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THE DEVELOPMENT AND EXECUTION OF PEV BIDIRECTIONAL CHARGER'S V2G ACTIVATED POWER ASSISTANCE FUNCTIONALITY

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ABSTRACT

The a single-phase on-board bidirectional plug-in electric vehicle (PEV) charger presented in the present research may help lessen the demand for reactive energy on the electrical grid in addition to recharging the car's battery. The two stages of the topology are a full-bridge ac-dc boost converter and a half-bridge bidirectional dc-dc converter. The charger has five separate functioning modes: charging-only, charginginductive, charging-only, and inferential-only. It operates in two regions of the active-reactive power (PQ) power plane. A single controllers for adhering to utility PQ standards in a smart grid setting is also provided by this work. In addition to generating direct current and battery charge references and providing a consistent dynamic response, the transmitted two-stage system controller receives active and reactive power commands on the grid. Reactive electrical usage has no effect on the vehicle's battery regardless of the modes of operation. Reactive power support capabilities for PEVs are successfully implemented in testing the integrated controller using a 1.44 kVA trial charger configuration for prospective smart grid applications.

Key Words: battery charger, plug-in electric vehicle (PEV), activated power, vehicle-to-grid (V2G)

I . INTRODUCTION

Sales of plug-in electric vehicles (PEVs), a more affordable alternative to vehicles battery-powered by traditional internal combustion engines (ICEs), are anticipated to rise in the coming years. PEVs operate more cost-effectively, which reduces fuel expenses [1]. But because PEV connections to the electricity grid result in such a significant increase in peak load, reliability issues with the power system, particularly at the reduced voltage arrangement network, are raised [2], [3]. The coordinated and intelligent charging of the PEVs will lessen the negative grid effects. The utilization of PEVs with on-board chargers for distributed energy storage could help the power grid further. [4], [5]. On-board chargers, that typically have unidirectional transfer of power capability, convert the ac power source into dc. The on board charging may additionally offer high-quality power functions including reactive power compensation (inductive or capacitive), regulation of voltage, harmonic filtering, and correction of power factors employing a complicated structure and controller compared with more commonly utilized strategies on the market [6]– [10]. Capacitor banks, static VAR compensates, static synchronous compensates, etc. are all present in the power grid. to correct reactive power used at the home load. The installation and maintenance expenses related to the aforementioned devices can be decreased by more effectively compensating the reactive power that is extremely close to the residential load. As a result, on-board chargers might be able to handle sophisticated functionalities with only minor adjustments to the established typologies. Additionally, reactive power hold up has no impact on the state of charge (SoC) or lifespan of the battery. The utility grid supplies the ac-dc converter losses during reactive power correction, preserving battery SoC. However, since there are more charge-discharge cycles, reactive power operation has an impact on parts like dc-link capacitors [6]. It has been concluded that smart charging by vehicle-to-grid (V2G) is useful and alluring in the long-run activity of the electrical grid. [5], [11] when taking its benefits into consideration. Future utilities will like to inform customers about PEV charging power and control it with a reward system [5, [11]–[13]]. Investigations have taken a look at the independent and connected operating modes of battery-supplied bidirectional converters [6]-[10], [14]-[19] because of increasing interest in V2G applications for the power grid. Enabling two main reasons, a two stage design including cascaded ac-dc and dc-dc converters is frequently recommended in articles for bidirectional charger operation: To prolong the life of lithium-ion (Li-ion) batteries, galvanic isolation should be used and the 2nd harmonic (2-f) ripple element of the dc battery assertion current should be decreased. The natural by-product of single phase ac-dc power rectification is the 2-f ripple [20]. Two independent controllers are frequently utilized in [8], [9], [16], and [18] for the ac-dc and dc-dc converter stages. As a result, the controller utilization distinct acknowledgment for ac–dc and dc–dc stages.

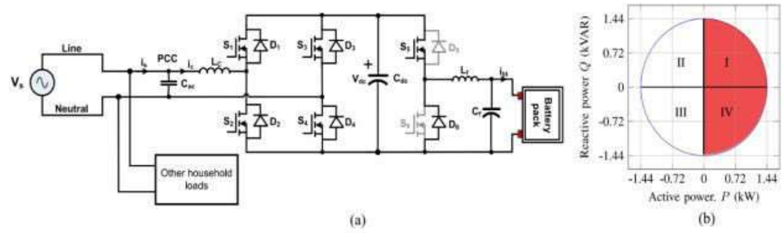


Fig. 1. Bidirectional PEV charger and its operation region in active-reactive power (PQ) plane. (a) Charger and grid connection. (b) Operation area of the charger (shaded).

Due to physical interoperability, a smart-grid link is more practical with a consistent controller that only communicates active power commands (Pcmd) and reactionary power commands (Qcmd) [or power feature (pf)] among EV and utility grid [21]. The utility grid can receive two signals (Pcmd and Qcmd) that can be used to generate other references because doing so is more practical and standardised. A uniform controller that responds to the Pcmd and Qcmd signals from the grid as suggested in this study is utilised in [10], [17], and [22]. Additionally, the ac-dc converter, which also govern the dc-link voltage, lead Qcmd and references the dc battery charging power using Pcmd. This means that the reference for Pcmd is not the genuine active power (P) measured at the point of common coupling (PCC). Because the losses in the active and passive components of the ac-dc converter were disregarded, this results in a power mismatch (among Pcmd and P). However, active power from the utility grid must come after Pcmd for the PCC to respond to Pcmd, and the controller must establish the needed battery reference current (ibt). Additionally, the studies mentioned above do not explicitly show how the controller performs in terms of how the fast charger responds to changes in Qcmd or Pcmd. To assist in the system integrating research of PEV V2G applications, a cascaded system controller presentation ought to be carried out. Under the supervision of an integrated controller, the utility grid should only transmit two signals (Pcmd and Qcmd), and the battery charger should act accordingly. This paper suggests a control strategy for a bidirectional on-board charger for supporting reactive power operations and charging of batteries. The network controller combines the control of ac-dc and dc-dc converters and executes Pcmd and Qcmd sent through the PEV and the power grid. In order to demonstrate the usefulness of the controller, a 1.44 kVA bench-top on-board charger is produced and tested after the recommended control approach was developed designed in power sim (PSIM). On the experimental model and in simulation, the on-board charging system's steady-state functionality and dynamical capabilities are tested. The findings demonstrate that the suggested method of control operates effectively, offers good dynamic responsiveness to changes in grid demand, and satisfies the necessities for steady-state functioning. Simulation and verification of the suggested system controller is Division IV's main goal.

II. DETAILS OF THE BIDIRECTIONAL PEV CHARGER'S SYSTEM

The architecture of this study is depicted in Fig. 1(a), that is utilized to look at the relationship between elements of the PEV grid. Ac-dc generation (full-bridge ac-dc rectifier) and dc-dc conversion (dc-dc buck converter) are commonly each of the steps in PEV on-board charging. Galvanic polarisation is often necessary for usage in reality. A nonisolated structure is used in this work.

This study's objective for establishing charging and activated power control that complies with the design requirements as stated in the system description. As a result, the majority of the work has gone into designing and implementing the controller as well as analysing the outcomes of the experiments. The frontend ac-dc converter employs bipolar modulation, thus the rectifier input voltage can be moreover +Vdc or Vdc. Switches S2 and S3 are twisted off when S1 and S4 are active, and so on.

The metal oxide semiconductor field-effect transistors (MOSFETs) and diodes have to function at a peak current of 2Ic, while Ic is the charger's rms current, in order to prevent the peak voltage of Vdc. PEV batteries typically have voltage ratings between 200 and 390 V [1]. As a result, this research tests two distinct dc link voltage levels of 250 V and 400 V [Vdc in Fig. 1(a)]. The switches S5 and D6 are used to execute the buck action. As the current passes through S5 and Lf when S5 is turned on, the battery and Cf get charged. While S5 is turned off, Diode D6 discharges Cf towards the battery while also directing the freely moving inductance current through Inductance Lf and the battery.

Because the battery is still fully charged, the switches S6 and D5 are not utilized in this paper. The hardware of the system, yet, is set up for V2G powered applications. Table I contains a list of the system parameters that are depicted in Figure 1(a). The grid current's overall harmonic distortion (THD) has to be less than 5% and each harmonic constituent must be strictly controlled [23], [24]. That is accomplished at the front end using an induction-capacitor filter.

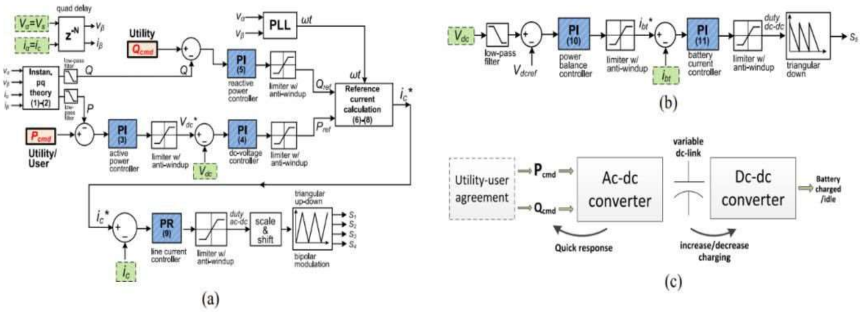


Fig. 2. Proposed system controller and operation. Controller for (a) ac–dc converter and (b) dc–dc converter. (c) Controller operation sequence.

and by correctly building the ac inductor current feedback controller. By adjusting the parameters of the current flowing from the output (ibt) controller or a low pass filter at the output, the battery charger's output voltage and current can be regulated. Charge Li-ion with/or lead-acid batteries, for example, using approaches like 1.5% of the battery's recommended voltage and 5% to 10% of the recommended charging current, correspondingly.. [25].

Table 1: Wearable System Parameters given in table

Parameter	symbol	Values
Charge Apparent Power	S	1.44 Kva
Grid Voltage	Vs	120 V
Grid Frequency	F	60 Hz
Coupling Inductance	Lc	1.0 Mh
Ac-Dc Converter	Fsw1	24 Khz
Dc-Link Voltage	Vdc	250v/400v
Dc-Link Capacitance	Cdc	330uf
Dc-Dc Converter	Fsw2	42 Khz
Battery Side Capacitor	Cf	200 Uf
Battery Side Incuctor	Lf	400 Uf

III.SIMULATION OF THE PROJECTED CONTROLLER

A replication situation is created to demonstrate how the charger functions and how well it responds to grid commands. A shortened version of the scenario is created because the amount of time needed to replicate the service level procedure of the device is too great. It is anticipated that PEVs are connected to the grid between 4:00 and 8:00 PM, when the load is at its peak and the battery has to be fully charged. The simulation therefore begins with charging-only functionality. Thus, it is anticipated that as the progressive and activated power consumption at the residential units increases, the voltage at the substation will decrease. The utility employs some of the PEVs for reactionary power supply in order to maintain the distribution voltage. The PEV may additionally utilise reactive power if the public utility intends to subsequently lower the substation voltage. The appropriate order of the steps in this scenario is shown in Table III. The execution of Table III makes advantage of a 7-s simulated. The PSIM simulated diagram is displayed in Fig. 4. The suggested charger controller's C code is included in the system's simulation architecture. The simulation makes use of the PSIM Li-ion battery design [30]. The required characteristics are extracted from the data sheet of the Li-ion batteries which are accessible in the lab. [31]. The investigation hardware unit would be described in following section uses the same system parameters as those utilized in the reproduction and displayed in Table I.

In order to realise Table III, the usefulness orders for progressive and activated power are integrated into the C code and turned on using a time counter technique. During startup and dynamic performance tests, simulation findings showed behaviour that was remarkably similar to that of the actual setup. As a result, it enabled the construction of controller code quickly and decreased implementation errors. Two different instances' simulation results are finished. Because the battery pack voltage determines which dc-link voltage to use, controller performance is confirmed for Vdc = 250 and 400 V. Fig. 5 displays the outcomes for 400

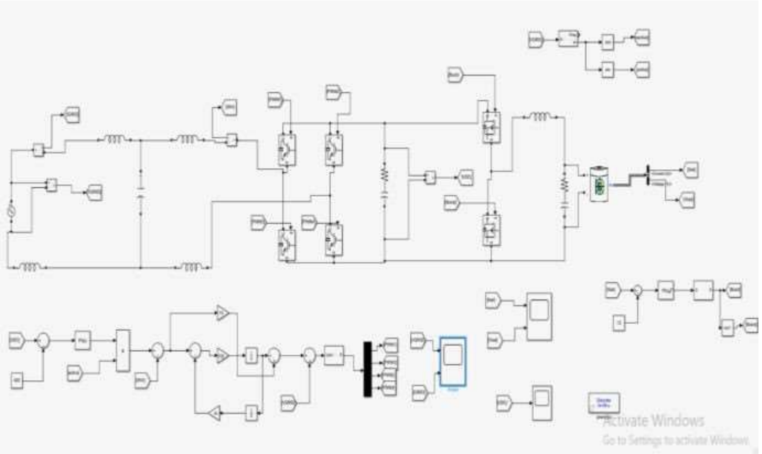


Fig 3: Simulation diagram of the charger developed in PSIM.

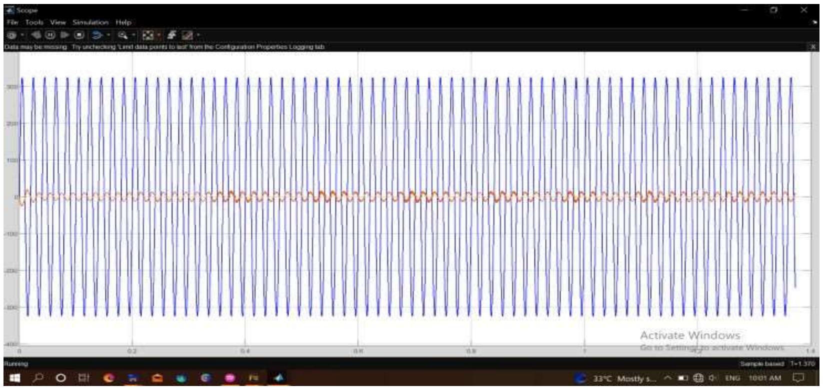


Fig 4: confirmation of the scheme controller by means of PSIM for 325 V dc-link voltages

Dc-link voltage. P and Q in the graphic represent the charger's intended progressive and activated power productivity at the PCC. Both the active and reactive power directives were successfully carried out by the controller.

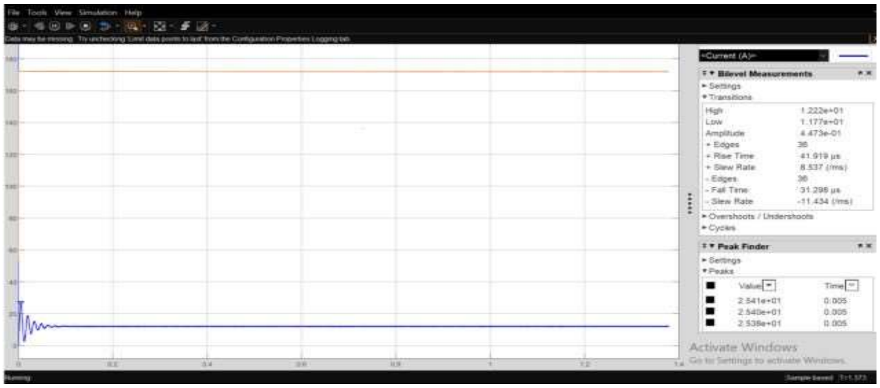
Because the apparent power is maintained steady throughout the simulation, it should be noted that the charger current RMS value (Ic = 1440/120 = 12 A) remains unchanged. Fig. 6 provides more information on the transitions between modes. The settling time for Fig. 6(a) and (b) is less than five grid cycles.

IV. RESULTS

A MATLAB programme called SIMULINK can be used to model, simulate, and analyse dynamic systems. It supports modelling of continuous-time, sampled-time, or a combination of both linear and nonlinear systems. Systems can also be multi rate, which means that they can have several components that are sampled or updated at various rates.

With SIMULINK, you can ask a question about a system, simulate it, and observe the results. Simulink makes it simple to create new models from start or to build upon old ones. Simulink is a modelling and problem-solving tool used by thousands of engineers across the globe. the creation of a novel converter or drive system control technique. Before creating the breadboard or prototype, it is frequently convenient to replicate the structure performance.

The reproduction not only confirms the functionality of the system, but also enables performance optimisation of the system through parameter iteration. The influence of plant parameter variation can be evaluated in addition to control and circuit parameters. This saves a lot of time during the product's development and design. The simulation programme also assists in producing real-time controller software codes for microprocessor or digital signal processor download.



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<Current (A)>
Bilevel Measurements
Settings
Transitions
High            1.222e+01
Low             1.177e+01
Amplitude       4.473e-01
+ Edges         36
+ Rise Time     41.919 µs
+ Slew Rate     8.537 (/ms)
- Edges         36
- Fall Time     31.298 µs
- Slew Rate     -11.434 (/ms)
Overshoots / Undershoots
Cycles
Peak Finder
Settings
Peaks
    Value        Time
    2.541e+01    0.005
    2.540e+01    0.005
    2.538e+01    0.005
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Fig 5: The output graph for the battery voltage and current

The dc battery current, ibt(t), is shown as well at the bottom of every graph. Consider that in modes #1 though #2, while there is no demand for recharging power, ibt(t) is virtually negative. The developed controller runs in a variety of operating conditions with no experiencing any instability problems. That demonstrates so as to the charger is capable of assuming various tasks for the sake of a more dependable electrical system.

CONCLUSION

This work uses a single-phase on-board bidirectional charger to illustrate controller development, experimental charging verification, and V2G reactive power functionality. The proposed unified system controller manages the line current and battery current while maintaining below THD extent after receiving progressive power and activated power inputs for charging by the quality grid. It offers both a quick dynamic response and effective steady-state operation.

The control unit has been evaluated using a single-phase, Level 1 120 V grid connection. But at greater power levels, the recommended controller may additionally be applied to Level 2 single-phase recharging. The SoC or battery life are not affected by reactive power operation. The controller demonstrated its quick reaction to utility directives by carrying out step-changes of inductive and capacitance reactive power commands in less than five grid cycles. The proposed PEV charger control approach is supported by computer simulations and experimental findings. functions successfully under fluctuations in grid demand, has a quick dynamic reaction, and exhibits good steady-state performance.

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