

Cybersecurity enabled electric vehicle charging and battery management system

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Abstract

Electric vehicles (EVs), which are become easier to get, are displacing conventional gasoline-powered cars. Because of this, there is a great demand for electric vehicle charging systems (EVCS), which has led to a major expansion of the public and private EVCS infrastructure. The threats related to cybersecurity have significantly increased as a result of the EVCS's growing network. In this light, this article offers an examination of the cybersecurity threats associated with the network of EVCS. First, recent trends in EV adoption, charging use cases, and the most recent advancements in the EVCS network give context for the research subject. Second, while describing cybersecurity features of EVCS, possible cyberattack scenarios as well as vulnerabilities centered on infrastructure and protocols have been taken into account. Thirdly, risks in EVCS have been confirmed through real-time data-centric analysis of EVs.

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1. Introduction

EVs are the mode of transportation of the future. Compared to traditional automobiles, electric vehicles (EVs) emit fewer pollutants into the air and have gained popularity in recent times [1-2]. Given the growing EV market and the declining cost of fossil fuels, it is imperative to develop more efficient EVs. Batteries are the primary source of storage in an EV. A BMS is an essential part of any EV. As a result, an EV's driving mileage after a single charging technique depends entirely on the battery's SOC (%) [3]. Regarding a battery When an EV is present, It typically comprises

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of more than 1,000 parallel cells that are gathered to provide the necessary voltage and capacity for an electric vehicle. It is made up of different circuits for converters and inverters, among other things, that are designed to keep an eye on and improve a battery system [4-7]. The battery's performance is impacted by the chemical processes. Like chemicals, battery performance declines over time. Thus, it's critical to always be aware of these battery features. An electric vehicle's (EV) battery powers the vehicle's motor as well as its auxiliary features, such as air conditioning (AC). Electric vehicles have more advantages than traditional cars. Due to features like excellent energy efficiency and zero air pollution emissions, they are becoming more and more popular in today's vehicles [8]. Because of this, a plethora of services have emerged in recent years to ensure driving safety and track battery energy information for users (such as energy capacity and battery energy usage). The study of BMS has become increasingly important since batteries play a significant part in battery storage modeling [9-10]. Lithium-ion batteries are primarily utilized in electric vehicle applications due to its longer battery life cycle and higher energy density. The electrons have a conducting medium thanks to the lithium-ion battery. Lithium batteries are effective for EV applications because they are portable and lightweight [11].

2. Fast Charging Technologies

There are several methods for charging the electric vehicle's battery pack. Having to select between many connector kinds and charging speeds can be a little daunting at first.

Managed Charge (Trickle): The most inefficient way to charge an electric vehicle at home is with a standard 220V, three-prong outlet. It is suggested only in extreme circumstances, cautiously, and following consultation with the electricity companies.

Charge of AC: Installing a wall box can increase the charging speed of AC home charging by three to four times. Additionally, public AC charging is available.

Charge of DC: An electric vehicle (EV) can be charged rapidly at a public DC fast charging station, which typically requires a minimum power output of 50 kW. With this method, it's possible to charge your battery from 20% to 80% in approximately 40 minutes. Moreover, there are now ultra-fast charging stations available that can deliver over 150 kW of power.

Electric vehicle supply equipment is what charging stations are commonly referred to as, while other terms like “charging station,” “charging outlet,” “charging plug,” “charging port,” “charger,” and “EVSE” are also commonly used to describe them.

Option 1: Charging at home

Currently, the vast majority of electric vehicles (around 80%) are charged at home. This is largely because many EV owners find it convenient to plug in their vehicles at the end of the day, allowing the batteries to charge fully while they sleep. By morning, the car is ready with enough range to meet most people’s daily driving needs, such as commuting or running errands.

There are two main types of home charging options available. The first is AC home charging, which involves installing a dedicated wallbox. This option provides a faster and more efficient charging process, making it ideal for regular use. The second option is trickle charging, which uses the standard household electrical outlet. While slower, trickle charging can be sufficient for those who have lighter daily driving demands or for topping off the battery. Both methods offer the convenience of charging at home, ensuring that your EV is always ready for the road.

Charging with wall box for AC household

The most common and recommended method for home charging uses a 230V outlet, enabling charging that can be up to four times faster than trickle charging, depending on the charger and the specific acceptance rate of your EV model. Installing a certain EV charging wallbox is necessary, and an experienced electrician should do it. If you need to travel farther, these stations, which are becoming more and more handy due to the network’s ongoing expansion and are commonly located across urban centers in particular, enable us to recharge our batteries while we are on the go. Public charging provides air conditioning. DC Fast Charging or using a wallbox for charging are the most common methods.

AC Quick Chargers: As of right now, the quickest way to charge an electric car can produce at least 50kW of charging power at 450V of voltage and up to 125A of current. It can charge from 20 to 80% of its initial battery in roughly 40 minutes.

AC versus DC charging: Instead of using AC power to charge their battery pack, electric cars use DC, which is supplied by the national grid.

In order to charge the battery of an electric car, the onboard charger transfers power from an AC charger to DC.

3. Management System for Batteries

To ensure the safety of electric vehicles, a Battery Management System (BMS) is crucial. This system regulates the electronics of a rechargeable battery, whether it's a single cell or a complete battery pack. By maintaining the cell's operation within safe parameters, the BMS safeguards both the battery and the user. The Battery Management System (BMS) plays a critical role in managing and safeguarding the performance of a battery. It gathers and analyzes data to monitor the overall health of the battery, including factors such as temperature, voltage, and current. By carefully regulating these external factors that can influence the cells, the BMS ensures that the battery operates efficiently and safely. One of its key functions is to balance the cells, maintaining a consistent voltage across the entire battery pack, which is essential for optimal performance and longevity.

Figure 1 shows a typical BMS architecture, highlighting its components and how they interact to protect and manage the battery. When a BMS is integrated with a data bus or an external communication system, it creates what is known as a smart battery pack. This smart battery pack not only controls the internal parameters of the battery but also allows for external communication, enabling real-time monitoring and management, which is particularly useful in advanced applications like electric vehicles. In addition to safety circuitry, it might contain other features and capabilities such as smart bus communication protocols and fuel gauge integration, GPIO possibilities, cell balancing, wireless charging, and embedded battery chargers to offer information about the battery's power level. The gadget can make intelligent use of this data to save electricity.

Optimum Use of Energy: With the help of BM technologies, the battery can age more slowly without experiencing harm while still remaining reliable and safe. A variety of techniques are used to monitor the battery's status, current, voltage, and outside temperature. To regulate and track the battery pack's charging, the BMS interfaces with the onboard charger. It also extends range by making the most of the energy that is stored in the vehicle. To avoid overcharging or over-discharging, which could damage the battery or the occupants, EV batteries need to be closely supervised.

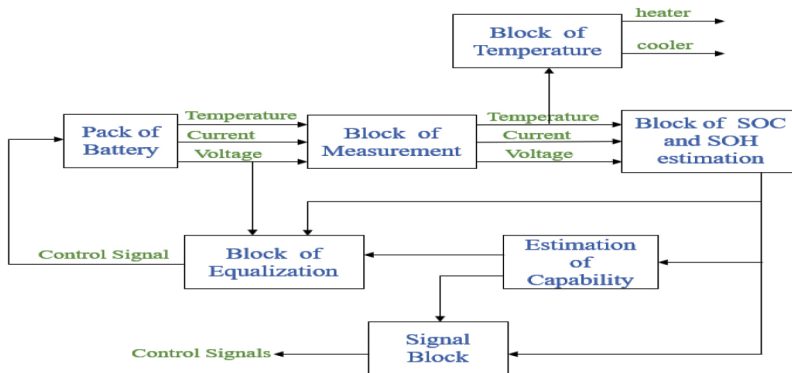


Figure 1
A Typical BMS Architecture

An EV's safety may be increased by installing a BMS. The section below provides a description of the tasks performed by the BMS. An essential component of an electric car, which advances the cause of ecologically friendly transportation, is the battery. The BMS is an essential component of both hybrid and electric automobiles. Its main goal is to provide secure and dependable battery functioning. As a provider of engineering services, Cyient collaborates closely with industry experts in our megatrend target areas of sustainable energy and electrification.

4. Control Algorithms

By injecting or absorbing the filter current through an active power filter that is in phase opposition with the harmonic components, the fundamental source current is produced. The control algorithms PSO-MPPT for photovoltaic panels and RLS and ALMS algorithms for multi-level voltage source converters (VSC) increase efficiency and reliability.

Particle swarm optimization (PSO) MPPT technique: By adjusting the PV panels' voltage and current values at various intervals of time, the PSO-MPPT algorithm maximizes the power that can be extracted from them. By accelerating the tracking, the PSO-MPPT is utilized to identify the best solutions. In Figure 4, the PSO-MPPT approach is displayed.

RLS Algorithm:

Recursive least mean square (RLS) is a method that lowers the system's total harmonic distortion (THD) level and makes up for reactive

power. There is no current flowing through the multi-level inverter when the load is balanced and the source and load active powers are equal. When there is an imbalanced load, the DC capacitor voltage causes the power difference between the source and load currents. As shown in Figure 5, the RLS algorithm regulates the voltage source converter (VSC) component to keep the DC capacitor voltage steady. The instantaneous current for each phase is given as

$$I_{ix}(ti) = I_{aix}(ti) + I_{nix}(ti) \quad (1)$$

Where $I_{ax}(t)$ Is the active current given as

$$I_{aix}(ti) = A_x V_{ix}(ti) \quad (2)$$

The active parameter is given as

$$A_{ix} = A_{aix} + A_{dc} \quad (3)$$

Where A_{dc} is given as

$$A_{dc} = P_{dc}(i) / V_{ix}^2 \quad (4)$$

$$P_{dc}(i) = [(V_{rf} + V(i))^2 - V_{rf}^2] * C / 2 \quad (5)$$

Adaline least mean square algorithm (ALMS):

The Adaline and LMS algorithms were combined to create the suggested ALMS algorithm that is depicted in Fig. 2. The LMS method is used to update the weights in Adaline. The multi-level inverter's reference current components are computed using the suggested algorithm, and the fixed step-size parameter determines the convergence rate. For a single phase x at time t , the weight equation for the active and reactive components is as follows:

$$w_{Ax}(k+1) = w_{Ax}(t) + \mu e_{Ax}(t) u_{Ax}(t) \quad (6)$$

$$e_x(t) = \{i_x(k) - i_A^* X^*\} \quad (7)$$

$$w_{Qx}(k+1) = w_{Qx}(t) + \mu e_{Qx}(t) u_{Qx}(t) \quad (8)$$

$$e_Q(t) = \{i_x(k) - i_Q^* X^*\} \quad (9)$$

Where $e_x(ti)$, is the error output of the reference current and load at phase x. and (μ_i) is the convergence factor which varies between 0.01 to 1.0. It is taken as 0.2 for the proposed multilevel ALMS system.

PI controller for active and reactive components is given as

$$w_{lA}(ti) = w_{lA}(k-1) + k_{pA}\{v_{eA}(ti) - v_{eA}(k-1)\} + k_{iA} v_{eA}(ti) \quad (10)$$

Where
$$v_{eA}(ti) = v_{refA}^*(t) - v_{DA}(ti) \quad (11)$$

$$w_{lQ}(ti) = w_{lQ}(k-1) + k_{pQ}\{v_{eQ}(ti) - v_{eQ}(k-1)\} + k_{iQ} v_{eQ}(ti) \quad (12)$$

Where
$$v_{eQ}(ti) = v_{refQ}^*(ti) - v_{DQ}(ti) \quad (13)$$

The reference currents for active and reactive components for phase 'x' are estimated as

$$i_x A^* = w_x A(ti) u_x A(ti) \quad (14)$$

$$i_x Q^* = w_x Q(ti) u_x Q(ti) \quad (15)$$

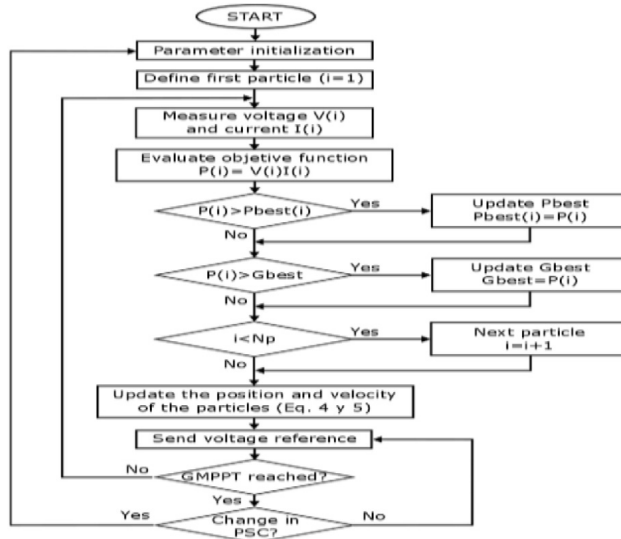


Figure 2

Particle swarm optimization MPPT technique

5. MATLAB Simulation Study

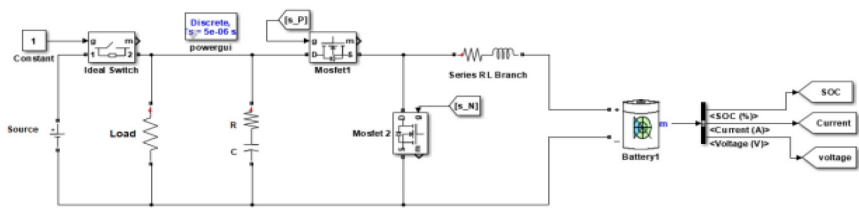


Figure 3
MATLAB Simulink model for charging system

AC Charging System: This is the most popular sort of charging system that can charge a vehicle using slow and moderate AC charging. Rectifiers are used to change AC power into DC electricity.

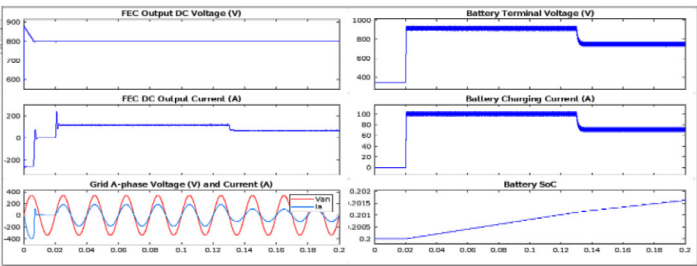


Figure 4
Voltage, Current and Battery SOC plot for the EV Charging station

The voltage and current plots for the battery terminals and charger output are displayed in Figures 3 and 4. Variations in battery state of

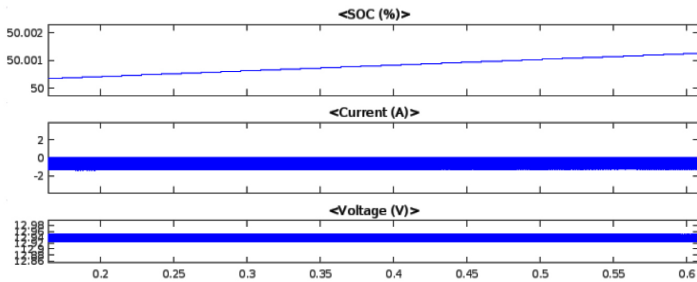


Figure 5
Voltage, Current and Battery SOC plot for the EV Charging station

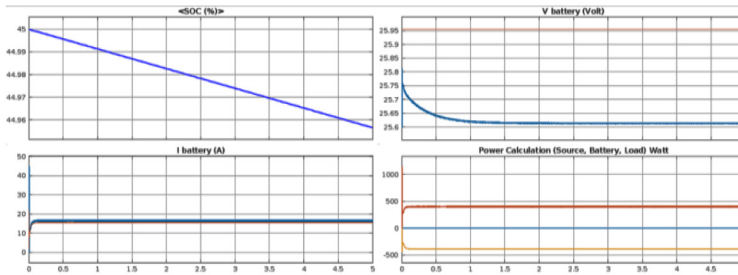


Figure 6

Voltage, Current and Battery SOC plot as well as Power for the EV Charging station

charge are also shown here. A rising SOC (%) indicates that more energy is produced from renewable sources than is needed to charge EVs.

The voltage, current, and battery SOC (%) variation plot are displayed in Figure 5. A rising SOC (%) indicates that more energy is produced from renewable sources than is needed to charge EVs. Figure 6 displays the power calculation for the battery bank along with the voltage, current, and battery SOC (%) variation plot. A declining SOC (%) indicates that less energy is produced from renewable sources than is needed to charge EVs. Optimizing Batteries In order to preserve the equilibrium of “the pack,” systems actively transfer energy across batteries, increasing the batteries’ robustness and longevity. When necessary, B.O.S. moves energy transfer between series-connected batteries to maintain a constant voltage before, during, and after charging.

6. Conclusion

One of the best weapons in the fight against global warming is electric transportation. Rechargeable battery packs are necessary for electric vehicles to live up to consumer expectations and lessen range anxiety. Determining the battery’s functional grade as a hologram primarily depends on battery modeling in EV applications, which involves evaluations of battery states and attributes. A suitable battery charging plan can be created to prevent damage to the battery, increase energy conversion effectiveness, and extend its usable life once certain crucial battery states have been identified. However, the majority of the BMS’s fundamental technologies are only created and tested in regulated settings. Accurate modeling, estimate, and performance under optimal and unfavorable conditions provide special problems for real-world charging

applications. We will talk about the benefits of a electric car battery management system in this essay. Charging techniques have been covered.

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