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Design And Development Of Magnetron Power Source From Three Phase Supply

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ABSTRACT: *Electromagnetic radiations are phenomena that takes the form of self propagating waves in a vacuum or in matter. Microwaves are a part of the electro-magnetic (EM) radiation spectrum, with a frequency range of 300Mhz to 300Ghz.Microwave heating applications ceramics, Metallic powder, Food products, Wood, Polymers, Rubber, Textile & Paper. Various sources of microwaves include the Magnetron, Klystron, Travelling-wave tube (TWT) and gyrotron. These devices work in the density modulated mode rather than the current modulated mode. This means that they work on the basis of clumps of electrons flying through them, rather than using a continuous stream. The scope of this project work requires us to focus on such device namely Magnetron.*

Microwave wave heating has advantages over the conventional heating due to which it is finding applications in industries for heating. The heart of every microwave oven is a high voltage system whose purpose is to generate "Microwaves". This high voltage system is called as Magnetron power supply.

Three phase supply design for magnetron power source by providing gate firing signal using control scheme to the thyristors can be achieved by using the power scheme design respectively. In power scheme design three identical thyristors are connected in each phase of the three phase line supply and output of the three thyristors are connected to the star connected load. Control scheme design is formed by using the comparators, diode and logic gate. In control scheme design input is taken from the mains supply and output of the control card which can be used for gate triggering pulses for thyristors. The objective is to design control pulses for the gate triggering signals, and also monitoring various parameters such as voltage, current and total power control for various applications. Using a three phase supply we can achieve high output power to the magnetron power source as compared to the single phase output control in single phase supply with much better ripple characteristics. Thus high power magnetron source for industrial and practical applications is conveniently used.

KEYWORDS: Microwaves, Magnetron, Power supply card, Control card, Thyristor card.

I. INTRODUCTION

Microwaves are electromagnetic waves with wavelengths ranging from as long as one meter to as short as one millimeter, or equivalently, with frequencies between 300 MHz (0.3 GHz) and 300 GHz. This broad definition includes both UHF (Ultra High Frequency) and EHF (Extremely high frequency) (millimetre waves), and various sources use different boundaries. In all cases, microwave includes the entire SHF band (3 to 30 GHz, or 10 to 1 cm) at minimum, with RF engineering often putting the lower boundary at 1 GHz (30 cm), and the upper around 100 GHz (3mm).

Fig.1.1: Electromagnetic Spectrum

The applications of microwaves are vast. The microwaves are used in various fields like, Communications, radar systems, radio astronomy, navigation etc. Microwave heating is used in industrial processes for drying and curing products heating.

Microwave heating is finding a wide application in industry for Ceramics, Metallic Powder, Food Products, Wood / Bamboo, Polymers / Rubber, Textile / Paper.

1.1 Microwave Heating

When materials are exposed to microwave radiation, it gets reflected(R),absorbed(A)or transmitted (T) depending on the dielectric properties of the material – permittivity (**ε**) and permeability (**μ**),which is a function of composition, size and temperature.

Practically all the three phenomena are present partially when a material is exposed to microwaves. The absorbed portion (A) of the incident microwave, heats the material by polarization of the atomic / molecular structure. As the microwave travel through the material, it gets attenuated, resulting in **volumetric heating**.

For most industrial heating applications the microwave frequencies are restricted to: **896 - 915 MHz, 2425 - 2475 MHz and 5775 - 5825 MHz** the rest of the frequency range is mostly reserved for communication purposes.

Advantages of Microwave Heating:

- Volumetric heating
- Eco-Friendly – No exhaust gases
- Energy Efficient
- Low Operational Cost
- Uniform heating

1.1.1 Microwave Sources:

Magnetron, klystron, traveling-wave tube (TWT), and gyrotron operate on the ballistic motion of electrons in a vacuum under the influence of controlled electric or magnetic fields. These devices work in the density modulated mode, rather than the current modulated mode. This means that they work on the basis of clumps of electrons flying ballistically through them, rather than using a continuous stream. Low power microwave sources use solid-state devices such as the field-effect transistor (at least at lower frequencies), tunnel diodes, Gunn diodes, and IMPATT diodes.

The heart of every microwave oven is the high voltage system. Its purpose is to generate microwave energy. The high-voltage components accomplish this by stepping up AC line voltage to high voltage, which is then changed to an even higher DC voltage. This DC power is then converted to the RF energy that cooks the food.

II.MAGNETRON

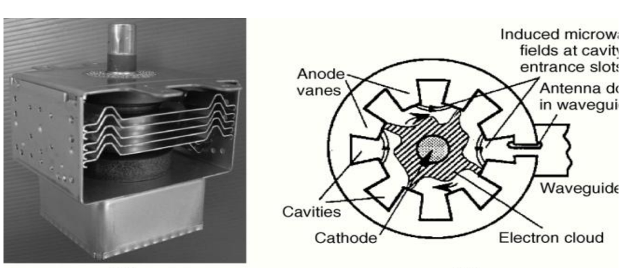

Fig.2.1: (a) A magnetron and (b) schematic cross-sectional view of the magnetron cavity

2.1 Basic Magnetron Structure

The nucleus of the high-voltage system is the **magnetron tube.** The magnetron is a diode-type electron tube which is used to produce the required 2450 MHz of microwave energy. It is classed as a diode because it has no grid just like an ordinary electron tube. A magnetic field imposed on the space between the anode (plate) and the cathode serves as the grid. While the external configurations of different magnetrons will vary, the basic internal structures are the same; these include the anode, the filament/cathode, the antenna, and the magnets.

The ANODE (or plate) is a hollow cylinder of iron from which an even number of anode vanes extends inward. The open trapezoidal shaped areas between each of the vanes are resonant cavities that serve as tuned circuits and determine the output frequency of the tube. The anode operates in such a way that alternate segments must be connected, or strapped, so that each segment is opposite in polarity to the segment on either side. In effect, the cavities are connected in parallel with regard to the output. This will become easier to understand as the description of operation is considered.

The FILAMENT (also called heater), which also serves as the cathode of the tube, is located in the canter of the magnetron, and is supported by the large and rigid filament leads, which are carefully sealed into the tube and shielded.

The ANTENNA is a probe or loop that is connected to the anode and extends into one of the tuned cavities. The antenna is coupled to the waveguide, a hollow metal enclosure, into which the antenna transmits the RF energy.

The MAGNETIC FIELD is provided by strong permanent magnets, which are mounted around the magnetron so that the magnetic field is parallel with the axis of the cathode.

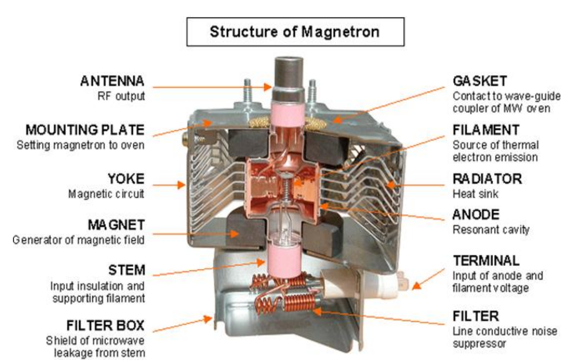

Fig.2.2: Structure of Magnetron

This paper discusses about design and development of the three phase power supply circuits for Magnetron power source for industrial microwave systems which require consistent, maintenance free, long life and superior controls for required output parameters through controlled design input parameters.

The power supply to the magnetron is achieved in the project by using a three phase input. The three phase input is given to the power scheme consisting of three thyristors, These thyristors are fired using a control scheme. The output of the power scheme design is given to the load.

III. METHODOLOGY

3.1. Power Supply Design Concept

The Paper scope includes design of power supply for a magnetron power source. The block diagram of the power supply is as shown Fig 3.1.

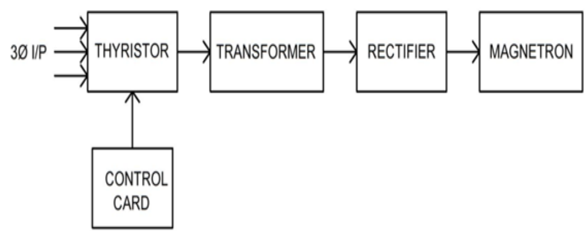

Fig.3.1: Block diagram of the power supply design for magnetron

3.1.1 Power supply card

Input to the power supply card is three phase 220vac and it converts AC to DC supplies the necessary power 5v,+12v,-12v to the control card.

3.1.2 Control card

Output of the power supply card is given to the control card to provide the proper supply to the control cad components such as comparator, diodes and AND gate which operates on low supply voltages. By design of control card gate triggering signals will be formed and output of this is given to the gate triggering and switching thyristor block.

3.1.3 Thyristor Block

Solid state switches used to control the flow of electric current often used for circuit protection. The input to the power supply is the three phase mains 415Volts/50Hz, the mains is stabilized. The microcontroller based power controllers control the output power to be delivered by the magnetron by controlling the two power supplies connected to the magnetron. One is the high current power supply with approximate rating of 20A/3.8V and the other is the high voltage DC power supply with approximate rating of 4KV/450mA.

The filament of the magnetron requires a high current power supply to emit electrons by the process of thermionic emission. The high current supplied to the filament can be AC or DC, here the alternating current is selected as it is the simplest method.

Once the electrons are emitted they start forming electron clouds around the filament, and need an extra energy to move towards the anode. This extra energy is provided by the electrostatic field produced by the high voltage DC power supply connected between anode and cathode.

3.2 Final Block Diagram of Modules

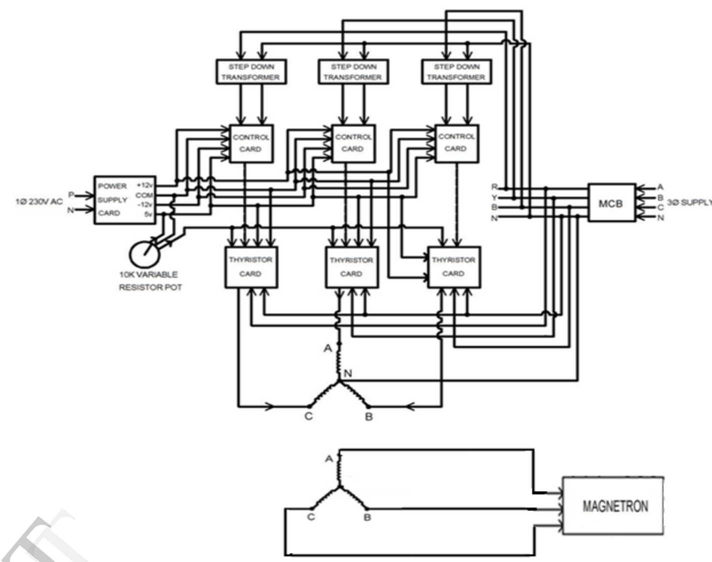

Fig.3.2:Final Block Diagram of Modules

Final diagram of Modules as shown in the Fig.3.2 consists of a four pole MCB, control cards, stepdown transformer, power supply card and thyristor card. Three phase Input from the MCB is given to the step-down transformers. Input to each step-down transformer is 230Vac and its secondary output is 5Vac.Output of the step-down transformer is given to the input of the control card because control card components operate on low supply voltages. Power supply gives the necessary dc supply of +12v,-12v,+5v, and com to the control cards. Output of the control card is given to the thyristor cards and input to the thyrisor card taken from three line supply. Output of the thyristor cards is given to the star connected load.

3.3 Power scheme design

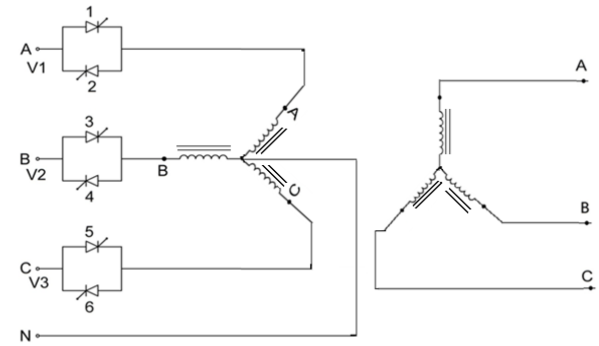

Fig.3.3: Power scheme diagram

Power scheme diagram consists of three identical thyristors which are connected in each phase as shown in the above Fig.3.3. Output of the each thyristor is connected to the load.

3.4 Control scheme design

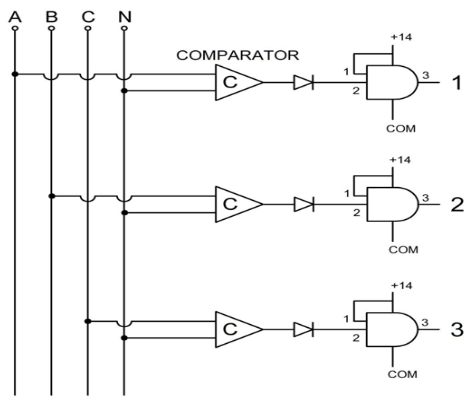

Fig.3.4: control Scheme

Control scheme design consists of comparator, diode and AND gate. Control scheme design as shown in the figure. Phase and neutral are the two inputs to the comparator. Output of the comparator is given to the diode which conducts only in forward direction and blocks the reverse current flow of current in the circuit. Output of the diode is given to pin number 2 of the AND gate and pin numbers 1 and 14 are shorted, Output of this AND gate is given to the thyristor gate signals.

IV. RESULTS AND ANALYSIS

For the load each of 500W sodium vapor lamps star connected was tested for variations in the input mains supply voltage from 415 Volts, to check the repeatability and consistency. The readings are tabulated and plotted.

The following readings of anode current are recorded when the power supply is operated at 415Vac mains supply and the current and voltage readings are tabulated for the same.

Table 4.1: Readings for voltage, Current and Output power for input voltage V_{in}=415 V_{ac}

Power Setting	R - Phase input (volts)	Y - Phase input (volts)	B - Phase input (volts)	R - Phase output (volts)	B - Phase output (volts)	Y- Phase output (volts)	R - Phase output (amps)	B - Phase output (amps)	Y- Phase output (amps)	R - Phase output (watts)	B - Phase output (watts)	Y- Phase output (watts)
10%	240	242	243	43	43	47	0.68	0.87	0.9	90.8	90.9	96.7
20%	240	242	243	116	115	118	0.87	0.87	0.9	110.9	113.7	121.2
30%	239	242	242	149	147	150	1.0	1.1	1.1	150.9	155.9	167.3
40%	239	241	242	179	180	182	1.3	1.3	1.3	238.5	243.9	265.9
50%	239	241	241	200	204	207	1.4	1.5	1.5	278.7	286.8	296.3
60%	238	240	241	220	224	225	1.5	1.6	1.6	335.9	340.2	347.8
70%	238	240	240	230	236	237	1.6	1.7	1.7	370.2	381.7	395.6
80%	238	239	240	238	242	242	1.7	1.8	1.8	400.7	410.5	420.7
90%	237	239	240	241	246	246	1.7	1.8	1.8	410.8	420.8	430.6
100%	237	238	239	242	256	247	1.75	1.8	1.9	430.9	460.5	440.9

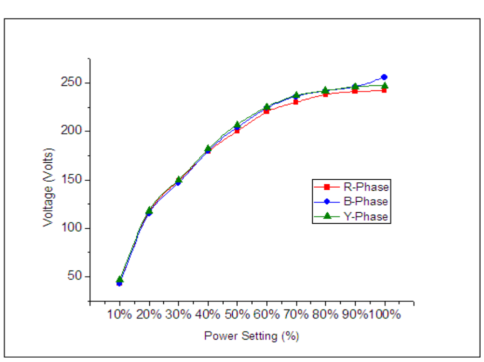

Fig.4.1: Voltage graph

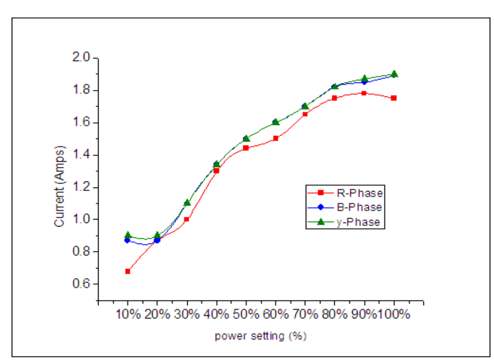

Fig.4.2: Current graph

Above graph voltage v/s power setting shows that as the power setting increases voltages in each phase also increases.

Above graph current v/s power setting shows that as the power setting increases current in each phase also increases.

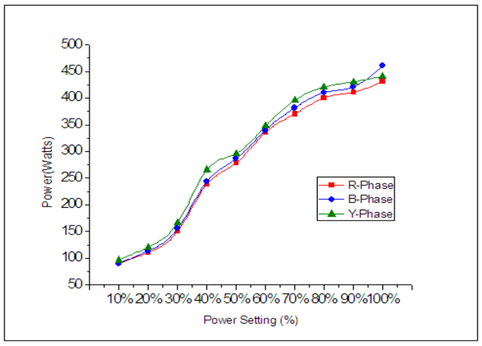

Fig.4.3: Output Power graph

Above graph output power v/s power setting shows that as the power setting increases output power in each phase also increases.

4.1 Current Waveforms on CRO

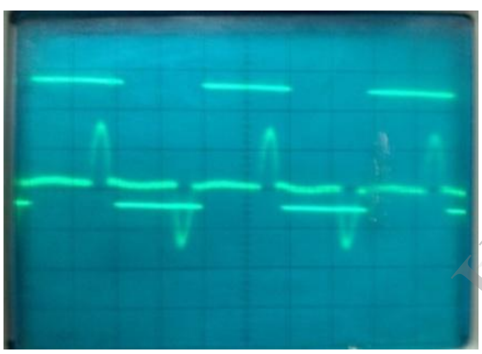

Fig.4.4:Output at 10%

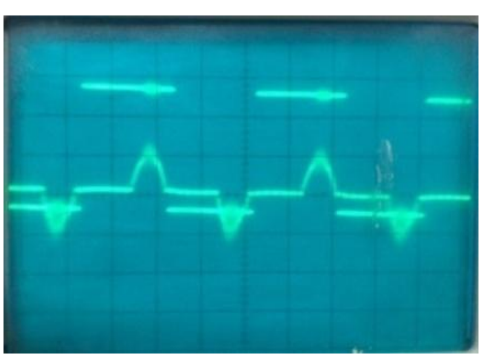

Fig.4.5:Output at 50%

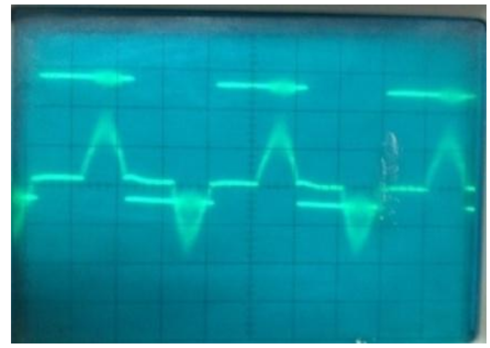

Fig.4.6:Output at 80%

4.2 Voltage waveforms on CRO

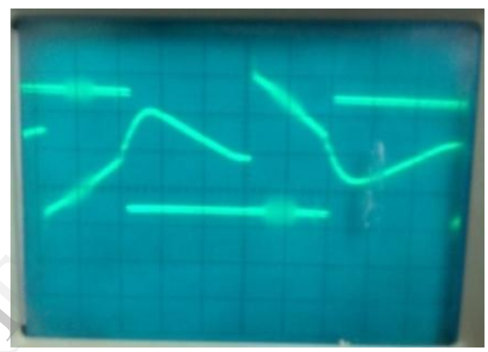

Fig.4.7:Output at 50%

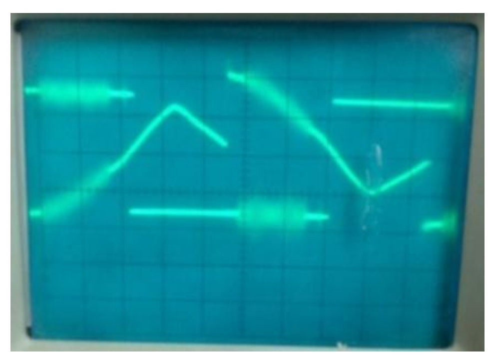

Fig.4.8:Output at 80%

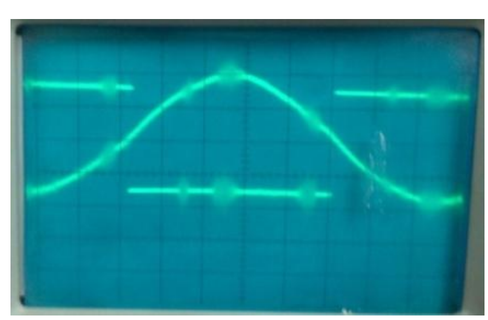

Fig.4.9:Output at 100%

CONCLUSION

Three phase supply design for magnetron power source by providing gate firing signal to the thyristors is achieved by using the power scheme, control scheme design respectively. The various parameters were monitored such as voltage, current and the output power. Therefore using the three phase supply we are able to provide phase to phase supply and balance the load.

Three phase-phase control has significant advantages over single phase firing and this was observed and confirmed through the readings as tabulated in the report. Three phase firing has provided the advantage of low ripple in the output dc quantity. We have also observed better smooth control of output power delivered to load as compared to the single phase firing.

Three phase supply design provides low losses and more accurate firing angles compared to single phase supply. Low ripple and high performance are the major advantages. Thus the three phase output power to the magnetron power source is achieved and high power magnetron source can be conveniently used for industrial applications.

ACKNOWLEDGEMENTS

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