routing	★★★☆☆	★★☆☆☆	★★★★☆
Bus structure strenghening reqd.	★★★★★	★★☆☆☆	★★★★★

6. Conclusions:-

While each installation option have its advantages and limitations, the final option has to be considered based on the vehicle application, operating conditions & range requirements. For EV Busses vehicle safety is of outmost importance considering the huge number of passengers travelling. Possibility of incidents such as thermal runaway incidents should also be studied from battery installation point of view. Other factors like serviceability, modularity, ease of packaging also to be considered.

Table presented above can be used as ref for taking decisions related to available packing options. To further optimize a combination of above options like (Chassis Rear + roof top) or (Chassis Rear+ Chassis centre) can be used depending upon the space availability & packaging constraints.

Ideal weight distribution of electric buses is similar to that of traditional buses, with a balanced weight distribution being optimal for handling, stability, and safety. However, because electric buses typically have a heavier battery pack than traditional buses, careful consideration must be given to the placement and distribution of the battery to ensure proper weight distribution. In general, electric buses should have a low centre of gravity to reduce the risk of rollovers and improve handling. Placing the battery pack low in the chassis can help achieve this, while also improving weight distribution. Ideally, the weight should be distributed evenly between the front and rear axles to ensure good traction, stability, and handling.

Some electric bus manufacturers use modular battery designs that allow for more flexibility in battery placement and weight distribution. This can help optimize weight distribution and improve overall vehicle performance. It is important to note that weight distribution can vary depending on the specific design of the electric bus, including the size and layout of the battery pack, the location of other heavy components, and the intended use and operating conditions of the vehicle. Designers and engineers must carefully consider these factors when designing an electric bus to ensure optimal weight distribution for the intended use and performance characteristics.

To measure electric vehicle battery vibrations, accelerometer sensors are typically used. These sensors can detect and measure vibrations, acceleration, and deceleration of the battery module or pack. Accelerometers are small devices that convert mechanical motion into an electrical signal that can be recorded and analysed. They are commonly used in industrial and automotive applications to measure vibration, shock, and acceleration. To measure battery vibrations, accelerometers are typically attached to the battery module or pack using adhesive or mechanical fasteners. The sensors can then record vibration data in real-time or over a period of time. This data can be analysed to determine the frequency, amplitude, and duration of vibrations, which can help identify potential issues with the battery or the vehicle .Battery vibration measurement is an important part of electric vehicle testing and development, as excessive vibration can damage the battery and reduce its performance and lifespan. By measuring and analysing vibration data, engineers can optimize the design and mounting of the battery system to minimize vibration and ensure optimal performance and reliability.

However, in general, a balanced weight distribution is desirable for optimal handling, stability, and safety. In a front-engine, rear-wheel-drive (RWD) vehicle, the ideal weight distribution is often around 50:50, with approximately equal weight on the front and rear axles. This helps ensure good traction, stability, and handling during acceleration, braking, and cornering. In a front-wheel-drive (FWD) vehicle, the weight distribution may be slightly front-biased, with more weight over the front wheels to help with traction and steering. Similarly, in a rear-engine or mid-engine vehicle, the weight distribution may be rear-biased to help with traction and stability.

Overall, battery placement is a critical design consideration for EVs, and careful consideration must be given to the location and weight distribution of the battery to ensure optimal vehicle performance, handling, and safety.

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