INDUSTRY 4.0: CHALLENGES IN ELECTRIC VEHICLES

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Abstract

Energy and environmental impacts are at the top of the list of major international challenges to be addressed at intervals in the ensuing few years. With transportation being one of the foremost waste management sectors, focus has been directed towards electric vehicles because of their considerably lower dependency on fossil fuels. Nonetheless, electrical quality is presently characterized by a restricted practice range, leading makers to work on new strategies that might increase variety and charging potency. Current analysis is especially centered on increasing battery performance and reducing charging time. This study concentrates on presenting a completely unique approach: supported commutation battery stations, wherever the vehicle's batteries are replaced with a completely charged one (available at the station), whereas new standard batteries may be created on the spot. The prevailing service station networks may be used for the replacement of electrical automobile batteries. This could be addressing the issue of long battery charging times. Through the assimilation of Trade 4.0 Key Sanctioning Technologies, individual challenges are often addressed. This can be illustrated through a holistic framework whereby the necessities for the context-aware style of the automobile itself are given and a selected answer supporting the mechanical mounting of batteries is mentioned.

Keywords: electric vehicle, battery replacement, Industry 4.0, car design.

Introduction

The automotive industry is positioned for a significant transformation as traditional manufacturing processes and digital technologies come together in its unwavering quest for innovation. This paradigm shift, also known as Industry 4.0, denotes a new era in which the way we design, manufacture, and interact with vehicles is being revolutionized by the integration of cloud computing, data analytics, artificial intelligence (AI), and the Internet of Things (IoT). Electric vehicles (EVs) are a central application point for Industry 4.0 in this dynamic landscape, offering previously unheard-of chances to improve productivity, sustainability, and connectivity.

The potential for Industry 4.0 and electric vehicles to work together could completely transform the automotive industry. With the integration of these technologies, the experience of electric mobility is set to be redefined. From intelligent manufacturing processes that adjust in real-time to changing demands to connected vehicles that communicate seamlessly with surrounding infrastructure, the possibilities are endless. This investigation explores the various uses of Industry 4.0 in the context of electric cars, providing insight into the ways in which these developments support energy management, predictive maintenance, smart manufacturing, and data-driven analytics, among other areas.

As we set out on this journey through the intersection of electric vehicles and Industry 4.0, we peel back the layers of innovation that open the door to a smart and sustainable transportation future. Combining state-of-the-art technologies not only drives the electric vehicle industry to previously unheard-of heights but also creates a model for how manufacturing procedures and customer experiences will change in many other industries. In this story, we travel through the complex network of related technologies that characterize the field of Industry 4.0 applications in electric car technology, leading us towards a future in which mobility is not only electric but also intelligent, effective, and deeply integrated.

The automobile sector could undergo a revolution if sector 4.0 technologies are incorporated into electric cars (EVs). The term "industry 4.0" refers to the fourth industrial revolution, which is defined by the combination of traditional production processes with digital technology, cloud computing, artificial intelligence, and the Internet of Things (IoT). The following are a few requirements of Industry 4.0 in relation to electric vehicles:

1. Smart Manufacturing and Predictive Maintenance:

01. Smart Factories: Using smart manufacturing techniques can boost productivity and flexibility when producing electric cars. Real-time data from connected sensors and equipment on the production line enables adaptive manufacturing and prompt adaptation to changes.

02. Predictive Maintenance: Internet of Things sensors are able to track the condition of electric car parts and forecast when maintenance is necessary. This prolongs the lifespan of EVs, minimizes downtime, and helps prevent malfunctions.

2. Connected Vehicles and IoT:
01. Vehicle-to-Everything, or V2X, communication is made possible by Industry 4.0 and allows for smooth communication between automobiles, infrastructure, and other linked devices. For drivers of electric vehicles, this can improve safety, traffic control, and the overall driving experience.
02. Fleet Management: The integration of Internet of Things (IoT) sensors in electric cars can yield significant insights for fleet management, including route optimisation, energy consumption monitoring, and operational efficiency.

3. Data Analytics and AI for Efficiency:
01. Big Data Analytics: By examining enormous datasets produced by electric cars, information about user behavior, charging trends, and performance indicators can be gained. The functioning and design of EVs can be continuously improved with the use of this data.
02. Artificial Intelligence: AI systems are able to maximize energy efficiency, improve self-driving performance, and customize user interfaces according to specific driving preferences.

4. Energy Management and Sustainability:
01. Integration with Smart Networks: By integrating electric vehicles with smart networks, charging schedules may be optimized according to renewable energy availability and grid demand. This guarantees more economical and sustainable energy use.
02. Battery management: By extending the life and performance of EV batteries, sophisticated monitoring and control systems can guarantee effective energy storage and utilization.

5. Cybersecurity:
01. Safe Communication: As electric cars become more connected, it's important to make sure the systems are secure. Robust cybersecurity measures are incorporated into Industry 4.0 technologies to guard against potential cyber threats and unauthorized access.

Challenges in electric vehicles

However, while EVs are becoming more and more popular, there are still a number of obstacles that they must overcome. Remember that the business is ever-evolving and that things can have changed or developed since then. The following are some typical issues with electric cars:

1. Battery technology and limited range (Battery Replacement)
Many prospective EV owners worry about range anxiety. Battery technology has advanced, but there is still room for development in the areas of energy density and charging infrastructure.

2. Infrastructure for Charging
One major obstacle to the broad adoption of electric vehicles (EVs) is the accessibility and availability of charging facilities. Building a strong infrastructure for charging is crucial for long-distance driving and boosting customer confidence.

3. Charging Speed
Even with fast-charging facilities, recharging an electric vehicle still takes longer than fueling a conventional gasoline-powered car. To make EVs more convenient, charging speed improvements are essential.

4. The retail cost of batteries
A major component of the price of an electric car is its battery pack. Making EVs more accessible to a larger market requires lowering the cost of battery manufacturing.

5. Lifecycle Environmental Impact
Even though EVs emit no emissions when in use, the production and disposal of batteries can have an adverse effect on the environment. To create more recyclable and sustainable battery materials, research is still being done.

6. Vehicle Diversity
The majority of the cars on the market right now are sedans and smaller cars. Increasing the variety of electric vehicle options, including bigger cars like trucks and SUVs, will appeal to a wider range of customer demographics.

7. Consumer Education
Some consumers may still be unaware of electric vehicles or have misconceptions about them, such as concerns about battery life, charging, and overall performance. To address these issues, education and awareness campaigns are critical.

8. Policies and incentives enacted by the government
Government policies and incentives can have an impact on the adoption of electric vehicles. Tax breaks and infrastructure investments, for example, can hasten the transition to electric vehicles.

9. Problems with the Supply Chain
Critical component supply chains, such as batteries and rare earth metals, can be disrupted, affecting the production and availability of electric vehicles.

10. Technological Advancement
Continuous research and development are required to improve the efficiency, performance, and safety of electric vehicles as technology evolves.

LITERATURE REVIEW

1. Overview of Battery Management Systems in Electric Vehicles

K. Vishnu Murthy, K. Sabareeshwaran, S. Abirami, and T. Bharani Prakash

Recent advancements in the fields of energy management and measurement have made it possible to manage the operation of utilities in an effective, dependable, and efficient manner. Because of the current energy crisis, there is a greater demand for power, which has made it possible to install new energy meters and develop new techniques for measuring and monitoring meter readings related to economical usage limits. This chapter discusses the shortcomings and restrictions of traditional metering topology and argues that an advanced metering scheme is required to satisfy Industry 4.0 requirements in the power sector. The components of the advanced intelligent meter and their functions are covered in detail. This chapter explains the planning and execution of a smart meter within the current system.

2. Analysis of Wheel Hub Motor Drive Application in Electric Vehicles

Yuechao Sun, Man Li and Cong Liao

After analyzing the performance characteristics of centralized and distributed drive electric vehicles, we discovered that the distributed drive wheel hub motor drive mode of these vehicles has many advantages, including a compact structure, a high interior vehicle space utilization ratio, a lower center of vehicle gravity, good driving stability, easy intelligent control, and many more. As a result, it meets the new requirements for the advancement of electric vehicle drive performance, and distributed drive will be the standard for electric vehicles going forward.

3. A Timely Review of Lithium-ion Batteries in Electric Vehicles: Progress, Future Opportunities, and Challenges
Hu Mengqi, Wang Yuhao

In human societies, energy is vital. It is impossible to ignore the growing need for new energy, such as electric energy, as science and technology advance. The battery is an essential part of electric vehicles, which will drive future advancements in the industry. Because of their superior performance, lithium-ion batteries offer significant advantages in applications involving electric vehicles. Lithium-ion battery development needs to be advanced if we are to make significant progress towards the development of electric vehicles. Lithium-ion batteries perform exceptionally well because of their high specific energy, low self-discharge, good cycling performance, lack of memory effect, and other benefits. This study examines the distinct advantages of lithium-ion batteries in comparison to other significant battery technologies for use in electric vehicle applications. It also offers suggestions for optimizing the anode, cathode, and electrolyte of lithium-ion batteries to improve their performance.

4. Analysis of the Performance of Wireless Transmission Systems for Application in Electric Vehicles
F. F. Mendonça; D. A. Andrade; and A. O. Cássio

In this paper, the effects of distance, resonance frequency, and constructive aspects of coils for wireless power transfer (WPT) are discussed. The optimal configuration for the application is demonstrated, with special attention to the charging of automotive batteries. Situational factors like alignment, coil size, and the distance between the emitter and the receiver can make implementation challenging. In order to determine which has superior performance, the behavior between the coils, which includes wire turns as well as additional coils with multiple wire turns, is computationally simulated and examined. Results are displayed for resonance frequencies ranging from 100 kHz to 1 MHz, with intervals of 1 to 180 cm, illustrating how the efficiency curve behaves for use in electric car applications. The diameters of the coil wires are varied in addition to their number of turns to address five different configurations. Yield curve simulations are compared with experimental findings to confirm the accuracy of the computation.

5. Robotic technology and application in electric vehicles
Yimin Zhou; Guoqing Xu

The evolution of robotic technology has been discussed in this paper. Three generations of robots have been created since the first one was created, starting with simple machines and progressing to intelligent ones in the 1960s. We introduce the general structure of an intelligent robot. There is also a description of possible robotic technology development paths. Additionally, the issues that arose during the research are also covered. Moreover, the application of robotized technology in intelligent electric vehicles enhances driving safety in the context of human-road vehicle interactions.

6. Mathematical modeling and control of hybrid sources for application in electric vehicles Nikolay Hinov, Vladimir Dimitrov, and Gergana Vacheva

A full model of a small electric car with a fuel cell, supercapacitor, and power conversion system, along with its control system, is presented in this paper. A vehicle model loads this electrical system by translating an input standard vehicle test cycle (NEDC, WLTP, or another) into current that needs to be supplied or consumed from the power conversion system. Two distinct hybrid energy source topologies—the parallel and cascade—are used to test the model. The research compares the simulation results for various topologies and makes inferences about their potential applications for various kinds of electric vehicles based on the studies that were carried out.

7. Investigation of Charging and Discharging Characteristics of Lithium-Ion Batteries for Application in Electric Vehicles

Sodhi, G. S., Jaiswal, A. K., and Vigneshwaran, K.

Due to its zero emission rates, the lithium-ion battery-powered electric vehicle (EV) is an environmentally friendly option in the current global warming scenario. Because of their long cycle life, high specific energy, power density, nominal cell voltage, low self-discharge rate, and shorter charging time than other batteries, lithium-ion batteries are the best choice for an electric vehicle. However, the intensity of the charging current affects both the cell's charge capacity and charging time. There are differences in the charge and discharge characteristics of batteries made by different manufacturers as well as between different cells from the same manufacturer. Using a charge-discharge testing device, tests with constant current and voltage are conducted to examine this variation (Chroma 17011). This study compares the charge and discharge characteristics of two cylindrical cells that have been subjected to a voltage that is lower than their maximum voltage and offers strategies for minimizing battery undercharging in electric vehicle (EV) applications.

Methodology

Approach to the concept of 'replacing battery' stations

The basic approach is to use a network of' replacing battery stations, together with the present gas stations, for a 'quick' battery replacement procedure. The replacement situation foresees that the driving force of associate electron volt ought to check the standing of his vehicle's batteries, and if the battery standing is specified, it ought to be changed or charged. He can check if their square measure battery replacement stations are around and proceed to the highest battery replacement station (Amin et al. 2020). It will be impossible to ensure secure communication between the BMS of the vehicle and the network of the battery replacement station because of the communication among the various departments of the battery replacement station.

Initially, the dynamic evaluation schemes within the distribution charging network might be monitored throughout the decision-making process of choosing the battery replacement station and support the driver's preferences. Within the battery replacement station, a procedure is going to be followed, wherever the battery, which is able to be removed from this automobile, is going to be placed during a selected space, wherever it'll be recharged for as long as it is needed. A replacement, absolutely charged, battery from the station's depot is going to be put into the driver's automobile. The payment for the battery replacement is going to be created in line with the standing of the batteries left by the driving force at the gasoline station versus the state of the batteries that may be enclosed in his automobile. This is often somewhat equivalent, as once a driver nowadays fills up his tank at a gasoline station and pays the number akin to it.

The battery is put in at the battery replacement station, and it's recharged within the correct space, supporting the principles and procedures adequate for the charging of this specific battery. Onewill envision that the length of the battery's full replacement method would possibly take a similar amount of time as that needed at a service station in today's surroundings.

There are a variety of obvious blessings of such an approach, specifically the fast refill of batteries, the employment of the present network of gas stations, and also the fast charging and payment for battery replacement, whereas the batteries are recharged by professionals safely in the correct places. The construct permits the fast 'refill' of batteries and provides flexibility to the drivers.

Challenges of 'battery replacement' stations

In order for this approach to be considered realistically, a number of challenges must be addressed, most likely with the help of I4.0 ideas and KETs. They can be divided into two major categories: those related to infrastructure and those related to vehicles.

Concerning infrastructure issues, one must consider the correct structure, style, and operation of the replacement battery station, particularly the building, electrical power processes, replacement processes, replacement tools, and so on. These challenges are squarely intertwined with the vehicle's challenges, with new batteries being designed to be lighter and thus easily replaceable. In addition, the vehicle style in terms of modularity and easily accessible batteries, as determined by the fast battery replacement construct, must be considered. These issues are also discussed in the following sections in light of I4.0 aspects.

1. Infrastructure problems:

a) Sensors networks, cycles/seconds, and IoT for observing the time period standing of each battery packs and also the substitution of the battery stations network

b) Additive production for jigs and plugs facilitates the production method of mechanical assembly and also the fitting of the battery packs.

c) Augmented Reality for facilitating the operators throughout the assembly and also the battery replacement method through the employment of holographic steering d) Cybersecurity for large knowledge protection and correct communication among the many tasks and departments to alter the quick and economical battery replacement

e) Collaborative robots, mobile robots, vehicle hoists, and extra instrumentation ought to be provided for the mixing and transfer of the standard batteries across the various departments of the station.

f) System integration for economical layout design and improvement for the physical setup of the instrumentation

g) Cloud computing for distributed {decision-making requires a higher PROOF cognitive method} in process design and planning.

. 2. Vehicle challenges:

a) The entire battery system is being monitored through BMS. The correct and economical operation of the BMS is crucial for the protection of the battery and, therefore, the maintenance of a secure operational space. The state of the battery is monitored by theBMS, through the acquisition and therefore the processing of information associated with voltage, temperature, fluid flow, and current that may be taken into consideration in terms of the state of charge, battery condition, voltage protection, and cell health.

b) The property between the modules and, therefore, the battery cells within the entire battery pack ought to be additionally thought of. This is often associated with the configuration and property (in series or/and in parallel) of the cells to larger modules, and therefore the integration of the modules into the battery pack that features electronic management controlled by the BMS. So as to investigate and properly interpret the non-heritable information in accordance with the manufacturer’s specifications, correct processing ought to be ensured (Schmitt et al. 2016).

c) Additionally, to address the challenges associated with the battery assembly, pure mathematics, the positioning of the battery pack from the digital computer to the battery packaging house ought to be considered. Throughout the processes occurring within the battery swapping station, access ought to be Bound to the vehicle’s battery pack so as to modify the combination of the standard pack, beside the mechanical transfer and mounting.

Envisioned I4.0 Solutions

1. Cloud-based BMS and also the use of Digital Twins might deliver period and correct process of information obtained from the standard battery pack so as for the vehicle's specifications to be met

2. Context-aware design of standard configurations through the genetic algorithms for the standard style and property (in series or in parallel) of the battery cells and modules (Breban 2016).

3. process of coming up with main criteria of value, time, safety (i.e., heat throughout welding), and roundness (Burda 2012).

4. Product-service system, as a hybrid technical-business model, to resolve material possession rights (IPR) information.

5. Block chain towards certification and IPR

Network protocols (CIP Safety, PROFI Safe, Open Safety, FSoE, etc.) and protocols used for the automation of processes (AS-I, BSAP, ControlNet, DeviceNet, CC-Link Industrial Networks, DNP3, UAVCAN, etc.) to ensure the safe operation of machinery within the replacement battery stations

PROCESSES

1. Designing the proper geometry for the car.
2. Building the modular blocks.
3. Final manufacturing assembly.

Applications for challenges in Electric Vehicles

1. Purpose: This paper aims to investigate the state of business 4.0 within the automotive sector to point out the associated expectations, opportunities, risks, and challenges.
2. Requirements and concrete approaches for future analysis desires are derived at intervals in the framework of a pursuit agenda.
3. Methodology includes a scientific literature review, establishing a well-founded definition of business 4.0 terms for the automotive business. Expectations, Opportunities, risks, and challenges are answered within the context of a PESTEL analysis. In addition, parts of a pursuit agenda supporting the belief-action-outcome model are highlighted.
4. As a part of the pursuit agenda for future investigations, 32 open analysis queries are planned, classified into three themes and four subcategories.
5. Originality: Within the current literature, to the most effective of our information, no approaches give even deeper insights into the establishment of business4.0 applications within the automotive sector. Thus, this paper is one in the entire primary to produce a considerable approach to key business 4.0 technologies and ideas during this sector employing a PESTEL analysis.

Conclusion

The investigation of I4.0 KETs, below the construct of battery modularity and therefore the development of intermediate battery replacement stations, may have high potential for addressing important barriers associated with long battery charging. The actual study focuses on the transfer of the standard battery construct, which remains at an awfully early stage, to the new construct of intermediate battery replacement stations.

From a development perspective, modularization correlates with a radical modification within the automotive trade. The standard battery pack style and distribution, below the construction of battery swapping stations, may lead to improved network capabilities and quality. Modularity may well be thought of as a replacement milestone within the automotive trade, targeting the optimization of world production networks and operational flexibility. The latest achievements within the field of complicated assembly decision-making and therefore the use of advanced technologies in style below the construct of I4.0 have rendered the required practicability and adaptability doable towards the implementation of standard ideas within the industrial sector.

Nevertheless, many problems and challenges can arise with the implementation of standard ideas

in the automotive business. Primarily, the distribution of standard battery packs can have a significant impact on the vehicle style and the battery-producing organization. So that standardization can be maintained, a major effort ought to be made by the automobile makers. This results in the necessity for an analysis of the required investments and adaptation to the current construct from the suppliers and manufacturers' perspectives, so as to obtain the best balance between an inexperienced economy and its impact on business.

From the analysis aspect, I4.0 KETs are progressively adopted within the production part, notably within the automotive sector. Despite the high potential of skyrocketing production's performance in terms of product quality, production time, and value, the broader implementation of those technologies remains at an early stage in nursing.

Given the current impact, a vital effort that would cause the quicker maturation of those technologies and increase irresponsibility ought to be created by progressively evaluating the implementation of such ideas in real-life applications and situations.

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