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Improved Integrated Battery Charging Circuit for Hybrid Electric Vehicle Applications

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Abstract
This research provides the battery charging&an estimation of voltage ripple controllers for hybrid electric vehicles based on the fuzzy logic controller (FLC). This article presents a circuit design for a 1-phase bi-directional OBCutilizing a starting generator&its driving inverter (HEVs). In HEV, a variety of power electronics components play an important role. By including the power relays into generator drive scheme, the suggested circuit includes the ability to charge batteries. As a result, traditional OBCs are often located distant from the car, increasing the vehicle's power density. The model predictive current controller with fuzzy logic is suggested. The charging circuit allows for bi-directional performance&reliability from the grid to the vehicle&from the vehicle to the grid, which may enhance the harmonic frequency of grid current. The simulation findings reveal that the recommended enhanced integrated required to charge system modeling&development technique is valid&viable.
Keywords: Battery, Electric vehicle, Fuzzy controller

I.INTRODUCTION

In general, electric cars (EVs)&HEVs have gained popularity in current years due to the need for pollution reduction in urban transportation. HEV is a compromise between a traditional combustion engine vehicle&an electric vehicle, due to limitations like as petroleum combustion, air pollutant emissions,&therefore a restricted golf range. Engine, transmission, traction motor, battery, charger,&drive inverter are all mechanical&electrical components of any planned HEV. An additional starting generator system, consisting of an additional generator&its controlling inverter, is also available as an option. To start the engine from a standstill, a starter-generator system is used. On-board chargers (OBC) are replaced with a starter-generator system that includes a charging function.As a result, the redesigned starter-generator system has two modes of operation. One is the functioning of the motor drive due to the usage of a traditional starter-generator. Then there's the charger. This integrated charging mechanism is used to replace traditional OBC,&as a result, traditional OBC are often removed from HEVs [1]. Volume&weight of the HEVs are reduced as a result of the system design, while capacity density is maintained. Facility converters have been in the focus in recent decades for their good performance thanks to feedback-based current control approaches.On the synchronous reference frame, the PI [2] current controller transforms time-variant things into time-invariable things, resulting in precise control outcomes. However, due to the controller's planning utilizing the system parameter, a number of drawbacks exist with this control approach.

Furthermore, when the system is complicated, it is tough to style the controller's benefit [3] [4]. Thus, while the suggested microcircuit is in the battery charging mode, the model predictive current control (MPCC) technique based on fuzzy logic is presented for controlling the 1-phase full-bridge inverter.

The previous MPCC results in a higher THD in the final current because it generates only three distinct output voltage vectors, whereas the 3-phase 2-level inverter generates eight distinct output voltage vectors[5][6][7].The sample time should be raised to minimize THD in output current, however this results in inadequate computation time [8-12]. This article uses fuzzy logic to reduce the di/dt of output power&increase the harmonic representative utilizing the advanced MPCC technique [13-15]. The proposed MPCC method increases fuzzy logic to provide rapid dynamic response. In addition, when compared to traditional MPCC approach [16-19], the THD characteristic of the output current is enhanced [20]. Before implementing the proposed upgraded integrated charging system, simulation results are utilized to check that its design&control mechanism are valid.

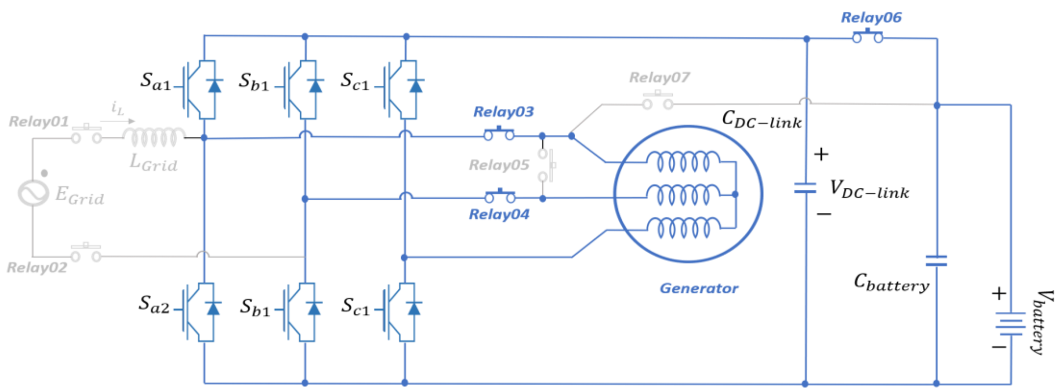
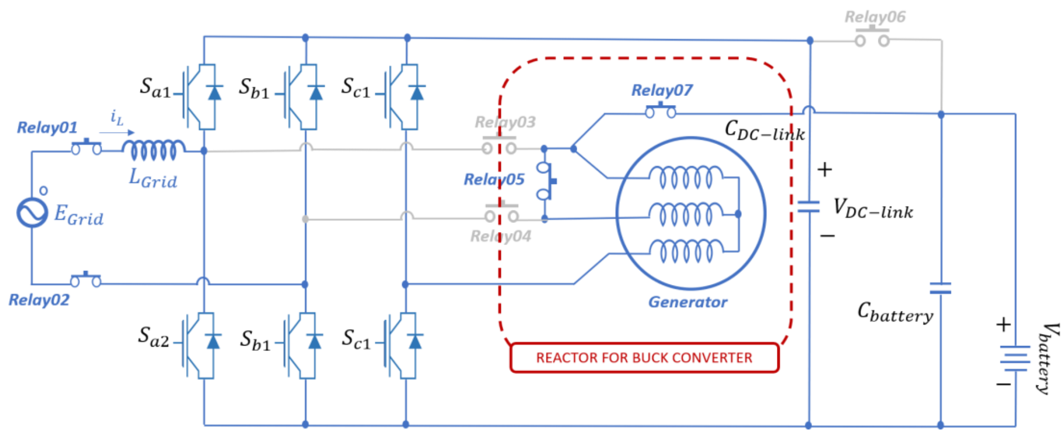


Fig. 1. (a)starter-generator drive mode



(b)

Fig. 1. (b) OBC mode 1-phase was implemented for the improved integrated charging system.

II.PROPOSED INTEGRATED CHARGING SYSTEM CONFIGURATION THAT USES A STARTER GENERATOR

The conventional HEV generator, the inverter, battery & OBC drive comprised of a starter generator. The higher power density is thus one of the major problems in the design of HEVs. This article presents the recharging of the battery & the motor power of the integrated circuit. The proposed circuit, as illustrated in Fig.1 consists of three-phase 2-level converters, power generators & seven power relay systems.

This circuit provides the battery with a higher rate of charge, since it uses the circuit's facility rating to charge the battery. Because the traction motor driving circuit has a high power rating, this circuit is often used to charge the battery.

A) The Starter-Generator Drive Mode

Figure 1 (a) indicates arrangement of the circuit in starting drive generator mode. The battery to the three-phase inverter is enabled in this mode via relay 06. The DC-Link & the battery have the power to power the starter generator using the 3-stage reverser. The electric node has the same value. Relay 03 & 04 are triggered & the 3-phase currents of the inverter are sent to the first generator. The first action in this manner is the same start-generator. That drives the generator or by employing regenerative energy to break the vehicle.

B) Bi-Directional OBC Mode

As described in Fig 1(b), the integrated circuit is altered to generate a single two-way OBC circuit. Circulation of OBC Mode includes a grid reactor, full bridge AC-DC, DC-DC & battery. The windings from Start-Generator shall be active as a DC-DC converter filter reactor. For connection to the entire-bridge converter, relays 01 & 02 are triggered. 1.5 times the inductance of the starter generator is associated with the inductance of the filter. The two distinct transmission statuses on this OBC circuit are provided by it. The situation is dubbed G2V (grid to vehicle power) when the vehicle is powered by grid electricity&the battery is charged.V2G mode provides saved power as a normal energy storage device for batteries to the grid.

III.THE IMPROVED MPCC METHOD IS USED TO CONTROL THE INTEGRATED CHARGING SYSTEM

As illustrated in Figure 2, an integrated charging system is controlled by a primary controller. The regulation of the DC-link voltage controller is the full-bridge converter's primary control objective. In this article, fuzzy logic is utilized to control the AC-DC side current. Each research period requires a reference current for DC-link voltage management. After conversion to a stationary coordinate system, this reference current is used as the current controller's reference.
The MPCC technique is often used in a variety of power converters, such as matrix converters&multilevel inverters, because of its efficiency&control flexibility. Based on three-phase system theory. A limitation of the MPCC technology in 1-phase is that it outputs three voltages, as

compared to seven in a three-phase system. As a consequence, the current error increases,&the THD decreases. It is possible to improve these problems by raising the switching frequency or improve the flexibility of the filter capacitance, but this is not a fundamental solution.
As a result, we evaluate the standard MPCC technique in 1-phase circuits,&then compare it to the Improved MPCC method for integrative charging system control applying fuzzy logic.

A) TheConventional MPCC Method

The basic MPCC technique used in the 1-phase system is reinforced by a similar theoretical basis in the 3-phase system. Because it takes into account way loads change over time, standard MPCC forecasts a future voltage&future current based on the relationship between load changes during the sample period. The 1-phase inverter may output three distinct voltages (Vdc-link, 0 –Vdc-link,&–Vdc-link). The connection among the output voltage&current generated by a 1-phase inverter is expressed as (1)

$$V_0 = Ri_L + L\frac{di_L}{dt} + E_{grid} \quad (1)$$

$$\frac{di_L}{dt} = \frac{i_{L((k+1)T_s)} - i_L(kT_s)}{T_s} \quad (2)$$

$$i_L((k+1)T_s = i_L(kT_s) + \frac{T_s}{L}\left[v_0(kT_s) - Ri_L(kT_s) - E_{grid}\right] \quad (3)$$

Equation (3) says that, given a 1-phase inverter state, the next step (k+1) current has three occurrences. The equation in a specific cost function in order to compare each of the current values with the following step reference current (4). (5). the previous step's current is combined with this new step's current,&by doing so, the Lagrange extrapolation formula often forecasts future step current.

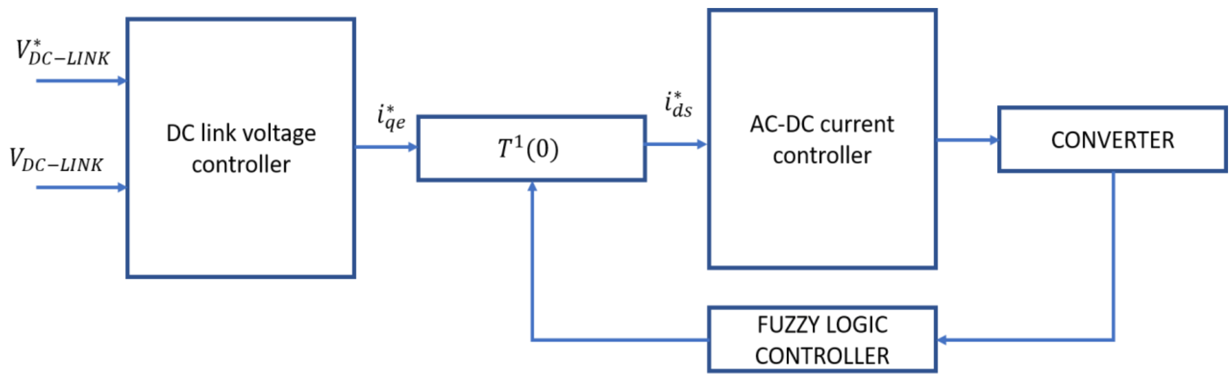


Fig. 2. Converter with Control block diagram.

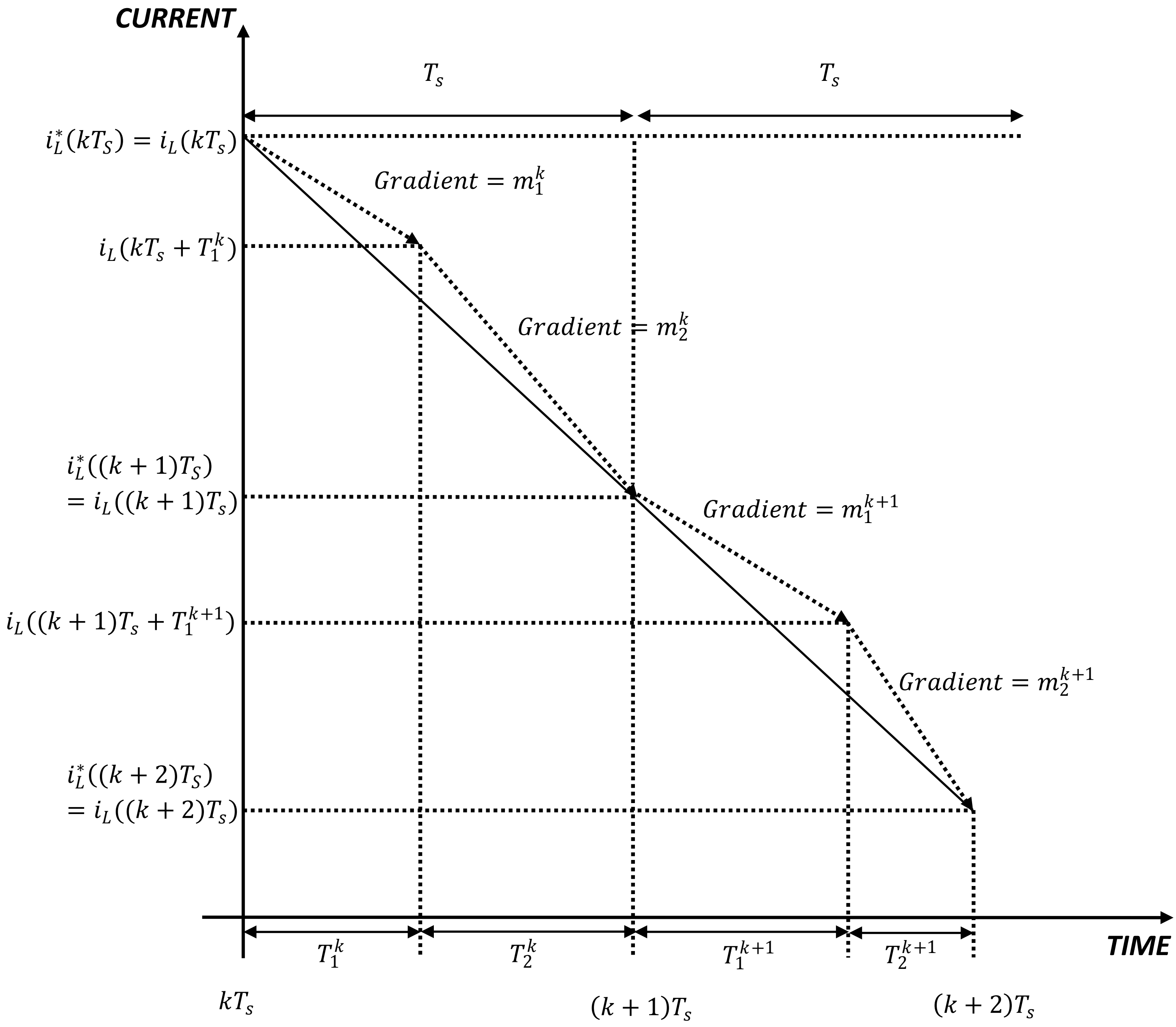


Fig. 3. The slope of current & time-span in recommendedEnhancedMPCC technique

$$i_L^*\big((k+1)T_s\big) = 3i_L^*(kT_s) - 3i_L^*\big((k-1)T_s\big) + i_L^*((k-2)T_s) \quad (4)$$

$$f_1 = \left|i_L^*\big((k+2)T_s\big) - i_L((k+2)T_s)\right| \quad (5)$$

Equation states that the cost function needs a 2-step future (k+2) predictions as well as an end-current prediction (5) setting the output current as (6)&(7)&moving the next-step (k+1) references could result in these future-step currents.

$$i_L((k+2)T_s) = i_L\big((k+1)T_s\big) + \frac{T_s}{L}\left[v_0\left((k+1)T_s\right) - Ri_L\big((k+1)T_s\big) - E_{grid}\right] \quad (6)$$

$i_L^*\big((k+2)T_s\big) = 3i_L^*\big((k+1)T_s\big) - 3i_L^*(kT_s) + i_L^*((k-1)T_s)$(7)

To reduce the cost function f1, three numbers of currents generated by a 1-phase inverter are compared to a reference current. The next-step current occurs inside the 1-phase inverter at following step (k+1), which may minimize the value function&therefore the output voltage to get this next-step current. Using the conventional approach, the 1-phase inverter produces the optimum voltage&currents for each of the sample intervals. However, when utilizing the traditional approach, the inverter only produces the output voltage once every sample time. As a result of these restrictions, the THD has deteriorated&the current problem has become more aggravated.

B) ProposedImproved MPCC Method by using Fuzzy Logic

Because the inverter produces just three numbers of output voltage, there are certain limitations to using the standard MPCC technique in a 1-phase inverter. The sample time Ts is split twice in the suggested MPCC technique to enhance the performance of the MPCC method. Each time period is represented as

$T_s = T_F^k + T_S^K$(8)

$i_L\big((k+1)T_s\big) = i_L(kT_s) + m_1^k T_1^k + m_2^k T_2^k$(9)

$$m_1^k = \frac{v_1^k - Ri_L(kT_s) - E_{grid}}{L}$$

$m_2^k = \frac{v_2^k - Ri_L\left(kT_s + T_1^k\right) - E_{grid}}{L}$(10)

$$i_L\big((k+2)T_s\big) = i_L\big((k+1)T_s\big) + m_1^{k+1}T_1^{k+1} + m_2^{k+1}T_2^{k+1}$$

$= i_L((k+1)T_s + T_F^{k+1}) + m_2^{k+1}T_2^{k+1}$(11)

$$m_1^{k+1} = \frac{v_1^{k+1} - Ri_L\big((k+1)T_s\big) - E_{grid}}{L}$$

$m_2^{k+1} = \frac{v_2^{k+1} - Ri_L\left((k+1)T_s + T_1^{k+1}\right) - E_{grid}}{L}$(12)

$i_L^*\big((k+2)T_s\big) = i_L\big((k+1)T_s\big) + m_1^{k+1}T_1^{k+1} + m_2^{k+1}T_2^{k+1}$(13)

$i_L\left((k+1)T_s + T_F^{k+1}\right) = i_L\big((k+1)T_s\big) + m_1^{k+1}T_1^{k+1}$(14)

$i_L\big((k+2)T_s\big) = i_L\big((k+1)T_s\big) + m_1^{k+1} + \frac{T_1^{k+1}}{L}(v_1^{k+1} - Ri_L\left((k+1)T_s + T_1^{k+1}\right) - E_{grid} + \frac{(T_s - T_1^{k+1})}{L}(v_2^{k+1} - Ri_L\left((k+1)T_s - E_{grid}\right) - \frac{RT_1^{k+1}}{L}(v_2^{k+1} - Ri_L\left((k+1)T_s - E_{grid}\right)$(15)

$$T_1^{k+1} = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

$$A=\frac{R}{L}(v_1^{k+1} - Ri_L\big((k+1)T_s\big) - E_{grid}$$

$$B= v_1^{k+1} - v_2^{k+1} + T_s R(\frac{Ri_L\big((k+1)T_s\big)-v_1^{k+1}+E_{grid}}{L})(16)$$

$$C= T_{samp}\, v_2^{k+1} - Ri_L\big((k+1)T_s\big) + Li_L\big((k+1)T_s\big)\text{-}\, Li_0^*\big((k+2)T_s\big)\text{-}E_{grid}$$

As a result, The next stage will last for a time period of (k + 1) is often calculated using the first&secondary output voltages of the next-step (k+1). The time-span T1 k+1 must be greater than a negative integer&less than or equal to the sampling period Ts in order for the controller to function properly. As a result, the formula's value is shown in the quadratic equation, which fails to meet the criterion, is rejected. Other time-spans T2k+1 may be calculated using equation after the application duration T1k+1 has been determined (8).

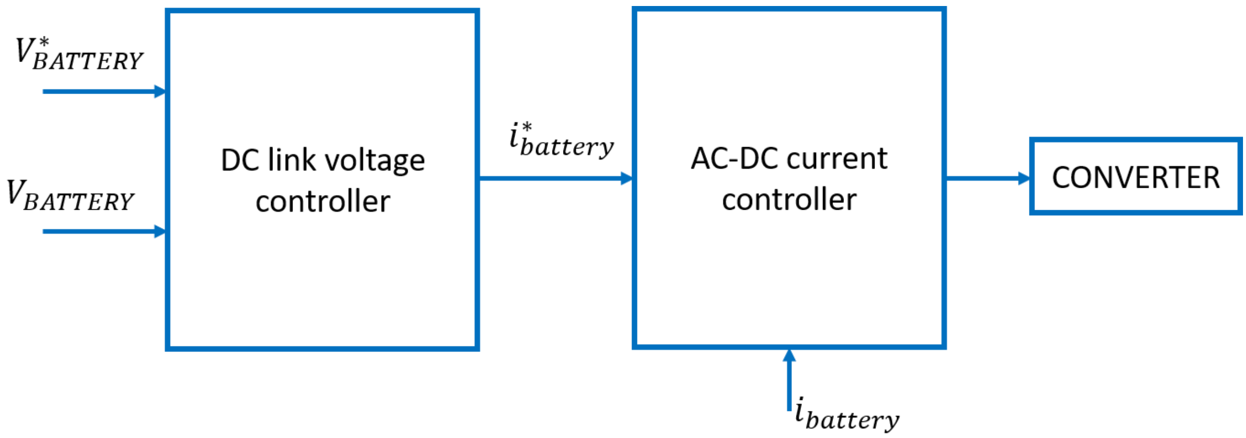


Fig. 4. DC-DC Converter control system

The suggested MPCC technique shall choose the optimum voltage settings&time-span based on the equation to minimize current error&ripple (17)

$$f_2 = \left|i_L^*\big((k+1)T_s\big) + T_1^{k+1}\big) - i_L\big((k+1)T_s\big) + T_1^{k+1}\big)\right| + \left|i_L^*\big((k+2)T_s\big) - i_L\big((k+2)T_s\big)\right|(17)$$

$$i_L^*\big((k+1)T_s\big) + T_1^{k+1}=i_L^*\big((k+1)T_s\big) + m_{ref}^{k+1}T_1^{k+1}$$

$$m_{ref}^{k+1}=\frac{i_L^*\big((k+2)T_s\big)-i_L^*\big((k+1)T_s\big)}{T_s}(18)$$

C) DC/DC converter Controller Design

The DCDC converter block diagram shows in Fig. 4. In order to accurately calculate the battery reference current, an FLC controller is applied to the real battery voltage. The current battery controller is used to calculate the c-phase leg service ratio. Two loading modes are available: CC (continuous current) and CV (constant voltage). This model switches between CC mode and voltage control operation while charging the battery, then sets a constant current for the battery before it reaches the nominal voltage. When the voltage controller is turned on, CV current is created internally.

III.SIMULATION RESULTS

The simulation results were presented to show that the integrated charge system&its control technique were correct. The grid voltage, which is 220V rms&60Hz, so amplitude&frequency are each 60Hz&220V rms respectively. The AC-DC converter's 1000 capacitor-based inductor&DC-link is connected to the 1.5-mH filter inductor. Start generator winding sets the DC-DC converter filter inductor. An inductance of 0.605 mH&a filter equal to 1 mH are associated with each winding. The condenser is attached to the battery in parallel&is 610 µF in capacitance. The sampling period is set to 50 µsec.
Figure 5 depicts the current waveform produced by the MPCC technique. Using the conventional MPCC technique, the current waveform contains a lot of current error&ripple, as illustrated in Fig. 5(a). The THD of the current in this instance is 3.93 percent. The current waveform produced by the suggested Improved MPCC technique utilizing fuzzy logic, on the other hand, includes less current error&ripple. As a result, grid current harmonics are improved,&its THD is just 1.90 percent.

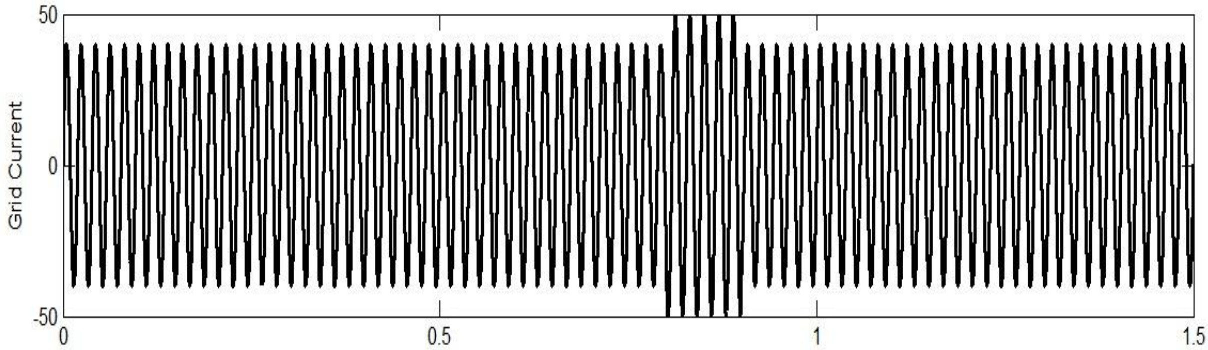


Fig.5.(a)Controlling the current using the MPCC technique Simulation result

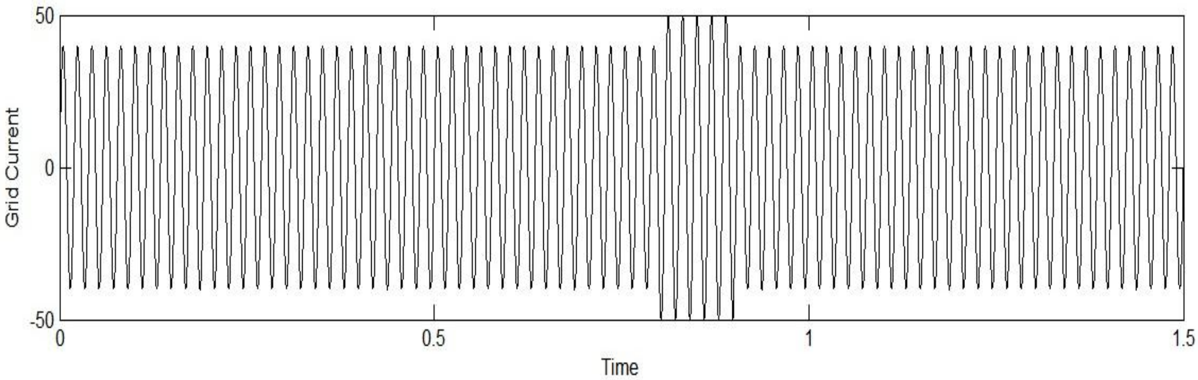


Fig.5. (b)The suggested Improved MPCC technique for current control Simulation result

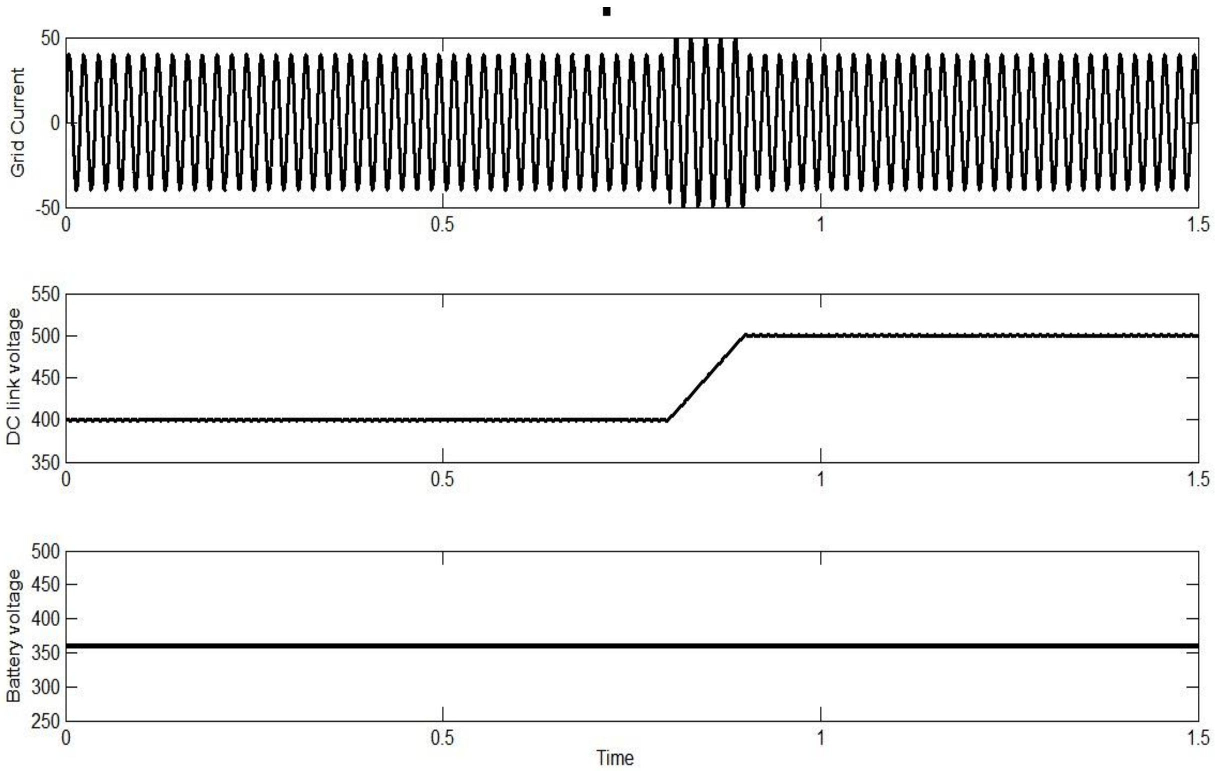


Fig. 6.(a)For the Improved integrated charging system, simulation waveforms depict various charging strategies: voltage control, which varies between DC link voltage

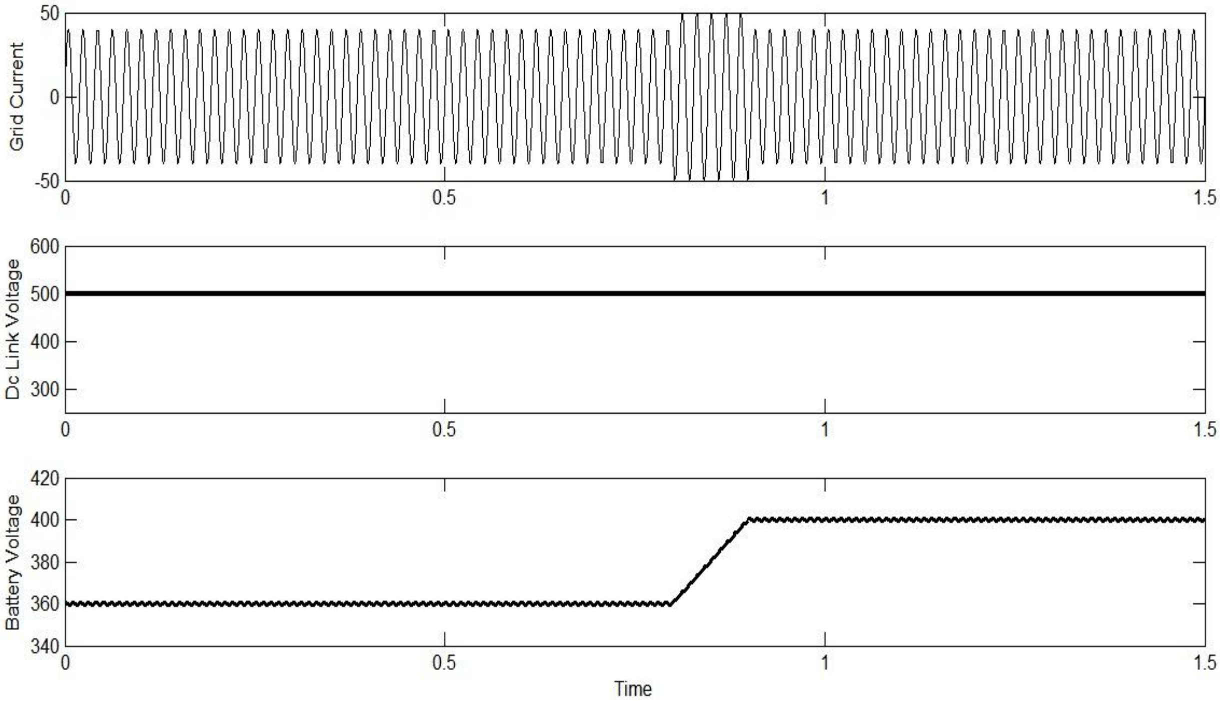


Fig. 6. (b) For the Improved integrated charging system, simulation waveforms depict various charging strategies: voltage control, which varies between battery voltage

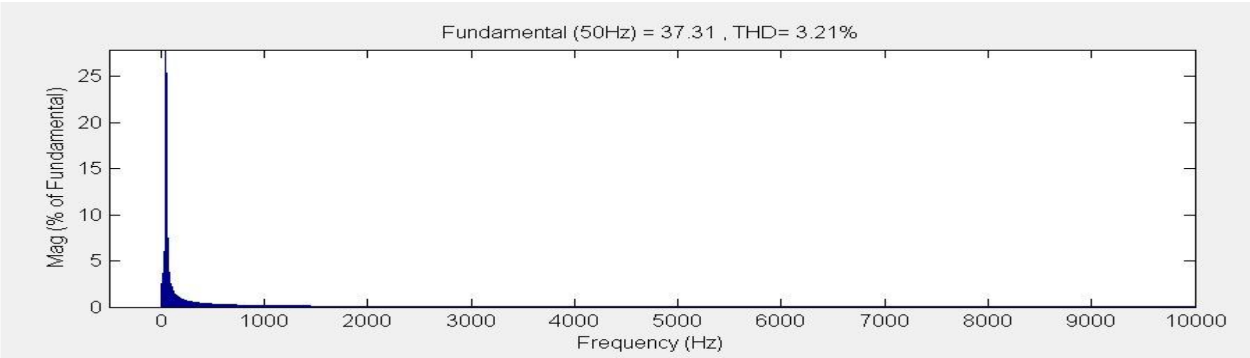


Fig.7. (a) PI Controller THD waveform

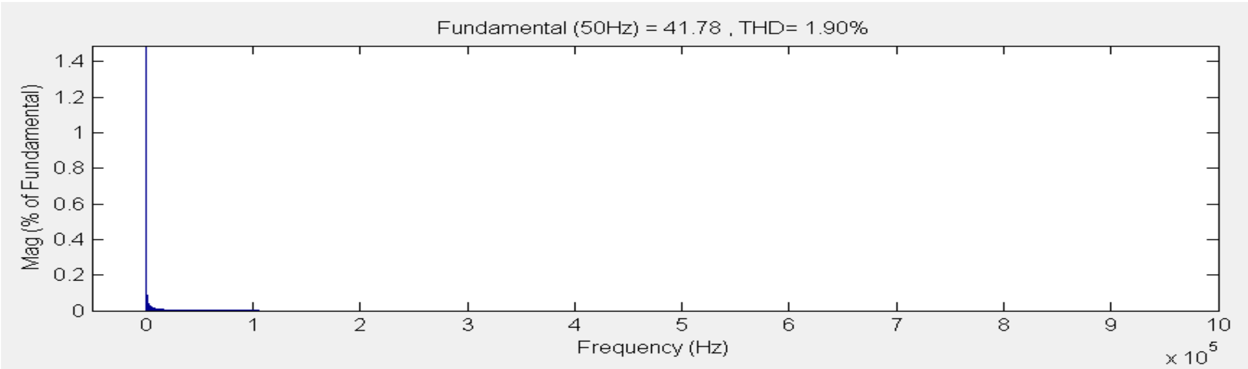


Fig.7.(b) Fuzzy Logic Controller THD waveform

CONCLUSION

A battery charging circuit based on Fuzzy logic controller (FLC)&a voltage ripple controller for hybrid electric vehicles are covered in this research. This research presents a single-phase bi-directional OBC design&control approach using a starter generator&its drive inverter in HEVs. In addition to typical starter-generator operation, the proposed circuit includes battery charging by controlling the power relay states. Because of this, conventional OBCs can be omitted from vehicles, resulting in higher power density. Additionally, an integrated charging system equipped with an FLC controller&MPCC is proposed employing a control approach using Fuzzy controller with MPCC. The design&control method of the proposed integrated charging system are validated by the simulation results.

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