Communications on Applied Nonlinear Analysis
ISSN: 1074-133X
Vol 30 No. 3 (2023)

Navigating Tomorrow Non-Linearly: A Holistic Exploration of Smart and Secure EV Charging Infrastructure in Parking Facilities

Dr. Sohel Bhura[1], Salil Deogade[2], Shantanu Ganvir[3], Shilpa Lalwani[4], Siddhant Patel[5], Dolly Bajaj[6]

[123456] Department Of Computer Science Engineering, JIT College, Lonara, Nagpur, Maharashtra, India.

s.bhura@jitnagpur.edu.in[1], salil.deogade@gmail.com[2], jitcse.shantanuganvir7@gmail.com[3], jitcse.shilpalalwani@gmail.com[4], siddhantpatel812@gmail.com[5], jitcse.dollybajaj2002@gmail.com[6]

Article History:

Received: *24-05-2023*

Revised: *20-06-2023*

Accepted: *10-08-2023*

Abstract:

Amidst the revolutionary transition to environmentally friendly transportation via electric cars (EVs), this research explores the complexities of guaranteeing a future in which intelligent and safe EV charging infrastructure is essential. Against the backdrop of India's changing energy landscape, the study examines the critical requirement for reliable EV charging stations. In light of the liberalization, privatization, and proliferation of renewable energy sources, the research thoroughly assesses the commercial feasibility of electric vehicles. Analyzing the function of aggregators in managing EV charging and offering additional grid services, the study faces both market-driven and governmental barriers. The strategic positioning of electric vehicle charging stations is crucial in tackling issues like battery costs, economic volatility, and complicated integrations. The suggested system develops gradually, adding crucial security elements like socket security, extra authentication levels, and Wi-Fi management. The hardware implementation creates a reliable and user-friendly charging environment by utilizing parts like Arduino, NodeMCU, and other security features. Many benefits are anticipated by the study, such as improved utility customer relations, a large-scale installation of charging stations, cost savings for EV drivers and station owners via demand response programs, and improved electricity planning made possible by data from EV charging infrastructure. As the study draws to a close, it emphasizes how crucial safe charging locations are to the general uptake of electric vehicles. The complete plan that is being presented tackles the plethora of opportunities and difficulties that are present in the Indian EV charging market, providing light on the way to a safe and sustainable future.

Keywords: Electric Vehicle (EV), Security, Smart Charging, Smart Grid (SG), Non-linear, Privacy.

I. INTRODUCTION

Electric vehicles (EVs) are developing as a sustainable and forward-thinking alternative to solve environmental issues and lessen dependency on traditional fossil fuels, signalling a paradigm change in the automotive industry. In addition to spurring technological developments in car design, this move to electric transportation has made a strong infrastructure for EV charging necessary [1]. This article attempts to investigate the need for safe EV charging stations in the context of the developing Indian electrical market, looking at the potential and problems in the nation's changing energy environment. India, a country with a fast expanding population and rising urbanisation, is facing two challenges at once: balancing the country's growing energy needs with its environmental concerns.

India's electrical industry is undergoing a metamorphosis at the moment, characterised by privatisation, liberalisation, and a significant rise in distributed and renewable power generation [2]. This evolution includes market mechanisms controlling energy allocation and the energy mix, as well as transmission and distribution operations. The current advancements are intended to improve the energy sector's dependability and efficiency.

In this regard, the article assesses the commercial potential of electric cars in the current energy market through a methodical examination of pertinent characteristics. An extensive overview of a scenario where an aggregator handles EV charging while providing ancillary grid services is provided by this exploration, which includes regulatory and market-based challenges as essential components [3]. The process of integrating electric vehicles (EVs) into the energy market is complex and requires careful consideration of economic, technological, and regulatory aspects. Drivers' top concern when it comes to EVs is finding charging stations, which emphasises the significance of putting in place a smart infrastructure network for charging infrastructure [4]. In order to ensure widespread adoption of EVs and mitigate associated risks like battery degradation and cost, economic uncertainty, inadequate infrastructure for charging, maintenance difficulties, smart grid integration problems, range anxiety, auxiliary loads, and driver behaviour, it is imperative that EV charging stations be strategically located. The strategic placement of charging stations is crucial as the Indian population shifts to electric vehicles in order to promote the wider adoption of EVs and smooth travel experiences [5].

The study presents a complete approach that tackles the various issues related to EV charging infrastructure. This is the suggested system. The system is designed to include security measures gradually. It begins with socket security and progresses to more complex layers such as Wi-Fi control and extra authentication processes. A careful approach to building a safe and convenient charging environment is demonstrated by the integration of technologies like NodeMCU, Arduino, and several security measures [6]. The core of the suggested system is the implementation of hardware elements such a power supply, an Arduino Nano, a NodeMCU, a relay, and a password pad. Every element has a distinct function in guaranteeing the safety and efficiency of the infrastructure for charging. There is financial transparency on the costs associated with putting such a system in place thanks to the cost breakdown for each phase.

In conclusion, a well-thought-out and secure EV charging infrastructure is necessary to serve India's rapidly expanding electric vehicle sector as it moves towards electric transportation. The suggested solution takes into account not only the technological issues but also the regulatory and economic environment [7]. This paper adds to the conversation by offering a comprehensive strategy for safe and effective EV charging. As India moves through its energy cycle, integrating electric cars into the mainstream calls for creative solutions.

II. Literature Review

In the recent year the research on electric vehicle (EV) charging infrastructure emphasises how important it is to the development of environmentally friendly transportation in the future. Academics and investigators have explored many aspects of this dynamic environment, scrutinising obstacles, prospects, and possible resolutions [1]. The effect of charging infrastructure on the uptake

of electric vehicles is a recurring issue in the literature. Studies indicate that customers' propensity to adopt electric mobility is highly influenced by the accessibility and availability of charging stations [2]. Researchers contend that a well-developed network of charging stations, positioned in suburban and metropolitan locations, reduces range anxiety—a psychological barrier associated with the fear of running out of battery power—and raises consumer acceptability and convenience levels for EVs [3].

The literature also highlights the necessity of smart charging systems in order to handle the dynamic nature of grid management and energy markets [4]. Researchers stress the need of creating intelligent charging systems that can optimise energy use, support grid stability, and ease demand response as electric cars become increasingly integrated into the larger energy ecosystem. Smart charging technologies being investigated as potential ways to improve the effectiveness and dependability of EV charging infrastructure [5]. These technologies include those that incorporate Internet of Things (IoT) devices and sophisticated communication protocols. Academics contend that these developments enhance the resilience and sustainability of the electricity grid generally in addition to providing benefits to individual EV customers [6].

The literature also examines legislative measures and regulatory frameworks designed to promote the expansion of EV charging infrastructure. Researchers examine how public-private partnerships, government initiatives, and incentives have shaped the development of EV charging networks [7]. The body of research emphasises how crucial uniform rules are to building an integrated and compatible charging environment. Research also examine the financial effects of these laws, taking into account the relative merits of various pricing schemes and how they affect the dynamics of the market. Overall, the literature review provides a thorough understanding of the many opportunities and challenges within this developing field by highlighting the interconnectedness of consumer perceptions, regulatory frameworks, and technological advancements in shaping the landscape of EV charging infrastructure 8[.

III. PROPOSED SYSTEM

The whole project is divided into these phases due to its level of complexity and immense work with the number of components and the cost that every phase has required.

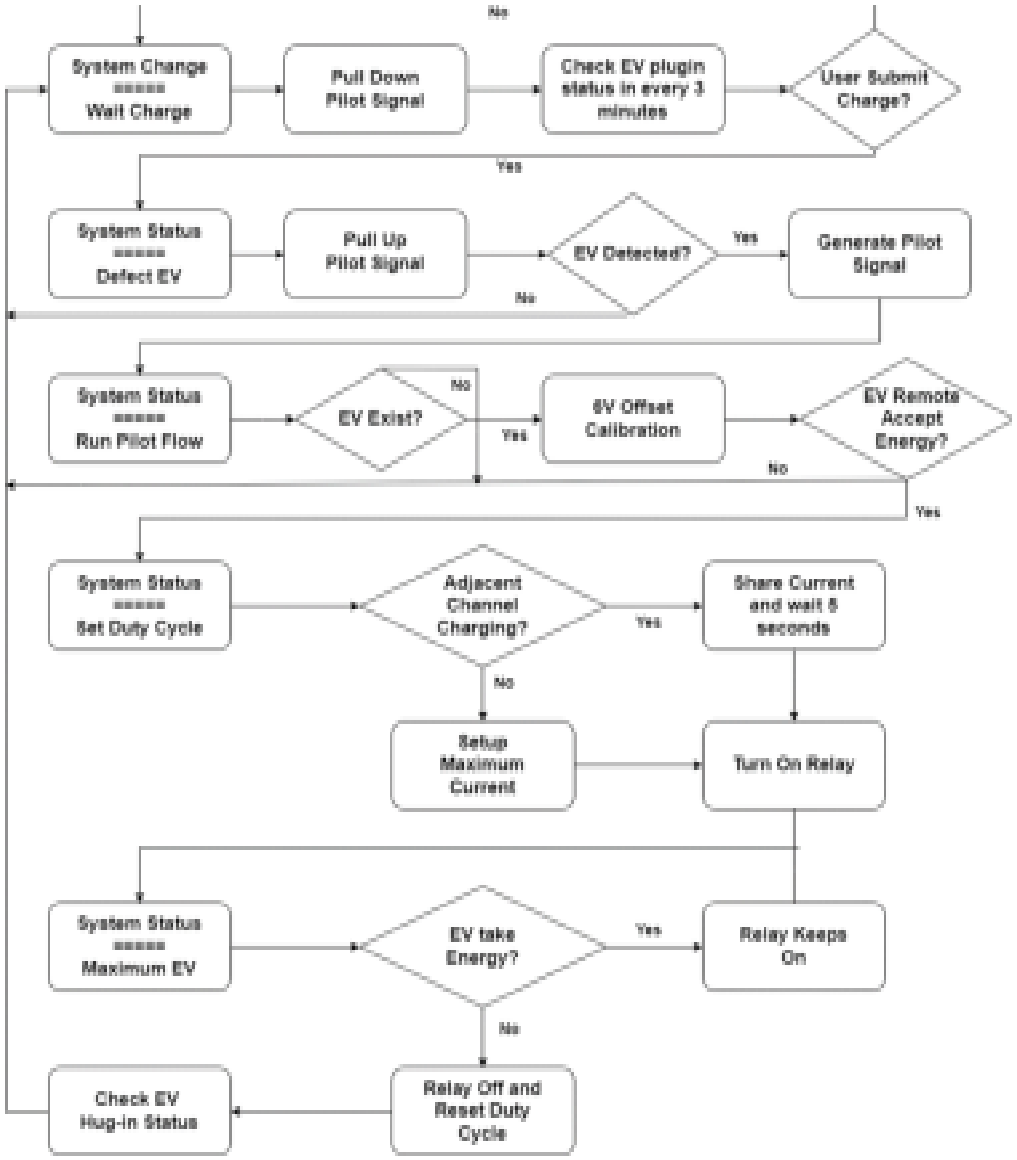

Figure 1. Proposed System

Phase 1:

Added the functionality of socket security where the current in socket will get on/off after entering the password. You can relate this with the log in and log out activities of a user in an application. The components that are used in this phase are password pad, Arduino, socket and the electric board. All this adds up to the budget of Rs.2800.

Phase 2:

Suppose you left your e-vehicle to charge at home and want to control the charging socket from inside your home without entering the password every time. You can accomplish this using Wi-Fi by downloading an application on your phone, provided that both your e-vehicle and phone are connected to the same Wi-Fi network. NodeMCU was successfully used to achieve this task. Coding in NodeMCU is done in Lua language locally. The component used here is NodeMCU,

which has added an additional cost of Rs.910 to the budget.

Phase 3:

Currently, one issue encountered during this phase is the potential for misuse of the enabled socket. This means that anyone can remove your charger and replace it with their own while the socket is enabled. To solve this issue, we have introduced a 'socket-remove-password' feature. This feature adds an additional layer of security to the charging socket by requiring the e-vehicle user to enter a password before attaching the charger to the socket. In other words, the password only needs to be entered when the charger is attached and the current will stop as soon as the charger is removed. We have also added a sensor with a PUSH button concept to the socket. We've placed a button inside the socket where the earthing pin is attached by cutting the plastic off the earthing pin. The button is pushed when the earthing pin is inserted. All of this cost a total of Rs. 5100, with Rs. 1300 allocated for these security measures.

IV. System Design and Implementation

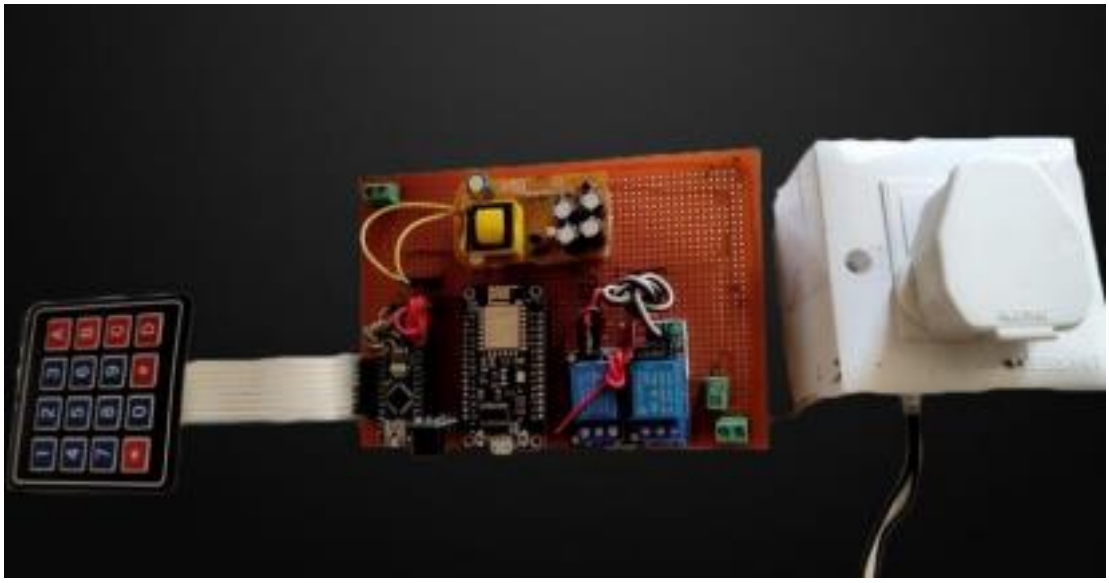

Figure 2. System Design

1. Power Supply:

A power supply in a circuit is an electronic device or circuit that provides electrical energy to other components or devices within the circuit. It converts the input power from a source, such as an AC mains supply or a battery, into a form that is suitable for use by the various components in the circuit. Here the output of the power supply is 1A for 5 volts. It is providing current to NodeMCU, Arduino and also to the relay.

2. Arduino Nano:

The Arduino Nano is a small electronic board that includes a microcontroller chip known as the ATmega328P. It has 14 digital input/output pins and 8 analog inputs which are capable of measuring signal voltage, as well as 6 pulse

width modulation (PWM) outputs. The Arduino Software integrated development environment (IDE), which can be used both online and offline, is a common feature of all Arduino boards and is used to program the Nano board. Connection of Pins –

· Pins 2 to 10 are used to take password as an input

· Pin 11 has a relay connection

· Pin 12 has sensor connection

3. NodeMCU:

NodeMCU is a development board and firmware that is open-source and based on the Wi-Fi chip ESP8266. It offers a simple and affordable solution to incorporate Wi-Fi connectivity into electronic projects. NodeMCU is extensively employed in the field of Internet of Things (IoT) applications and can be programmed through either the Arduino IDE or the Lua scripting language.

4. Relay:

A 5V relay can be utilized to switch the 120-240V current and the relay can be controlled by Arduino. Essentially, a relay enables lower voltage to effectively operate higher power circuits. On our board, we employed two relays, one for NodeMCU and the other for Arduino Nano. The reason for using two relays is that if a single relay is used for both microprocessors, the pin that is used to transmit signal to the relay will eventually get shorted and cause both microprocessors to stop.

5. Password Pad:

A password pad in a circuit is an electronic device or module that is used to secure access to a system or device by requiring the user to enter a correct sequence of digits or characters. The password pad is one of the most important component of our hardware because it helps the user of the EV vehicle to secure it's charging point by setting up a password and ultimately use it to cut on or off the current.

V. RESULTS AND DISCUSSION

Parameters	**Expected Gain**
Reduced Costs:	
Making EV drivers part of demand response initiatives	$500 savings per driver annually
Exposing consumers to demand side management	20% reduction in operational costs for station owners
Avoiding long-term utility investments through load management	15% reduction in utility costs over 5 years for all ratepayers
More Charging Stations in More Places:	
Incorporating infrastructure costs into general rate cases	60% reduction in charging station prices
	50% increase in the number of stations in various locations
Enhances Positive Utility Customer Relations:	
Supporting EV charging infrastructure	90% customer satisfaction rating
Providing clean, affordable electricity for vehicle	Increased positive public perception of utilities

power	
Improved Electricity Planning:	
Gaining access to data from EV charging infrastructure	30% improvement in predicting station deployment and changes in local energy requirements

Table 1. Evaluation of Secure EV Charging Infrastructure

a. Reduced Costs:

Making it possible for EV drivers to take part in utility demand response initiatives and exposing consumers to demand side management will significantly lower expenses for drivers and station owners. In addition, avoiding long-term utility investments through load management will reduce costs over time for all ratepayers, as utility generation, distribution, and transmission assets are more fully utilized.

b. More Charging Stations in More Places:

If utilities are allowed to incorporate the infrastructure costs necessary to install a charging station into general rate cases, the price per station can be reduced by more than half. This can increase the number of charging stations in more locations, such as workplaces, retailers, schools, hotels, homes, and apartments.

c. Enhances Positive Utility Customer Relations:

Utilities have a long-standing and strong relationship with ratepayers across their service areas. By supporting the deployment of EV charging infrastructure, utilities can provide customers with the added benefit of access to clean, affordable electricity to power their vehicles.

d. Improved Electricity Planning:

By gaining access to data from EV charging infrastructure, utilities can better predict the deployment of new stations and changes in local energy requirements.

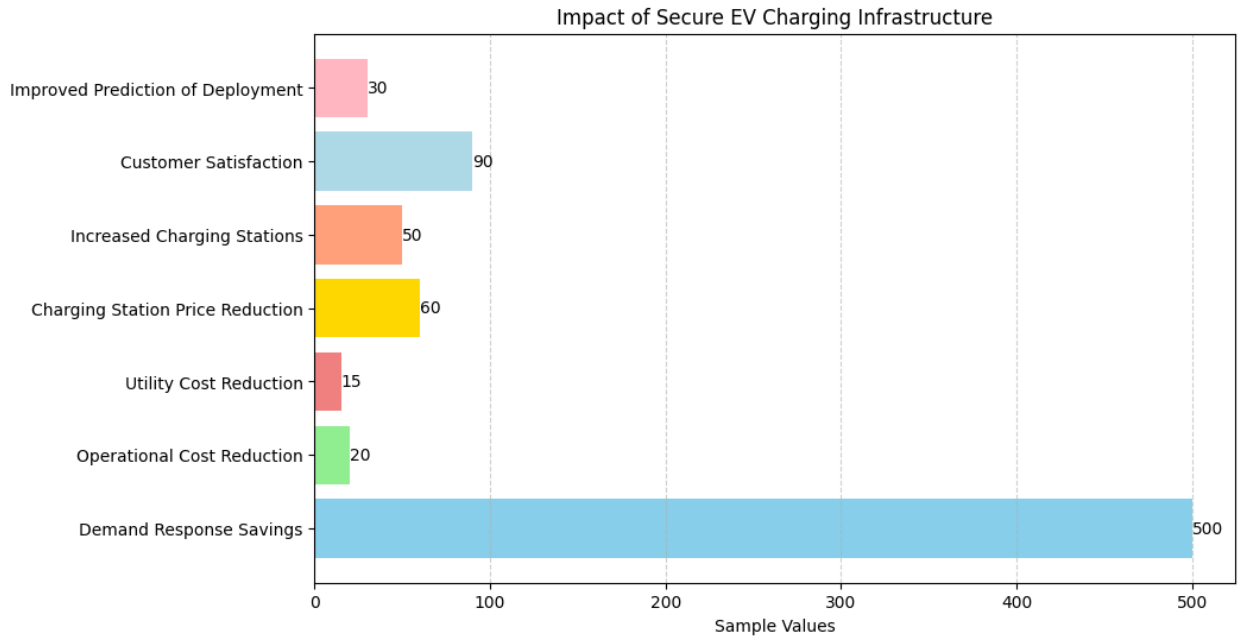

Figure 3. Impact of Secure EV Charging Infrastructure

VI. CONCLUSION

The operator is granted the ability to control and adjust the amount of power at the safe charging station. Even City & Highways might be responsible for the installation of charging stations. Therefore, this arrangement will be effective for the purpose of shielding the charging stations. The use of a charging station in a residential setting to make the process of charging faster and more secure, as well as to maintain a track record and reduce overall energy use. Additionally, it enables real-time management of a charging event, which serves the purpose of preventing unauthorised access to the charging station. In the context of physical activity, "clever charging" refers to a charging tool that is connected to a back-up provider and that enables monitoring, regulating, and restricting of the tool's use.

References:

[1] Smart Electric Vehicle Charging Management for Smart Cities Wiley www.researchgate.net/publication. March 2020.

[2] IoT enabled smart charging Station for electrical vehicle Akhila v1, Rajath S. Bhushan2, Raghotham C. International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007 Certified Impact Factor 7.105 Vol. 9, Issue 5, May 2022.

[3] Rita Gonçalves Ramada. “V2G - Modelo de simulação”. End Year Project at ISEL, 2019. B. D. Pitt and D. S. Kitschen, 1999. Application of data mining techniques to load profiling. IEEE International Conference on Power Industry Computer Applications Project at ISEL, 2019.

[4] S.Acharya, Y. Dvorkin and R. Karri, "Public Plug-in Electric Vehicles + Grid Data: Is a New Cyberattack Vector Viable?" IEEE, 2020.

[5] Shahriar Saadat, Samantha Maingot, Sahba Bahizad “Electric Vehicle Charging Station Security Enhancement Measures”, 2020 5th IEEE Workshop on the Electronic Grid (eGRID).

[6] D.Kettles, "Electric Vehicle Charging Technology Analysis and Standards", Florida Solar Energy Center, Florida, 2015.

[7] The working principle of an Arduino “Yusuf Abdullahi Badmasai” published in 2014 11th International Conference on Electronics, Computer and Computation (ICECCO).

[8] Elliman, R., Gould, C., & Al-Tai, M. (2015). Review of current and future electrical energy storage devices. 2015 50th International Universities Power Engineering Conference (UPEC). International Conference On Transportation Engineering (5th: 2015: Dalian, China). ICTE 2015: Proceedings of the Fifth International Conference on Transportation Engineering: September 26-27, 2015, Dalian, China.

[9] Leviton Evr-Green Electric Vehicle Charging Stations and Retrieved from http://www.leviton.com/OA_HTML/Section Display.jsp?section=37818 &minisite=10251

[10] Li, H., Sun, G. M., & Chu, Y. (2012). Design of Integrated Monitoring System for Electric Vehicle Charging Station Based on WebLogic. AMM, 241-244, 2004-2009.

[11] Marcincin, O., & Medvec, Z. (2015). Active charging stations for electric cars. 2015 16th International Scientific Conference on Electric Power Engineering (EPE).

[12] Khetani, V. ., Gandhi, Y. ., Bhattacharya, S. ., Ajani, S. N. ., & Limkar, S. . (2023). Cross-Domain Analysis of ML and DL: Evaluating their Impact in Diverse Domains. International Journal of Intelligent Systems and Applications in Engineering, 11(7s), 253–262.

[13] Deepak Mathur (2023). Emerging Trends in Electric Vehicle Technology: A Mechanical and Electrical Engineering Perspective. International Journal on Recent Technologies in Mechanical and Electrical Engineering, 10(2), 05–12.

[14] Sable, N. P., Shende, P., Wankhede, V. A., Wagh, K. S., Ramesh, J. V. N., & Chaudhary, S. (2023). DQSCTC: design of an efficient deep dyna-Q network for spinal cord tumour classification to identify cervical diseases. Soft Computing, 1-26.

[15] V. Khetani, Y. Gandhi and R. R. Patil, "A Study on Different Sign Language Recognition Techniques," 2021 International Conference on Computing, Communication and Green Engineering (CCGE), Pune, India, 2021, pp. 1-4, doi: 10.1109/CCGE50943.2021.9776399.

[16] R. Patil Rashmi, Y. Gandhi, V. Sarmalkar, P. Pund and V. Khetani, "RDPC: Secure Cloud Storage with Deduplication Technique," 2020 Fourth International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC), Palladam, India, 2020, pp. 1280-1283, doi: 10.1109/I-SMAC49090.2020.9243442.

[17] Kharate, N., Patil, S., Shelke, P., Shinde, G., Mahalle, P., Sable, N., & Chavhan, P. G. (2023). Unveiling the Resilience of Image Captioning Models and the Influence of Pre-trained Models on Deep Learning Performance. International Journal of Intelligent Systems and Applications in Engineering, 11(9s), 01-07.

[18] Ma, C., Rautiainen, J., Dahlhaus, D., Lakshman, A., Toebermann, J. C., & Braun, M. (2015). Online Optimal Charging Strategy for Electric Vehicles. Energy Procedia, 73, 173-181.

[19] Falk, R., & Fries, S. (2012). Electric Vehicle Charging Infrastructure Security Considerations and Approaches. Proc. of INTERNET, 58-64.
[20] Liu L, Kong F, Liu X, Peng Y, Wang Q (2015) A review on electric vehicles interacting with renewable energy in smart grid. Renew Sustain Energy Rev 51:648–661.
[21] Electric Vehicle Charging System Mr. Satish Kumar B, Aishwarya S, International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007 Certified Impact Factor 7.105 Vol. 9, Issue 5, May 2022.
[22] Wojciech Lubośny, Zbigniew Lubośny (2023). Advanced Materials for Energy Harvesting and Storage Applications. Acta Energetica, (02), 40–48.
[23] Almost all about Rus-Hicks-Rhoades maps in quasi-metric spaces. (2023). Advances in the Theory of Nonlinear Analysis and Its Application, 7(2), 455-472.