

# Three Level Electric Vehicle Charger Control Algorithm

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**Abstract** Electric vehicles (EVs) could be used to address the issues of environmental pollution and the depletion of non-renewable energy resources. EV chargers play a significant role in the expansion of EVs. order to successfully launch Electric vehicles (EVs) over the actual world, EVs battery chargers have a crucial role to predict the charging time. This work presents the design process of a universal EV charger, The proposed charger is able of providing a controllable and constant charging voltage for a various EVs, which is composed of three levels of charging, 650 V/100 A DC for bus or lorry The input current of an EV charger with a high total harmonic distortion (THD) and a high ripple distortion of the output voltage can impact battery life and battery charging time. Furthermore, the high cost and large size of the chargers are considered other issues in EV development. This work presents the complete design process of a ANN controlled universal EV charger with a special focus on its control algorithms. In this regard, a novel control algorithm based on the integration of voltage-oriented control (VOC) and the sinusoidal pulse-width modulation (SPWM) technique is proposed to ensure effective Levels 3 battery charging. A simulation of the universal EV charger was conducted and assessed in MATLAB–Simulink.

**Keywords:** EV, VOC, THD, SOC, ANN, EV battery

## 1. INTRODUCTION

Since the start of the twenty-first century, the number of electric cars (EVs) has been gradually increasing [1]. However, the technology's use is hampered by the battery's charging constraints [2] and its lack of control [3]. The immediate impact is that power cords and charges are a part of daily life, which tends to limit the amount of mobility that vehicles can provide. [4]. There has been a lot of study put into finding solutions to these issues, additionally, EV wireless power transfer (WPT) has emerged as a viable option [5]WPT devices with high strength, time-varying electromagnetic fields were first introduced many years ago. However, the WPT was not particularly necessary at that time as a result of cable electricity delivery networks were usually more economical and efficient for power equipment. Industrial goods are increasingly using electromagnetic induction-based wireless short-range power transmission devices for contactless charging today [6]. However, due to the limitation on the energy transmission distance, this technology cannot charge EVs to cover distances of more than one-fifth (1/5) the dimension of the power transmitter [7]. The transmission distance could be increased to more than 2 or 3 times the size of the emitter or recipient using an enhanced resonant coupling technique [8].

A few years later, wireless power transfer transmission for electric cars (EVs) was developed, which can overcome the disadvantages of cable charges and remove certain barriers to car electrification and long-term mobility. WPT enables significant decreases in the interior EV battery's capacity in addition to being more practical than wired charges [9].

Electric vehicles were also thinking about using the stationary WPT recharge technique. The frequent loading and unloading of people at bus stops can decrease the onboard battery by at least two-thirds [10]. Because of these in-route costs, it is possible to transport a much smaller internal battery while still meeting the vehicle route requirements. Inductive Power Transfer (IPT) techniques are widely available and work well with wireless power transfer technology. Despite the fact that resonance IPT

techniques are growing in popularity in the business sector [11]. The auto industry also plans to use IPT for completely electric vehicles to make charging easier and improve customer satisfaction.

Despite the payment solution's significant development, this system still has numerous flaws and issues that have evolved and are still scalable. The main associated disadvantages were covered in [12]. In this study, the authors examined the inconsistencies in the electromagnetic protection components and coil loop designs for wireless charging systems and demonstrated how electromagnetic interference reduces system efficiency. The writers also discussed the issue of coil location, the effect of the receiver coil count, and the effect of the distance between the coils in [13]. transmission and reception. The writers made note of the fact that these factors have detrimental effects on the calibre of supplied electrical power. They also mentioned that the coil factors relating to the sort of metal used have significant effects on efficiency. On the other hand, it is crucial to note that the high frequency resonant supplied by the emitter will influence the car's interior. especially when the EV is charging and the wireless charging device is being used.

New technologies and techniques are being developed in numerous study articles to enhance the circumstances for using wireless charge systems.

## 2. LITERATURE REVIEW

A predictive current control method to minimize the THD by using a switching frequency of 8 kHz with a voltage source inverter. In [14], the researchers implemented a four-leg converter by applying a model predictive current control algorithm, where the THD and switching frequency were observed at low values of the filter parameter. A comparative study between a finite-control-set MPC (FCS-MPC) and synchronous proportional integral (PI) controller with space vector modulation (PI-SVP) was presented in [15]; it was observed that the FCS-MPC is able to generate waveforms with fewer low-order harmonics than the PI-SVM. The MPC method is able to operate with different voltage/frequency values while maintaining a lower THD value [16]. However, MPC requires complex implementation as compared to linear controllers. Meanwhile, in the single-phase on-board bidirectional charger proposed by [17], PI controllers were employed in AC/DC converters and DC/DC converters to provide constant voltage and constant current charging, as well as reactive power compensation.

However, the total THD of the line current was high. In [18], the authors proposed a unidirectional EV charger managed by direct power control. The charger was sufficient in providing a utility with reactive power support and other vehicle-to-grid benefits, but the work did not study the grid-to-vehicle (G2V) impact. This work presents the novel design and development of a universal EV charger. This EV charger is capable of three levels of EV charging, providing single-phase AC, three-phase AC, and DC charging, as shown in Figure 1. Hence, it is suitable for all three levels of charging. As such, this work focuses on scenarios where there are limitations in terms of space and resources available. In this regard, a more compact universal charging strategy will be advantageous. Specifically, in this work, the voltage-oriented control (VOC) technique is proposed to control the three-stage converters of the EV charger. These stages are a pulse-width modulation (PWM) rectifier, sinusoidal pulse-width modulation (SPWM) inverters, and a diode bridge rectifier. The proposed VOC technique demonstrates highly dynamic operation, appropriate output voltage, and a low THD of the input current.

### 3. PROPOSED METHODOLOGY

The proposed universal charger shown in Figure 1 is composed of a three-stage converter that is controlled by the VOC algorithm. The first stage consists of a three-phase AC source, a three-phase rectifier controlled by the VOC technique (named the VOC rectifier), and a DC-link capacitor. For closed-loop operation, the voltage and current controllers are used to obtain feedback voltage from the load-side battery of the EV. This is the most important control stage and consists of two main functions: (1) Regulating the output DC voltage to a pre-determined value, and (2) controlling the input AC phase currents to have a nearly sinusoidal wave shape and also to work in phase with the AC phase voltage. The second stage contains an inverter controlled by the SPWM switching technique (named the SPWM inverter). The output of the PWM signal which has been filtered by the inductor–capacitor (LC) circuit, is further connected to a transformer (three-phase transformer of 50 Hz) for either step-up or step-down purposes. Note that the inverter and rectifier share the same DC-link capacitor  $C_{dc}$ . Generally, the inverter produces a PWM waveform, with its width varying periodically. The PWM waveform is commonly filtered by an LC filter, which generates the desired sinusoidal waveforms. A high switching frequency provides a better filtered sinusoidal waveform. The desired output voltage is generated as a result of continuous changes in the amplitude and frequency of a reference or modulating voltage. The amplitude and frequency variations of the reference voltage will change continuously. This results in pulse-width patterns of the output voltage. However, the modulation pattern will remain sinusoidal.

The modulation process is executed by comparing a low-frequency sinusoidal modulating signal with a high-frequency triangular carrier signal. Pulses with varying duty cycles are formed when the two signals intersect with each other. The intersection locations determine the switching times for each switching state of a specific variable. As , three balanced-sinusoidal controlled voltages are compared with their respective triangular voltage waveforms. The resulting pulses are used to control the switching operating of the switching devices in each leg of the inverter. The switching frequency applied for the SPWM technique is set to 12 kHz. Basically, the switches in each phase are operating in a complementary manner: When the upper leg is in the open position, the lower leg will be in the closed position, and vice versa. The third stage is a three-phase diode bridge rectifier, where the control strategies of the whole charger are realized through VOC closed-loop control.

### 4. ESTIMATIONS AND RESULTS

Simulink is a software package for modeling, simulating, and analyzing dynamical systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. For modeling, Simulink provides a graphical user interface (GUI) for building models as block diagrams, using click-and-drag mouse operations. Models are hierarchical, so we can build models using both top-down and bottom-up approaches. We can view the system at a high level, then double-click on blocks to go down through the levels to see increasing levels of model detail. This approach provides insight into how a model is organized and how its parts interact. After we define a model, we can simulate it, using a choice of integration methods, either from the Simulink menus or by entering commands in MATLAB's command window. Using scopes and other display blocks, we can see the simulation results while the simulation is running. In addition, we can change parameters and immediately see what happens, for "what if" exploration. The Figure 2 shows the harmonic control circuit.

The simulation results can be put in the MATLAB workspace for post processing and visualization. Simulink can be used to explore the behavior of a wide range of real-world dynamic systems, including electrical circuits, shock absorbers, braking systems, and

many other electrical, mechanical, and thermodynamic systems. Table 1 shows component values.

Simulating a dynamic system is a two-step process with Simulink. First, we create a graphical model of the system to be simulated, using Simulink's model editor.

During a simulation, Simulink updates the states and outputs of a model's blocks once per time step. The order in which the blocks are updated is therefore critical to the validity of the results. In particular, if a block's outputs are a function of its inputs at the current time step, the block must be updated after the blocks that drive its inputs. Otherwise, the block's outputs will be invalid. The order in which blocks are stored in a model file is not necessarily the order in which they need to be updated during a simulation. Consequently, Simulink sorts the blocks into the correct order during the model initialization phase

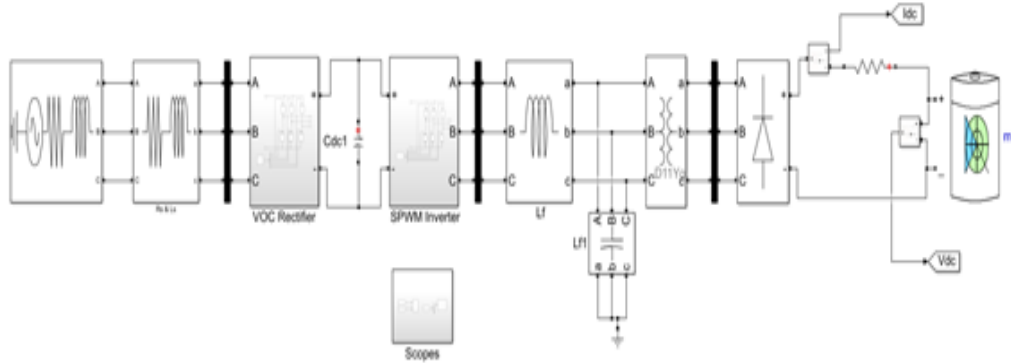


Fig 1 Proposed system simulation

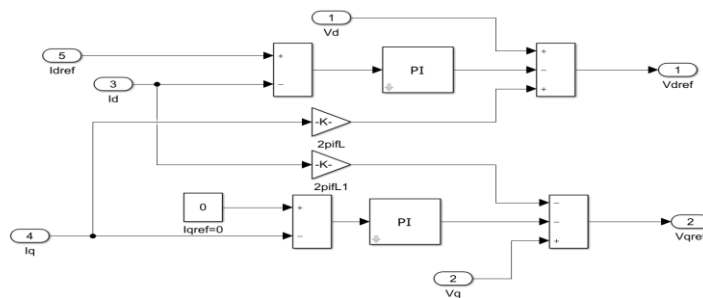
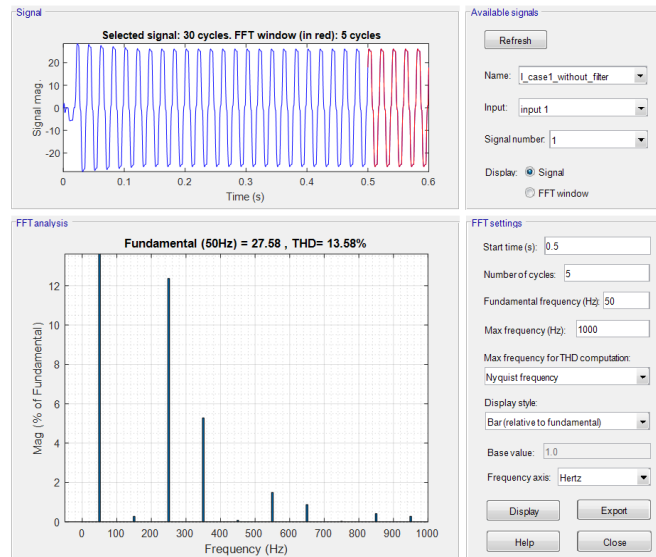


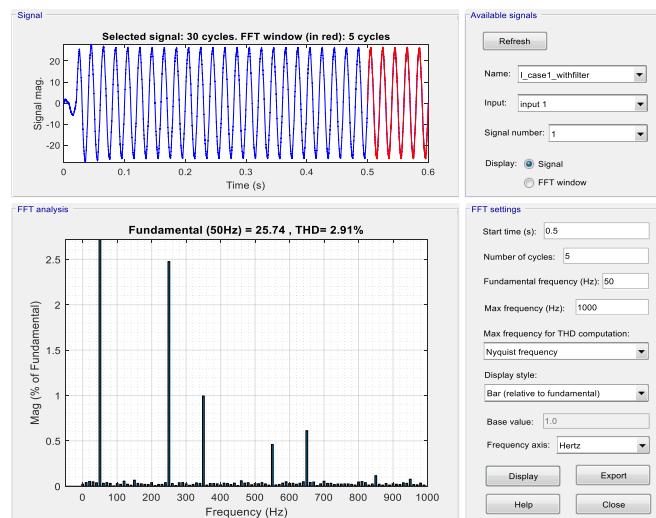
Fig 2 Harmonic controller circuit

Table 1: For level 3 component values

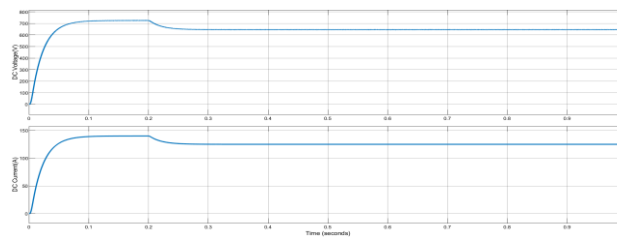
Parameter	Symbol	Unit	Value
Resistance load	$R_{load}$	$\Omega$	20
Input inductance	$L_f$	mH	5
DC-link capacitor	$C_f$	$\mu F$	6
Grid voltage frequency	$f$	Hz	50
Switching frequency	$f_s$	KHz	12
Input resistance	$R_f$	$\Omega$	5
Input voltage	$V_{in}$	volts	120



**Fig 3 Output current without filter**



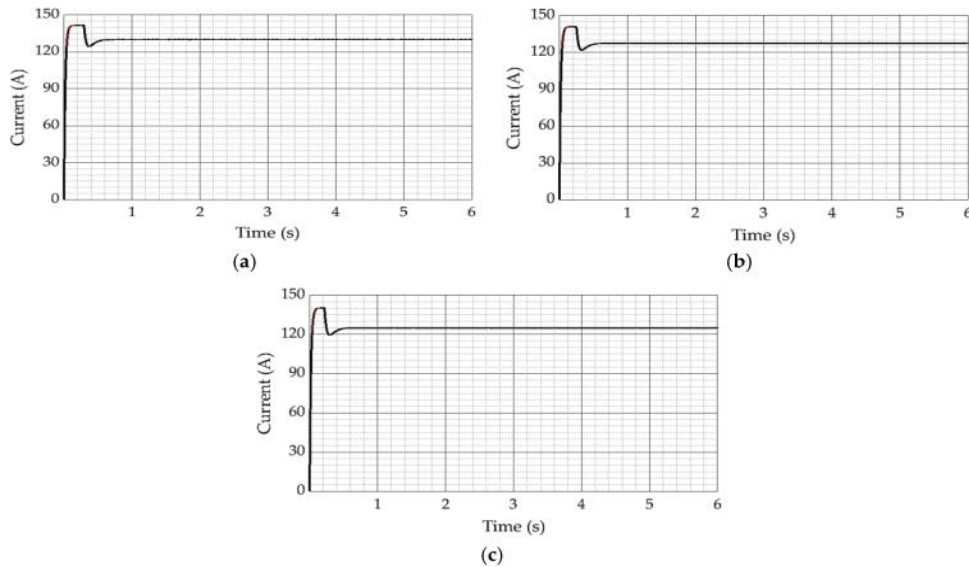
**Fig 4 Output current with filter**



**Fig 5 Dc link voltage and current waveforms**

### Level 3 Charging

For Level 3 charging, the proposed EV charger was tested for its effectiveness at providing a constant output DC current that can be directly applied for DC battery charging. The simulation parameters applied for this part of work are summarized in **Table 3**. Three types of batteries: Nickel metal, lithium ion, and lead acid were used to test the charging performance of the proposed charger. The simulation results obtained for Level 3 charging are shown in Figure 3, Figure 4 and Figure 5. Figure 6 shows the output DC link voltage of Level 3 charging for different types of batteries.



**Figure 6. The output DC-link voltage of Level 3 charging for (a) nickel metal, (b) lithium ion, and (c) lead acid batteries.**

More importantly, as can be observed from Figure 4, it is clear that the proposed control scheme is able to maintain the THD of the input current at 0.39% while performing the DC charging, thus leading to an almost unity power factor. Once again, the proposed universal EV charger is proven to provide effective DC charging without causing any noticeable harmonic distortion to the connected grid.

## 5. CONCLUSION

The proposed charger is able to provide a controllable and constant charging voltage for various EVs and is composed of three level of charging. The three-phase PWM converter, based on the VOC of conversion theory and appropriate for Level 3 of charging, was proposed. A new control algorithm based on the integration of the VOC and SPWM techniques for the effective operation of three battery charging level circuits was presented. It is clear that the control algorithm accurately regulates the output DC voltage. At the same time, it ensures a sinusoidal input current with minimum switching ripples and distortions. The power factor of the system is almost unity, and the total harmonic distortion (THD) for the input current is less than 0.39%. However, due to limitations in terms of available facilities and resources, the ability of the proposed charging strategy in performing Level 1 and Level 2 charging have not been practically verified in this work, in which only the simulation findings have presented for this aspect.

Overall, as reported by the simulation results, the design concept of the proposed universal EV charger itself and, subsequently, the operation of the VOC and SPWM algorithms in a control system, can be confirmed to be valid. The proposed universal EV charger is designed to perform three types of charging: Single-phase AC charging (Level 1), three-phase AC charging (Level 2), and DC charging (Level 3). Furthermore, the proposed VOC and SPWM control techniques are applied to minimize the harmonic distortion in the grid. As can be seen from the simulation work, the THD value is well below 5%. In other words, the proposed charging strategy does not cause significant harmonic distortions to the grid while charging.

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