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RESEARCH ARTICLE

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# THREE PHASE TO SINGLE PHASE MATRIX CONVERTER FOR HIGH FREQUENCY METAL HEATING USING R L LOAD IN PSIM SIMULATION SOFTWARE

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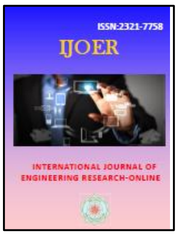


**ABSTRACT**

A Modern multilevel resonant converter assigned for direct three phase utility frequency AC to high frequency AC power used for the industrial metal hardening; induction heating applications are presented in this paper. An AC-AC converter designed for soft switching with the minimum number of bidirectional switches is implemented for direct frequency conversion. The conducting current of bidirectional switches can be reduced effectively by the multi resonant tank while keeping a high power in the induction heating or R L load. Accordingly, the practical power converter with simplicity, cost-effectiveness, and high efficiency can be realized Based on simple pulse frequency modulation. The circuit topology and operating principle of the proposed converter are described, by which the design procedure of the multi resonant tank and the switching frequency is presented. The performances on the soft switching, and the steady-state pulse frequency modulation characteristics of the AC-AC converter are evaluated by using PSIM software with R L load.
Keyword: Induction heating, High frequency, AC-AC Converter, Resonant tank.

## 1.INTRODUCTION

High-frequency Induction heating systems have been familiar in the industrial fields because of their heating efficiency and the surface hardening and tempering treatment of metals has been contributing greatly to the improvements of the quality of steel materials. By taking into account the skin effect and surface depth of heating, a high frequency converter is designed for effective heating of metal objects. A high frequency current contributes to a surface hardening of the heating object is obtained from the principle of High frequency induction heating for the metal surface heating treatment. The power stage which transfers the three phase utility frequency ac to a single phase high frequency ac plays a major role in attaining high efficiency and high performance of the IH and the relevant inductive power transfer applications. The well-known basic circuit topologies for industrial IH applications are composed of three phase thyristor rectifiers and current source or voltage source high frequency inverters and a high frequency matrix converter is designed exclusively for this project. Those conventional IH systems face some technical issues in terms of power density improvements and efficiency due to some bulk capacitors and inductors in the dc link, which causes large volume and short life cycles of the entire system. A matrix converter is designed for providing the high frequency required for industrial heating.

In this operation we use the AC-AC converter or matrix converter, cyclo converter by reducing the number of bi-directional switches, Normal cyclo converter converts utility frequency to Utility frequency, This matrix converter converse three

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phase Utility frequency to single phase high frequency to heat the metal.This project made the prototype model so I use a resistance and inductance load, this inductance load acts like metal so output high frequency will show in CRO because if we use a metal output we need to make high rating components and high protective device, Its make high cost and expensive circuit topology so we only use RL load for a high-frequency output operation.In a three phase ac to ac converter is challenged in many industrial applications because circuits and components more expensive so I designed the prototype of three phase utility frequency ac to three phase high frequency ac matrix converter.

This paper explained below: the proposed circuit and operating principle in section 2,Proposed topology important components of matrix converter resonance tank and parameter of components explained in section 3 and finally section 4 is Simulation design as PSIM simulation software.

## 1. CIRCUIT TOPOLOGY

*A.Circuit Configuration*

The three phase utility frequency AC source connected a half-high frequency AC-AC matrix converter to give power to the single phase high frequency ACRL load. The three phase current through the bidirectional MOSFET switches can be reduced effectively aid of the multi resonant tank filter circuit. The load resonant tank is composed of RL load, series or output capacitor *Co,*and power factor tuned or parallel capacitor *Cp*. The output capacitor *Co* has to reduce the reactive current by creating series resonance with the induction load. The load is Suppress the impedance of the parallel resonant circuit under the high frequency switching operation. The gate turns on and turns off timings are determined by the principle of two phase modulation which utilizes the maximum voltage and the minimum voltage of the three phase power source it varies the primary and secondary frequency in low to high The switches connected to the maximum and minimum voltage phases in each section drive the interchange while those connected to the intermediate. The three sets of bidirectional switches are operated by each pair one is the positive side other one is the negative side and operate the interval of the utility frequency AC source voltage.

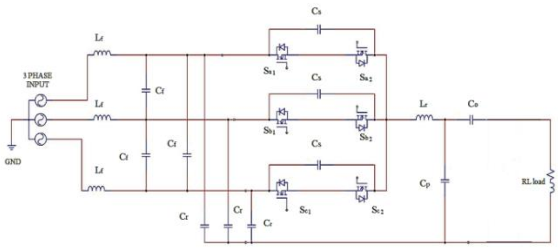

Fig.1. Circuit diagram – Three phases to single phase Matrix converter

*B. Block Diagram Depiction*

In the Block diagram, the first block represents the three phase input supply coupled with a filter. At this block, the input frequency is the utility frequency which is then fed into the second block known as Direct AC - AC converter called Matrix converter. Then the controlled AC voltage is fed into the resonant tank with a filter. At this block, the utility frequency gets converted into the single phase high frequency AC supply which is used for high frequency applications example, metal heating, induction heating, and metal hardening.

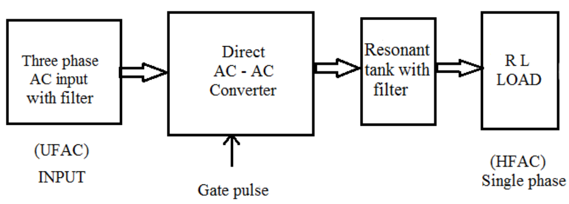


Fig.1.Block diagram - Three phase to single phase Matrix converter

*C. Operating Principle*

The input voltage and current waveforms for three phase utility frequency ac-ac converter are normal usable three phase power supply R,Y, and B or A,B and C three phase lines which are controlled by MOSFET switches based on the high frequency specifications, ac-ac converter bidirectional switches are controlled input sine wave positive and negative polarities it is proposed for back to back switch connection, Each mode two switch conduct positive and negative polarity in two different phase because each phase differences is

120 degrees one phase is positive at the same time other in negative polarity. This circuit operates three modes based on switch on and off logic based on the PSIM simulation. Switching frequency is high we need specific operating components in this project I used a MOSFET switch because it's suitable for high frequency applications and voltage controlling, The operation modes as follows:

**Mode 1** Sa1 and Sb2 switches are turned on in zero degrees so phase A conducted and phase B close the circuit, Sa1 conducts phase A positive polarity Sb2 conducts phase B negative polarity, at the same time two switches close the positive and negative polarity others are off condition.

**Mode 2** Sb1 and Sc2 switches are turned on in phase shift of 120-degree continuation to mode 1 so phase B positive cycle conduct by an Sb1 and phase C negative cycle conduct by an Sc2 positive and negative polarity completed in mode 2.

**Mode 3** Sa2 and Sc1 switches are turned on in phase shift of 240 degrees continuation of mode 1 and 2, Phase C positive cycle conducted by an Sc1 and phase A negative cycle conduct by a Sa2 this mode are operated continuously its simulation operation you don't have logic for switching I was used a pulse generator for switch control by varying the switching frequency and triggering angle.

**3. DESIGN AND CIRCUIT TOPOLOGY**

Design of the parameters are calculated for PSIM simulation model it's not suitable for real-time applications, Value of the filters in a simulation model can vary but real-time we need to design by a voltage and current rating in the circuit, In this project used the RL load it's equivalent for inductance load so the first state we find the output load type and parameters,

*A . Switching Frequency*

Switching frequency is the same as output frequency or resonance frequency if you vary a switching frequencyResonance frequency will change resonance it's controlled bya switching frequency in this resonant filter and MOSFET switches designed for high frequency application because this output is high frequency.Resonance frequency depends on output R L load or heating metals in this system I used equivalent R L load, I set the value of output resistance is $R_0$ =2Ω Capacitance $C_0 = 50\, nf$ and inductance is $L_0 =$ 47μf.The formula of the resonance or switching frequency calculated by a resistance capacitance and inductance values is,

$$f_s = \frac{1}{2\pi\sqrt{L_0 C_0}}$$

**B . Resonant Filter**

A resonance filter or resonance tank is an output filter circuit it filters the output high frequency output waveform, Resonance filter circuit of one inductor one parallel capacitor, and one output capacitor we need the find the parameters of the resonant filter by used to resonance frequency inductance and capacitance values. The formula of the output capacitance is,

$$Co = \frac{1}{(2\pi f_r)^2 L_0}$$

Output capacitance and inductance parameters used to determine the parallel capacitor value, Formula of the parallel capacitor in the resonant filter is,

$$C_p = \frac{1}{(2\pi f_{r2})L_0 - \frac{1}{C_0}}$$

Resonance inductor $L_r$isconnected to an R L load in series connection so it's called series resonant filter on the output side, This inductor is used to the high frequency application for filter the current so we need to find the resonant inductor value used to average voltage and minimum value of the current in the output side and fix the value of snubber capacitor $C_s$ it,s connected the ac-ac converter switches in parallel connection shown as a circuit diagram this capacitor product the converter like dv/dt protection, The value of the snubber capacitor is 3 nf so we can find the value of the resonant inductor used to voltage current and snubber capacitor, the value of the $V_c = 200v\ i_{min} = 4A.$ Formula to find the series resonant inductance is,

$$L_r = \frac{3 C_S V_{CS}{}^2}{i_{pmin}{}^2}$$

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*C . Input Filter circuit*

This project uses the three-phase three wire system this three phase input supply connected the filters it's a tank of inductor and capacitors like shown as the circuit diagram, This Three phase supply all phases connected to the inductor in series connection because the inductor is a current control device this inductor charge and discharge the current so it's called filter inductor $\mathbf{L_f}$, filter capacitor connected to the phase to phase connection between the two phases capacitor filter the input voltage capacitor is a voltage control device so it's used for filter the three phase input voltage it's called filter capacitor $\mathbf{C_f}$,Three phase input filter designs by the basic parameters ofinput supply so we donot need any parameter calculation but your range of input voltage and current is important to choose the inductance and capacitance, all components parameters values in bellow the tabulation for use in the PSIM simulation model.

Resonant capacitor$\mathbf{C_r}$ connected to all phases with output single phase load it's designed maximum value of output power because it connected output directly and high frequency operation this capacitor used for single phase output connection with high frequency.

**Table 1.PSIM Simulation Model Parameters**

| | Parameters | values |
|---|---|---|
| 1 | Three phase Input | 100V,50HZ |
| 2 | Filter Capacitor Cf | 300 nf |
| 3 | Filter Inductor Lf | 200µh |
| 4 | Resonance Capacitor Cr | 150 nf |
| 5 | Resonance Inductor Lr | 25µh |
| 6 | Output Capacitor Co | 75 nf |
| 7 | Snubber Capacitor Cs | 3 nf |
| 8 | Parallel Capacitor Cp | 300 nf |
| 9 | Output Resistance $R_0$ | 2 Ω |
| 10 | Output Inductance $L_0$ | 47µh |

**4. SIMULATION ANDRESULT**

*A.Simulation Circuit Diagram*

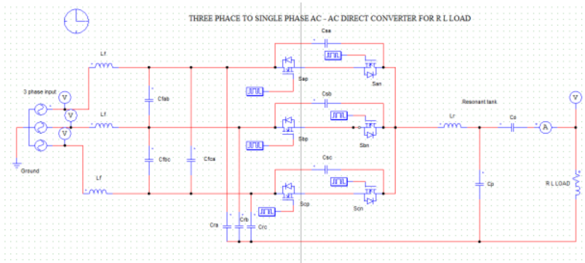


Fig.3.PSIM Simulation Circuit Diagram of Resonant Matrix Converter with RL Load

In this simulation draw at PSIM software this connection circuit model in fig.3.In this circuit MOSFET switches are used for MOSFET controllers is basic pulse generator used because this circuit is an open-loop control circuit not any type of closed-loop feedback circuit is there because it reduces the expense of the project and this metal heating or RL load application do not need the accurate output waveform we need to metal heating induction or High frequency AC output. One ammeter and one voltmeter connected on the output side to measure the output voltage and current waveform we don't need other measurement devices in this circuit because this circuit had only one type of ac-ac converter.

*B.Simulation Result and Waveform*

In this simulation, we measure the output voltage and current in various high frequency 1 HKZ to 80 kHz varies frequency for changing to the MOSFET switching frequency did not change the other components parameters in PSIM simulation but the hardware wants to change the parameters for varies output load type switching frequency and power rating.1 kHz,20 kHz,40 kHz, and 80 kHz resonant frequency or switching frequency output voltage and current waveform are measured using simulation this varies frequency used to varies metal applications so we analysis an all type of switching frequency's, Output waveform in varies frequency is bellow shown.

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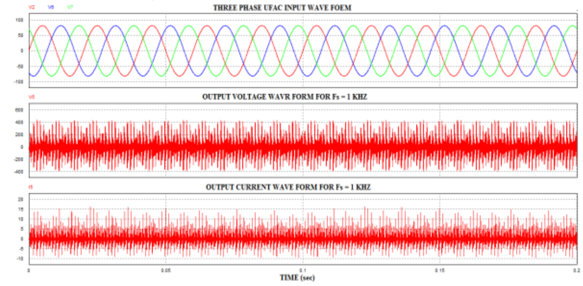

Fig.4. Output Voltage and Current Wave Form for Fr = 1 kHz

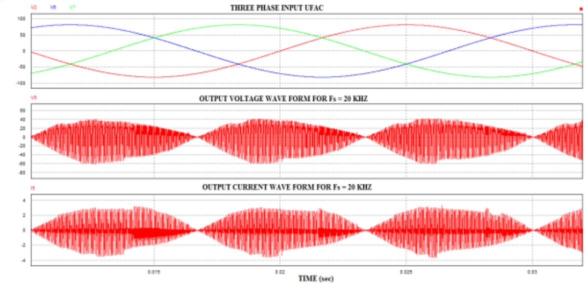

Fig.5. Output Voltage and Current Wave Form for Fr = 20kHz

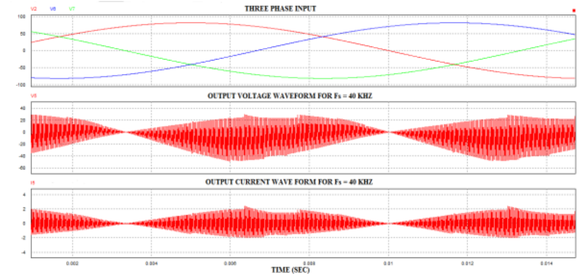

Fig.6. Output Voltage and Current Wave Form for Fr = 40kHz

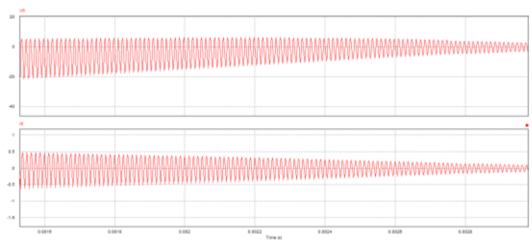

Fig.7. Output Voltage and Current Wave Form for Fr = 80kHz

High frequency output voltage and current waveform at variable frequency are shown the highest level of resonant frequency is 80 kHz this zooming waveform is shown positive and negative polarity change continually, All frequency voltage and current waveform are similar.

The main thing is if you increase the frequency automatically reduce output voltage and current so we need to calculate the correct specific parameters in hardware topology, Output load is needed to the high frequency at the same time needs power for a specific operation, In the simulation condition frequency is increase output power will be reduced frequency is decreased output power will be an increase in a condition of directly proportional.

*C. FFT and THD of the Simulation*

FFT is Fast Fourier Transform and THD is Total Harmonic Distortion these two analysis values are measured by simulation software, FFT value in voltage is 14 maximum Current is 1.3 maximum, Waveform of the FFT is shown as fig.8. THD of the simulation output voltage 3.3 Percentage and Current is 1.1 Percentage.

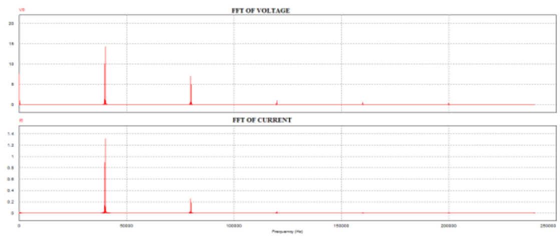

Fig.8. Fast Fourier Transform of simulation

FFT is Fast Fourier Transform and THD is Total Harmonic Distortion these two analysis values are measured by simulation software, FFT value in voltage is 14 maximum Current is 1.3 maximum, Waveform of the FFT is shown as fig.8. THD of the simulation output voltage 3.3 Percentage and Current is 1.1 Percentage it's an analysis of the PSIM simulation software.

*D. Output Voltage and Current*

**Table.2. Simulation Output Voltage and Current in Varies Frequency**

| | **Resonant Frequency** | **Output Voltage** | **Output Current** |
|---|---|---|---|
| 1 | 1 KHZ | 360V | 15A |
| 2 | 20 KHZ | 40V | 4A |
| 3 | 40 KHZ | 30V | 2.5A |
| 4 | 80 KHZ | 10V | 0.8A |

**5. CONCLUSIONS**

Three phase to Single phase Matrix converter or ac-ac converter is developed high frequency output for R L Load in the applications of Metal hardening and Metal heating applications. In the simulation R L load is used because induction heating metal similarly like this load, It's perfect can be used in an industrial application, Finally, The output of the converter is single phase high frequency ac good bur some harmonics created in the waveform but it's not a problem in a metal heating application, Full control of the converter is resonant frequency if we need to vary the output high power and frequency can change the resonant or switching frequency, Compared to other types of ac-ac converters this converter is better Compactness, Low cost, fewer components, High efficiency, and long life so this converter is good for industrial metal tempering. In this paper we only develop the converter circuit in the PSIM simulation software, Prototype hardware can be made using this simulation circuit and parameters.

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