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# A Bidirectional Electric Drive Reconstructed Onboard Converter for Electric Vehicle Applications

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**ABSTRACT:** In this paper, an Electric-drive-reconstructed onboard converter (EDROC) based on a switching network in the DC side is proposed. The system can utilize the existing hardware of electric vehicles and does not need extra equipment. When the EDROC connects to the power grid through the power outlet at the office or home, there is not by additional equipment(relay) on the AC side. Compare with traditional EDROC, the proposed EDROC has advantages in cost and volume. The EDROC can realize the unity power factor in the charging mode and discharges to drive the motor in the driving mode. A proof-of-concept prototype has been built to verify the charging function and driving function of the proposed EDROC.

**KEYWORDS**Power conversion, electric vehicles, bidirectional converters, electric-drive-reconstructed systems.

## I.INTRODUCTION

An electric vehicle charging station, also called EV charging station, electric recharging point, charging point, charge point, electronic charging station (ECS), and electric vehicle supply equipment (EVSE), is an element in an infrastructure that supplies electric energy for the recharging of plug-in electric vehicles including electric cars, neighbourhood electric vehicles and plug-in hybrids for charging at home or work, some electric vehicles have converters on board that can plug into a standard electrical outlet or a high-capacity appliance outlet. Others either require or can use a charging station that provides electrical conversion, monitoring, or safety functionality. These stations are also needed when traveling, and many support faster charging at higher voltages and currents than are available from residential EVSEs. Public charging stations are typically on-street facilities provided by electric utility companies or located at retail shopping station, restaurants and parking places, operated by a range of private companies, Charging stations provides range of heavy duty or special connectors that conform to the variety of standards. For common DC rapid charging , multi-standard chargers equipped with two or three of the Combined Charging System (CCS), CHAdeMO, and AC fast charging has become the de facto market standard in many regions.

## II.RELATED WORK

Smart grid communication:

Recharging a large battery pack presents a high load on the electrical grid, but this can be scheduled for periods of reduced load or reduced electricity costs. In order to schedule the recharging, either the charging station or the vehicle can communicate with the smart grid. Some plug-in vehicles allow the vehicle operator to control recharging through a web interface or smartphone app. Furthermore, in a vehicle-to-grid scenario the vehicle battery can supply energy to the grid at periods of peak demand. "Communication between Plug-in Vehicles and the Utility Grid" ISO and IEC are also developing a similar series of standards known as ISO/IEC 15118: "Road vehicles -- Vehicle to grid communication interface".

Renewable electricity and RE charging stations:

Charging stations are usually connected to the electrical grid, which often means that their electricity originates from fossil-fuel power stations or nuclear power plants. Solar power is also suitable for electric vehicles. Solar City is marketing its solar energy systems along with electric car charging installations. The company has announced a partnership with Rabo bank to make electric car charging available for free to

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owners of Tesla vehicles traveling on Highway 101 between San Francisco and Los Angeles. Other cars that can make use of same charging technology are welcome

SPARC station:

The SPARC (Solar Powered Automotive Recharging Station) uses a single custom fabricated mono crystalline solar panel capable of producing 2.7 kW of peak power to charge pure electric or plug-in hybrid to 80% capacity without drawing electricity from the local grid. Plans for the SPARC include a non-grid tied system as well as redundancy for tying to the grid through a renewable power plan.

E-Move charging station:

The E-Move Charging Station is equipped with eight mono crystalline solar panels, which can supply 1.76 kWp of solar power. With further refinements, the designers are hoping to generate about 2000 kWh of electricity from the panels over the year

Wind-powered charging station:

In 2012, Urban Green Energy introduced the world's first wind-powered electric vehicle charging station, the Sanya Sky Pump. The design features a 4 kW vertical-axis wind turbine paired with a GE Watt Station

## III. PROPOSED SYSTEM

In this work, an Electric-drive-reconstructed onboard converter (EDROC) based on a fuzzy switching network in the DC side is proposed. The system can utilize the existing hardware of electric vehicles and does not need extra equipment. When the EDROC connects to the power grid through the power outlet at the office or home, there is not any additional equipment (relay) on the AC side. Compare with traditional EDROC, the proposed novel EDROC has advantages in cost and volume. The EDROC can realize the unity power factor in the charging mode and discharges to drive the motor in the driving mode

TOPOLOGY AND ANALYSIS OF ELECTRIC-DRIVE-RECONSTRUCTED
CONVERTER

The proposed electric-drive-reconstructed onboard converter in PEV is realized by connecting an auxiliary circuit between battery and traction hardware, as shown in figure. The auxiliary circuit and the inverter of traction hardware forma switching network to reconstruct converter. And the proposed fuzzy control method is applicable for any traction hardware with the three-phase inverter, and there is no need specially designed motor. The converter only uses a single phase power supply without additional equipment such as inductance or relay at the AC side. The system has two working modes,

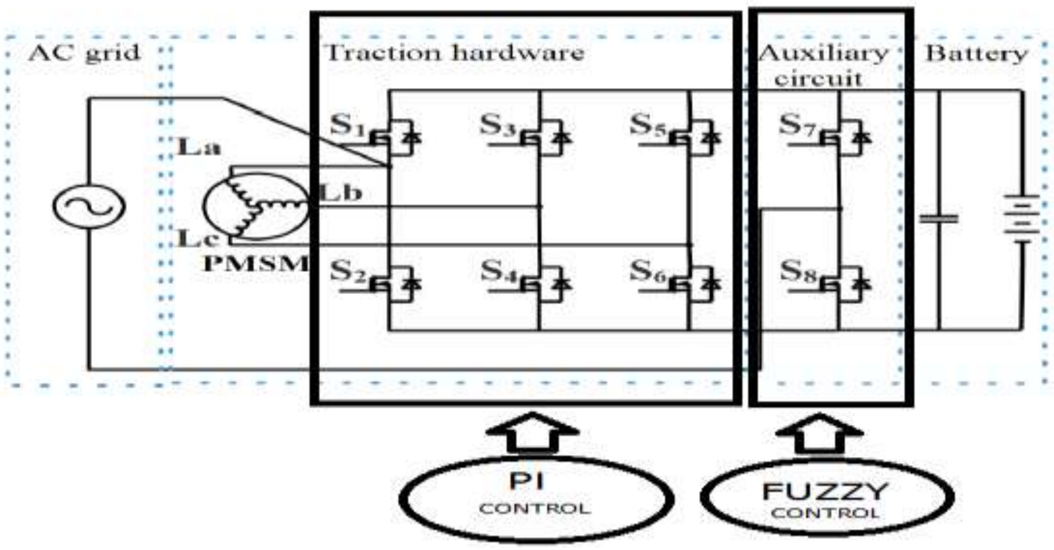


**Fig. 4.1.** Proposed System

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Whiche are charging mode and driving mode.

A.CHARGING MODE

During the charging mode, the switches S3-S8 are enabled. The switches S1 and S2 are disabled. The switching states are divided into eight states, as shown in figure. When the grid voltage is positive, the system work in states I - IV. When the grid voltage is negative, the system work in states V- VIII. In states I, the switch S7 is turned off, and the switch S8 is turned on, The switches S4 and S5 are turned on and switches S3 and S6 are turned off. The current flows back to the grid through switch S8, as shown in Fig 4.1. The state equation of the system can be written as

$$\begin{cases} L_s \frac{di^I_{La}}{dt} = \frac{2V_{in} - V_B}{3} \\ L_s \frac{di^I_{Lb}}{dt} = \frac{-V_{in} - V_B}{3} \\ L_s \frac{di^I_{Lc}}{dt} = \frac{-V_{in} + 2V_B}{3} \end{cases} \quad \text{----------------- (1)}$$

Where Vinis input voltages of AC side; VB is battery voltages; iILa, iILb, and iILcis the inductive current of the three-phase motor in state I, respectively. Lsis stator inductance. In states I, inductor Lbstores energy; the inductor Lcdischargethe stored energy to the battery by the switch S5. In states II, the switches S3, S6; and S8 are turned on, and the switch S4,S5; and S7 are turned off; as shown in fig

$$\text{-----} \begin{cases} L_s \frac{di^{II}_{La}}{dt} = \frac{2V_{in} - V_B}{3} \\ L_s \frac{di^{II}_{Lb}}{dt} = \frac{-V_{in} + 2V_B}{3} \\ L_s \frac{di^{II}_{Lc}}{dt} = \frac{-V_{in} - V_B}{3} \end{cases} \quad \text{----------(2)}$$

The state equation can be expressed as in states II, the inductor Lbis discharged the stored energy to the battery by the switch S3; inductor Lcstores energy

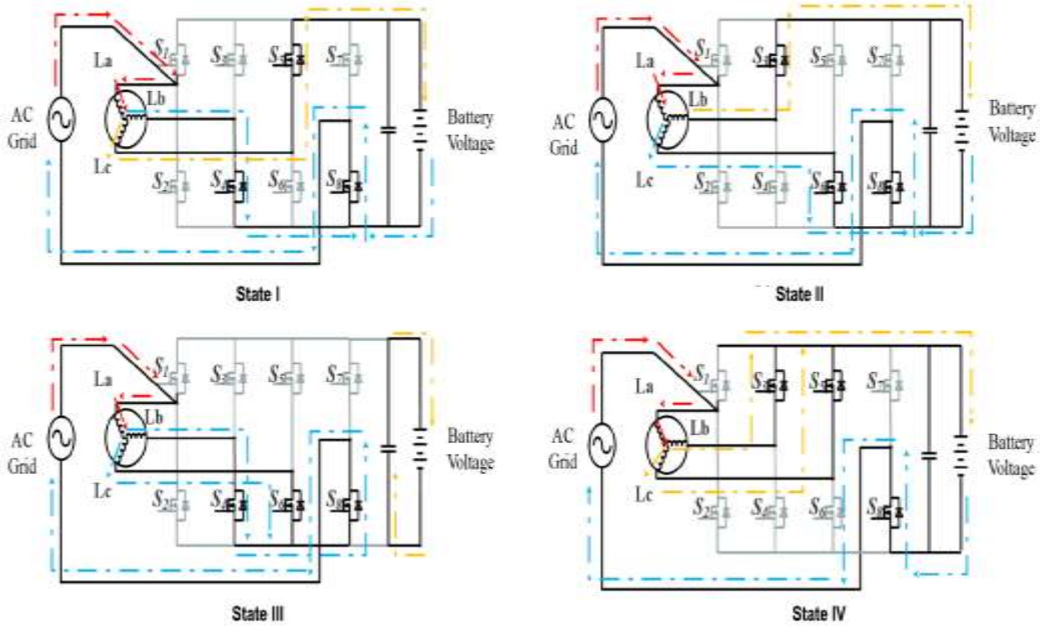


**Fig4.2.** Switching states of the proposed EDROC in charging mode.

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During the grid voltage is positive, the proposed converter has two ways of working operation, according to the duty cycle (D) of switch S4 & S6. When 0 < D < 0.5, the circuit operation has a switching sequence of states I states III - states II - states III - states I. When 0.5 < D < 1, the switching sequence changes to states I - states IV - states II - states IV - states I. During the grid voltage is negative, the working operation is similar that in positive grid voltage.

B.DRIVING MODE

During the driving mode, the switches S1-S6 are enabled; the switches S7 and S8 are disabled. The converter can work in eight vector states of PMSM similar traditional fuzzy control method, as shown in figure. The proposed converter can be controlled by fuzzy. The state equation and produced electromagnetic torque of PMSM in the d-q frame is expressed as follows:

$$\begin{cases} u_d = R_s i_d + P\psi_d - \omega_r \psi_q \\ u_q = R_s i_q + P\psi_q + \omega_r \psi_d \\ T_e = P\left(\psi_d i_q - \psi_q i_d\right) \end{cases} \quad \text{---------------------- (3)}$$

Where Rsis the stator resistance; id and iqare d-axes stator currents and q-axes stator currents respectively; d and q are the permanent magnet _ux linkage in d-axes and q-axes, respectively.

## IV. SIMULATION RESULTS

MATLAB(Matrix Laboratory) is a multi-paradigm numerical computing environmentand proprietary programming language developed by Math Works. MATLAB allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation user. The MATLAB model simulated to verify the charging function and driving function of the proposed EDROC.The proposed EDROC has a good suppression effect on the ripple of the input current.

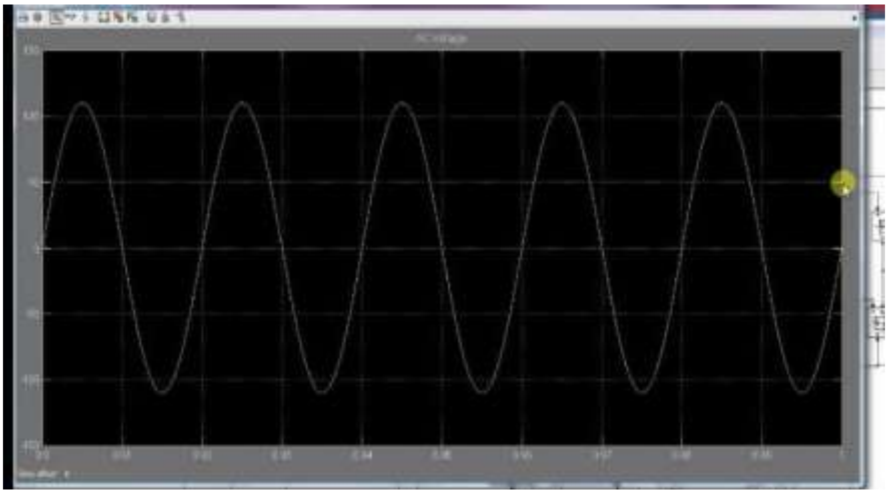

**Fig1**.Input AC waveform

The following figure2 shows the simulations result of battery voltage waveform. The voltage charging is a widely used charging method involving constant voltage between the battery poles. The starter battery uses constant voltage charging when the vehicle is running.

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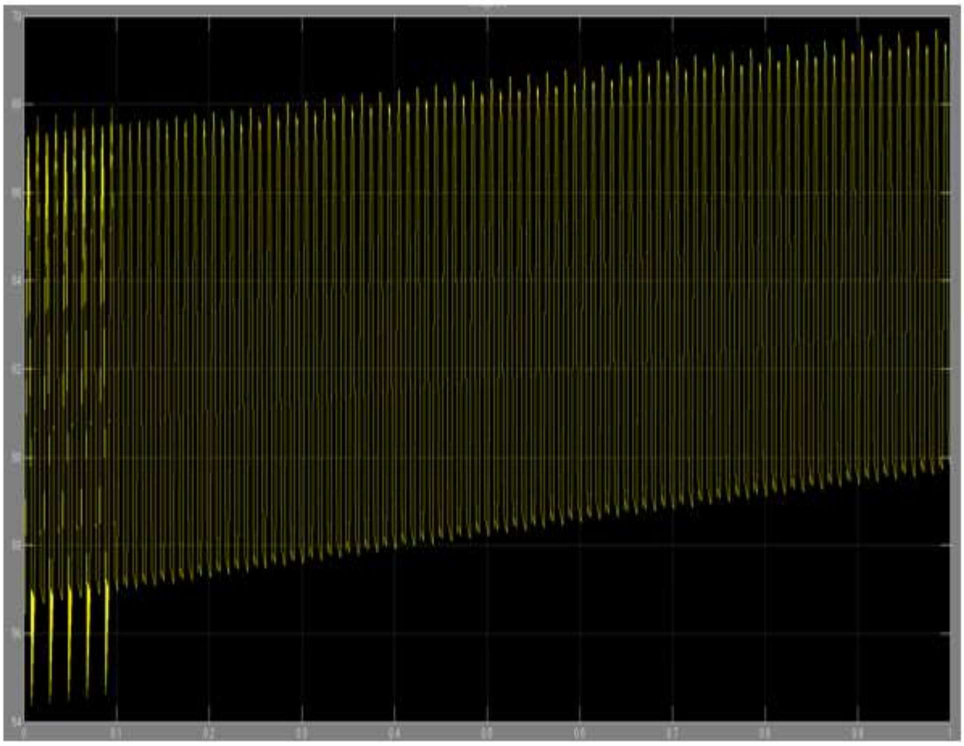

**Fig 2**Battery voltage

If specified voltage constant value is appropriate, it can ensure that the battery is fully charged, while also minimizing gas and water loss. Standard power lead plugged into normal outlet. Charger in vehicle converts AC to DC and controls battery charging

The following figure 3 shows the simulations result of motor speed. The significant even after the completion of the transient part of the required feed forward contribution to make the vehicle follow the reference understeer characteristic, different from the one of the baseline vehicle.

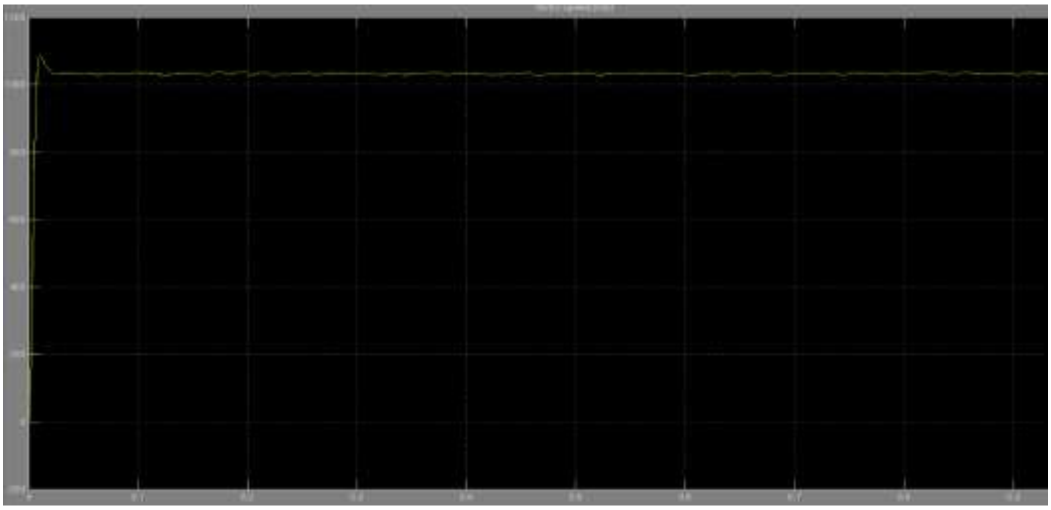

**Fig 3** Motor speed

In general, for same steering wheel angle and vehicle velocity, the vehicle in sport mode, driving mode requires more input power than the vehicle in normal mode, because of the higher lateral acceleration values, the results were

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obtained from a sequence of sinusoidal tests with an amplitude.

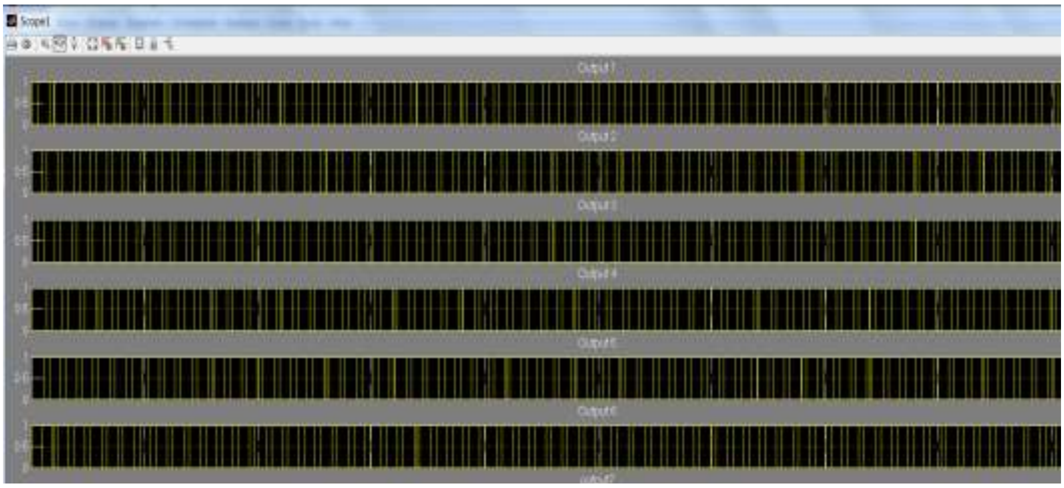

**Fig 4** Controlling pulses

If we switch the power on and off quickly enough, the motor will run at some speed part way between zero and full speed. This is exactly what a PWM. controller does it switches the motor on in a series of pulses. To control the motor speed it varies (modulates) the width of the pulses hence Pulse Width Modulation. As the figure shows the simulations result of PWM

## V.CONCLUSION

In the project, a fuzzy and PI controlled Electric-Drive-Reconstructed Onboard Converter is proposed for PEVs. The proposed reconstructed converter is simple without specially designed motor or ac additional equipment. The proposed converter is modified from the three-phase motor drive converter. It only needs a set of auxiliary switches in the DC side. The proposed EDROC can be connected to the power outlet at the office or home without extra power supply equipment. The ripples were reduced by using interleaving control. The effect of ripple suppression is better than that of the traditional converter. Compared with the existing EDROCs, the proposed EDROC has some advantages include small size and low cost. The proposed EDROC is verified through workbench, the functions of motor drive and charger are realized.

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