PR Controlled Hybrid Cuk Converter Inverter fed Induction Heating System

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Abstract- **Cuk-converter is utilized to step-up voltage with reduced ripple in the output. Cuk-converter is a better interface between D.C. source and resonant inverter. This research proposes Hybrid Cuk Converter Inverter (HCCI) for induction heating. This paper works with modelling and simulation of closed-loop controlled HCCI system. The response of the battery system is stepped-up using a Cuk converter. The output of the Cuk converter is inverted & applied to a DC load. Closed loop PI and PR controlled HCCI systems are simulated and their time responses are compared. The hardware of HCCI is engineered & tested. The results indicate that PR controlled Cuk-converter system has enhanced time-domain response.**

Keyword - HCCI- Hybrid Cuk Converter Inverter, IH- Induction Heating, THD- Total Harmonic Distortion. EMI- Electromagnetic Interference, PR- Resonance controller

I.   INTRODUCTION

Hybrid-converter with boost-converter and resonant-inverter is presented in [1].Synchronous-control of boost-inverter for stand-alone nano-grid is proposed in [2]. Induction-heating is one of the huge uses of power--amplifiers.

Class—EF amplifier with high switching frequency is depicted [3]. Reduction of harmonic-content in CF-AS is given in [4]. Theory of R_F-Amplifier is given in [5]. Experimental-Results of CEIH is given in [6]. Current-mirroring of CDAS is given in [7]. Phase-shifted PWMI for IH is presented in [8]. IH using spiral inductors is depicted in [9]. Nature of CFAS and CIFAS is described in [10].

The collected works discussed above does not incorporate with PR controlled HCCI based induction heating system. This work proposes PR controller for enhancement of dynamic response of HCCI system.

This paper encloses the subsequent sections; section-2 deals with IH system. Details of existing system and recommended system are appeared in section II. Analysis of HCCI is appeared in section-3. The simulation-results obtained are displayed in section -4. Hardware results are displayed in section –5. The work is concluded in section-6.

II. IH SYSTEM

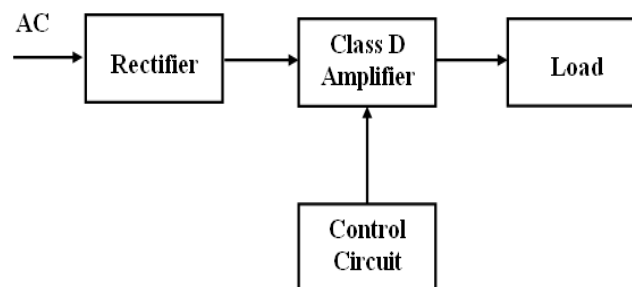Prevailing Class-D amplifier fed IH system is shown in Fig. 1.

Fig. 1. Prevailing Class-D amplifier fed IH system

The HCCI based IH system is presented in Fig. 2. The response of the Cuk converter is transformed into high-frequency AC using resonance inverter. Actual load voltage is matched with the fixed value of set-voltage and the difference is given to PR Controlled Cuk converter. The output of error detector is stipulated to pulse generator. The output voltage is regulated using PR.
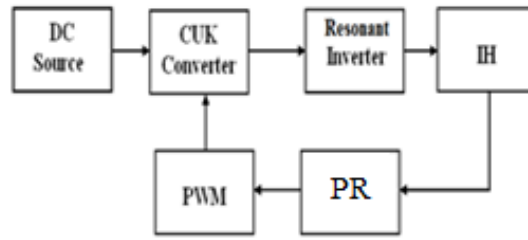
Fig. 2. Proposed HCCI based IH system using PR Controller

III. ANALYSIS OF HCCI

The analysis of HCCI is appeared in this section

The current across the load is

$i = K\,e{-}\smallint t Sinwt$ ……………………… (1)

Output of PI controller is

$V_{PI} = K_p\,e + K_I \smallint edt$ ……………………...(2)

The output of PR in S domain in as follows

$V_{0(s)} = K_P\,E_{(S)} + K_I\,E_{(S)}/S^m + K_D S^n\,E_{(S)}$ ….. (3)

The power-loss in the Induction Coil is

$P = I^2\,R + K_1\,B^2\,f^2\,t^2 + K_2\,B^{1.7}\,F_V$ .... (4)

IV. SIMULATION RESULTS

Open-loop HCCI system with variations in the input is appeared in Fig. 3.1. A step amendment in DC-input voltage is pertained. The DC voltage is fed to HCCI-System is shown in Fig. 3.2. The current response of HCCI is shown in Fig. 3.3. The voltage and power response of HCCI system as shown in Fig. 3.4 and 3.5.The increase in output parameters is due to the rise in input voltage.
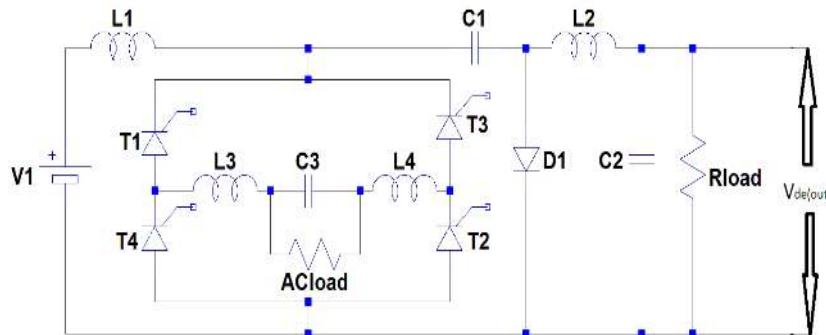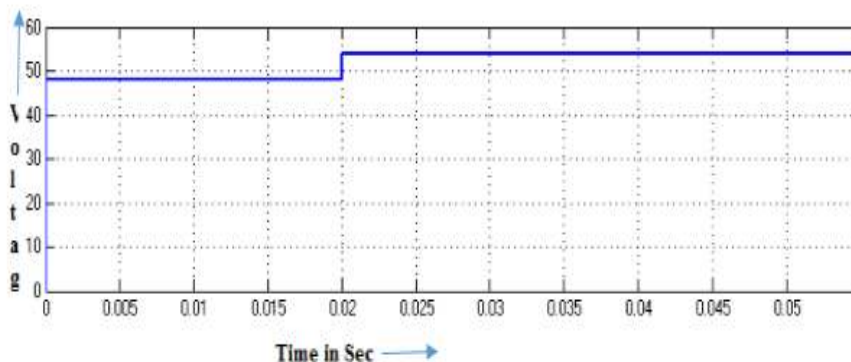

Fig. 3.1. Open-loop HCCI system with variation in input
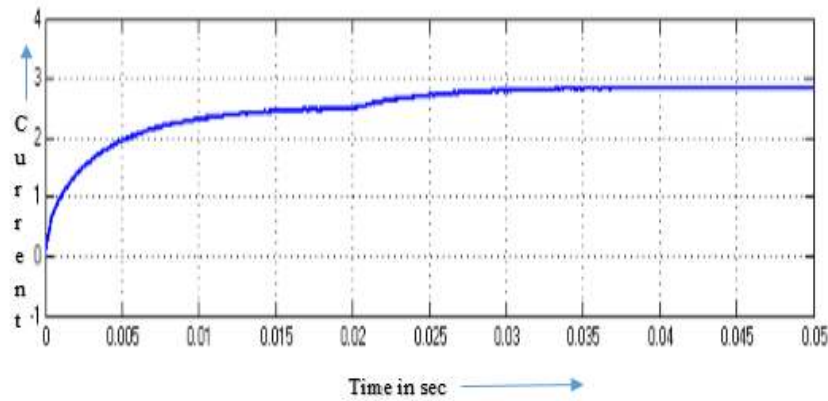

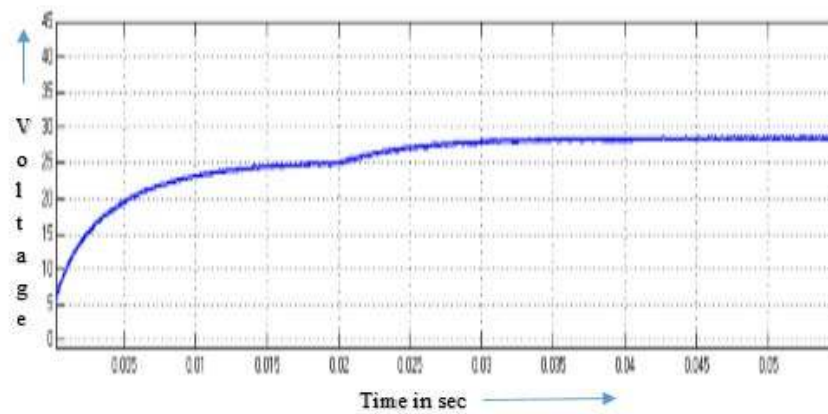Fig. 3.2. Voltage fed to HCCIS

Fig. 3.3. Current response of HCCIS
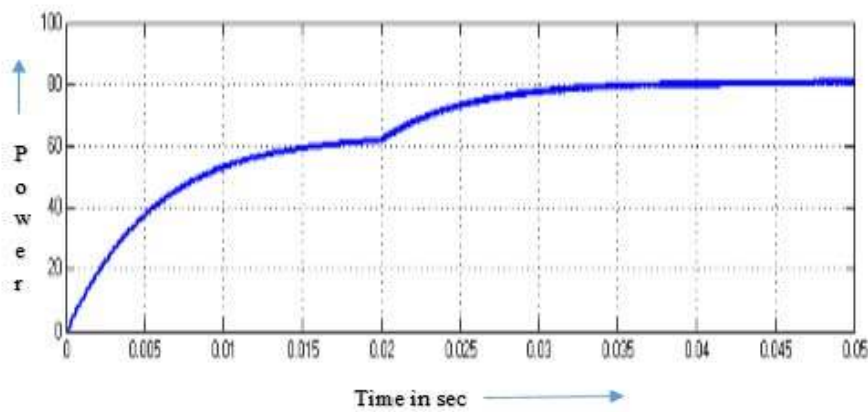

Fig. 3.4.Voltage response of HCCIS

Fig. 3.5. Power response of HCCIS

Closed loop HCCI system with proportional-integral controller is shown in Fig. 4.1. The output pulses from the comparator drives the shunt MOSFET of CUK-converter. The DC voltage fed to HCCI-System is shown in Fig. 4.2. The current response of HCCI is shown in Fig. 4.3. The Voltage and Power response of HCCI system are shown in Fig. 4.4 and 4.5.
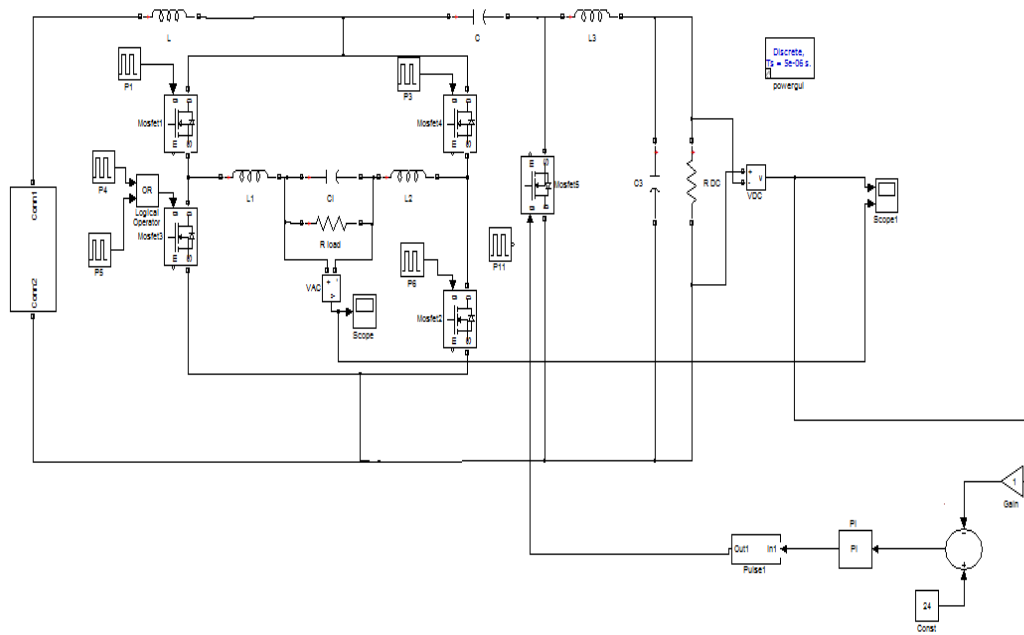
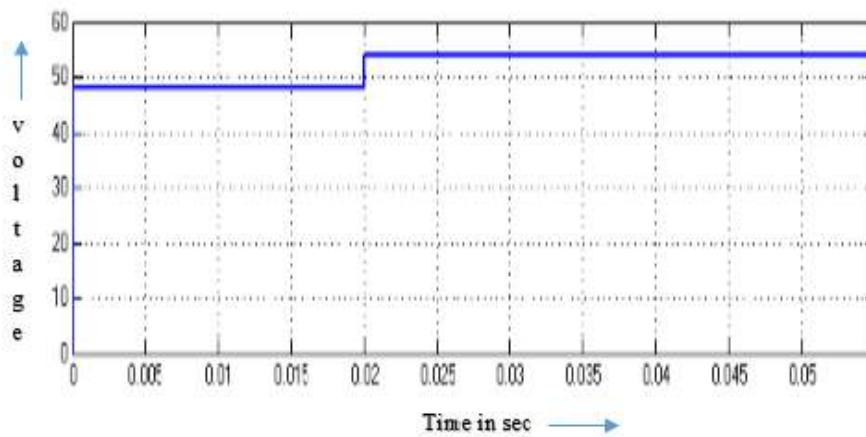Fig. 4.1. Closed-loop HCCI system with PI controller

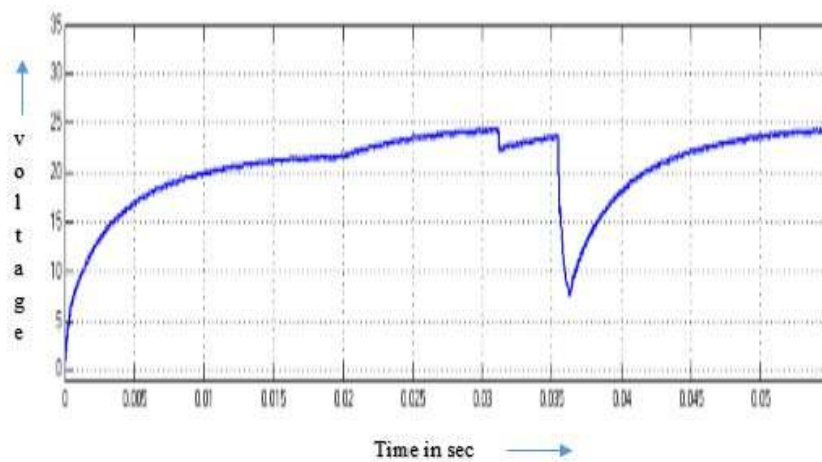Fig. 4.2. Voltage fed to HCCI
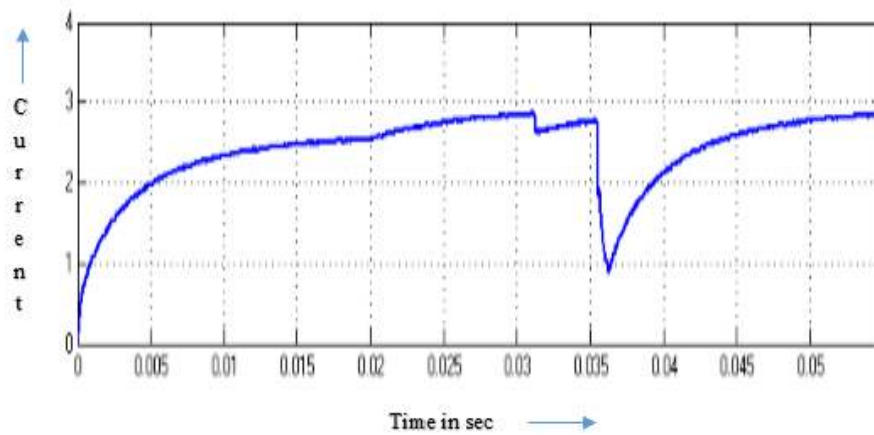

Fig. 4.3. Voltage response of HCCI

Fig. 4.4.Current response of HCCIS
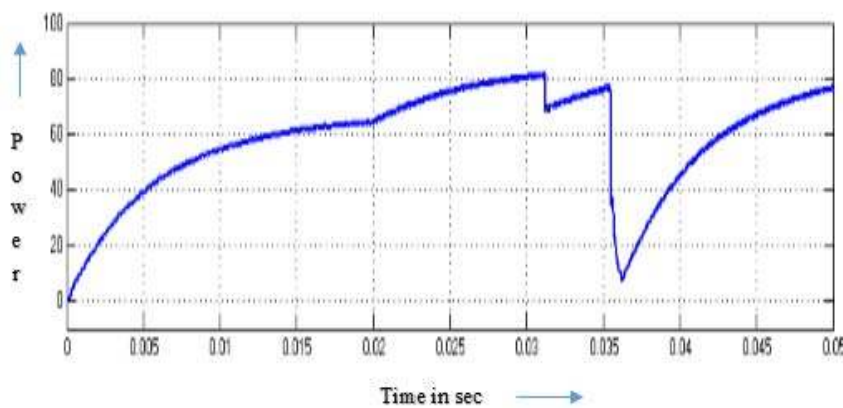
Fig. 4.5. Power response of HCCIS

Closed loop HCCI with PR controller is appeared in Fig. 5.1. The FOPID-controller in the previous circuit is substituted by PR controller. Summary of Time-Domain Parameters with PI & PR Controllers for V_{ref} =2 2 V are given in Table 1. Time-Domain-Parameters with PI & PR Controllers for V_{ref}=24 V are given in Table 2. Summary of Time-Domain Parameters with PI & PR Controllers for V_{ref}=26 V are given in Table 3.
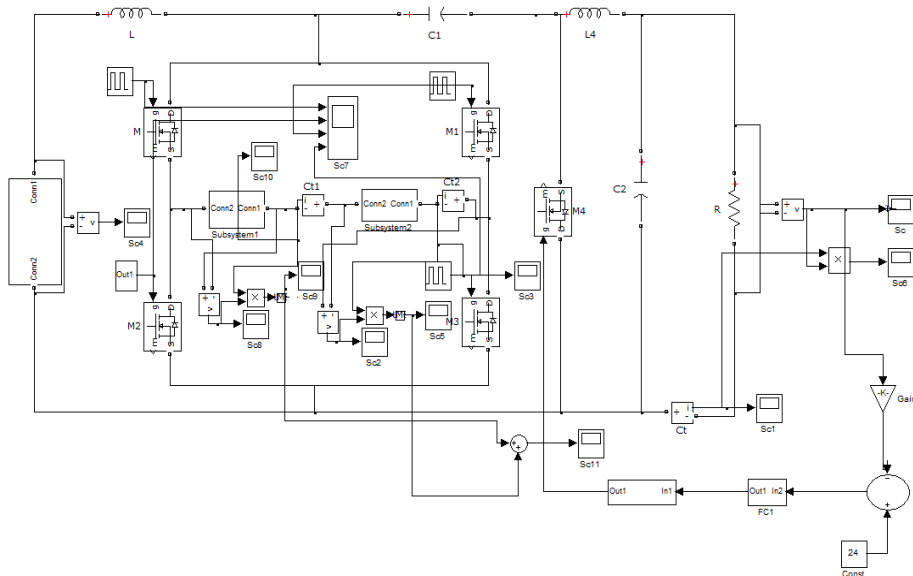
Fig. 5.1. Closed loop HCCI system with PR controller

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The fed voltage is appeared in Fig. 5.2 and its value is 55 V. The current response of HCCI is shown in Fig. 5.3. The voltage and power response of HCCI system are shown in Fig. 5.4 and 5.5.

Fig. 5.2. Voltage fed to HCCIS

Fig. 5.3. Voltage response of HCCIS

Fig. 5.4. Current response of HCCIS
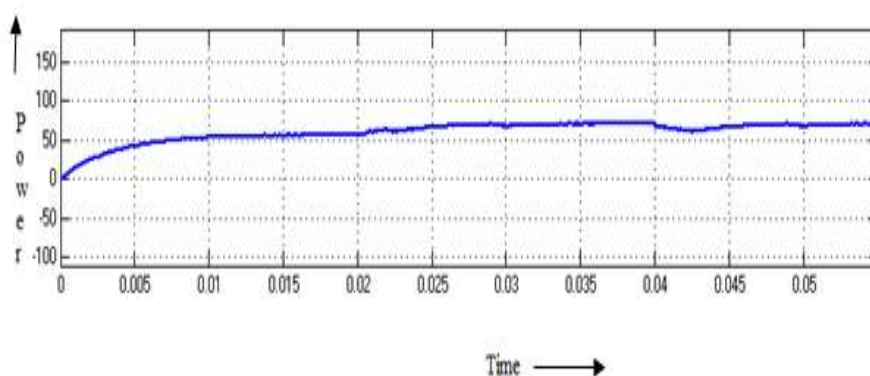
Fig. 5.5. Power response of HCCIS
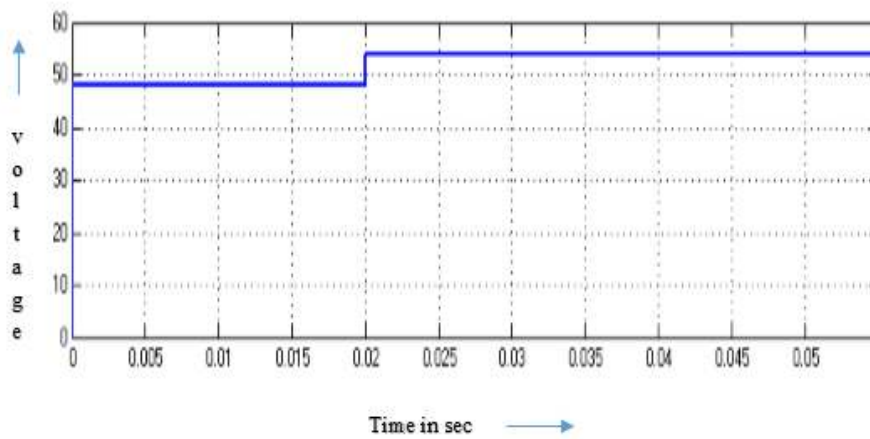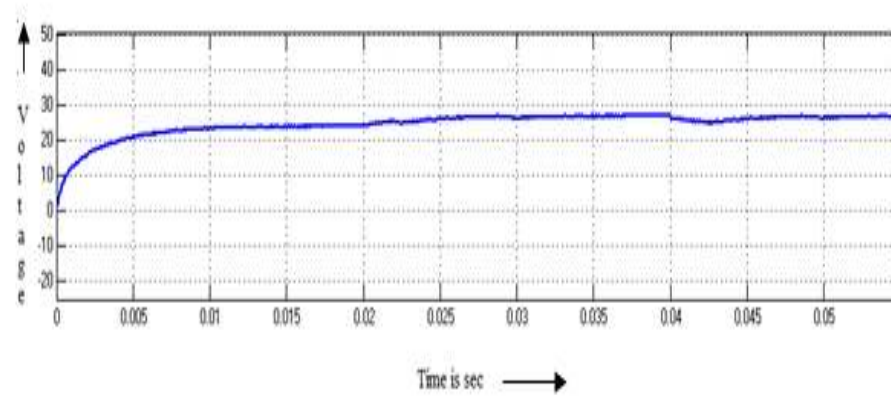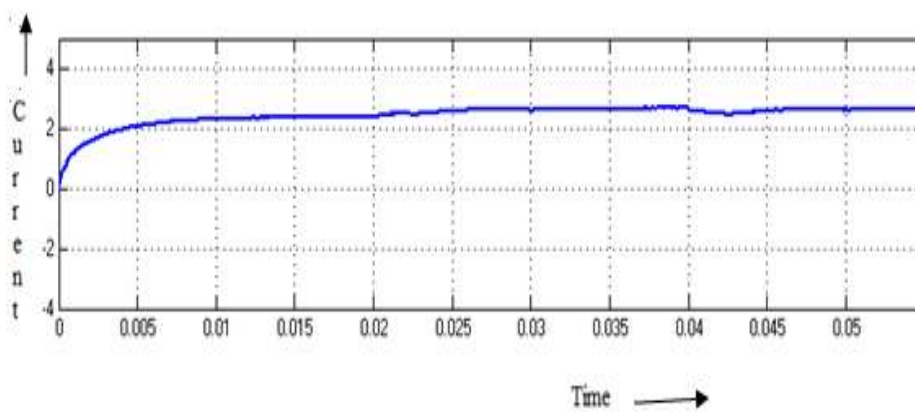
TABLE 1 Instantaneous of Time-Domain Parameters with PI & PR Controllers for Vref=22V

Type of Controller	Rise Time (Sec)	Peak Time (Sec)	Settling Time (Sec)	Steady State Error (Volts)
PI	0.028	0.045	0.050	3.3
PR	0.024	0.038	0.046	2.1

TABLE 2 Summary of Time-Domain Parameters with PI & PR Controllers for Vref=24V

Type of Controller	Rise Time (Sec)	Peak Time (Sec)	Settling Time (Sec)	Steady State Error (Volts)
PI	0.026	0.030	0.045	2.8
PR	0.023	0.025	0.040	1.7

TABLE 3 Summary of Time-Domain Parameters with PI & PR Controllers for Vref=26V

Type of Controller	Rise Time (Sec)	Peak Time (Sec)	Settling Time (Sec)	Steady State Error (Volts)
PI	0.027	0.032	0.047	2.9
PR	0.024	0.030	0.043	1.8

V. EXPERIMENTAL RESULTS

The hardware for HCCI system is fabricated and tested. The hard ware consists of control board, inverter board and Cuk board. The total hardware circuit diagram of HCCI is appeared in Fig. 6.1.The snap shot for total hardware of HCCI is appeared in Fig. 6.2.
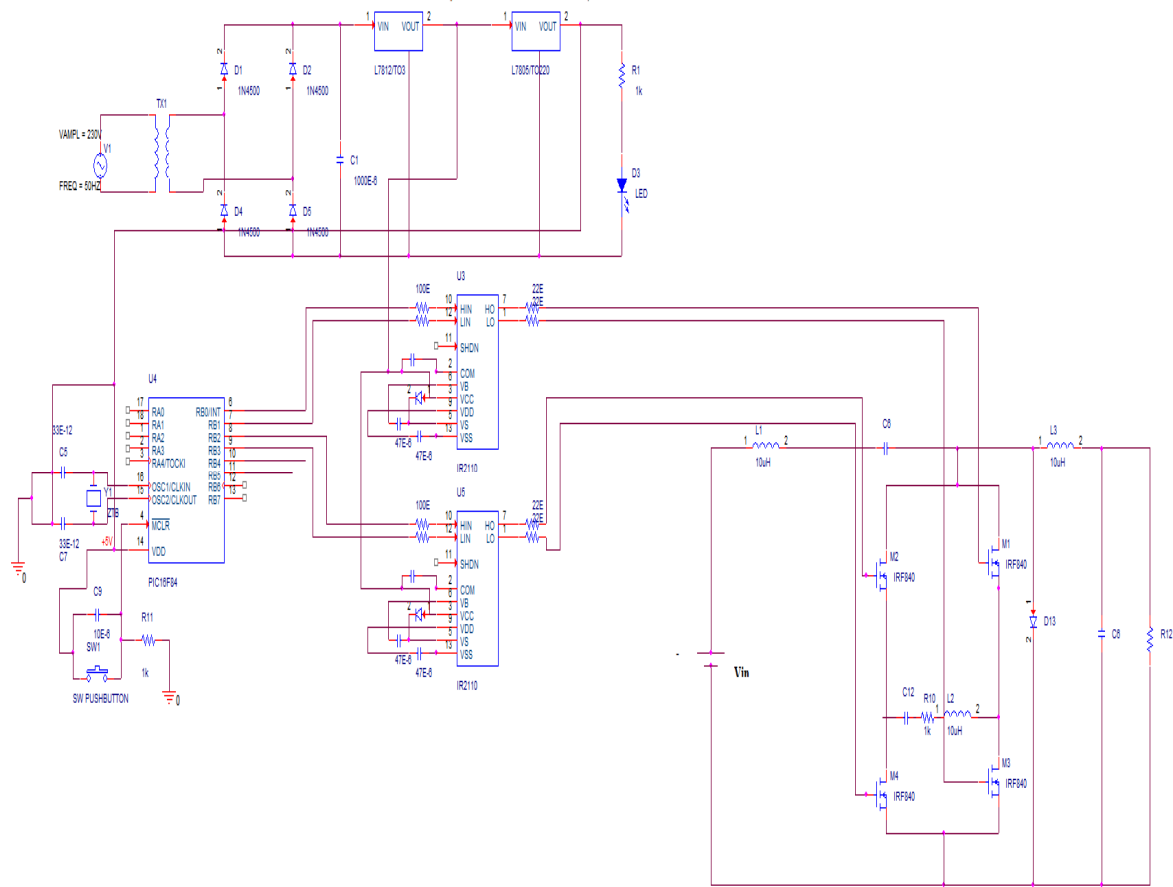
Fig. 6.1. Hardware circuit diagram
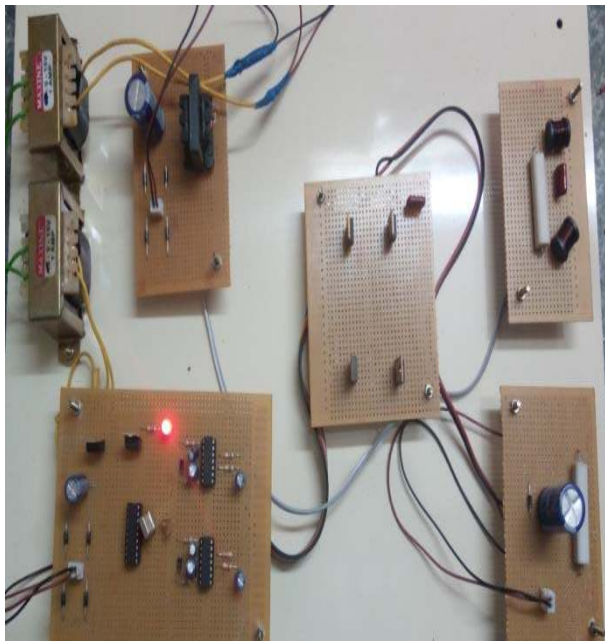
Fig. 6.2. Hardware snap shot

Table 4 Comparison of simulation and hardware results

Quantity	Simulation	Hardware
Vin	48v	48v
L1	50µH	45 µH
L2	2.3 µH	4 µH
C1	2.8 µF	3 µF
Co	2000 µF	2200 µF
Mosfet	IRF840	IRF840
Diode	1n4007	1n4007
Vco	24v	24v

The input voltage is shown in Fig. 6.3. The switching-pulses for switches M1 & M2 are appeared in Fig. 6.4.The output-voltage of cuk-converter is appeared in Fig. 6.5.

Fig. 6.3. Input-voltage

Fig. 6.4.Switching Pulses for M1 and M2

Fig. 6.5. Voltage response of inverter

Fig. 6.6. Voltage response of cuk converter

VI. CONCLUSION

Digital-simulation was performed for open-loop and closed-loop HCCI systems with PI and PID-controllers. These studies were executed utilizing the Simulink-based models for cuk converter – inverter system. The settling time is as low as 0.03 sec. The steady-state error in output-voltage is 1.5 V. Therefore PR controlled system gave improved response as compared with PI controlled system. The hardware results are similar to simulation ones. The assistances of the recommended system are high-gain and enhanced response. The conduction-losses are amplified since first leg is for shoot through and inverter operation.

The extent of the present work is the examination of PI and PR controlled closed loop HCCI systems. The comparison between PI & two loop PR based HCCI systems will be focused in future. Hardware at higher power level may be implemented at a later date.

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