ANALYSIS OF 12 PULSE CONVERTER AND INVERETER FED MEDIUM FREQUENCY INDUCTION MELTING FURNACE

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Abstract : Induction melting furnace operation is based on induction heating .Induction heating (IH) works on the principle of electromagnetic induction and, in it, the energy is transferred from a work coil to a work piece. Unlike a transformer in which energy is transferred from the primary to the secondary winding at 50 or 60 Hz, the transfer of energy in induction heating typically takes place at higher frequency. In industry, this heating process is accomplished through induction furnaces which are used for different heating jobs e.g. melting, annealing, forging and tempering etc. The structure of the Induction melting system can be built up with the help of a Phase shifting transformer, 12 pulse Voltage source converter, DC reactor, Half bridge series inverter and series arrangement of capacitor and inductor to form the resonant circuit.

Index Terms **- Induction melting furnace, 12 pulse converter, Current limiting reactor, z-control board, Dual track system.**

I. INTRODUCTION

Induction melting furnace (IMF) offers a clean, energy-efficient, and easily controllable melting process for both ferrous and nonferrous materials, as compared to other means of metal melting. IMFs become very popular for steel melting process in small and medium capacity steel foundries and mills, because of the advantages in low installation cost, low operating cost, good heating efficiency, controlled heating operation and automatic stirring property [1]. The power supplies of high power IMFs are generally formed from AC-DC-AC power converter with series resonant load and operate in medium frequency range of 100-500 Hz. The capacity and operating power of IMFs reach 40 tons and 20 MW.

Among various types of IMFs, the medium-frequency coreless IMFs have shown a growing interest in small steel melt shops and alloy steel plants, due to their significantly reduced capital cost for a given melting rate. This is due to the development of high-power-density IMF fed from solid-state inverters operating at medium frequency [2]. Resonant load inverters have been designed to allow the output power frequency to change during a melting cycle, in order to maintain tuning to the natural frequency of the work coil.

II. SYSTEM DESCRIPTION

In this system, there are four main parts are included. There are Phase sifting transformer, 12 pulse converter, Half bridge Series inverter and Coreless induction melting system. Along with AHFC(Automatic harmonic Filter Capacitor) panel and CLR(Current Limiting Reactor) are connected in the circuit.

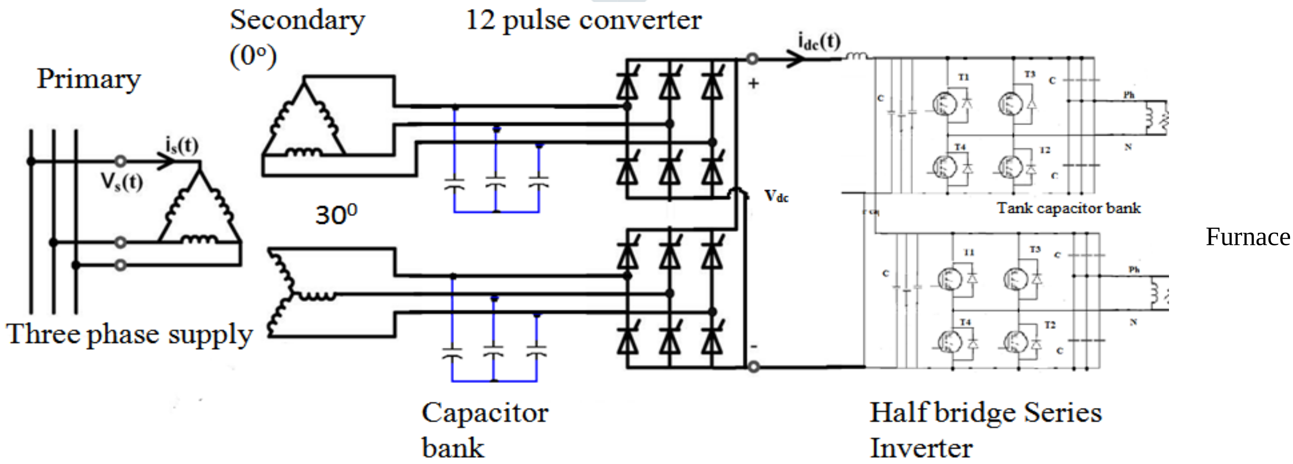


Fig (1): Power circuit of induction melting system

The parallel connections of the furnaces with the same power supply are operated by using track system i.e. Dual track system or tri track system etc. It is a butterfly batch operation. In dual track system two furnaces are connected to two half bridge inverters which are connected in parallel with the converter section as shown in figure(1). So that the two furnaces are connected to the same power supply and these two converters share the power as one is operated at its rated power and another one is operated at rest of power. The rating of the input system is slight greater than the furnace rating.

The power sharing is achieved by the digital control board which is attached to the inverter and this sharing can be adjusted in any ratio by controlling the knobs and these are provided for each inverter. For example if one furnace is operating at maximum power and to increase the power for second one, by simply increasing the knob of the second furnace, the power for the first furnace is automatically reduced. This controlling is achieved by z-control board which is shown in figure (2) at the inverter.

Fig (2) : z – digital control board

The phase shifting transformer is connected to the power supply. This is a step down transformer (33kv to 595v) and it has one primary winding which is delta connected and two secondary windings in which one is delta connected winding and another is a star connected winding as shown in figure. So there is a 30º phase shift exists between the two secondary windings. The output voltage of the two secondary windings is same. AHFC panel is connected at the output of the transformer and it reduces the harmonics produced by the converter and to increase the power factor. It can be operated either in automatic mode or manual mode.

III. 12 PULSE CONVERTER AND INVERTER

Each secondary winding of the transformer is connected to six pulse converters and these are interconnected to each other and constitute the 12 pulse converter. The advantage of the 12 pulse converter is the harmonics produced in the system can be decreased as one six pulse converter produces harmonics as follows

$h = np \pm 1$

Where h = Harmonic Number

n = Integer

p = Pulse number

For six(p) pulse, the harmonics are 5,7,11,13,17,19 etc. and for twelve(p) pulse converter the harmonics are 11,13,23,25 etc. So for 12 pulse converter, some of the harmonics produced in the six pulse converter are eliminated and it is achieved by providing phase shift if 30^O and some harmonics produced by one six pulse converter cancelled by another six pulse converter[3].

The Current Limiting Reactor is provided at the output of the 12 pulse converter for smooth the output converter current which is fed to the inverter and the three capacitor banks also connected at the dc side for filtering the voltage and to maintain constant voltage. The inverter used is the half bridge series inverter. The inverters are connected in parallel to the output of the 12 pulse converter. It has more number parallel legs to handle the high power rating and even if one leg get failed remaining legs supplies the power to the load [4].

Fig (3) : Diagram of SCR

Fig (4) : Tank capacitors

The legs have a inverter grade SCR's for high power handling capacity. The scr model used in converter and inverter is shown in figure (3).

The voltage at the inverter input is 800v and at output is 2500v approximately because the capacitors used in inverter has high power rating as the load. These capacitors build up the high voltage for the load.

The typical diagram of the capacitors used in melting system is shown in figure (4). The total input power is 3000kw and the rating of the each furnace is 2500v. The connection dual furnaces to power supply is shown in figure (1). The two furnaces are connected to the each half bridge series inverter as shown in figure (1). So that when one furnace is operating at it's rated power of 2500kw and other furnace can take the power of 500kw. In this way power between two furnaces can be varied in any ratio.

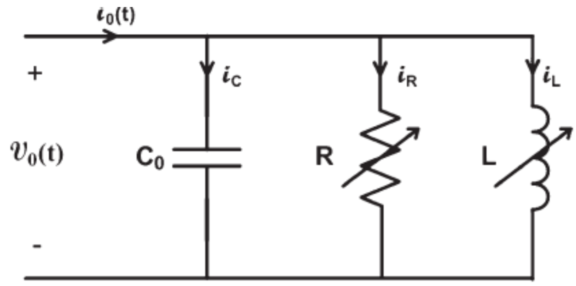


Fig (5) : Induction Melting Furnace equivalent circuit

Here the load is coreless induction melting furnace[5]. The furnace has work coil and work piece and the work coil has two coils connected in parallel in order provide the uniform temperature in melting metal. The coil is a hollow section coil and water is flowed in this coil to cool the coil. And there is a dummy coil for cooling the bottom of the furnace as shown in below figure (4).

Fig (6) : Induction Melting Furnace coil

The crucible of the IMF is initially filled with scrapmetal materials having various metallurgical properties and dimensions. The skin depth δ is a function of resonant frequency f_o of the work coil and electrical resistivity ρ and magnetic permeability μ of various scrap materials [6], as given in

$$\delta = \sqrt{\frac{\rho}{\pi f_o \mu}}$$

where $\mu = \mu_o\mu_r$, with μ_r as the relative permeability and μ_o as the permeability of free space.

IV. RESULTS AND DISCUSSION

The Phase shifting transformer, converter and Induction melting transformer have different ratings. So the power ratings of the devices used in the system are listed below.

The rating of the system is as follows

- Rating of the system is

  Input supply voltage - 33kv

  Input KVA - 3450 KVA

  Frequency – 50Hz
- Phase shifting transformer Rating is

  Primary voltage - 33000V

  Secondary voltage1 : 595 V

  Secondary voltage2 : 595 V

  Primary Current - 60.35A

  Secondary current1 : 1673A

  Secondary current2 : 1673A
- Converter Rating is

  Input voltage - 575V(ac)

  Output voltage - 800V(dc)
- Inverter Rating is

  Input voltage - 800V

  Output Voltage – 2500V

  Frequency – 600Hz

  Tank capacitors – 2850V,200MFD

  Filter Capacitor – 900V,3300MFD

The given system is 33 kv input system. So that the figure (7) shows the graphical representation of the input supply of 33kv line voltage and it's phase voltage is approximately 19 kv. The power and voltage conversion is done at various stages i.e the phase shifting transformer is a 33kv/595v -595v step down transformer having two secondaries of 595v. This supply is provided to the twelve pulse converter through two secondaries of phase shifting transformer and it converts the voltage to 800v dc which is further converted to 2500v ac using Half bridge series inverter and it applied to furnace.

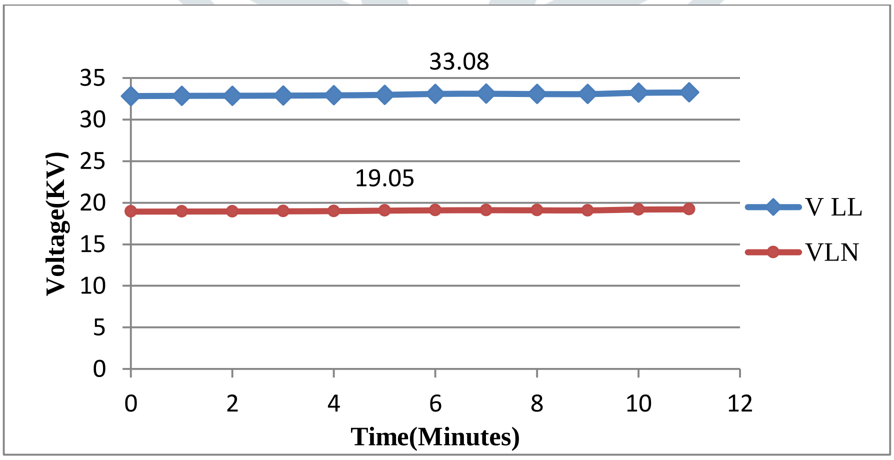


Fig (7) : Input voltage analysis

The frequency of the input supply is 50Hz.The frequency which is applied to the system while furnace is running is shown in the above figure (8).It is nearly maintains at 50Hz.

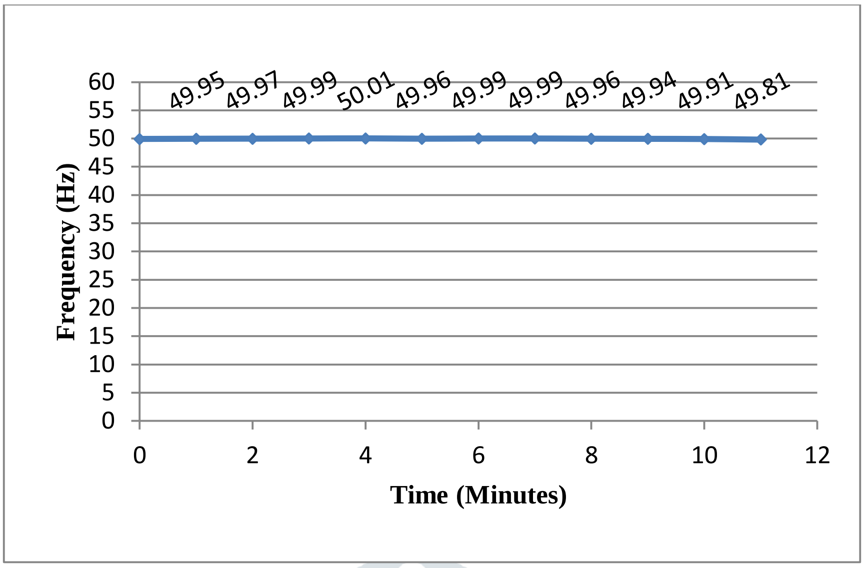


Fig (8) : Input Frequency

The figure (9) shows the power and voltage at the output of inverter i.e. input side of the one furnace. Initially the fluctuations in power is more because the number of buckets of hard metal charge is put into the furnace. After some time the constant power is achieved and at the final stage the charcoal power is added to remove the sludge at these times furnace power on and off operations are done. Similarly the voltage also varies according to the power.

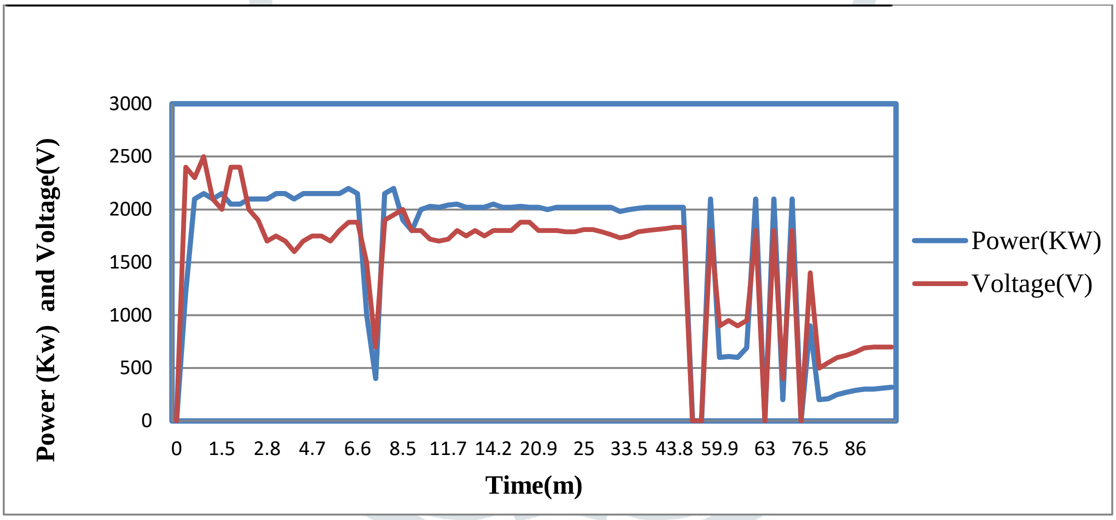


Fig (9) : Load power and voltage

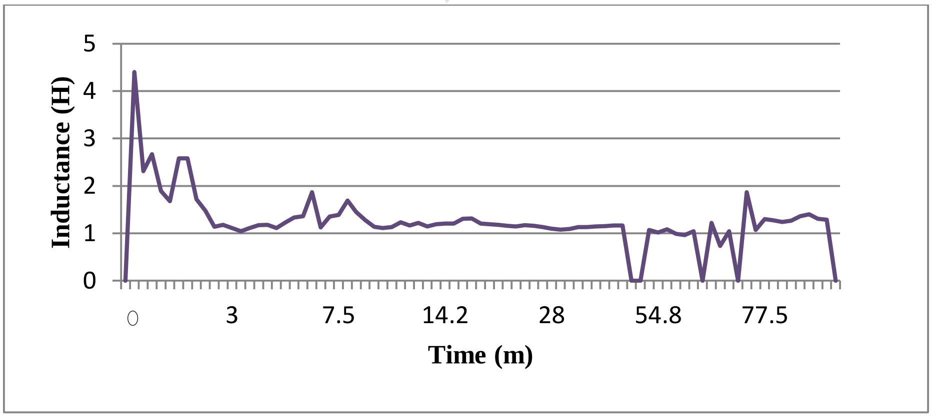
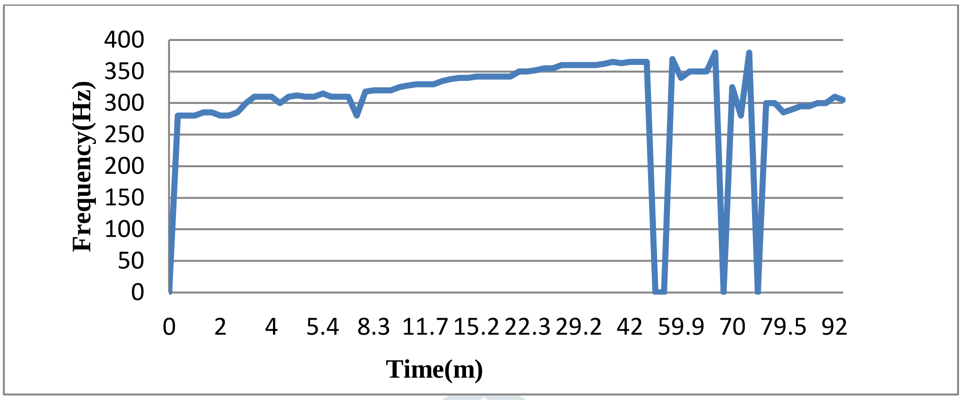


Fig (10) : Inductance

The inductance variation of the furnace is shown in above figure (10). Initially when hard metal is kept in the crucible the inductance of the coil is high enough. But during melting time the metal gets melted and its temperature increases and finally reaches a curie temperature. In this time the magnetic property of the charge is reduced and the inductance is simultaneously decreased as shown in the figure (10). And to achieve the resonant condition the frequency is increased as shown in figure(11) because the capacitor at the inverter has constant value.



Fig|(11) :Load Frequency

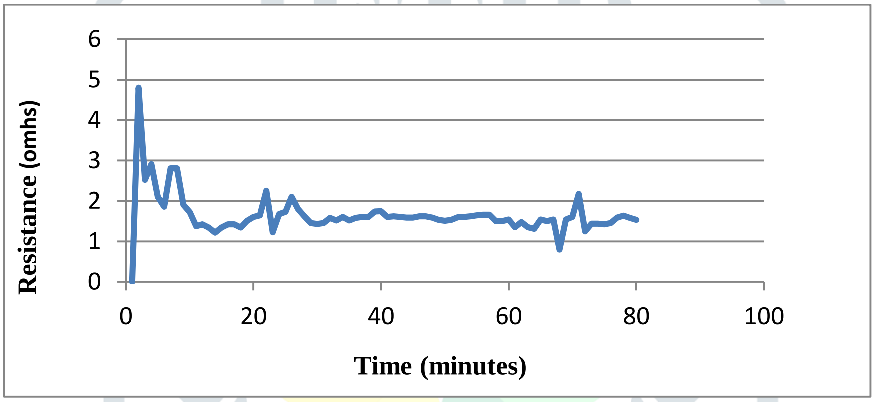


Fig (12) : Load Resistance

The figure (12) shows the resistance during the melting cycle. It varies according to the metal adding.

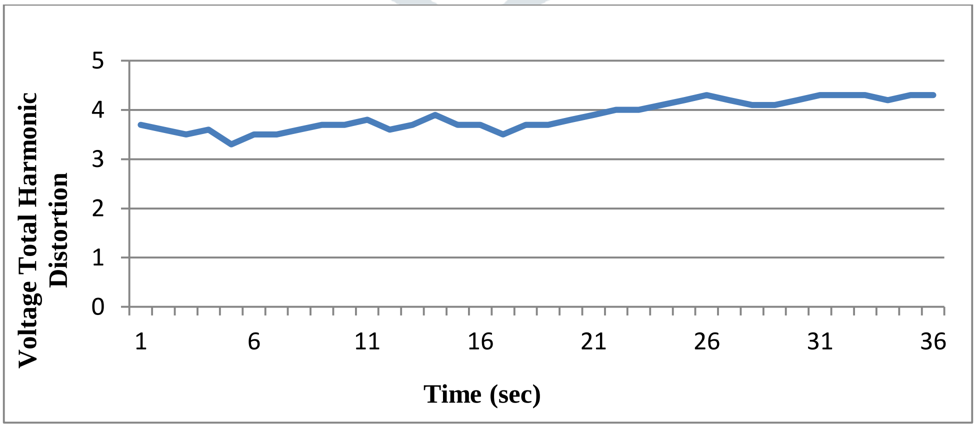


Fig (13) : Voltage THD at input side

The total harmonic distortion for the 12 pulse converter melting furnace are small. The figure (13) shows the voltage THD and it is varied under the value of approximately 3 and 5 and the average value is 3.9

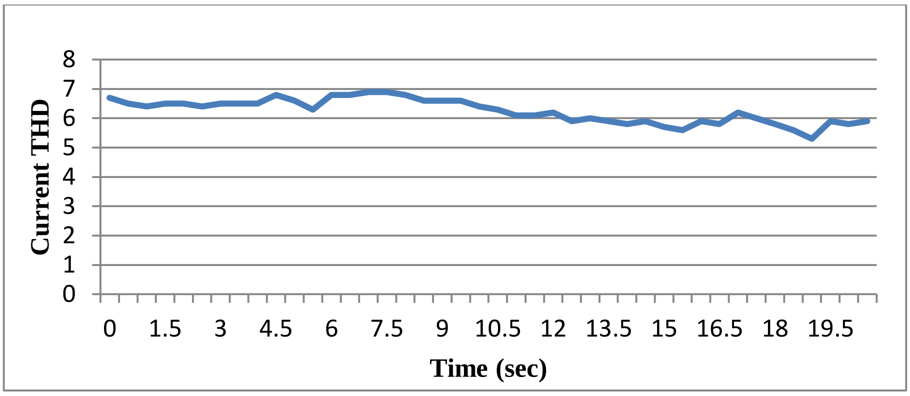


Fig (14) : Current THD at input side

The current total harmonic distortion is shown in the figure (14). The current THD is varied in between 5.0 to 6.5 as shown in figure 7.

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