Supervisors' Training Centre,NBQ

HANDOUT FOR
MECHANICAL ENGINEERING DEPARTMENT

Title: Types of Arc Welding Power Sources



Contents:

Presented By

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This chapter presents the need of welding power source and their classification besides the basic characteristics of welding power sources. Selection of suitable type of power source for different welding processes has also been described. Further, the concept of self regulating arc has been elaborated.

Keywords:
Welding power source, classification, basic characteristics of power source, OCV, power factor, constant current(CC) and constant voltage(CV) power source, self regulating arc, operating point, Dynamic characteristics, Duty cycle, class of insulation, HF unit, arc length, feed drives .

INTRODUCTION:

One of the main requirements of a welding power source is to deliver controllable current at a voltage desired according to the demands of the welding process. Each welding process has distinct features from other processes in the form of process controls required. Therefore, arc welding power sources play very important role in successful welding. The conventional welding power sources are:

SN	Power Source	Supply
1	Welding Transformer	AC
2	Welding Rectifier	DC
3	Welding Generators	AC/DC
4	Inverter type welding power source	DC

Welding transformers, rectifiers and DC generators are used in shops while engine coupled DC and AC generators are used at site where domestic line supply is not available. Rectifiers and transformers are usually preferred because of lower noise, higher efficiency and lower maintenance as compared to generators. The inverter type welding power source first transforms the AC into DC. The DC power is then fed into a step-down transformer to produce the desired welding voltage/current. The pulse of high voltage and high frequency DC is fed to the main step-down transformer and there it is transformed into low voltage and high frequency DC suitable for welding. Finally, low voltage and high frequency DC is passed through filters and for rectification. The switching on and off is performed by solid state switches at frequencies above 10,000. The high switching frequency reduces the volume of the step down transformer. The inverter type of power source provides better features for power control and overload protection. These systems are found more efficient and better in respect of control of welding parameters than other welding system. The invertors with microcontrollers allow changes in electrical characteristics of the welding power by software in real time. This can be done even on a cycle by cycle basis so as to provide features such as pulsing the welding current, variable ratios and current densities, stepped variable frequencies.

Selection of a power source mainly depends on the welding process and welding consumables to be used for arc welding. The open circuit voltage normally ranges between 70-90 V in case of welding transformers while that in case of rectifiers varies from 20-60 V. Moreover, welding arc voltage becomes lower than open circuit voltage of the power source. Welding power sources can be classified based on different parameters related with them as under:-

- **Type of current**: A.C., D.C. or both.
- **Cooling medium**: Air, water, oil cooled.
- **Cooling system**: Forced or natural cooling
- **Static characteristics**: Constant current, constant voltage, rising characteristics.

Characteristics of power source:

Each welding power source has set of characteristics indicating the capability and quality of the power source. These characteristics help in selection of suitable welding power source for a given welding condition. **Basic characteristics of a welding power source are given below**:

- Open circuit voltage (OCV)
- Power factor (pf)
- Static characteristics
- Dynamic characteristics
- Current rating and duty cycle
- Class of Insulation

Open circuit voltage (OCV):

OCV shows the potential difference between the two terminals of the power source when there is no load. Setting up of correct open circuit voltage is important for stability of welding arc especially when AC is used. The selection of an optimum value of OCV (50-100V) depends on the type of base metal, composition of electrode coating, type of welding current and polarity, type of welding process etc. Base metal of low ionization potential (indicating ease of emitting free of electrons) needs lower OCV than that of high ionization potential metal. Presence of low ionization potential elements such as K, Na and Ca in electrode coating/flux in optimum amount reduces OCV setting required for welding. AC welding needs higher OCV compared with DC owing to problem of arc stability as in case of AC welding current continuously changes its direction and magnitude while in case DC it remains constant. In the same line, GTAW needs lower OCV than GMAW and other welding processes like SMAW and SAW because GTAW uses tungsten electrode which has good free electron emitting capability by thermal and field emission mechanism. Abundance of free electron in GTAW under welding conditions lowers the OCV needed for having stable welding arc.

Too high OCV may cause electric shock. OCV is generally found to be different from arc voltage. Arc voltage is potential difference between the electrode tip and work piece surface when there is flow of current. Any fluctuation in arc length affects the resistance to flow of current through plasma and hence arc voltage is also affected. Increase in arc length or electrode extension increases the arc voltage. Further, electrical Electrical resistance heating of electrode increases with electrode extension for given welding parameters.

Power factor (pf):

Power factor of a power source is defined as a ratio of actual power (KW) used to produce the rated load (which is registered on the power meter) and apparent power drawn from the supply line (KVA) during welding. It is always desired to have high power factor (pf). Low power factor indicates unnecessary wastage of power and less efficient utilization of power for welding. Welding transformers usually offer higher power factor than other power sources. However, sometimes low power factor is intentionally used with welding transformers to increase the stability of AC welding arc. The basic principle of using low power factor for better arc stability has been explained in section 6.2.2. Application of a welding power source with high power factor offers many advantages such as:

- Reduction of the reactive power in a system, which in turn reduces the power consumption and so drop in cost of power
- More economic operations at an electrical installation (higher effective power for the same apparent power)
- Improved voltage quality and fewer voltage drops
- Use of low cable cross-section
- Smaller transmission losses

Static Characteristic of power source:

Static characteristic of a welding source exhibits the trend of variation in voltage with current when power source is connected to **pure resistive load**®. This variation may be of **three** types, namely :

®**Resistive loads** are typically used to convert current into forms of energy such as heat. Unlike inductive **loads**, **resistive loads** generate no magnetic fields. Common examples include most electrical heaters, and traditional incandescent lighting **loads**.

i) Constant current (CC)
ii) Constant voltage(CV)
iii) Rising voltage (RV)

i) **Constant Current power source(CC):**

The **volt-ampere** output curves for **constant current** power source are called '**drooper**' because of substantial downward or negative slope of the curves. With a change in arc voltage, the variation in welding current is small and, therefore, with a consumable electrode welding process, electrode melting rate remains fairly constant even with a minor change in arc length (Fig.1). These power sources are required for processes that use relatively thicker consumable electrodes which may sometimes get stuck to work piece or with non-consumable tungsten electrode where touching of electrode with base metal for starting of arc may lead to damage of electrode if current is unlimited. Under these conditions, the short circuiting current shall be limited which would provide safety to power source and the electrode.

In **constant current** power source, variation in welding current with arc voltage (due to fluctuations in arc length) is very small therefore welding current remains more or less constant despite of fluctuations in arc voltage / length. Hence, this type of power source is also found suitable for all those welding processes where large fluctuation in arc length is likely to take place e.g., MMA and TIG welding.

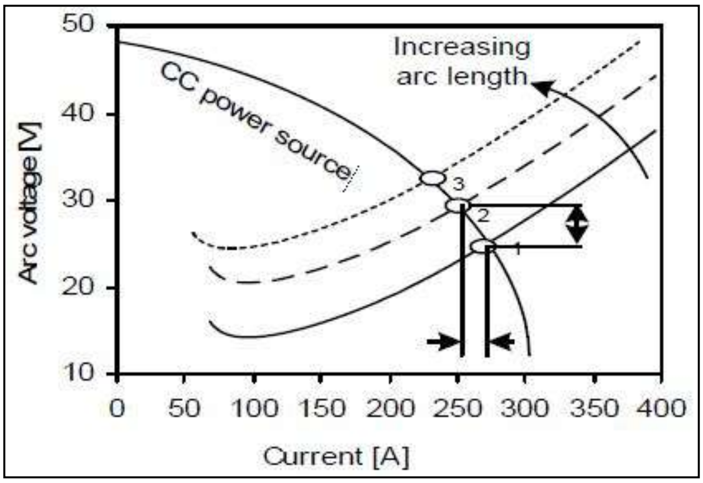
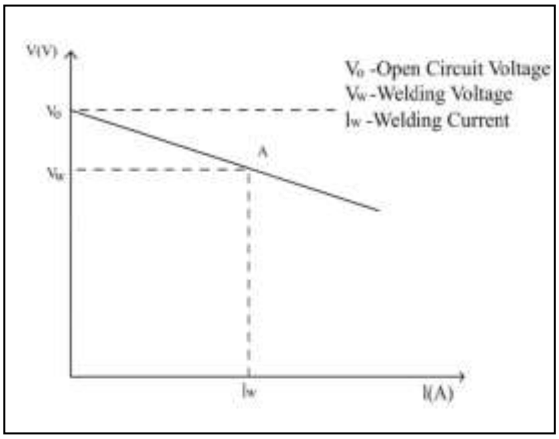


Fig.1 Static characteristics of constant current welding power source

ii) **Constant voltage power source(CV):**

In CV power sources, a small variation in arc voltage (due to fluctuations in arc length) causes significant change in welding current. Since arc voltage remains almost constant during welding despite of fluctuations in arc length therefore this type of power source is called constant voltage type. Moreover, the constant voltage power sources do not offer true constant voltage output as current voltage relationship curve shows slightly downward or negative slope. This negative slope is attributed to internal electrical resistance and inductance in the welding circuit that causes a minor droop in the output volt-ampere characteristics of the power source (Fig.2). This type of power sources is found more suitable for all those welding processes where fluctuations in arc length during welding is limited like in semiautomatic welding process MIG, SAW and PAW. The power source shall supply necessary current to melt the electrode at the rate required to maintain the preset voltage or arc length. The speed of electrode drive is used to control feed rate of the electrode which in turns affects the arc gap/voltage. The variation arc voltage changes the average welding current. The use of such power source in conjunction with a constant speed electrode wire feed drive results in a self regulating or self adjusting arc system. Due to some internal or external fluctuation if the change in arc length occurs then it regulates the **electrode Melting Rate MR** (by regulating current) to regain the desired arc length.

Fig 2. Static characteristics of constant voltage welding power source



iii) **Self regulating arc:**

In semi-automatic welding processes where constant voltage power source is used in association with automatically fed (constant speed) small diameter consumable electrode, arc length is maintained by self-regulating arc. Self-regulating arc is one, which governs the melting / burn off rate of the electrode (by changing the current) so that feed rate becomes equal to melting rate for maintaining the arc length. For example, increase in arc length due to any reason shifts the operating point from 2 to 3 thus increases the arc voltage (Fig.3). Operating point is the point of intersection of power source characteristics with arc characteristics. Rise in arc voltage decreases the welding current significantly. Decrease in welding current lowers the melting rate (see melting rate equation) of the electrode thus decreases the arc gap if electrode is fed at constant speed. Reverse phenomenon happens if arc length decreases (shifting the operating point from 2 to 1).

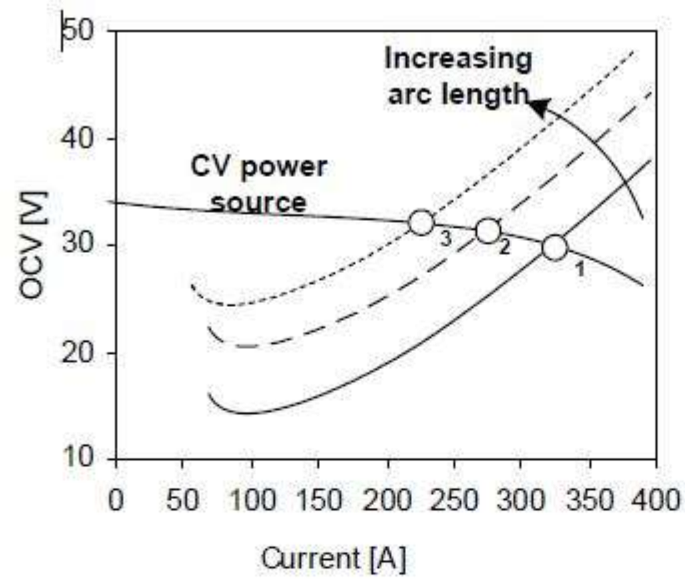


Fig.3 Static characteristics of constant voltage welding power Showing operating points with increasing arc length

Rising Characteristics:

Power sources with rising characteristics show increase in arc voltage with increase of welding current (Fig.4). In automatic welding processes where strictly constant voltage is required, power sources with rising characteristics are used.

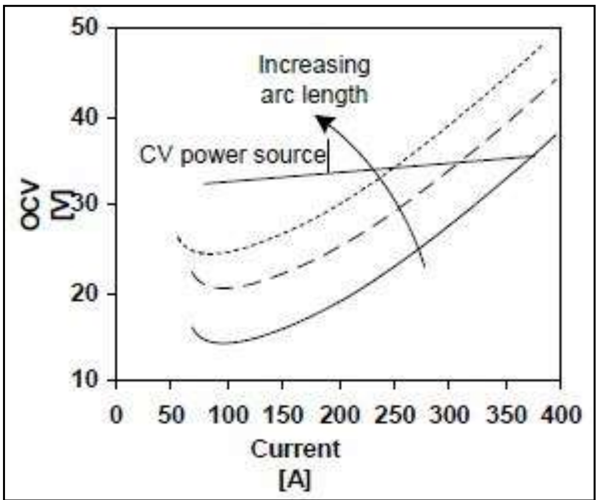
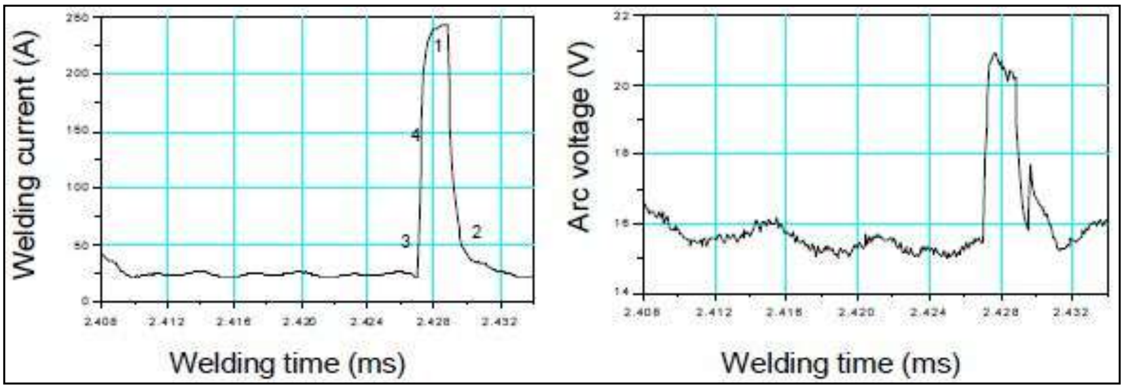


Fig.4 Static characteristics of rising voltage welding power showing operating points with different arc length

Dynamic characteristic :

Welding arc is subjected to severe and rapid fluctuations in arc voltage (due to continuous minor changes in arc length) and welding current (Fig.5). Number from 1 to 4 in figure 5 indicates different stages of welding arc during welding, suggesting that welding arc is never in a steady state. It causes transients in starting, extinction and re-ignition after each half cycle in A.C. welding. To cope up with these conditions power source should have good dynamic characteristics to obtain stable and smooth arc. Dynamic characteristic of the power source describes the instantaneous variation in arc voltage with change in welding current over an extremely short period of welding. A power source with good dynamic characteristic results in an immediate change in arc voltage and welding current corresponding to the changing welding conditions so as to give smooth and stable arc.



(a) (b)

Fig.5 Dynamic characteristics of a power source showing (a) current vs time and (b) voltage vs time relationship

Duty Cycle:

Duty cycle is defined as ratio of arcing time to the weld cycle time multiplied by 100. **Welding cycle** time is either **5 minutes as per European standards** or **10 minutes as per American standard** and accordingly power sources are designed. If arcing time is continuous for 5 minutes then as per European standard it is considered as 100% duty cycle and that will be 50% duty cycle as per American standard. At 100% duty cycle, minimum current is drawn from the welding power source. Welding power source operating at low duty cycle allows high welding current for welding purpose safely. The welding current which can be drawn at a duty cycle can be evaluated from the following equation:

$D_R \times I_R^2 = I^2_{100} \times D_{100}$……………………………………………..(equation 10.1)

Where I - Current at 100% duty cycle
D_{100} - 100% duty cycle
I_R- Current at required duty cycle
D_R- Required duty cycle

Example
Current rating for a welding power source is 400 A at 60% duty cycle. Determine the welding current for automatic continuous welding i.e. 100% duty cycle.
Solution:
Rated current: 400 A
Rated duty cycle: 60%
Desired duty cycle: 100%
Desired current ?

$$\text{Desired duty cycle} = \frac{(\text{rated current})^2 \times \text{rated duty cycle}}{(\text{desired current})^2}$$

$$100 = \frac{(400)^2 \times 60}{(\text{desired current})^2}$$

Answer: Desired current: 310 A .

Importance of Duty cycle:

During the welding, heavy current is drawn from the power source. Flow of heavy current through the transformer coil and connecting cables causes electrical heating. Continuous heating during welding for long time may damage coils and cables. Therefore, welding operation should be stopped for some time depending upon the level of welding current being drawn from the power source. The **total weld cycle is taken as sum of actual welding time and rest time**. **Duty cycle** refers to the percentage of welding time of total welding cycle i.e. **welding time divided by welding time plus and rest time**. Total **welding cycle of 5 minutes** is normally taken in India as in European standard. For example, welding for 3 minutes and followed by rest of 2 minutes in total welding cycle of 5 minutes corresponds to 60% duty cycle. Duty cycle and associated welding current are important as it ensures that power source is safe and its windings are not damaged due to increase in temperature due to electrical resistance heating beyond specified limit. Moreover, the maximum current which can be drawn from a power source at given a duty cycle depends upon size of winding wire, type of insulation and cooling system of the power source. In general, large diameter cable wire, high temperature resistant insulation and force cooling system allow high welding current drawn from the welding source at a given duty cycle.

Class of Insulation:

The duty cycle of a power source for a given current setting is primarily governed by the maximum allowable temperature of various components (primary and secondary coils, cables, connectors etc.), which in turn depends on the quality and type of insulation and materials of coils used for manufacturing of power source. The insulation is classified as A, E, B, F& G in increase order of their maximum allowable temperature 60, 75, 80, 100 & 125^{0}C respectively.

High Frequency Unit:

Some power sources need high frequency unit to start the arc like in TIG and plasma arc welding. High frequency unit is introduced in the welding circuit. Filters are used between the control circuit and HF unit to avoid damage of control circuit. High frequency unit is a device which supplies pulses of high voltage (of the order of few kV) and low current at high frequency (of few kHz). The high voltage pulse supplied by HF unit ionizes the gaseous medium between electrode and work piece/nozzle to produce starting pilot arc which ultimately leads to the ignitions of the main arc. Although high voltage can be fatal for operator but at high frequencies current passes through the skin and does not enter the body. This is called skin effect i.e. current passes through the skin without any damage to the operator.

Feed drives for constant arc length:

Two types of feed systems are generally used for maintaining the arc length ..

a) constant speed feed drive and
b) variable speed feed drive.

In constant speed feed drives, feed rollers rotating at fixed speed are used for pushing/pulling wire to feed into the weld so as to maintain the arc length during welding Fig.6(a). This type drive is normally used with constant voltage power sources in conjunction with small diameter electrodes where self regulating arc helps to attain the constancy in arc length.

In case of variable speed feed drives, feed rollers used for feeding electrode wire (in consumable arc welding processes like SAW and GMAW) are rotated at varying speed as per need to maintain the arc length during welding. Fluctuation in arc length due to any reason is compensated by increasing or decreasing the electrode feed rate. The electrode feed rate is controlled by regulating the speed of feed rollers powered by electric motor Fig.6(b). Input power to the variable speed motor is regulated with help of sensor which takes inputs from fluctuations in the arc gap. For example, an increase in arc gap sensed by sensor increases the input power to the variable speed motor to increase the feed rate of electrode so as to maintain arc gap.

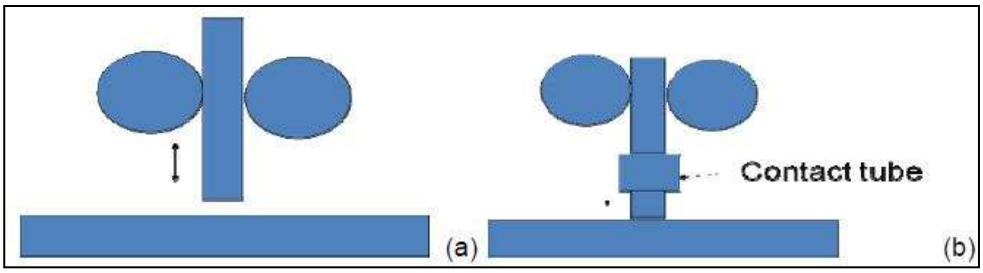


Fig.6 Schematics diagrams show electrode feed drives for controlling arc length a) variable speed feed drive and b) constant speed feed drive

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