Research Paper Engineering

# A Multi-Output High Frequency Cycloinverter for Induction Heating

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ABSTRACT

*In this paper, a low frequency AC (LFAC) to high frequency AC (HFAC) power conversion system without a DC smoothing Capacitor filter is introduced. The operating principle of a utility frequency AC-high frequency AC power frequency conversion circuit defined as a high frequency cycloinverter is described. The synthesized converter can be considered as a multi-output extension of a full-bridge topology. It allows the control of outputs, simultaneously and independently, up to their rated powers, saving the component count compared with the multi converter solution.*

*To verify the theoretical predictions, the conversion system is designed and simulated using the MATLAB simulink with an induction-heating prototype. The performance of the multi-output high frequency cycloinverter simulated with switching frequency 30 KHz and RMS input voltage 220 V.*

Key word : Induction heating, High frequency converter, Cycloinverter

**Introduction**

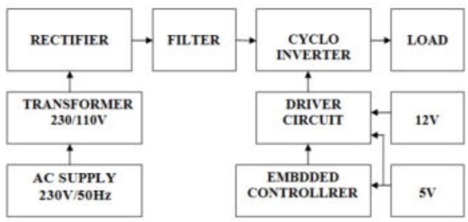
In general, electromagnetic Induction Heating (IH) is concerned with the non-contact, high efficiency and clean electric heating method due to the energy conversion heated device by the induction eddy current based on Faraday's law of the electromagnetic induction principle in addition to the Joule's heating principle [2]. The attractive IH technology used for industrial and consumer applications is roughly classified as low frequency IH and high frequency IH (over 20 kHz). The full bridge inverters [1] and [4] are based on the use of the quasi square wave control technique; the harmonic effects of output voltage and current are not considered, while the output voltage and current are contain harmonic with this technique. The equivalent circuit modeling of the electromagnetic induction heating [3-7] load is discussed.

This paper proposes the low frequency AC (LFAC)-high frequency AC (HFAC) power conversion circuit, defined as a high frequency cyclo-inverter or cyclo-converter, with a multi output series resonance inverter and does not include the DC smoothing filter stage. Also, the paper gives the circuit operation of the inverter with the quasi square wave control technique for the induction heating cooking appliances. Then, the circuit operation verification of the high frequency cyclo-inverter is carried out using simulation. Finally, the power regulation characteristics and power conversion efficiency characteristics of the high frequency cyclo-inverter are evaluated and discussed, concerning the active filtering characteristics of the harmonic line current components, and the total harmonic power factor on the AC power grid utility side.

*Block Diagram*

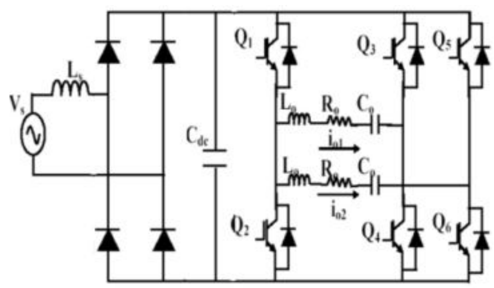
The 230V AC supply is step down using a step down transformer to 110V and the voltage is rectified using a full bridge rectifier circuit and using a low pass filter the DC output is filtered. The DC output is again converted to AC high frequency by a reasonant inverter and the output is given to the two loads. Thus the operation includes LFAC to HFAC conversion system.

*Figure 1: Block diagram*




*Cycloinverter*

*Fig 2: A typical arrangement of LFAC-HFAC conversion about here*



In the high frequency IH, an improvement of high frequency power supply due to AC-smoothing DC-HFAC indirect power conversion processing is required practically. The high frequency cycloinverter due to utility frequency AC-HFAC power conversion processing is more effective for the unity power factor and the sine wave current in the utility AC grid high-frequency power conditioning on the IH load side.A typical arrangement of the proposed LFAC-HFAC conversion system is shown in Fig. 2. The circuit structure of the AC-HFAC power converter or high frequency cycloinverter in which converts utility frequency AC into high frequency AC without the electrolyte capacitor DC link or complete DC smoothing bus line is shown in Fig.3

The power frequency conversion circuit as a high frequency cycloinverter is a power frequency changing circuit topology which converts the utility frequency AC into high frequency AC voltage of over 20 kHz. This circuit structure is defined as the high frequency cycloinverter, which is different from the conventional high frequency inverter.

The main power conversion circuit structure is composed of: The utility frequency (low freq.) of the voltage grid AC power supply source with 50Hz,220V, Filter Inductor (Ls) in utility AC input side to smoothing the AC input current , non smoothing capacitor (Cdc) in DC Link Voltage , multi output high freq. series resonance inverter, which is composed of six power switching blocks (IGBT, anti parallel diode) Q1, Q2, Q3, Q4, Q5 and Q6

where Q1, Q2 are in the same branch (common branch), and Q1 is switched by a square wave gating signal with duty cycle Dc (Eq.1)

$$D_c = T_{onc}/T_o \quad (1)$$

$T_{onc}$ On-Time of Q1, $T_o$ Periodic Time of Output

$$F_o = 1/T_o \quad (2)$$

where Fo: is the output Freq. The switching signal of Q2 is the complement of Q1.

Q3, Q4 are in the same branch (branch of Output No.1). Q4 is switched by a square wave gating signal with duty cycle D1 (Eq.3)

$$D_1 = T_{on1}/T_o \quad (3)$$

$T_{on1}$ On-Time of Q4, The switching signal of Q3 is the complement of Q4.

Q5, Q6 are in the same branch (branch of Output No.2). Q6 is switched by a square wave gating signal with duty cycle D2 (Eq.4).

$$D_2 = T_{on2}/T_o \quad (4)$$

Ton2 On-Time of Q6, the switching signal of Q5 is the complement of Q6; the switches Q1, Q4 are operating in the positive half cycle to produce +Vs and the switches Q2, Q3 are operating in the negative half cycle to produce -Vs for output No.1. The switches Q1, Q6 are operating in the positive half cycle to produce +Vs and the switches Q2, Q5 are the operating in negative half cycle to produce -Vs for output No.2. By observing the circuit configurations for the one-output , two-output and three-output inverters, we can conclude that for the one-output, according to full-bridge topology, it needs 4 power switches, for the two-output as previously presented in [1], It needs 6 power switches, and finally for 3-output 8-power switches. Besides, per n output according to the full-bridge topology, it needs 4n switches; so, by merging the right legs into one common leg, two switches are eliminated. In general 2*1+2 switches are needed for the one-output inverter and for the two-output inverter 2*1+2+2*1=2*2+2=6 and for the three-output inverter: 2*3+2=8 switches are needed respectively. As a result 2*n+2 switches for the inverter of the n-output are desired. Consequently, 2n-2 switches or 2n-2 control circuits are eliminated; the proposed system allows the control of two output voltages, power simultaneously and independently by keeping the duty cycle DC of the common branch constant, and varying the duty cycle D1, D2. The two loads consist of flat inductor coils coupled to standard cooking pans. This is represented by the equivalent effective inductor (Lo) in series with the equivalent effective resistance (Ro) and each load series with the resonance capacitor (Co).

**COMPUTER SIMULATION**

Simulation for a multi-output high frequency cyclo-inverter for induction heating is performed by using MATLAB 7.4 and the simulation is shown in Fig. 3a. The input here, is a 220V AC sinusoidal and after rectification the output voltage across the capacitor or DC link is shown in Fig. 3b. The driving pulses are shown in Fig. 3c - Fig. 3e. The output voltage and current for different loads are shown in Fig. 3f-3i.

*Figure 3 : Simulation circuit*

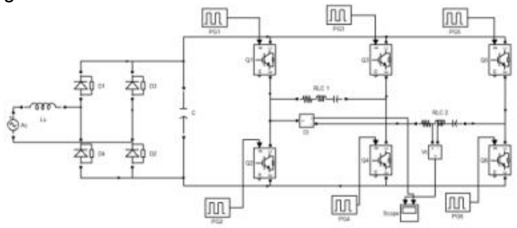


*Figure 4: Voltage across capacitor or DC link voltage*

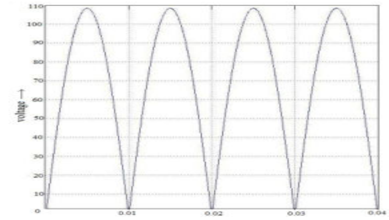


*Figure 5: Pulse input for switch Q1 and Q2*

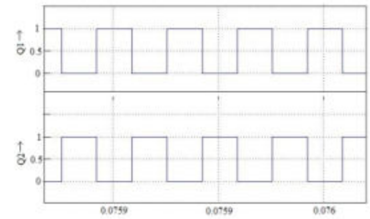



*Figure 5: Pulse input for switch Q1 and Q2*

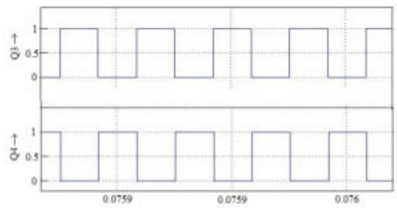



*Figure 6: Pulse input for switch Q3 and Q4*

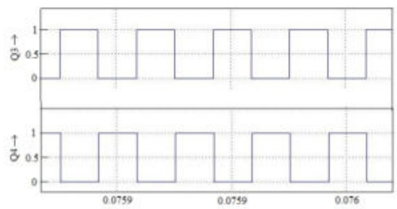



*Figure 7: Pulse input for switch Q5 and Q6*

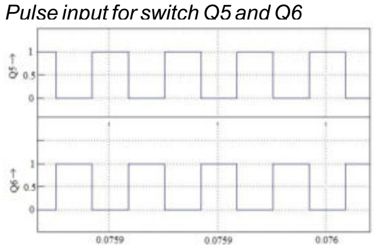



*Figure 8: Output load 1 current for 50% duty ratio*

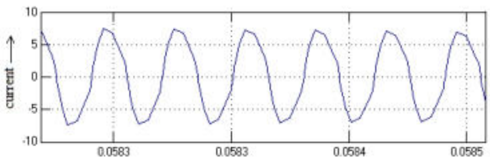


*Figure 9: Output load 1 voltage for 50% duty ratio*

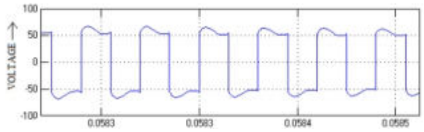



*Figure 10: Output load 2 current for 40% duty ratio*

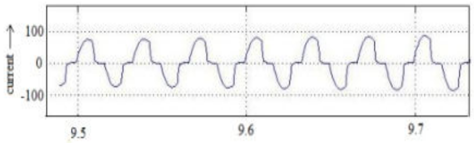
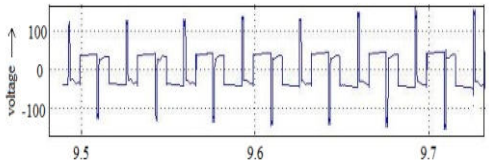



*Figure 11: Simulation circuit and results about here*




**Conclusions**

This paper introduces the high frequency cycloinverter system based on the LFAC to HFAC power converter with a non electrolytic capacitor DC voltage smoothing filter link. The system can achieve compactness in a volumetric physical size and weight, low cost, high reliability, high efficiency, low noise and long life. A multi-output (two-output) series-resonant inverter has been obtained from some specifications, using a quasi square wave control strategy. The synthesized converter allows supplying two inductive loads up to their rated values simultaneously and independently with only one converter saving two transistors compared with the full bridge alternative solution. The two output inverter is generalized into an n-output series-Resonant inverter with saving switching devices (i.e. 2n+2 switching device instant of 4n switch device). The LFAC to HFAC conversion system has been simulated by MATLAB simulink software and applied to induction heating cooking system with good results performances for a multi-burner Appliances. In the studied system , the input current from the AC source does not contain harmonic and operating at unity power factor.

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