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Advancements in electric vehicle safety and charging infrastructure

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ABSTRACT

In electric vehicles (EVs), safety measures must be taken to prevent dangerous accidents. Safety regulations must be in place for two important things: electric or EV batteries and EV equipment. Operating an electric vehicle charging stations (EVCS) is a challenging task. This holistic approach is used to evaluate when renewable energy is produced. It's best to focus on the popularity of EVs as more and more people choose this mode of transportation. It is important to know that power plants can be risky. Therefore, safety issues related to EV charging must be addressed quickly and appropriately. Potential safety issues with EVs include overcurrent, ground faults, and overheating. If the charging system does not work, the electric car's battery may heat up and catch fire, and overcharging may cause other problems. To avoid security risks, you must comply with security regulations, use payment devices that meet security requirements, and follow the manufacturer's instructions.

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1. INTRODUCTION

In today's time, the electric vehicle (EV) evokes thoughts of sustainability, innovation, and the future of transportation. Organizations help to set ambitious goals to integrate EVs into daily energy projects to create and operate a clean, energy-efficient environment [1]. Now that the prices of electric cars have fallen, their use has increased, and many electric vehicle charging stations (EVCS) have been built. The main concepts discussed and summarized in the policy and research group, where the Policy and Research Group examines electrical safety issues related to EVs from the perspective of EVCS employees. Fire safety in EVs needs to be considered, and this article discusses safety aspects related to the EV charging process that are directly related to the electric current value. This revised communication framework is used to demonstrate the application of communication technology [2].

About communication-assisted protection technology that can reduce errors and ensure the security of electronic payments. Cloud-based online EVCS data monitoring, analysis, and energy quality measurement are discussed. In summary, the evidence shows what needs to be done to ensure the electronic security of EVCS. This means complying with legislation, carrying out routine inspections, considering fire safety, reviewing the lifespan of transformers, embracing renewable energy sources, and using state-of-the-art communication tools [3]. According to the information provided, many EVCS have a charging capacity between 5 and 25 kW, while some have a charging capacity of up to 60 kW. Although it is known that there is still more capable electric vehicle supply equipments (EVSEs) (electric trucks) with a capacity of over 60 kW, they use less but also have increasingly powerful batteries, due to the high-cost problem, especially without electric cars, prices are higher at peak times [4].

Provide EV payment services. Control center monitors and control all functions of EVCS. Two directional DC/DC converters are needed to manage active power [5]. The architecture is flexible, especially when DC power is used to charge EVs. DC/DC converters with joint summing and parallel operation. Although many EVSEs now have separate AC/DC converters independently connected to the AC bus, the proposed architecture allows EVSE to operate an AC/DC it shows that you can share a converter. DC bus bar, many connected DC/DC converters are needed to charge EVs using DC power. In summary, the document provides detailed information on the architecture and decision-making process of the EVCS system, addressing the need for a cyber-physical system architecture with effective tools for management, communication, and payment [6].

EVCS has three main components: security aspects, risk assessment, and risk management. For safety reasons, electrical safety says that dangerous electricity should not be associated with facilities. This should be taken into consideration, especially in public, as it can be dangerous. Companies must protect customers from the electrical current coming from the charger during the charging process. This protection is provided in layers, namely basic protection and protection against errors [7]. In addition to the safe communication process of EVs and EV electrical equipment, EV supply equipment, IEC also offers many types of EV charging. Type 3 and 4, charging type 3 is the name of the AC charging mode. Large EVCS that require DC charging speed are recommended to use type 4 charging. Protection and control operation, charging modes 3 and 4 permanently established control and protection operation. The regulatory body must monitor the reliability of electrical safety for EVSE products [8]. Continuous safety is required to evaluate the reliability of the electrical safety protection of EVSE products. Functionality of security features. Defining factors that can cause security failures include aging processes, other environmental factors, and potential hazards such as copper theft [9]. Let's assume the total capacity of EVCS is 1 MW and the total charging capacity of EV supply equipment is 20 kW. This section presents a comparison of EVCS performance with risk assessment. Mention the following four EVCS cases: uncoordinated payment and lack of communication. Smart payment using public communications but not supporting electricity. Smart payment and operation according to distributed energy resources (DER). Using separate electronic equipment advanced metering infrastructure (AMI) and servers to send the signal [10]. Symbols which are used in equations. A large EVCS may encounter a variety of electrical hazards that cause electrical hazards. Electrical accidents fall into the following categories EV users suffer electric shock and workers are exposed to lightning flash and electric shock effects. Electricity from an EV can cause personal injuries. Things to remember, the power category of the charger (such as a class II charger with an isolation transformer) has a large impact on the risk of electric shock during charging [11]. We use a range of risk assessment methods to focus on the potential harm to the health of Se and such events occurring in EVCS.

As shown in Table 1, we consider the EVCS in case 1 to have Se(i) and Po(i) values. All cases in the study had similar Se. When the risk scores I for each hazard sums to 138, Rt equals 138. The probability of a hazardous event occurring (Pr), the number of times of exposure, and the probability of preventing or reducing health damage (Av) are all-encompassing outcomes. When comparing EVCS consumers and producers, Fr and Av values are also compared in each case. In EVCS, Pr decreases with the improvement in network structure [12]. We predict that the Pr values for the three hazard groups will decrease to 2, 2, and 1 in cases 2 and 3, respectively. To extend the network security and reliability, the EVCS in case 4 will reduce the Pr value to 1. Figure 1 shows the charging components for an EV.

Since EVCS in the four tests share the same physical layer, case 1 EVCS has a lower network layer investment cost and “lower” Cu. In cases 2 and 3, the Cu value of EVCS using public communication is “Medium” [13]. The Cu cost of EVCS with discrete communications is "extremely high" considering the additional costs associated with communications. However, in case 1, EVCS will not be able to manage oversubscribed EV supply equipment, and changes to transmission lines and utilities will be required, increasing operating costs. Therefore, the Cu value of file 1 can be increased. If utilities create AMI with independent communications to upgrade new networks, the benefits of EVCS using independent communications will be diminished. For case 4, the EVCS separate communications system will require additional funding, but the utility provider will prefer it. In (1), the risk score is a product of the occurrence of damage and severity. In (2), the total risk score is the sum of the risk scores. In (3), Cu shows the circle of the EVCS.

Enlarging EVs on the roads every year is crucial to get in the future. But this also increases the risk of EV charging stations becoming dangerous. The demand for power stations is due to concerns about the risk of fire and electric shock. Electric stations have different security features. Stage 1 charges only a 120-volt AC outlet, requires no additional equipment, and takes overnight to fully charge the vehicle [14]. Level 2 charging, on the other hand, is usually available at public charging stations and requires a 240-volt

AC outlet. It takes about an hour for the car to fully charge. DC fast charging: charge the battery to 80% in less than an hour, but requires a major electrical connection and specialized equipment [15].

$$R = Po \times Se \tag{1}$$

$$Rt = \Sigma R \tag{2}$$

$$Cu = (Operational\ cost + Capital\ cost) \div Rated\ Capacity \tag{3}$$

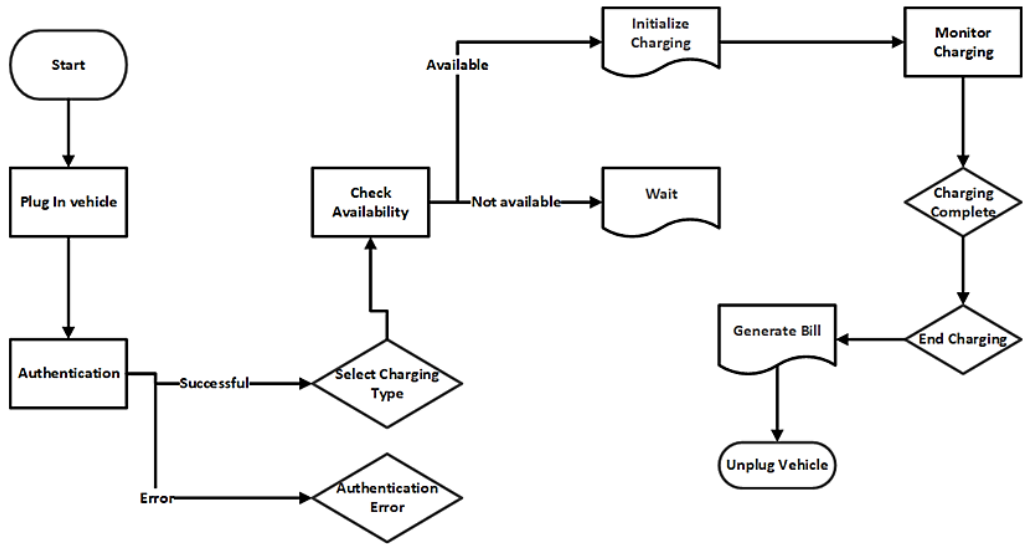

Figure 1. The working flowchart of EV charging

2. PROPOSED METHODOLOGY

The charging capacity of EVCS is hardly impacted by EV users. We would like to highlight that, by IEEE 1547-2018 grid specification, EVCS is the DER of the grid in cases 3 and 4 [16]. EVCS functions by level III DER standards under abnormal conditions in the EPS area. The dead center frequency is 0.2 Hz [17]. Assumed to have three identical EVCS with a nominal power of one MW is node 635. The total capacity of EVCS is about 3 MW. Furthermore, at the 635 MW node is a 4 MW photovoltaic system featuring a maximum power point detection mechanism and a power factor of 1 [18]. The EVCS field is shown as DER in MATLAB/Simulation software, which is also used for electromagnetic transient (EMT) simulations. 2.5×10×7 s was the sample rate [19]. This can be avoided by maintaining the power for an extended period. The EVCS in case 3 is vulnerable to malfunctions and communication failures since it chooses the control and monitoring center through open communication [20]. The EVCS predicts the oscillation event time greater than 0.2 seconds for the grid frequency approaches the 59.8 Hz dead center [21]. In situations 3 and 4, the degree of EVCS support for other models rises in tandem with the number of EVCS [22]. Also, when renewable energy sources like sun and wind are plentiful, the system performs admirably [23]. The public cloud controls the EV transmission in case 3, but this also affects the communication delay and error due to the EVCS support frequency [24]. The risks associated with sexual activity. Since EVCS guards the network when there are no cyber threats, it has an "average" Sr value in case 3. The EVCS for case 4 has a "low" Sr value since cyber-attacks are uncommon [25].

The steps involved in charging an electric car can be seen in the EV charging flowchart in Figure 1. Authentication and plug connection come first, then initialization and charging parameter configuration. The charging station monitors and regulates voltage and current along with regulating power flow.

In Table 1, three primary requirements are used to evaluate each danger category: the resulting risk score, probability (likely), and severity (effect). Higher numbers denote more severe impacts. Severity evaluates the potential results or level of harm a hazard could produce. Higher numbers indicate a greater risk of the hazard occurring. Probability evaluates the likelihood of the hazard occurring. Next, the risk score is computed by multiplying the probability by the severity, yielding a numerical result that expresses the total risk connected to every hazard.

Table 1. Risk score

Hazard category	Severity	Probability	Risk score
1	5	9	45
2	7	9	63
3	6	5	30

If already own an EV or want to buy one soon, you should be aware of the various payment algorithms. The electric car has made great progress in recent years. The use of electric buses in transportation systems is gaining major attention due to their low release and sustainable qualities; yet, the issue of how to recharge them over extended periods of continuous operation remains unanswered [26]. The US Environmental Protection Agency reports that the current average EV range is 234 miles [27]. In other words, the average electric car can travel more than 200 miles before needing to be recharged. However, electric cars use different charging strategies. The charging algorithm creates a charging system for EVs [28]. The same value of current and voltage algorithms is both the most commonly used charging algorithms for EVs. Fixed payments, as the name suggests, use constant current [29]. At the same time, EVs continue to be available. The current does not change when the electric car is charged [30], [31]. The process of charging an EV with a steady current is shown in Figure 2. It simulates how the constant flow of electrical current occurs during the charging process. Using simulation, scientists can examine how the charging system behaves and makes safety and efficiency improvements.

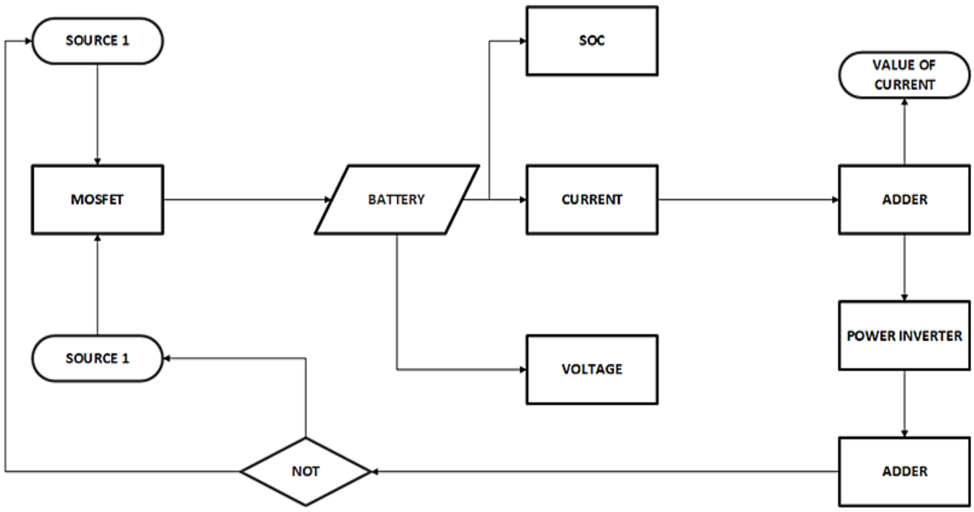

Figure 2. The simulation of EV charging through constant current

3. RESULT AND DISCUSSION

It is important to remember that an EVCS consists of many parts. These items include chargers, connectors, and cables. The only thing connecting the EVCS is to power the cables. Therefore, it is important to ensure that it does not get damaged. Paying sites should have at least one or two links of each type. Connectors are important as they are used to connect cables and they can come in different types to ensure everyone can use them. The safety of power plants is of great importance and many precautions are taken to ensure their safe operation [32], [33]. This section covers four main safety features, including communication safety, temperature protection, over-current protection, and ground protection. Over-current protection is an important safety feature designed to check extra or overflow current flows into the circuit. Therefore, damage to EVs, charging stations, and electronic equipment is minimal. Preventing ground fault is the main element in controlling current leakage to the ground during payment. This is very important to prevent electric shock. A charging station's ground fault circuit interrupter (GFCI) can immediately stop charging if a leak is detected. The thermistor is an important safety measure to prevent your device from overheating while charging. The charging station is equipped with sensors that monitor the temperature of the charging cable and other necessary components. If hazardous temperatures are found, charging should be stopped or slowed down to reduce the risk of fire. The communication protocol facilitates the exchange of information between EVs and charging stations. This process allows the payment center to communicate with the vehicle management system to manage the payment process and make necessary changes. For example, in case of a security problem, the payment center may freeze or stop the payment process. First and foremost, make sure the toll booths are set up correctly to keep everyone safe. EVCS that are not properly installed or maintained can put others at risk, so they must be designed and maintained correctly.

Figure 3 displays the results or output of the simulation. It shows various parameters related to the charging process, such as the battery's state of charge over time, the voltage and current levels during charging, or any other relevant data. In Figures 4 and 5 there are both graphs one is current vs DC voltage and the other one is voltage vs current in which we can see the variation due to different values. Figure 4 illustrates the relationship between the DC voltage and the current in an EV. As the voltage increases, the current typically rises as well, representing the power being drawn from the charging source to charge the EV battery. Figure 5 shows the graph between voltage and current, and also specifies the increasing voltage with an increase in current.

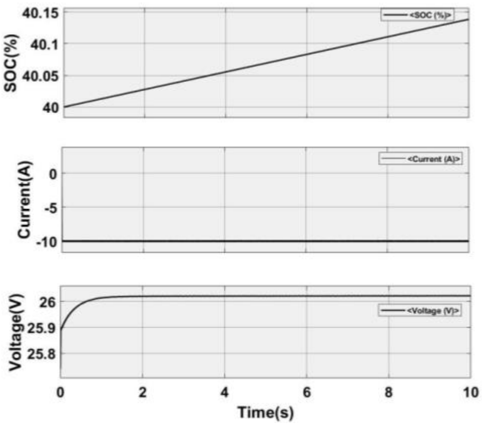

Figure 3. Change in Li-Ion battery, current, and voltage

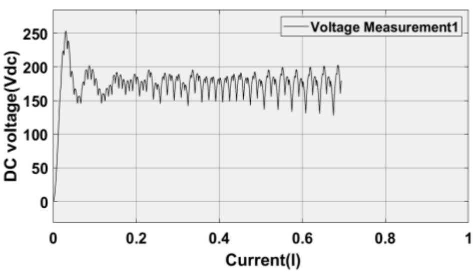

Figure 4. Graph between DC voltage and current

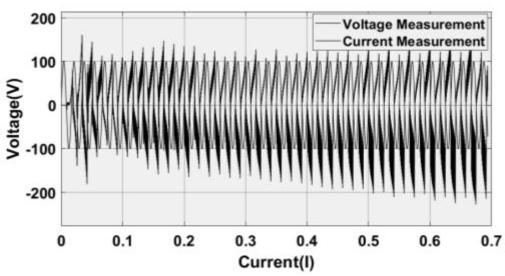

Figure 5. Voltage vs current graph

4. CONCLUSION

A comprehensive plan covering infrastructure investment, safety, and communication is required to integrate EVCSs into energy and transportation infrastructures. It is crucial to ensure electrical safety and reduce the risk of fire, particularly in public areas. This calls for compliance with laws and routine inspections. Sophisticated payment technologies and cloud-based data monitoring are effective communication systems that improve security and operational efficiency. The charging capacity of EVCS varies; the majority range from 5 to 25 kW, although some can reach up to 60 kW. This means that EVCS require a substantial infrastructure investment, especially for heavy-duty cars. To identify possible risks and put preventative measures in place, a thorough risk assessment and management process is essential. Various demands are met by different charge levels (level 1, level 2, and DC rapid charging), each with its electrical requirements and charging durations.

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AUTHOR CONTRIBUTIONS STATEMENT

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors state no conflict of interest.

ETHICAL APPROVAL

This article does not contain any studies with human participants or animals performed by any of the authors.

DATA AVAILABILITY

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable requests.

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