Design and Construction of A 5kva Arc Welding Machine

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Abstract

The aim of this research paper is to design and construct a 5KVA arc welding machine from locally made materials that can be used to weld metals. The transformer constructed is a shell type single phase able to deliver input voltage of240Volts and output voltage of 80volts.The transformer is mounted on a rectangular metal frame and enclosed in a case with ventilation for cooling the machine. Double insulation used for better protection from short circuit when working in moist environment. The system was tested using multi meter and results revealed it transforms low voltage, low amperage power and primary power to low voltage, high amperage used for welding at high frequency. The machine is efficient, durable and reliable.

Keywords: Ampere, Multi meter, Transformer, Voltage, Welding.

Introduction

Welding is the process of joining two pieces of metal or non-metal at faces rendered plastic or liquid by the application of heat or pressure. Filler materials may be used to ensure the union (Theraja, 2018). An electric arc is formed whenever electric current is passed between two metallic electrodes separated by a short distance from each other. The arc is started momentarily touching the positive electrodes and to the negative metal or plate and then withdrawing it to about 3mm to 6mm from the plate. When electrode first touches the plate, a large short circuit current flows and as it is later withdrawn from the plate, current continues to flow in the form of a spark across the air gap so formed. Due to this spark (or discharge) the air in the air gap becomes ionized which split into negative electrons and positive ions. Consequently, air becomes conducting and current is able to flow across the gap in the form of an arc. This type of welding which uses a power supply to create an electric arc between an electrode and the base material to melt the metals may be manual, or automated (Asiwe et al, 2018). The machine is used to carry out welding operation by connecting through the output terminal to the welding cables. The output of the machine function such that it can be varied by adjusting the crank of the machine in a clockwise or anticlockwise direction, or to increase or decrease the output current depending on the size of the material used (Takasaki, 2003).Furthermore, electric arc welding machine can be used in ship building, automobile manufacturing and repair application (Lincoln, 1994).

The major component of the arc welding machine is the transformer. Asiwe et al, 2018 investigated the design and construction of an arc welding machine transformer which uses a single-phase shell type, lamination core and insulated windings of copper coils. They reported that with the help of an angle iron and lamination core, the core loss, iron loss can be reduced to minimum. They observed that the scaling factor and turn factor at terminal A was almost the same indicating that the higher the turns, the better the transformer. These characteristics assist to avoid high current which may result to spark, and also improve the efficiency of the transformer. Ibrahim et al, 2016 investigated the construction of a welding machine which used a low frequency transformer that operated at the utility mains frequency of 50Hz or 60Hz variable current selector to avoid power quality challenge such as voltage, current and

frequency deviation from nominal value in electrical distribution and utilization system. The welding machine was presumed heavy with regards to construction details of the work done. Ovbiagele and Obaitan, 2015 designed an inverter circuit arc welding machine to solve problem of weight and size of conventional arc welding machine. The inverter provided much higher frequency than the 50Hz for the transformer used in welding, if therefore reduce the weight, size and noise level of the transformer used for the welding. Furthermore, Evboghai et al 2007 investigate the realization of 3kVA single phase electric arc welding machine with facility for charging batteries. In contrast to existing study, they present a novel design and construction of an arc welding machine which transformed low voltage, high amperage power used for welding at high frequency with a digital display to show the output voltage. This high frequency transformation helped to reduce the weight and size of the transformer.

Welding machines are usually classified as a constant current (CC) or constant voltage (CV) machine. So, to supply electrical energy necessary for arc welding processes, a number of different power supplies can be used. The CC and CV are the common classification. In arc welding, the voltage is directly related to the length of the arc, and the current is related to the amount of heat input. Constant Current (CC) power supplies are most often for manual welding process such as gas tungsten arc welding machine and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies. It is important in manual welding, because it can be difficult to hold the electrode perfectly steady, then the arc length and the voltage tends to fluctuate (Theraja, 2008).Constant Voltage (CV) power supplies hold the voltage constant and vary the current, they mostly used for automated welding processes such as gas metal arc welding, flux cored arc welding machine and submerged arc welding. In these welding processes, arc length is kept constant, since any fluctuation in the distance between the wire and the base material is quickly rectified by a large change in current. For example, if the wire and the base material get too close, the current will rapidly increase and the tip of the wire to melt, returning it to its original separation distance.

The direction of current used in arc welding plays an important role in welding. Consumable electrode processes such as shielded metal arc welding and gas metal arc welding generally use direct current but the electrode can be charged either positively or negatively. In welding, the positively charged anode will have a greater heat concentration and, as a result changing the polarity of the electrode has an impact on weld properties. If the electrode is positively charged, it will melt more quickly, increasing weld penetration and weld speed. Alternatively, a negatively charged electrode results in more shallow welds. Non-consumables electrode processes, such as gas tungsten arc welding can use either direct current as well as alternating current with direct current however, because the electrode only creates the arc and does not provide filler material, a positively charged electrode causes shallow welds. Alternating current rapidly moves between these two, resulting in medium penetration welds. One disadvantage of AC is that the arc must be re-ignited after every zero crossing has been addressed with the invention of special power units that produce a square wave pattern instead of the normal sine wave, eliminating low voltage time after the zero crossing and minimizing the effects. Duty cycle is a welding equipment specification which defines the number of minutes, within a 10minutes period, during which a given arc welder can safely be used. An 80Ampere welder with a60% duty cycle must be rested for continuous welding (Mohan,2014). Failure to observe duty cycle limitations could damage the welder. Commercial or professional grade welders typically have a 100% duty cycle.

Safety issue of arc welding

Arc welding operation can be dangerous and unhealthy practice without the proper precautions, however with the use of new technology and proper protection the risks of injury or death associated with the process can be greatly reduced.

Materials and Methods

The welding of metal occurs when the arc welding machine melt the work piece and adding a filler material to form a pool of molten material that cools to become a strong joint. In this design, the overall system is built into sub-section and illustrated in a block diagram. The block diagram is illustrated in figure 1.

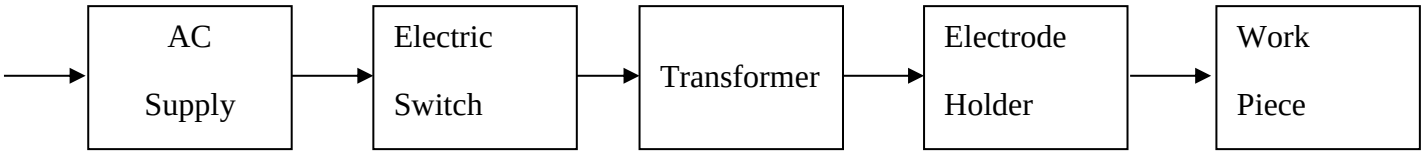


Fig.1: Block diagram of Arc welding**.**

Components Identification and Description

The components used for the construction of an arc welding machine are explained

Switching Unit

The switch is used as source of power to the device. It is used for ON and OFF. The circuit breaker protects the arc welding machine from over current band acts as an isolator. An isolator breaks an electrical circuit, interrupting the current or divert it from one conductor to another.



Fig.2: Switch

Transformer

The transformer is a static device or apparatus by means of which electric power is transformed into electric power of the same frequency in another circuit. It is used to step down the voltage of appreciable level to accommodate the holder.

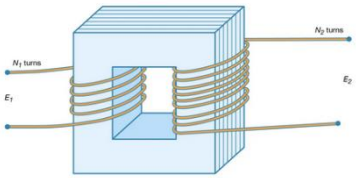


Fig.3: Basic AC transformer circuit.

Digital Voltmeter

A digital voltmeter measures the electric potential differences between conductors. This device measures either direct or alternating current on a scale graduated in Volts. The typical commercial or laboratory standard voltmeter in use today employ electromechanical mechanism in which current flow through turns of wire translated into a reading of voltage.

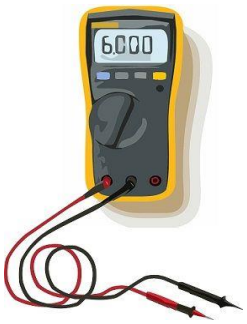


Fig.4: Digital Voltmeter

Electrode Holder

This is a clamping device used for holding the electrode securely in any position. The welding cable is attached to the holder through the hollow insulated handle. The design of the electrode holder permits quick and easy electrode exchange.



Fig. 5: An electrode holder

Metal Oxide Varistor

The metal oxide varistor also known as MOV is a voltage dependent non-linear device that provides excellent transient voltage suppression MOV have a fast response, high stabilization for circuit voltage, excellent voltage ratio and can serve as surge protector (Theraja,2008).



Fig.6: Metal oxide varistor

Digital Clamp Meter

The digital clamp meter is an electric device having two jaws which open to allow clamping around an electrical conductor. These properties allow electric current in the conductor to be measured without having to make physical contact with it or to disconnect it from insertion through the probe.



Fig.7: Digital clamp meter.

Micrometer Screw Gauge

It is used to measure the diameter of the copper conductor. It is incorporated with a calibrated screw, widely used for precise measurement of component in machining.



Fig.8: Micrometer Screw Gauge

Other Components
Cables: Used for winding the primary and secondary coil.
Cables connector: For joining firmly every termination.
Varnish: For proper insulation
Bolts and Nuts: For fastening tight connection.
Masking tape: Used for cable insulation
Laminating Sheet: Used for generation of magnetic flux.
Metal Sheet: Used for casing and protection of device.
Three pin plugs: Used for connecting to alternating current.
Bobbin (former): Used for winding the coils or conductors.

Design Parameters.

Arc Welding machine design parameters

Rating	5KVA
Frequency	50Hz
Number of Phases	Single
Design Type	Shell type
Primary Voltage	240Volts
Secondary Voltage	80Volts
Cooling Medium	Natural Air

Current density	3.0A/mm2
Stacking factor	0.9
Lamination thickness	0.5mm
Assumed efficiency	95%
Power Factor	unity (1)

Design of Area of Coil.

Volt perturn Vt = K$\sqrt{s}$. where k is chosen as 0.55.

S=KVA of the arc welding machine which is taken as 5, then Bm = 1.5wb/m2=1.5x10-6mm2.

Vt = 0.55$\sqrt{5}$

= 0.55x2.236

Vt = 1.23Volt per turn.

Vt = 4.44fBmAi

1.23=4.44x50x1.5x10-6xAi

Ai= $\frac{Et}{4.44xfxBm}$=$\frac{1.23}{4.44x50x1.5x10-6}$

Ai = $\frac{1.23x10^6}{333}$

= 3.694x10-3mm2

Flux = BmAi

=1.5x3.694x10-3

Flux (Om) = 5.5x10-3wb

= 0.00554wb

Using the formula

Kw (window space factor) = 0.1+0.07log10$\frac{KVA}{0.1}$-0.2log10KV

= 0.1+0.01log5/0,1-0.2log (240x10-3

= 0.1+0.07x1.6989-0.2 x (-0.619)

= 0.218923+0.1238

Kw = 0.34.

Window Area (Aw) =

Using the formula

S=2.22fBmAiAwKwJx10-3

Aw=S/(2.22xfBmAiAwKwJx10-3)

Take S=5KVA, f=50, Bm=1.5; Ai=3693.94mm2; Kw=0.34; J=3A/mm2.

Aw=5/ (2.22x50x1.5x3693.94x0.34x3x0-9).

Aw=(5x10^9)/627341.8302.

Aw=7970.136=7970mm2

Aw=LxW

=length x breath; where length is 3W=Window Length

Window length W = Aw⁄3

=√2656.71

=51.54mm.

Window length = 51.54mm.

L=3W=3x51.54 = 155mm.

Cross sectional Area is related to gross cross sectional area Ag

Ag=Ai/0.9 = 3693.94/0.9 = 4194.377

Ag=4104.38mm.

Stack height = Ag/(width of central limb)

For a central limb of 103.00mm

Stack height=4104.37/103
Stack height=40mm
Lamination pieces n = (stack height)/ (lamination thickness)
=40/0.5
n=80lamination sheets.
Calculating Number of Turns
Turns per Volt (T/v) = 1/(k√s) = 1/1.23
T/V = 0.813Turn per Volt.
For the primary turns; N1 = Primary Volt x Turn Per Volt
N1 = 240x0.81
=194.4turns.
For the secondary Turns; N2=Secondary Voltage x Turns per Volt
N2=80x0.81=64.8
=65turns.
Winding Calculations
Primary Current = (KVA Rating)/ (Input Voltage)
Ip = (5000)/240
Ip = 20.83Amps.
Secondary Current = (KVA Rating)/ (Output Voltage)
Is = 5000/80
= 62.5Amps.

Conductor Size

Current density J = 3.0A/mm2
Cross-sectional area of conductor A = $\frac{I}{J}$
For a primary current Ip = 20.83Amps.
A = $\frac{I}{J} = \frac{20.83}{3}$
= 6.94mm2
A= $\frac{\pi D2}{4}$
Primary diameter dp = $\sqrt{\frac{4A}{\pi}}$
= $\sqrt{8.835}$
= 2.97mm/guage 14
For the secondary winding current of62.5Amps.
A = $\frac{I}{J} = \frac{62.5}{3}$
A = 20.83mm2
Secondary diameter ds = $\sqrt{\frac{4A}{\pi}}$
=$\sqrt{26.518}$
Ds=5.2mm/guage 8
Mean Length per turn
MLT = 2x (width of central limb x stack height window width)
= 2x (103x40x51.54) mm
= 389mm.
Total length of Winding
T_L= Mean length of winding x total number of turns
For primary L_1=389x194=75466mm
For secondary L_2=389x65=25285mm

Total Length L_1+L_2=100751mm
From the calculations and given values of the transformer
N_1=194turns; N_2=65turns; E1=240volts; E_2=80volts.
Construction of 5kva arc welding machine

Transformer Construction

A fairly use transformer with suitable size and low cost was purchased. The existing coils were removed and thrown away since it is a new design. Then, a new transformer coil was bought and applied in rewinding the transformer secondary side, then the primary with a coil of appropriate number of turns. In the construction of the transformer, the primary side is more than the secondary side to aid smooth welding. This design has primary turnsas194turns and secondary as 65turnswith center tapped. The transformer coil wound around plastic former placed in the lamination forming a transformer. Using the ideal transformer equation (Theraja,2008).

$$\frac{Ep}{Es} = \frac{Np}{Ns}$$

Ep = applied primary voltage; Es = applied secondary voltage; Np =Number of primary turns; Ns = Number of Secondary turns.

The primary voltage coming into the machine is too high for safe working. Therefore, it is stepped down to a useable voltage. The welding transformer consist of a step-down transformer with a tapped secondary having an adjustable reactor in series for voltage dropping. The secondary is tapped to give difference voltage/current settings (Catarina,2014). The start and end point of the secondary coil serve as the welding terminals. The lamination provides continuous magnetic path with a minimal air gap. It helps minimize eddy current loss and sheet used are named Land I shape. The total sheets used are 160sheets.

Shell form Construction

The core provides multiple paths for the magnetic circuits. It is stacked directly around the windings. Due to advantage in short circuits and transient voltage performance, shell forms tend to be used more frequently in the largest transformers, where conduction can be more severe (Howard, 2005). Windings from the core and placed in their respective core assembly (Howard, 2005). For single phase application, the windings are typically divided into both core legs. The wires are insulated with enamel with a diameter of 0.5mmand no problem of partial contact. The winding is often wound around a coil form made of plastic to hold it in place (Howard & Helzer, 2005). The ends of the wire are brought out and attached to an external circuit. Windings may have additional electrical connections along their length, these are called taps. A transformer winding which has a single tap in the centre tapped which is design and constructed in this research work.

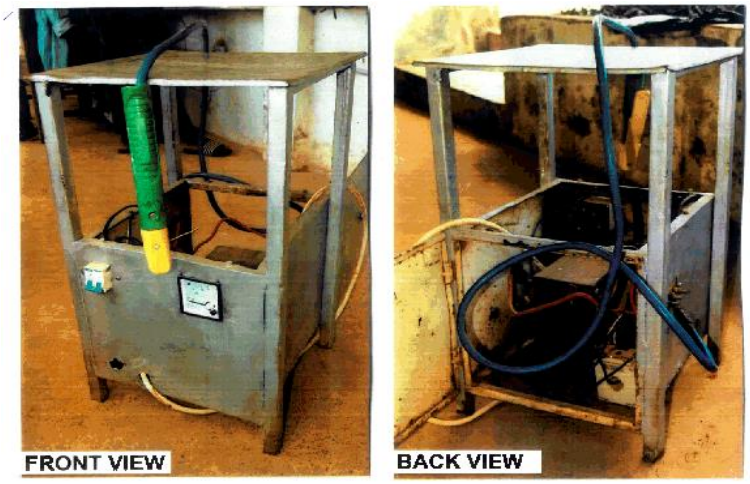


Fig. 9: Single phase shell form construction (Theraja,2008).

Connections

The major kinds of connection that can be given to this kind of construction include:
Star-delta connection or End to Start Connection
Star-delta connection or Start to Start Connection
Delta-Delta Connection or End to End Connection

The connection adopted in this work is start to start connection involving the starting wire of the primary circuit connected to the secondary circuit. As a result of this connection, the primary side and the secondary connection, the primary turns will be higher with respect to current. At the secondary circuit the starting wire is connected is connected to earth of the welding machine and the end connected to the tong bearing the electrode. The earth cable and the electrode were connected to the output terminals of the transformer.

Testing of the constructed arc welding machine

Testing of the machine confirmed the certainty of design, construction and connection. Insulation test against shock and vibration was carried out using current tester and testing lamp touch the body of the casing. The tester nor lamp did not glow which indicates no current flow. For the earth fault test, one probe of the multimeter connected to the case while the other probe connected to each of the terminal of the arc welding machine. During the testing, the voltage at zero load and when on load operation measured and recorded.

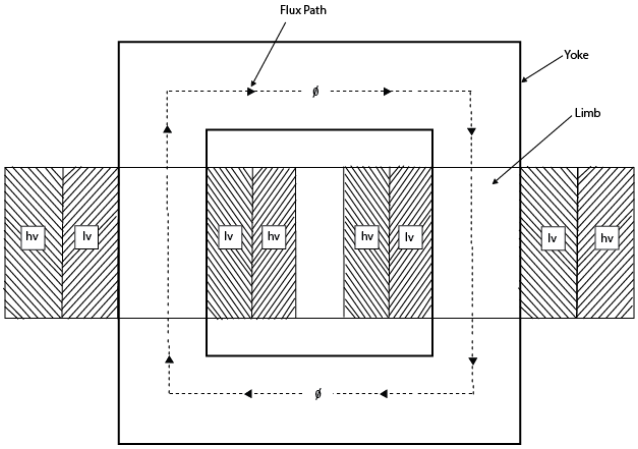


Table 1: Tabulated Reading for input and output Voltage

S/N	Terminals	Input Voltage (Vin)	Output Voltage (Vout)	Primary Turn (Np)	Secondary Turns (Ns)	Ns/ Np	Vout/ Vin
	A	240	80	194	65	0.32	0.33
	B	240	76	114	65	0.57	0.32
	C	240	71	94	65	0.69	0.30
	D	240	66	64	65	1.02	0.28

Results

The transformer is a step down with a tapped secondary having an adjustable reactor in series. The secondary is tapped to have different voltages/current settings.
The input voltage Vin was determined directly from the mains power supply and recorded. The output voltage Vout was recorded when the transformer was connected to the power supply at zero while the output at 230Volts.

Discussions

The result reveals that the arc welding machine connected had eddy current loss, winding resistances losses hysteresis loss and mechanical loss. The determination of input and output current aid to vary the current supply and use the right voltage for the welding arc. For the primary winding gauge wire 14 and secondary winding gauge wire 8. The determination of the various input and output current enables the user to vary the current in supply and also the appropriate volts for the welding machine.

Working Principle of 5KVA Arc Welding Machine

An electrical current can be induced into a conductor when it is moved through a magnetic field to produce alternating current. When this alternating current flows through a conductive wire, a pulsating magnetic field will surround the exterior of that conductive wire in which magnetic field is built in intensity through the first ninety (90) degree first cycle. From that point, the magnetic will decay during the next quarter cycle until the voltage or current reaches zero at 180 electrical degree. Immediately, the current direction reverses and the magnetic field will begin to build again until it reaches a maximum at 270 electrical degree in the cycle. From that point the current and the magnetic field again begin to decay until it reaches reach zero at 360 electrical degree, where the cycle begins again if that conductor wound around a material with high magnetic permeability(magnetic permeability is the ability to

accept large amount of magnetic lines of forces) such as steel, the magnetic field permeates that core. The conductor or conductive wire called the primary coil, if voltage is applied to one of its terminals and the circuit is completed, current will flow when the secondary coil is wound around that same steel core, the energy that is stored in this fluctuating magnetic field in the core is induced in the secondary coil. The buildup and collapse of this magnetic field excise the electron in the secondary coil of the transformer. This causes an electrical current of the same frequency as the primary coil to flow when the secondary circuit is completed by striking the welding arc(Goueishankar,2004).The duty cycle of an arc welder is based on a working period of 10minutes.Ifa welder is operated for 2minutesin period of10minutes,thenits percentage duty cycle is2/10x100=20%.Conversely,a10percentduty cycle would mean that the welder would be operated for 10percent of10ominutes which means for one minute only in a period of 10minutes.Itmeanworking contrary to the duty cycle resulting to internal insulation will deteriorate and cause early failure(Theraja,2018).

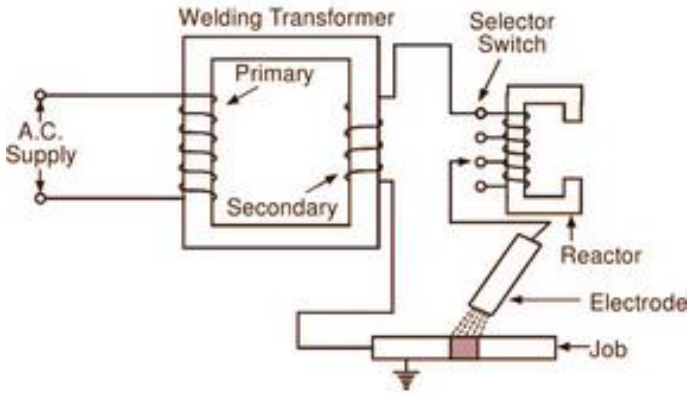


Fig. 11: Welding transformer circuit.

Conclusion.

The aim of the research paper was to construct an arc welding machine that can easily maintain constant current supply desired to check the power quality associated with the machine and improve on the leakages through the turn ratio calculated. The high turn ratio is the primary side made it for efficient for making permanent joining of metal parts, because it is durable.

Recommendation

This research work is functional and operating characteristics displayed excellent result. The work is recommended to Government so that more will be produced for marketing to improve the economic growth of the Country. Government shall be involved in research and development to boost the technological advancement of the economy.

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