DEVELOPMENT OF A SOLAR POWERED WELDING POWER SOURCE

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Abstract - *With the growing industrial conscience for producing green energy solutions to real time problems, renewable sources of energy have become an indispensable tool. Welding being one of the most prominent manufacturing processes, entitles it to be a suitable candidate for the renewable energy utilization. The objective of present research is to develop a solar powered arc welding power source. The present work has been carried out by interfacing the Monocrystalline solar panels with the TIG welding power source using electrical connections made with the solar powered batteries through an inverter, to develop a cost and energy efficient solar powered welding power source prototype. This modification once commercialized will help to fulfil the needs of welding in areas that lack electric power supply thereby expanding its application foray to remote areas and disaster struck places that have lost the power generation capability to facilitate the starting of reconstruction work involving welding. Present system consists of two 180 Ah batteries connected in series, a 2.5 KW inverter, a TIG welding power module and two solar panels. It is expected that the system will prove to be beneficial for industrial applications.*

Key Words: Green energy, power source, renewable energy, solar panels, TIG welding.

1. INTRODUCTION

In conventional means, welding process requires the presence of conventional sources of electric power supply and is one of the major bottlenecks that limits its applications to a constrained, remote environment that has no access to electricity. Also, welding being one of the most prominent manufacturing processes, total amount of yearly non-renewable resource consumption for the purpose of providing power for welding has to be very high, which is exacerbated by the high wattage required for a general welding process. This necessitates the consideration of welding using unconventional sources of electricity supply methods.

Solar Energy proves to be the ideal solution for the aforementioned concerns. The output of a photovoltaic system depends upon the solar irradiance, which is the power in the form of electromagnetic radiation received from the sun per unit area [1]. High solar irradiance is a critical parameter for a solar power system to generate power efficiently and in large quantity [2]. As per the analysis of the global solar irradiation data (as shown in figure 1), it is evident that the untapped potential is sufficient enough to be used for prolonged consumption and can be used to replace the traditional electricity-run systems in the manufacturing industry [3].

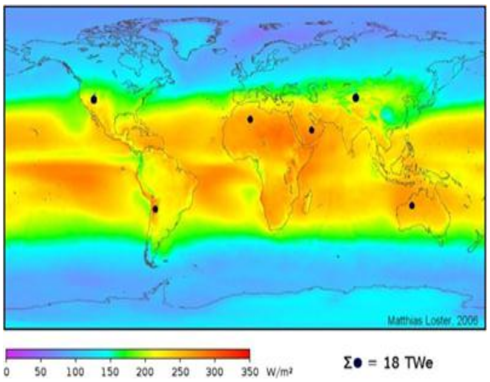

Fig-1. Global Map of Global Horizontal Radiation.[4]

Solar Energy has very high untapped potential to serve as the basis for satisfying the needs of welding on a large scale, the only limitation lies in the low solar panel efficiency per m2 of land, which is about 20% on an average [5]. The present work focuses on tackling incompatibility of the low wattage solar power source as the power supply for a TIG welding machine and developing an economical and portable solar powered welding power source.

2. EXPERIMENTAL SETUP

The experimental setup consists of two 180 Ah batteries connected in series, a 2.5 KW inverter, a TIG welding power module and two solar panels, is shown in figure 2. The role of the major components in the system is explained under the following headings:

2.1 Solar Panel

A Solar Panel is an assembly of photovoltaic cells mounted on a frame. They are generally used for small scale energy generation, especially for commercial or residential use in complexes or buildings. These panels have an average efficiency range of 12 – 18 % and there are two different type of solar panels, based on the type of silicon crystal used for the purpose of making the photovoltaic cells, polycrystalline and monocrystalline [6].

In present work, the monocrystalline Solar panel used had a rating peak power of 300 W, peak voltage rating of 36 V and peak current rating of 8.3 A with an efficiency of 15.63%.

2.2 Batteries

The storage battery or secondary battery is a battery where it is possible to store electrical energy as chemical energy and then transform this chemical energy into electrical energy as and when necessary. Secondary batteries are of various types as classified on the basis of chemistry involved in their working, such as Lithium-ion (Li-ion), Nickel Cadmium (Ni-Cd), Nickel-Metal Hydride (Ni-MH) and Lead-Acid [7].

In present work, two 180 Ampere-hour (Ah) Lead-Acid batteries were used in the series formation. The overall discharge reaction is given as follows:

$Pb + PbO_2 + 2H_2SO_4 \rightleftarrows 2PbSO_4 + 2H_2O$ [8]

The main advantages of Lead-Acid batteries are their low cost, simple and well-known technological process, almost 100%effective recycling, long operation in floating charge conditions, and low self-discharge [9].

2.3 Power Inverter

A power inverter is a power electronic device or circuitry that changes direct current (DC) to AC. The input voltage, output voltage and frequency, and overall power handling depend on the design of the specific device or circuitry. The inverter does not produce any power; the power is provided by the DC source. In present work, one 2.5 KW inverter was used.

2.4 TIG Welding Module

Tungsten Inert Gas (TIG) also known as Gas tungsten arc welding (GTAW) uses a constant current welding module, which means that the current remains relatively stable even if the voltage across the electric arc changes, which depends upon the arc length. This is important as most applications of GTAW are manual or semiautomatic which requires an operator to hold the torch [10]. GTAW uses a non-consumable tungsten electrode to produce the weld. Under the correct welding conditions, the tungsten electrode does not melt. In GTAW, weld can be made with or without filler metal [11]. GTAW is widely used for welding of high strength, reactive metals and alloys such as stainless steel, aluminium and magnesium alloys [12].

2.5 Charge controller

A charge controller also known as a charge regulator is basically a device that protects the batteries from overcharging and overvoltage. It keeps the current and voltage from the solar panels going to the battery in check [13]. They also prevent the batteries from sending back the stored charge back to their charging source, in this case the solar panels. Charge controller should be capable enough to withstand the current from the solar panel grid and the output current provided to the load [14].

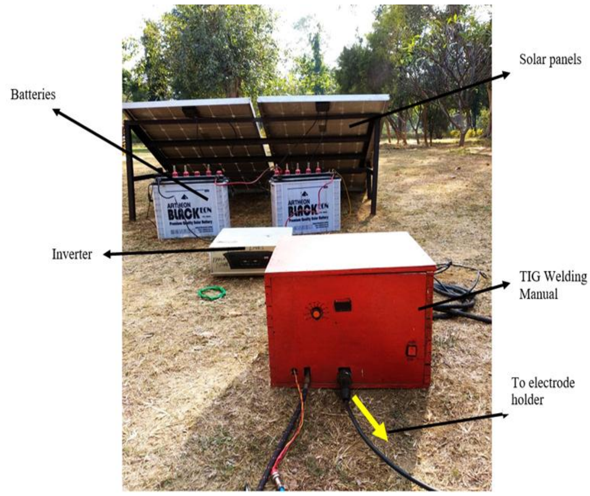

Fig.2. The Experimental Setup.

3. WORKING

In the present work two 300-watt monocrystalline solar panels have been used which were connected in parallel combination in order to increase the charging current provided to a set of two 180Ah, 12V batteries connected in series to 16A as compared to a charging current of 8A (which would have been the case if they were connected in series). Solar panels were connected to the batteries through a charge controller in order to protect the batteries from overcharging. A 2.5 KW inverter is used to convert Direct Current (DC) coming from the batteries into Alternating Current (AC), which serves as the input current for the TIG welding module. The present setup has been devised for welding Stainless-Steel plates of up to 3 mm in thickness. The work-flow diagram with the suitable connections is shown in figure 3.

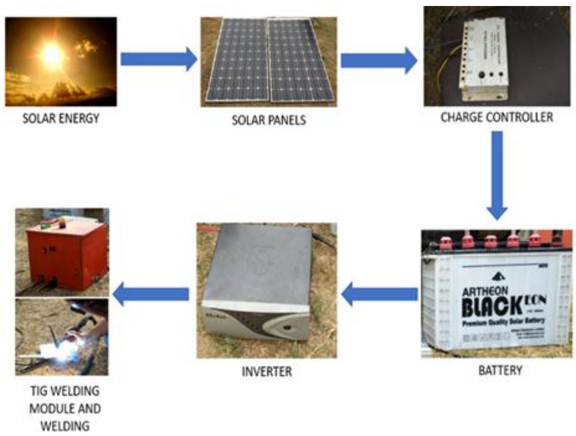

Fig.3. Work-flow Diagram.

4. CALCULATIONS

In a basic TIG welding process, when the arc is yet to be formed between electrode and workpiece, the OCV (Open Circuit Voltage) is around 70 to 80 V (RMS) in order to help initiate the arc. Once the arc has been initiated the voltage drops and fluctuates between 16 – 20 V (RMS) [15]. The proposed prototype is designed with an objective to perform butt welding on stainless-steel workpieces of up to a 3mm thickness, for which the RMS current required is 60 – 100 A [16]. Considering 20 volts and 100 Amperes for calculation purposes, the power requirement can be calculated as follows:

$$P = V \times I$$

$$P = 20 \times 100$$

$$P = 2000\ Watts$$

Energy consumed if machine runs continuously 3 hours,

$$Energy\ consumed = 3 \times 2000$$

$$Energy\ consumed = 6000\ Wh$$

Considering the time required for clamping, unclamping and work adjustment, generally the actual weld time would be much more than 3 hours.

4.1 Battery specifications

Energy to be stored in the battery is given by the following equation:

$$Energy\ Stored = V \times Q$$

Where V is the net voltage of the solar panel grid and Q is the charge transferred into the battery. V is equal to 36 V as the two solar panels connected in parallel generate a net solar panel grid voltage of 36 V under peak sunlight hours as per specifications.

So, charge to be stored in the battery (Q) can be given by,

$$Q = \frac{Energy\ Stored}{V}$$

$$Q = \frac{6000\ Watt - hour}{36\ Volts}$$

$$Q = \frac{6000 \times 3600\ Ampere - sec}{36\ Volts}$$

$$Q = 600{,}000\ Coulombs$$

$$Q = \frac{600{,}000\ Ampere - hour}{3600}$$

$$Q = 167\ Ampere - hours$$

This is easily satisfied by using a 180 Ah battery.

While charging the Lead Acid batteries it is especially important to keep the input current around 0.1C (C represents the capacity of the battery in ampere-hour (Ah)), which is 1/10 of the total Ah rating of battery [17], [18].

$$Charging\ Current = \frac{Battery\ capacity}{10}$$

$$Charging\ Current = \frac{180\ Ah}{10} = 18\ A$$

The charging current provided by the solar panels is 16.6A, which is within permissible range.

Thus, Charging Time required for Battery

$$Time = \frac{Ah}{A}$$

$$Time = \frac{180\ Ah}{16.6\ A} = 10.8\ hours$$

4.2 Inverter / UPS Rating

Inverter / UPS rating should be greater than 25% of the total load (for the future load as well as taking losses in consideration)

That is, 2000 x (25/100) = 500W

So, Total Load + 25% Extra Power = 2000 + 500 = 2500 Watts

Thus, the rating of the UPS (Inverter) required = 2500 Watts = 2.5 kW.

4.3 Rating of Charge Controller

Charge controller are rated depending upon the Amperage and voltage. The amperage rating of the charge controller can be calculated using the following formula:

$$Current\ rating = I \times N \times F$$

Where I is the current produced by a single solar panel which is 8 A, N is the number of solar panels which is two and F is the factor of safety which is usually taken as 1.25, to account for certain factors such as light reflection or cloud effect at irregular intervals can increase current levels [14],[19].

$$Current\ rating\ =\ 8.3 \times 2 \times 1.25$$

$$Current\ rating\ = 20.75\ A$$

Hence, a charge controller with current rating more than 20.75 amperes can be used.

5. RESULTS AND DISCUSSIONS

5.1 Cost Analysis

Total Cost of production of any product is one of the major concerns in any manufacturing process and specifically in welding process the high wattage requirement increases the cost incurred as electricity bill Thereby increasing the total cost of production. The solar powered welding power source provides a reasonable solution for the above problem, where the initial investment in the solar panel and related equipment is high, but the electricity bill saved reimburses the high initial investment in a few years.

Cost of various components proposed for the design are as follows:

The following equipment cost is as per the equipment used in the present work.

Solar panels = $ 450

Batteries = $ 210

Inverter = $ 100

Charge controller = $ 40

Welding transformer = $ 100

Total Estimated Cost = $900

Time for reimbursement of cost of investment can hence be calculated as follows,

While doing the calculations of the total energy stored by the solar panels, the number of hours the sun remains in the sky, or the total number of peak hours received per day, are defined as the number of hours solar panels generate a specific level of energy. A tropical country like India receives about 6 hours of peak sunlight hours during any summer day and an average of about 2300 – 3200 hours of sunlight every year [20],[21].

For calculations, considering the average of peak hours in a year to be 3000 hours,

Average sunny hours every day = 3000 / 365

= 8.2 hours

Amount of Energy stored by two 300-watt Solar Panel in the battery in 1 hour,

Energy stored= 2 ×300 Wh=600Wh

Estimated number of sunny hours on an average day = 8.2 hours

Total amount of energy stored by Solar Panels in 1 day = 8.2 x 600Wh = 4920 Wh

Since there is a wide disparity of cost of electricity per unit between various countries as per the data shown in figure 4, the average cost per unit of one electricity unit is equal to $0.21 (global average).

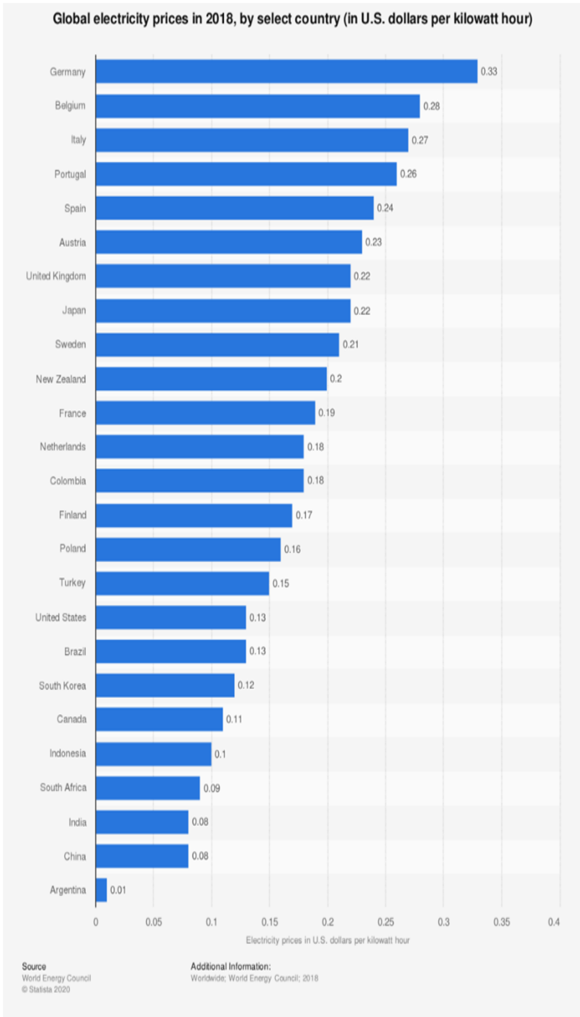

Fig-4. Global electricity prices in 2018, by select country (in U.S. dollars per kilowatt hour) [22].

Cost Saved per Day by using Solar Energy = 0.21 x 4.92 = $ 1.03

Considering the welding machine is not operational for working every day as time required for charging is 10.8 hours and charging hours per day are taken to be 8.2 hours, so it would be plausible to assume that in a real-time setting, the welding machine works for about only 70-85 % of the year.

If the machine works only on 80% days in a year:

The number of days the machine works = 80% of 365 = 292 days.

Therefore, the cost saved per year = 292 x 1.03 = $ 301

Thus, the initial investment will be recovered in a period of:

Return on Investment = 900 / 301 years = almost 3 years.

5.2 Comparison of Proposed Prototype and Conventional Methodology

The Solar Powered Welding Power Source developed is a success when it comes to arc initiation, arc maintenance and arc stabilization.

The solar welding power source was tested at 100 A of welding current by welding 3mm thick stainless-steel plates as shown in figure 5, The weld bead produced utilizing solar energy is uniform across the length of the work piece and is comparable to the generic weld beads produced by non-renewable sources of electricity.

Fig-5. Work-flow Diagram.

6. CALCULATIONS

The proposed solar powered welding power source has proved to be efficient in welding of Stainless-Steel plates up to 3mm thickness with a continuous welding time of 3 hours. The expected return on investment of 3 years, with no further liability will prove to be profitable for long-term industrial applications. The proposed solar powered welding power source helps bridge the infrastructural gap in regions with no electric power supply and proves to be a green and clean welding process that promotes the use of renewable sources of energy.

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