DESIGN OF A 3KVA SOLAR POWERED ARC WELDING MACHINE

ZAHRADDIN UMAR DAHIRU; ABUBAKAR ABDULKADIR; I.H. USMAN; BALA A.M.; & FATIMA MUHAMMAD

Department of Electrical Electronic Engineering Technology, Federal Polytechnic, Bauchi

ABSTRACT

The unavailability of stable and reliable power supply from the grid for small and medium scale industries has resulted into the use of other sources of power like the generators. The generator is generally characterized by air and sound pollution as well as high running and maintenance cost. Also, the conventional arc welding machines are usually characterized by high weight and large size. This paper focuses on the design of a 3KVA solar power as an alternative to the generator and also an inverter circuit to solve the problem of weight and size of conventional arc welding machine. The inverter provides much higher frequency than 50Hz or 60 Hz for transformer used in welding. Welding is a fabrication process that join metals or thermoplastics together as a result of the application of high heat to melt the parts together and allows it to cool, causing fusion. The designed electric arc welding machine is capable of withstanding 150 A, when subjected to insulation test, short circuit and open circuit test.

Keyword: *Welding, Arc, joint. Inverter, MOSFET, solar Photovoltaic*

Introduction

Welding is a fabrication process that joins materials, usually metals or thermoplastics, by the application of high heat to melt the parts together and allowing them to cool, causing fusion. When the heat is applied, the work piece is melted and a filler material is added to form a molten material that cools and becomes a strong joint. Its applications include the joining of metallic beams when constructing buildings, bridges, joining of pipes in pipelines, in power plant at the construction sites and in home appliances.

There are many types of welding which includes the arc welding, resistance welding, and gas welding among others. The most popular of the welding process is the arc welding methods (Catarina, 2014). The arc welding is a type of welding process using an electric arc to create heat to melt and join metals. A power supply creates an electric arc between a consumable or non-consumable electrode and the base material using either direct (DC) or alternating (AC) currents.

Welding requires a constant and reliable power supply, the instability in power supply is a big challenge in welding, one of the solutions to this problem is to design an inverter type arc welding machine. For the inverter design, a Power switch (MOSFET) is used due to its high switching ability. An arc welding machine provides the required current and voltages at different stages of the arc process.

High voltage is produced at no load, which is also called open-circuit voltage. When the electrode is touched to the piece a short circuit occurs and the current increases suddenly. After the output current reaches the reference current level, the arc welding machine regulates the output voltage to maintain a constant current, which is required for metal transfer. The voltage produced in the steady state is proportional to the current.

This depends on the arc length and electrode diameter. During the transient state of the arc process, the load varies between open circuit and short circuit.

In welding machines, a transformer is used for voltage transformation and isolation, and inductance at the output stage to filter output current.

Problem Statement

Lack of constant and reliable power supply from the grid is a serious challenge most especially in rural areas, this has resulted in the use of alternative energy supply systems like generators for power. the use of diesel engine is characterized by the high cost of diesel, air and sound pollution. The inverter operated arc welding machine in the other hand, is economical when battery is used as power source.

Brief History of Welding

The history of welding can be traced back to several millennia that are Bronze Age or Iron Age in Europe and the Middle East (Reed, 2018). At that time, the

process of joining similar or dissimilar materials is by forge welding. Arc welding did not come into practice until much later.

In 1802, Vasily Petro discovered the continues electric arc and subsequently proposed its possible practical application including welding. The French electrical inventor Auguste De Metitens in 1881 produced the first carbon arc torch, which was successfully used for welding lead in the manufacture of lead-acid batteries (A. Alexander, 2000).

The French electrical inventor Auguste De Metitens in 1881 produced the first carbon arc torch, which was successfully used for welding lead in the manufacture of lead-acid batteries.

A Russian inventor Nikolai Bernados, in 1882 created the electric arc welding method for steel known as carbon arc welding. This type of arc welding uses carbon electrodes (Grill, 2019).

The advantages in arc welding continued with the invention of metal electrodes in the late 19th century by a Russian Nikolai Slavyanor and an American, L.C.C. project round 1900, A.P Strohmenger released in Britain a coated metal electrode which gave a more stable arc. In a related development, a Russian scientist Vladimir Mitkerich in 1905 proposed the usage of three phase electric arc for welding. Alternating current welding was invented by C.J Hoslag in 1919 but did not become popular for another decade.

The Arc welding machine is the type that uses an electric power as an input, which is being supplied through the primary and then transferred t secondary winding by induction which can be used to carry out welding work by connecting to the output terminal the welding cables (Takasaki, Development of a portable spot welding machine, 2003). The output of the machine is designed in a way that it can be varied by adjusting the crank of the machines in clockwise and anti-clockwise direction in either to increase or decrease the output current respectively depending on the size of the material it is to be used on

Arc Welding

Is a welding process that uses an electric arc to create heat for melting and joining of metal. Power supply is used to create electric arc between a consumable or non-consumable electrode and the base material using either direct current or alternating current. It consists of an electric circuit that

produces a high current flow with low voltage output. The parts to be welded are connected to one terminal of the circuit and the other is to an electrode.

In arc welding, an arc is generated between the base metal and the electrode. The heat of the arc is used to melt the base metal and welding consumable produce the weld metal for joining structural components (A. Althouse, 2004). When the electrodes are touched to the work piece and slightly withdrawn, an arc is produced. This is because the two ends of the electric circuits are close enough for the current to jump to the gap. The temperature of the arc is about 5500^0C which is enough heat or melt most metals. As the arc is drawn along the joint, the tip of the electrode melts together with the electrode. The most common form of arc welding is manual shielded metal arc welding.

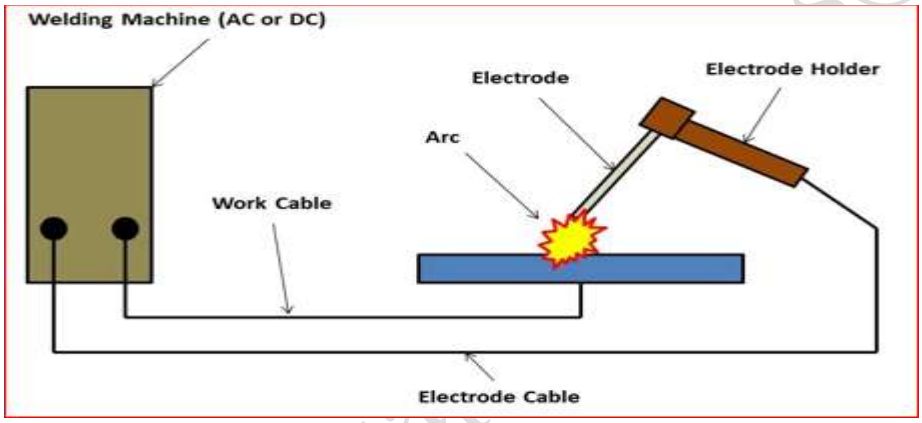

Fig. 1.0: Basic arc welding machine (TOM, 2017)

The Arc welding machine is the type that uses an electric power as an input, which is being supplied through the primary and then transferred to secondary winding by induction which can be used to carry out welding work by connecting to the output terminal the welding cables (Takasaki, Y., Sonoda, T and Fujii, S. , 2003).

Arc Welding Power Supplies. Different types of power supply can be used in powering a welding machine. In arc welding machine, the amount of voltage determines the length of arc that can be produced while the amount of heat produced is proportional to the amount of electric current.

Automated welding processes such as submerged arc welding, gas metal arc welding and flux cored arc welding requires a constant voltage power supply while hold the voltage constant and current is varied. Constant current power supplies are most often used for manual welding processes such as gas tungsten

arc welding and shielded metal arc welding, because they maintain a relatively constant current even as the voltage varies. Constant current is used in manual welding because it can be difficult to hold the electrode perfectly steady, and as a result, the arc length and thus voltage tend to fluctuate.

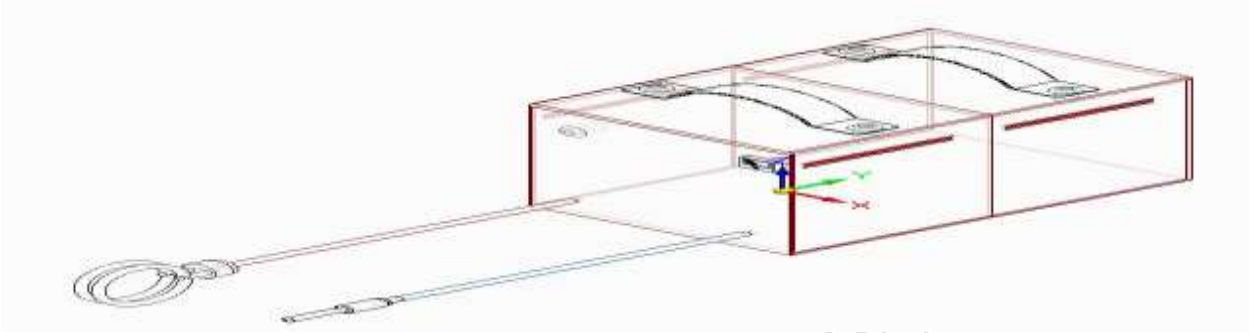

Fig 2: an arc welding machine

The direction of current used in arc welding also 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 electrodes has an impact on weld properties. If the electrode is positively charged, it will melt quickly, increasing weld penetration and welding speed.

Welding Transformer

Transformer is defined as a static (or stationary) piece of apparatus by means of which electric power in one circuit is transformed into electric power of the same frequency in another circuit. The physical basis of a transformer is mutual induction between two circuits linked by a common magnetic flux.

The major component of the electric arc welding machine is the transformer. Its operation principle is based on electromagnetic induction. When an alternating current passes through a conductor, a pulsating magnetic field will surround the exterior of the conductor i.e the magnetic field will build in intensity through the first the first cycle.

During the next quarter cycle, the magnetic field will decay until the voltage or current reaches zero at 180 electrical degrees. When the of flow of current is in the reverses direction, the magnetic field will begin to build again until it reaches a maximum at 270 electrical degrees in the cycle (ASIWE Uchechukwu, 2018).

Current and Electrode

In arc welding, the type of current used plays an important role (Six, 2018)**.** Shielded metal arc welding and gas metal arc welding which are types of consumable electrode process uses direct current but the electrode can be charged either positively or negatively. The positively charged anode usually has a higher concentration of heat as a result changing the polarity will change the amount of heat supplied during welding. Also, the base metal is hotter if the electrode is positively charged and also increases the penetration and welding speed. But when a negatively charged electrode is used, it will result in a shallow weld.

Some welding processes especially the non-consumable electrode processes such as gas tungsten arc welding can use both alternating and direct current. When direct current is used, the electrode only creates the arc and does not provide a filler material. While a positively charged electrode creates a shallow welds and negatively charged electrodes makes a deeper weld.

Design Stage

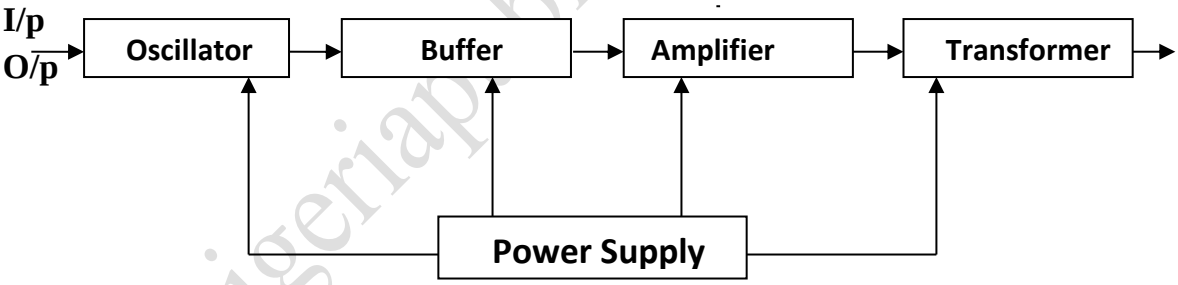

Fig 3.1 Block Diagram of an Inverter Welding Machine

The block diagram fig. 3.1 above, is made up of the power supply unit which is comprised of the solar PV panel, battery and a MOSFET that serves as an inverter. Also a step up transformer is used to step up the voltage from the output of the inverter circuit.

Research Methodology

The realization of this system and the approach is based on the design and implementation of the solar power supply unit as a source of power, its control

unit, input and output subsystems. The solar panel absorbs solar energy from the sun and fed into of 12V batteries that provides 36V DC. It is then fed into the MOSFET that inverts DC to AC power. The output of the inverter is connected to the transformer and steps it up. The welding process takes place when the conductive object to be welded are linked together with the control unit and the output subsystem.

Design

Table 3.1 Design Specification

S/N	Parameter	Rating
1.	Output Voltage	40Vac
2.	Input Voltage	36Vdc
3.	Output Current	75A
4.	Transformer Power rating	3KVA

Power Supply Design

Solar PV Panel design

The system is rated 3KVA $3KVA = 3000 \times 0.8 = 2400W$

Considering 3 hours of operation in determining the power consumption demand

The consumption demand $= 2400W \times 3 = 7200Wh$

The total PV panel energy needed $=$ consumption demand $\times$ energy Lost in the System

$$= 7200 \times 1.3 = 9{,}360Wh/day$$

To size the PV panel, the total watt capacity of the PV panel needed:

$$= \frac{Total\ PV\ panel\ energy\ needed}{Panel\ generation\ factor} = \frac{9{,}360}{3.4} = 2{,}752.94$$

Considering a 300W PV panel, the number of PV panel needed

$$= \frac{2{,}752.94}{300} = 9.2 \approx 8\ panels\ of\ 300W, 12V\ will\ be\ considered$$

Battery Sizing

Battery Capacity$= \frac{Total\frac{watthour}{day} \times Days\ of\ autonomy}{0.85 \times 0.6 \times Nominal\ battery\ voltage} = \frac{9{,}360 \times 2}{0.85 \times 0.6 \times 2} = 2{,}352.9AH$

If a 200AH battery is selected;

$$= \frac{2{,}352.9}{200} = 11.7 \approx 12\ batteries$$

Charge Controller

To determine the size of a charge controller that can be used on a 300W solar PV panel, the total power produced by the solar panel is 2,752.9, battery bank of 36V is: $\frac{2{,}752.9}{36} = 76.5A$

Transformer Design

A small size and less in weight transformer is usually considered when designing an inverter type welding machine.

An arc is maintained at a voltage of about 24 to 30 volts. The relation for the transformer transformation constant can be applied to calculate the number of turns of primary and secondary winding given by:

$K = \frac{V1}{V2} = \frac{N1}{N2} = \frac{I2}{I1}$

Transformer Core Dimension;

Voltage per turn $E_t = K\sqrt{KVA}$ Assume K = 0.55, Power rating = 3KVA

$\therefore\ E_t = 0.55 \times \sqrt{3} = 0.95V$

For square wave, $E_t = 4fmA_i$, the area of core A_i=?

$$A_i = \frac{0.95}{4 \times 50 \times 1.1} = 4.3 \times 10^{-3} cm^3$$

Transformer Winding;

Primary winding Turns $T_1 = \frac{E1}{Et} = \frac{36}{0.95} = 38$

Total number of turns at the primary is 76 (center tapped)

To calculate the primary winding current I_1, we use $P = E_1 I_1$,

$$I_1 = \frac{3KVA}{36} = 83.33A$$

IC Sg 3524 Oscillator

An IC SG3524 is use to generate the necessary pulse needed to drive the MOSFET (IRF150) to alternate the DC supply. The output from the oscillator stage is amplified using transistor (9013). The frequency at which circuit operate is determined with the oscillator stage as shown below.

$f = \frac{1.18}{R_T C_T}$, If assuming $C_T = 0.1 \times 10^{-6} f, frequency\ f = 50HZ$

Therefore, $R_T = \frac{1.18}{(0.1\times10-6\times50)} = 236K\Omega$

Circuit diagram of an inverter type arc welding machine

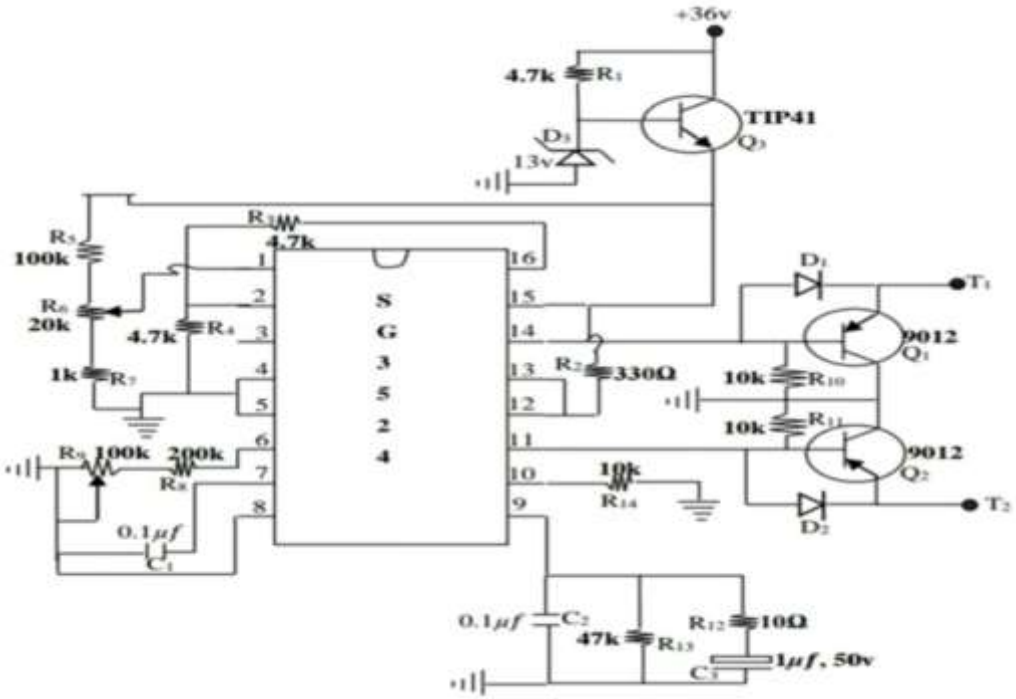

Fig 3.1(a) Oscillator/buffer stage (Aremu E. O., 2020)

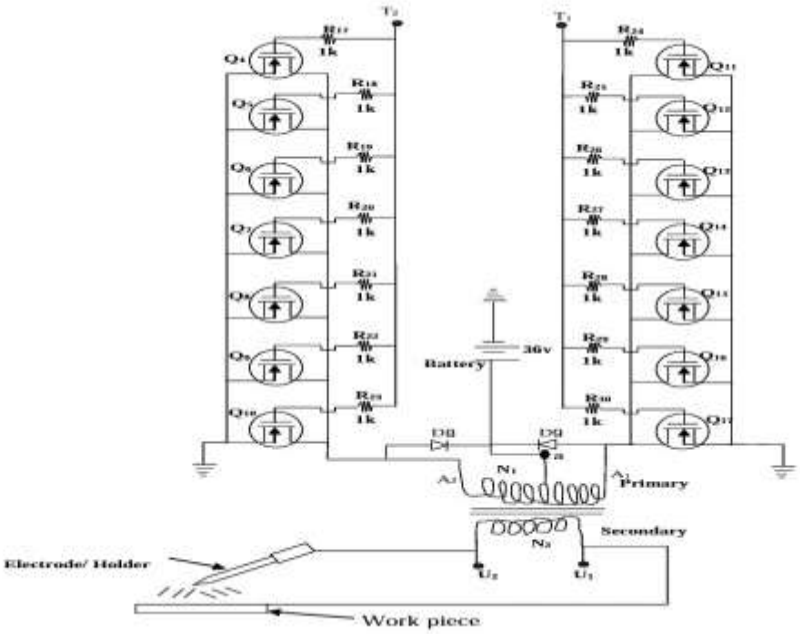

Fig 3.1(b) power amplifier/ transformer stage (Aremu E. O., 2020)

Design and Construction of a 3kva Inverter Operated Arc Welding Machine
Aremu Ezekiel Olarewaju, Ezeaka Nkiruka Gladys, Godwin Omadefu Nehemiah
January, 2020

Operating principle of Fig 3.1

The frequency of the ICs internal oscillator is set by Resistors R_S and Capacitor C_1. The oscillator frequency can be varied bi the preset Resistor R_9. The collector terminals of the driver transistors (pin 13 and 12) are connected together and linked to the Q_3 (+12.3V).

Q_1 is switched on when the signal at pin 14 is high, this makes transistor Q_{11} and Q_{17} ON leading to the flow of current to flow from the +36V battery source. Half of the transformer primary is grounded through the transistors Q_{11}, Q_{12}, Q_{13}, Q_{14}, Q_{15}, Q_{16}, and Q_{17} that induces voltage in the secondary of transformer secondary and this voltage contributes to the upper half cycle of the output waveform. During this period Pin 11 will be low and its succeeding stages will be inactive.

Q_2 is switched ON when the signal at Pin 11 goes high and in the process switching Q_4 and Q_{10}. Current will then flow from the +36V source through the lower half of the transformer primary and grounded through transistors Q_4, Q_5, Q_6, Q_7, Q_8, Q_9, and Q_{10} and the resultant voltage induced at the A_2 secondary contributes to the lower half cycle of the output wave form**.**

Inverter

Metal Oxide Semiconductor Field-Effect Transistor (MOSFET) can be used to build a switched-mode power supply that can withstand the high loads of arc welding. The process of this design is known as inverter welding machine.

When the AC mains power supply is not available, an oscillator circuit produces the 50HZ MOS drive signal. This MOS drive signal is amplified by the driver section and start switching between ON and OFF state at a rate of 50HZ and it is then send to the output section. MOSFET are connected to the primary of the inverter transformer

Equations for MOSFET calculations are as follows.

$$I_D = K(V_{GS} - V_{GS(TH)})^2$$

$V_{DG} = V_{DS} - V_{GS}$
$V_{DS(sat)} = V_{GS} - V_T$
Where ID = drain current, K = constant which depends on the particular MOSFET

VDG = Drain-Gate voltage, (th) = VT = threshold voltage,
VDS = Drain- Source voltage, VGS = Gate-Source voltage

Test

After the design and construction, insulation test, open circuit and short circuit test can be carried out to determine the physical working of the arc welding machine. The tongs of the electrode holder should be used to grip the electrode tight for different welding positions to avoid arcing effect on the tong.

Conclusion

Welding is a fabrication process that joins materials, usually metals or thermoplastics. This is often done by melting the work-piece and adding a filler material to form a pool of molten material that cools to become a strong joint. Different power supply can be used for welding such as inverter arc welding power supply. Inverter arc welding machine transform low voltage low amperage primary power into the low voltage, high amperage power used for welding at high frequency. This high frequency transformation helps to reduce the weight and size of the transformer. The output power is precisely control by the inverter due high operating frequency

Recommendation

i. The system is a good source for powering arc welding machine especially in places where the grid supply is not adequate
ii. The need to use correct components as stated in the design so as to avoid endangering the operator
iii. The system should be used where there is adequate sun shine

References

A. Alexander, R. B. (2000). The Fundamentals of Welding, Cutting, Brazing, Soldering and Surfacing of Metals. London: John Deere Publishing.
A. Althouse, K. B. (2004). *Mordern Welding.* London: Goodheart-Wilcox Company.

Aremu E. O., E. N. (2020). *Design and Construction of a 3KVA Inverter Operated Arc Welding Machine*.

ASIWE Uchechukwu, E. A. (2018). Design and Construction of an Electric Arc Welding Machine. *International Journal of Trend in Scientific Research and Development (IJTSRD)*, 924-929.

Catarina, S. (2014). Finite Element Analysis of a welding transformer. 212-221.

Grill, J. (2019, December 1). *https://weldguru.com/welding-history*.

Reed, B. (2018, March 20). *www.fairawntool.com* . Retrieved from FAIRLAWN TOOL INC.

Six, J. L. (2018, January 01). Current and Electrodes. 71. Chino, Valley.

Takasaki, Y. S. (2003). Development of a portable spot welding machine. *Magnetics Conference* (p. 66). IEEE International conference.

Takasaki, Y. S. (2003). Development of a portable spot-welding machine. *Magnetic conference* (p. 66). IEEE International Conference.

Takasaki, Y., Sonoda, T and Fujii, S. . (2003). Development of a portable spot-welding machine. *Magnetic Journal* (p. 66). IEE International Conference.

TOM. (2017, April 11). Retrieved from www.theweldingmaster.com.