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# Blockchain Smart Contracts for EV Infrastructure Payment System- A Systematic Literature Review

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**Abstract**

The integration of electric vehicles (EVs) into the existing energy grid presents numerous challenges, including the efficient management of charging infrastructure and ensuring secure and transparent transactions. Blockchain technology has emerged as a promising solution to address these challenges by providing decentralized, tamper-resistant, and immutable transaction records. This paper presents a comprehensive review of the applications of blockchain using smart contract in EV charging infrastructure, highlighting its potential benefits, current implementations, and future research directions. The review encompasses various aspects, including billing and payments, data privacy and security. Through this review, we aim to provide insights into the potential of blockchain technology in revolutionizing the EV charging ecosystem.

***Keywords:*** *EV charging infrastructure, blockchain, distributed computing, smart contract security, shared charging.*

## 1. Introduction

Now a day's electric vehicles (EVs) are becoming more relevant in the transportation sector. EVs are considered to be the most encouraging to conventional fuel-based vehicles because of their effectiveness in reducing the dependency on fossil fuels and in reduction of greenhouse gas emissions and cost benefits [1]. However, there are certain challenges concerning the effective applications of electric vehicles such as cost of batteries, battery lifetime, efficient charging systems, slow charging mechanism, Tariff insecurity restricted energy density, weight, and reliability, which affect the performance of EVs and hence needs to be resolved [2], [3]. Among various problems, a lack of secure and efficient charging stations for EVs is constituted as a major problem [4].

### 1.1 Motivation

As compared to present EV infrastructure, new solution not require any central entities and completely automated, including the payment transactions for the units consumed by EV Vehicles. Also, it includes route, car battery charging status, traffic information real time and preferences by driver, on the route a car could request charging best price bids from various charging which will happen with the blockchain based smart contracts [5] used charging stations. Selection of EV charging is most appropriate one based on best offered prices, and other parameters such as, e.g. waiting times, estimated charging duration and alike. In this paper we focus on how the block chain smart contract useful in EV infrastructure and different application in EV.

### 1.2 Literature Review

As per "Electric vehicle charging infrastructure and its grid integration in India" report three discussed about business models for EV charging infrastructure, as of now across globe there are four EV charging infrastructure business model [6]

1) Ubitricity- This model required less space and easily integrated into the public or private places.

| | | |
|---|---|---|
| Country of Operation | | Germany, UK |
| Business Model | Who | It provides business-to-business (B2B) and business-to-customer (B2C) and public B2B and B2C charging solutions |
| | What | The customer is provided with a smart cable with built-in meter and the required connector type to connect the EV and a charging point. The company also provides space saving charger options along with software solutions. |
| | How | Ubitricity has partnerships with the power retailers as well as other EV charging providers for e-roaming via PlugSurfing. |
| | The Value | The Ubitricity business model is subscription-based where the price depends on the contract of the users with their energy provider and the energy consumption is logged by the smart cable. It also provides 'pay-as-you-go' billing for users without the smart cable. |

**Table – a**

2) Nuvve - It has feature of bi-directional power flow, grid to vehicle charging (G2V) and vehicle to Grid (V2G). Features are in table-b

| | | |
|---|---|---|
| Country of Operation | | USA, UK, Denmark, France |
| Business Model | Who | The company mainly provides to B2B market. |
| | What | The primary service provided by Nuvve is the provision of V2G capability to its users. It achieves this though its GIVeTM platform and its Powerport chargers. |
| | How | It has formed partnerships with different fleet operators, including electric bus users. |
| | The Value | The pricing is predominantly subscription based. |

**Table-b**

3) Tesla- Tesla model provided free use of supercharge model of 2017 vehicles. Features of business model as per table-c.

| Country of Operation | | Global |
|---|---|---|
| Business Model | Who | The company mainly provides to B2C market. |
| | What | The primary product of Tesla is its range of EV models. It has created the extensive charging network to cater to the charging needs of its EV users. Tesla also provides private charging solutions to its customers. |
| | How | It has formed partnerships with different businesses such as retail outlets, hotels, restaurants etc, to install chargers at their premises. |
| | The Value | The company provides 'Pay-as-you-go' billing based on the energy/time used for charging. However, the company also provides free charging as and when applicable. |

**Table- c**

4) Share & Charge - This model based blockchain and used for peer to peer charging. Features as per below table - d

| Country of Operation | | USA, UK, Denmark, France |
|---|---|---|
| Business Model | Who | The company mainly provides public B2B and B2C charging solutions. |
| | What | It uses blockchain technology to provide peer-to-peer matchmaking between charging service provider and EV users. |
| | How | It has formed partnerships with charging service providers and mobility service providers. |
| | The Value | The pricing is determined by the charging service provider selected by the user. |

**Table- d**

[7] "A Secure Charging Scheme for Electric Vehicles with Smart Communities in Energy Blockchain" by Su Z, Wang Y, Xu Q, Fei M, Tian Y and Zhang N paper propose a reputation based delegated Byzantine fault tolerance (DBFT) consensus algorithm for energy blockchain, and optimal contract design is proposed for secure EV charging in Smart Community.[8] "Blockchains and Smart Contracts for the Internet of Things" by KONSTANTINOS CHRISTIDIS, (Graduate Student Member, IEEE), AND MICHAEL DEVETSIKIOTIS, (Fellow, IEEE) proposed possible ways to overcome when block chain with smart contract on internet of things (IoT) used. [9] "Blockchain-Based Autonomous Selection of Electric Vehicle Charging Station" by Pustišek M, Kos A, Sedlar U, the paper proposed concept on autonomous blockchain-based negotiation for selecting the most preferable and suitable electric vehicle charging station.[10] "Energy Trading of Electric Vehicles using Blockchain and Smart Contracts" by Asfia U, Kamuni V, Sheikh A, Wagh S, Patel D, in this paper proposed to

implement security for charging services of electric vehicles with the execution of smart contracts by using the decentralized and authorized blockchain system.[11]

## 2. Overview of Blockchain Technology

Blockchain technology is a digital ledger that involves a chain of blocks, each containing transactions. It's essentially a decentralized and distributed database that allows multiple parties to have a synchronized copy of the data.

The key aspect of blockchain is its security, transparency, and immutability. The information in a blockchain is secured through cryptography, making it very difficult to alter or hack. Transactions or changes made on the blockchain are also transparent, meaning that anyone can see them, although the identities of parties involved may remain anonymous.

Blockchain technology has various applications, ranging from finance to supply chain management, digital identity verification, voting systems, and much more. It offers a secure and efficient way to execute transactions and maintain records that cannot be tampered with easily.

## 3. Smart contract and how it works

Smart contracts are set of programs on an Ethereum blockchain which is formulated by bookkeeper of the transactions and that executes when predetermined terms and conditions are met. Smart contracts written using Ethereum with solidity, and Hyperledger Fabric's chain code.

Working of Smart contracts with Simple predefined phrases that are typed into code and placed on a blockchain.[12] When predefined circumstances have been verified to have been met, a network of computers will carry out the actions. These actions allow to paying out money to the right people, registering a car, sending out notices. When the transaction is finished, the blockchain is then updated. Final result the transaction cannot be altered, and only authorized parties has been granted can view the outcome. The main objective of the smart contracts is to satisfy common mutually agreed contractual terms.

As many conditions as are required to reassure the participants that the activity will be successfully accomplished can be included in a smart contract. Participants must agree on the phrases rules that govern how transactions and their data are displayed on the blockchain in order to set the terms.

## 4. Description

With the help of Block-chain Smart contracts can address trust issues related to payment, billing, and energy records in the EV infrastructure business model. Here's how it can be implemented:

1. Automated and Transparency in Payments: Smart contracts facilitates automated and transparency in payment processes. They programmed to execute payments automatically once the EV vehicle charging time is completed, it also eliminating the need for manual invoicing and reducing the chances of errors, malpractice, lowering fraud loss, any other hidden cost.

2. Immutable stored Energy Records: Blockchain technology provides an immutable and tamper-proof record of charging electricity transactions. Also, blockchain stores the EV Energy consumption data from EV charging stations, which ensures transparency and trust in the accuracy of energy records.

3. Decentralized Billing and Settlement: With blockchain, the billing process can be decentralized, removing the need for a central entity to handle billing and settlements. Smart contracts can automatically calculate and distribute payments to the respective parties involved, such as charging station owners, grid operators, and energy suppliers.

4. Enhanced Security and Authentication: Blockchain's cryptographic features provide a secure framework for authentication and verification. Smart contracts can ensure that only authorized vehicles and charging stations interact with each other, preventing fraudulent activities and establishing trust in the system.

5. Interoperability and Standardization: Blockchain technology can facilitate interoperability and standardization among different EV charging networks and service providers. By utilizing a common blockchain protocol or adopting industry standards, EV users can experience a seamless charging experience regardless of the charging network they use.

6. Privacy and Data Protection: Blockchain can offer privacy features that allow for secure storage and sharing of data while maintaining the confidentiality of sensitive information. Users can have control over their data and decide how it is shared, ensuring trust in data protection.

Implementing blockchain smart contracts in EV infrastructure can build the trust among EV user, land user, EV operator, and makes streamline payment processes, prevent billing disagreements, and transparent to all stakeholders and efficient charging ecosystem. Although, it's important to keep in mind that the electricity consumption and EV charging infrastructure scalability, and regulatory compliance when implementing blockchain solutions.

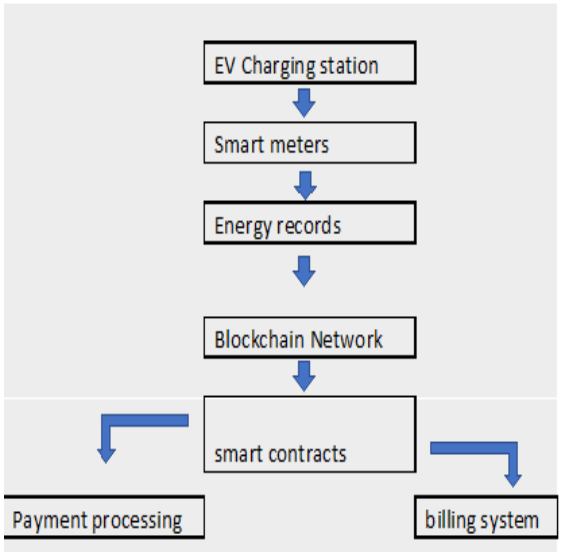


**Fig 1**

### 4.1 Architecture flow

Here's how the architecture flow works Fig1:

1. Charging Station: charging station means Electric vehicles are connected to charging piles to charge their batteries.

2. Smart Meter: A smart meter is used to record accurately energy consumption and track as per charging time.

3. Energy Records: The energy consumption records from the smart meter are securely stored on the blockchain network, providing transparent access and an immutable history of energy consumption.

4. Blockchain Network: The blockchain network serves as a decentralized ledger that validates and stores the energy records securely. It also ensures trust among participants and data integrity.

5. Smart Contracts: Smart contracts are set of programs on an Ethereum blockchain which is formulated by bookkeeper of the transactions and that executes when predetermined terms and conditions are met. They facilitate payment processing and billing based on predefined rules and conditions. These contracts execute automatically calculate the charging cost, verify payment transactions, and ensure accurate settlements.

6. Payment Processing: Smart contracts initiate payment processing once a charging session is complete. They automatically trigger the payment transaction from the EV owner to the charging station or other relevant parties.

7. Billing System: The billing system retrieves the energy records from the blockchain network and generates transparent and accurate invoices for EV owners. The system can provide detailed information about the charging session, cost breakdown, and other relevant billing details.

## 5. Conclusion and Future work

The speed at which the Electrical vehicle market exponential growth, we should be ready to address the problem of security and trust issues between the stakeholders involved into this sector.

In this paper we have discussed and proposed the blockchain smart contract based secure EV charging infrastructure system. Blockchain Smart contracts is powerful tool for future and which allow any sector to automate by self-executing agreements of multi-step processes.

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