STM JOURNALS

International Journal of
Advanced Robotics and
Automation Technology

Volume 2, Issue 1, 2024
January–June
DOI (Journal): 10.37591/IJARAT

https://journals.stmjournals.com/ijarat

Research IJARAT

Hybrid Battery Swapping Station for EV Using Robotic Arms

Ashwin R Saji[1,*], Nithin Prasanth[2], Prarthana U. Kumar[3], Veena S.[4], Rakhi Das[5]

Abstract

The Robotic Arm-Based Battery Swapping System indeed marks a significant stride in merging technology and sustainability. Its integration of robotics, computer vision, and renewable energy positions it as a ground breaking solution, reshaping the landscape of electric vehicle charging. This automated approach not only tackles inefficiencies in current methods but also serves as a blueprint for future advancements in the domain. The inefficiencies inherent in conventional electric vehicle battery replacement methods, characterized by time-consuming processes and manual interventions, are precisely what the Robotic Arm-Based Battery Swapping System aims to address. Through the integration of precise robotics, computer vision, and sustainable energy sources, the project seeks to provide a streamlined, precise, and eco-friendly solution in response to the growing demand for improved efficiency and environmental alignment in the electric mobility landscape. Focuses on the precision and automation of battery swapping processes in electric vehicles. The project features a robotic arm with 3D-printed components and servo motors for accurate movements. The system includes a computer vision system using OpenCV for battery recognition and positioning. Safety measures are implemented through the use of a smoke sensor and temperature monitoring with voice feedback. The project also incorporates a solar charging system, consisting of a solar panel and charge controller, to reduce reliance on conventional power grids and promote sustainability. The system's performance can be monitored through a 16x2 LCD display, which provides real-time information on charging status and system parameters. The event of potential hazards, the smoke sensor promptly triggers responsive actions, ensuring the swift and effective mitigation of risks.

Keywords: Computer vision, LCD, OpenCV, RFID, Streamline, Swapping, Triggers

INTRODUCTION

The rapid adoption of electric vehicles has underscored the need for innovative charging solutions that can overcome the limitations of traditional charging methods. Automated battery swapping systems offer a promising alternative by enabling swift battery replacement without the need for lengthy charging times. This project introduces a comprehensive approach to automated EV battery swapping, leveraging a custom-built robotic arm and advanced computer vision technology to enhance efficiency and user experience.

This document provides information about the working principle, temperature and smoke detection features, as well as the use of a solar charging system in the proposed solution. To realize optimal day-ahead operation of battery swapping and

***Author for Correspondence**
Ashwin R Saji
E-mail: ashwinrsaji2@gmail.com

[1-4]Student, Department of Electrical and Electronical Engineering, UKF College of Engineering and Technology, Kerala, India
[5]Assistant Professor, Department of Electrical and Electronical Engineering, UKF College of Engineering and Technology, Kerala, India

Received Date: May 20, 2024
Accepted Date: June 22, 2024
Published Date: August 05, 2024

Citation: Ashwin R Saji, Nithin Prasanth, Prarthana U. Kumar, Veena S., Rakhi Das. Hybrid Battery Swapping Station for EV Using Robotic Arms. International Journal of Advanced Robotics and Automation Technology. 2024; 2(1): 16–23p.

© STM Journals 2024. All Rights Reserved

charging systems (BSCSs), a closed loop supply chain (CLSC) based management scheme is proposed, where the game theory is adopted for benefits allocation [1]. In the quest for sustainable transportation solutions, electric vehicles (EVs) have emerged as a promising alternative to traditional combustion engine vehicles. battery swapping appears to be an appropriate solution for the present-day scenario. As against the conductive method for charging through EVSE, the swapping of the EV battery proposes one key benefit, i.e. quick recharging of the xEVs [2]. The rise of electric vehicles and the challenges of their charging process, leading to the emergence of battery swapping stations (BSS) as a potential solution. The BSS provides an overview of the state-of-the-art literature and various BSS business models, as well as the decision scenarios in different operational areas To address these challenges, innovative technologies are continually being explored, one of which is the Battery Swapping System (BSS) integrated with robotic arms and computer vision. The Battery Swapping System is a transformative approach that aims to overcome the constraints of traditional charging methods. On the basis of meeting the customer battery demand, an objective function and a dispatching strategy are formulated for the SBS system to maximize net revenue [3]. By employing advanced robotic arms and computer vision technology, this system enhances the efficiency, speed, and user experience of the battery replacement process for electric vehicles. focuses on investigating and studying the EV development situation, travel distribution pattern and users' response to government subsidy policies in China [4]. In this introduction, we will delve into the key components and benefits of this cutting-edge technology. optimization objective is to minimize the cost of electricity purchased from the utility grid with the chance constraints of swapping demand satisfaction and the confidence level of the minimum cost [5]. At the heart of the Battery Swapping System is a sophisticated robotic arm system designed to automate the battery replacement process. Battery degradation is one of the key barriers to the correct deployment of electric vehicle technology [6]. These robotic arms are equipped with precision and speed, enabling them to seamlessly remove depleted batteries from electric vehicles and replace them with fully charged ones. integration of distributed renewable energy sources (RESs), such as solar and wind, is considered to be a viable solution for cutting energy bills and greenhouse gas (GHG) emissions of 5G base stations (BSS) [7]. The automation not only reduces human involvement but also ensures accuracy and consistency in the battery-swapping procedure. The station also improves the user interface. Optimized BCS models cannot reduce the charging time, which also results in queuing for charging and range anxiety among EV drivers [8]. The paper also introduces the concept of a shared battery station (SBS) with multiple Hybrid Battery Swapping Station For Electric Vehicle Using Robotic Arm functionalities, addressing the needs of EV users for fast and efficient battery management. The approach for resolving the issue of electric car charging safety through an electric vehicle charging safety warning system is suggested in this research. The suggested solution uses an adaptive optimization of long short-term memory neural network (A-LSTM) [9]. The SBS operates on a shared economic model, offering various services such as charging, discharging, sleeping, and swapping. The integration of computer vision technology is pivotal in enhancing the intelligence of the Battery Swapping System. optimum location and size that maximize the revenue of a swap station in an MG system are investigated. To the best of our knowledge, this study is first to solve the placing and sizing problem in the MG from the perspective of a BSS [10]. Computer vision enables the system to identify the electric vehicle's battery compartment accurately, align the robotic arms with the precision, and execute the battery replacement process seamlessly. This technology also plays a crucial role in real-time monitoring, error detection, and ensuring the safety of the entire operation.

CONVENTIONAL SYSTEM

Conventional approaches to electric vehicle battery replacement suffer from inherent inefficiencies, including time-intensive processes and manual interventions. The Robotic Arm-Based Battery Swapping System seeks to rectify these issues by leveraging presicesd robotics, computer vision, and sustainable energy sources. The project is a response to the imperative need for a more streamlined, precise, and eco-friendly battery swapping system that aligns with the evolving landscape of electric mobility.

HYBRID BATTERY SWAPPING SYSTEM

© STM Journals 2024. All Rights Reserved

A hybrid battery swapping station using robotic arms combines the convenience of battery swapping with the efficiency of automated systems. This concept enhances the speed and precision of the battery swapping process, reducing the need for human intervention and potentially increasing the scalability of such stations.

Associated systems are:

- Robotic arm
- Battery attaching system
- Solar charging system
- Safety system
- User friendly interaction
- RFID module
- ESP32 module
- Computer vision

Robotic Arm

The system is equipped with a robotic arm that is designed with precision and automation in mind. The robotic arm is responsible for picking up the discharged battery from the electric vehicle and replacing it with a fully charged one from the charging station. It is driven by servo motors, ensuring accurate movements. Robotic arms in battery swapping systems are designed for precise and automated battery replacement in electric vehicles, enhancing efficiency and reducing downtime. They use sensors and actuators to securely grasp, remove, and replace batteries, streamlining the process for quicker turnaround.

Battery Attaching System

Grippers made of acrylic sheet are used to handle the batteries during the swapping process. These grippers securely hold the discharged battery and allow for smooth replacement with a fully charged battery. Battery grippers are mechanical devices designed to securely hold and manipulate batteries. In the context of battery swapping systems or robotics, these grippers play a crucial role in safely extracting and inserting batteries into devices or vehicles. They are often equipped with adjustable arms or clamps to accommodate various battery sizes and shapes.

Solar Charging System

The battery swapping station incorporates a solar charging system for a sustainable power source. It includes a solar panel and a charge controller. The solar panel harnesses solar energy, reducing reliance on conventional power grids. The charge controller regulates the solar energy to charge the system's batteries, ensuring efficient and eco-friendly charging.

Safety System

The system includes temperature and smoke sensors for enhanced safety measures. The NTC temperature sensor continuously monitors the temperature, while the smoke sensor detects the presence of smoke. In the event of potential hazards, the sensors trigger responsive actions to mitigate risks promptly. Temperature and smoke monitoring systems are crucial for safety and early detection of potential issues. These systems use sensors to measure temperature levels and detect smoke or fire. In various applications, such as buildings, industrial settings, or smart homes, these systems can provide real-time alerts, allowing for swift responses to prevent damage or danger.

User-Friendly Interaction

The battery swapping station features a user-friendly interface to engage users effectively. It includes a Charging Feedback System with voice alerts, allowing users to receive real-time updates and critical information about the system's performance. Additionally, a 16x2 LCD display provides visual

© STM Journals 2024. All Rights Reserved

information on the charging status and key system parameters, enhancing monitoring capabilities.

RFID Module

RFID (Radio Frequency Identification) module is a device that allows for easy integration of RFID technology into various applications. RFID technology uses electromagnetic fields to automatically identify and track tags attached to objects. The RFID module consists of several components that work together to read and communicate with RFID tags. The reader, also known as the transceiver, is the part of the module that sends and receives data to and from the RFID tags. It modulates and demodulates the radio frequency signals.

ESP32 Module

The ESP32 module is a powerful and versatile microcontroller module developed by Espressif Systems. It is based on the ESP32 system-on-chip (SoC), which integrates Wi-Fi and Bluetooth connectivity along with a dual-core processor, making it suitable for a wide range of IoT (Internet of Things) applications. The ESP32 module has gained popularity among hobbyists, developers, and engineers due to its capabilities, ease of use, and affordability. The ESP32 features two Xtensa LX6 microprocessor cores running at up to 240 MHz. This dual-core architecture allows for efficient multitasking and better performance.

Computer Vision

The system utilizes computer vision technology powered by OpenCV. This allows the system to identify the location of the battery on the electric vehicle. By analyzing visual information, the computer vision system guides the robotic arm to perform the battery swapping process with precision. Computer vision involves teaching machines to interpret and make decisions based on visual data. It enables computers to analyze images or videos, identify patterns, and understand the content within them. Applications range from facial recognition and object detection to autonomous vehicles and medical image analysis.

The software architecture of the automated EV battery swapping system involves a combination of Arduino and Python scripts, each serving specific functions within the system. Arduino scripts are responsible for low-level control of hardware components, such as the robotic arm and sensor inputs, while Python scripts handle higher-level tasks such as computer vision and algorithmic decision-making. Python scripts are used for high-level tasks requiring complex processing and decision-making capabilities, such as computer vision and algorithmic control. Specifically,

Python scripts utilize libraries such as OpenCV to perform computer vision tasks, such as ArUco marker detection. ArUco markers are used for precise localization of objects (e.g., vehicles, battery packs) within the environment. Python scripts detect and track ArUco markers to determine the position and orientation of objects, enabling accurate pick-and-place operations.

Python scripts implement pick-and-place algorithms to guide the robotic arm's movements based on information obtained from computer vision systems and sensor inputs. These algorithms determine the optimal trajectory for the robotic arm to grasp and release the battery pack during the swapping process, ensuring efficiency and accuracy.

By dividing software tasks between Arduino and Python scripts based on their complexity and requirements, the automated EV battery swapping system achieves a balance between real-time control and high-level decision-making capabilities, enabling seamless operation and reliable performance (Figure 1).

The structural design of robotic arms involves careful consideration of materials, geometry, and mechanics. Engineers aim to achieve a balance between strength, weight, and flexibility. Common materials include aluminum and carbon fiber for a lightweight yet sturdy construction. The arm's joints and links are designed to withstand forces while providing precise movement. Additionally, factors like

© STM Journals 2024. All Rights Reserved

payload capacity, reach, and end-effector attachment play a role in determining the overall structural design. Commonly used for its lightweight properties and corrosion resistance. Aluminum is a popular choice for robotic arms, especially in applications where weight is a crucial factor. Known for its high strength-to-weight ratio, carbon fiber is used when a balance between strength and reduced weight is essential. This material is often favored in applications where minimizing inertia is critical for achieving high precision and speed. The geometric design of the robotic arm influences its reach, range of motion, and overall flexibility. Engineers must carefully consider the kinematics and dynamics of the arm to ensure optimal performance. Articulated, cylindrical, and Cartesian are common robotic arm configurations, each with its advantages and disadvantages depending on the application. Joints and links are the fundamental components of a robotic arm. Joints allow for movement, and links connect the joints, forming the overall structure. The design of joints and links must balance strength, precision, and weight. Different types of joints, such as revolute or prismatic joints, may be used based on the application requirements. The robotic arm must be structurally robust to withstand the forces and torques generated during its operation. Rigidity is crucial for maintaining accuracy and repeatability (Figure 2).

Finite Element Analysis (FEA) is often employed to simulate and analyze the structural behavior of the arm under various loading conditions. The design must account for the maximum payload the robotic arm is expected to handle. This includes the weight of any tools or end-effectors attached to the arm during its operation. The design should provide an optimal reach and range of motion to cover the workspace required for a particular application. This is crucial for the arm to access and manipulate objects effectively. The end-effector, or tool, attached to the robotic arm is another critical consideration. The arm's design should accommodate different types of end-effectors based on the intended tasks, such as grippers, welding tools, or sensors. The mechanical design should ensure precision and accuracy in movement. This involves minimizing backlash and play in joints to achieve the desired positional accuracy.

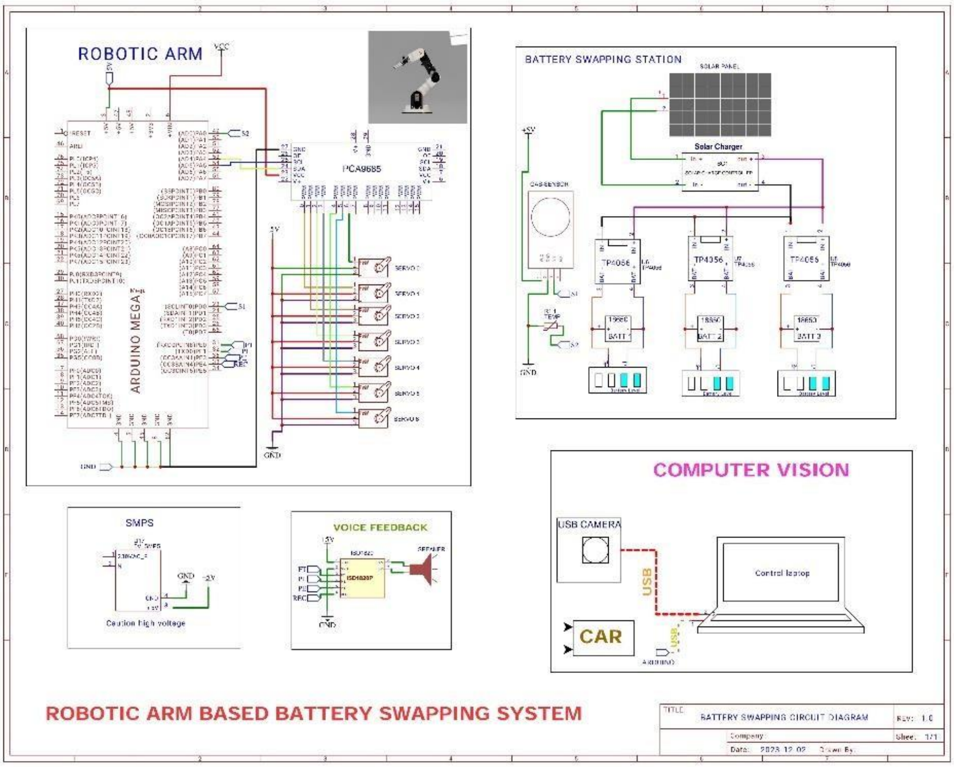

Figure 1. Schematic of hybrid battery swapping station using robotic arm.

© STM Journals 2024. All Rights Reserved

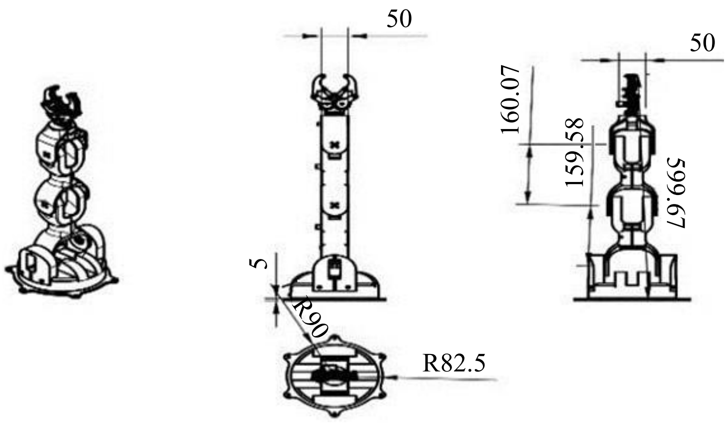

Figure 2. Structural Design.

STRUCTURAL DISCRIPTION OF PROPOSED SYSTEM

3D-printed components with MG995 and MG90 servo motors for precise movements. Grippers made of acrylic sheet for battery handling. Computer Vision: Utilizes OpenCV for accurate battery recognition and positioning. NTC temperature sensor integrated for continuous monitoring. ISD8210 voice recorder for conveying essential information through voice alerts. 16x2 LCD display for real-time information presentation. Smoke sensor for safety measures. Solar panel for harnessing solar energy. Charge controller for regulating solar energy to charge the system's batteries.

WORKING PRINCIPLE

Battery Swapping

Through the synergy of computer vision powered by OpenCV and the precision of the robotic arm, the system precisely identifies the battery's location on the electric vehicle, executing flawless movements to replace discharged batteries with fully charged counterparts. OR The computer vision system identifies the location of the battery on the vehicle The robotic arm, driven by servo motors, picks up the discharged battery and replaces it with a fully charged one from the charging station.

Temparature and Smoke Detection

Continuous monitoring by the NTC temperature sensor ensures the system operates within optimal temperature ranges. Voice alerts from the ISD8210 dynamically communicate crucial information about temperature status and charging feedback to users. The 16x2 LCD display offers a comprehensive visual interface, presenting real-time information on charging status and system parameters. Simultaneously, the smoke sensor detects smoke, triggering responsive actions to mitigate potential safety risks, HERE ALSO VOICE ALERT IS PROVIDED. OR The NTC temperature sensor continuously monitors the system temperature. The ISD8210 voice recorder provides voice alerts, conveying crucial information about temperature status and charging feedback. The smoke sensor ensures the system's safety by detecting the presence of smoke and triggering appropriate responses. The 16x2 LCD display presents real-time information on the charging status and system parameters

Solar Charging System

Harnessing solar energy, the solar panel feeds the charge controller, ensuring efficient utilization of solar power to charge the system's batteries. This harmonious synergy between technology and nature minimizes the system's environmental impact and promotes sustainable energy practices. The solar panel harnesses solar energy, and the charge controller regulates the energy flow to charge the system's batteries, providing a sustainable power source.

CHARACTERSTICS

Characterized by precision and automation, the Robotic Precision and Automation feature of the project centers around a meticulously crafted robotic arm. Engineered with components produced through advanced 3D printing techniques and propelled by the reliability of MG995 and MG90 servo

© STM Journals 2024. All Rights Reserved

motors, this robotic arm is designed to execute battery swapping processes with unparalleled accuracy. The combination of these technologies ensures not only precision but also a seamless, automated experience in the intricate task of replacing batteries, thereby significantly reducing the reliance on manual labor. Temperature Control stands as a cornerstone in optimizing operational conditions within the system. The project employs the NTC temperature sensor as a vigilant guardian, diligently monitoring and regulating the system's temperature. This proactive approach ensures that the system operates within the optimal temperature range, preventing potential overheating issues and promoting longevity. The NTC temperature sensor emerges as a critical component, contributing to the system's overall efficiency and performance by maintaining a conducive temperature environment. User Interaction takes on a dynamic dimension through the incorporation of the ISD8210 voice recorder. This technology serves as the system's communicative hub, facilitating dynamic user interaction through personalized voice alerts. Users receive real-time information, critical updates, and feedback in a manner that transcends traditional interfaces. The ISD8210 not only enhances the user experience but also establishes a sophisticated and engaging means of communication, making the interaction between the user and the system more intuitive and effective.

RESULTS & DISCUSSIONS

One of the primary advantages of battery swapping with robotic arms is the significant reduction in charging time. Unlike traditional charging stations, which may require hours to recharge an EV, battery swapping can be completed in a matter of minutes. This is crucial for improving the convenience and practicality of electric vehicles. Robotic arms automate the battery swapping process, making it more convenient for users. Drivers can simply park their vehicles over the swapping station, and the robotic arms take care of the entire process. This is particularly beneficial for commercial fleets and businesses where time is of the essence. Battery swapping systems typically require standardized battery designs to ensure compatibility with the robotic arms. This can lead to industry-wide standardization of battery specifications, making it easier for manufacturers to produce interchangeable batteries and promoting interoperability among different EV models. Implementing battery swapping technology requires a network of swapping stations equipped with robotic arms. Developing this infrastructure involves significant investment and collaboration among stakeholders, including automakers, energy companies, and government agencies. The success of battery swapping depends on the widespread availability of these stations. The implementation of robotic arms in battery swapping stations involves initial costs for research, development, and installation. However, as technology matures and becomes more widespread, economies of scale may lead to a reduction in overall costs.

Robotic arms need to be highly reliable to ensure a smooth and error-free battery swapping process. Regular maintenance and monitoring are essential to address any technical issues promptly. The reliability of the robotic arms directly impacts the overall efficiency and user trust in the battery swapping system. Battery swapping can have environmental benefits, particularly if the batteries are charged using renewable energy sources. Additionally, the ability to recycle and repurpose batteries becomes more feasible with standardized designs. However, it's essential to consider the environmental impact of manufacturing and maintaining robotic arms and battery swapping infrastructure.

The success of battery swapping technology with robotic arms relies on user acceptance. Educating consumers about the advantages, safety, and reliability of the technology is crucial. Ensuring a positive user experience through user-friendly interfaces and clear communication is essential for widespread adoption. The scalability of battery swapping technology with robotic arms is a critical factor for its long-term success. As the electric vehicle market grows, the system must be adaptable to accommodate increased demand. Ongoing research and development are necessary to improve the efficiency, speed, and reliability of the battery swapping process.

In conclusion, battery swapping technology with robotic arms holds great potential for revolutionizing the charging infrastructure for electric vehicles. While challenges exist, advancements in technology, standardization efforts, and investment in infrastructure can contribute to the widespread

© STM Journals 2024. All Rights Reserved

adoption of this innovative approach to EV charging.

CONCLUSION

In conclusion, battery swapping technology employing robotic arms presents a promising solution to address key challenges associated with the adoption of electric vehicles (EVs). The efficiency and speed *of the battery swapping process, coupled with the potential for standardization, contribute to the* feasibility and appeal of this innovative charging approach. Battery swapping with robotic arms significantly reduces charging time, offering a practical solution for users with time constraint s. Automation through robotic arms enhances the convenience of the battery swapping process, making it more accessible for a wide range of users.

The technology encourages standardization of battery designs, potentially fostering interoperability among various EV models. The success of battery swapping relies on the establishment of an extensive network of swapping stations, requiring substantial investment and collaboration among stakeholders. Continued research and development are vital to address existing challenges, enhance the scalability of the technology, and improve its efficiency, speed, and reliability. On going advancements in battery technology and increased adoption of EVs globally may further contribute to the viability and growth of battery swapping with robotic arms. While battery swapping technology using robotic arms holds significant potential to transform the landscape of EV charging, its success hinges on addressing infrastructure challenges, ensuring user acceptance, and advancing technology for long-term sustainability. As the electric vehicle market continues to evolve, battery swapping technology remains an exciting and dynamic aspect of the broader effort to promote sustainable transportation solution

REFERENCE

1. Tianyang Zhao, Jianhua Zhang, Peng Wang, *Closed-loop Supply Chain Based Battery Swapping and Charging System Operation A Hierarchy Game Approach*, Date of publication 1 march 2019, Volume 5,(35-45p).
2. Furkan Ahmad, Mohammad Saad Alam, Ibrahim Saad Alsaidan, Samir M. Shariff, *Battery swapping station for electric vehicles opportunities and challenges*, Date of publication March 6, 2019, Volume 3,(280-286p).
3. Jie Yang, Weiqiang Wang, Kai Ma, And Bo Yang, *Optimal Dispatching Strategy for Shared Battery Station of Electric Vehicle by Divisional Battery Control*, Date of publication March 20, 2019, Volume 7,(38224-38235p).
4. Liang Zhang, Sihang Zhou, Jing An, Qi Kang, *Demand-Side Management Optimization in Electric Vehicles Battery Swapping Service*, Date of publication July 12, 2019, Volume 7, (95224-95232p).
5. Hong Liu, Yuhan Zhang, Shaoyun Ge, Chenghong Gu, And Furong Li, *Day-Ahead Scheduling for an Electric Vehicle PV-Based Battery Swapping Station Considering the Dual Uncertainties*, Date of publication August 16, 2019, Volume 7, (115625-115636p).
6. Gaizka Saldaña, José Ignacio San Martín, Inmaculada Zamora, Francisco Javier Asensio1, (Member, Ieee), Oier Oñederra, And Mikel González, *Empirical Electrical and Degradation Model for Electric Vehicle Batterie*, Date of publication August 25, 2020, Volume 8,(155576-155589p).
7. Xiyuan Liu, Zhaohong Bie, *Cooperative Planning of Distributed Renewable Energy Assisted 5G Base Station With Battery Swapping System*, Date of publication August 26, 2021, Volume 9, (119353-119366p).
8. Hao Wu, *A Survey of Battery Swapping Stations for Electric Vehicles: Operation Modes and Decision Scenarios*, Date of publication 8 August 2022, Volume 23, (10163-10185p).
9. Xiaohong Diao, Linru Jiang, Tian Gao, Liang Zhang, *Research on Electric Vehicle Charging Safety Warning Based on A-LSTM Algorithm*, Date of publication 31 May 2023, Volume 11(55081-55093p).
10. Mustafa Cagatay Kocer, Ahmet Onen, Jaesung Jung, Hakan Gultekin, Sahinalbayrak, *Optimal Location and Sizing of Electric Bus Battery Swapping Station in Microgrid Systems by Considering Revenue Maximization*, Date of publication 17 April 2023, Volume 11,(41084-41095p).

© STM Journals 2024. All Rights Reserved