DEVELOPMENT OF ARC SIMULATOR FOR THE EVALUATION OF WELDING POWER SOURCE OUTPUT CHARACTERISTIC

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ABSTRACT - Output of arc welding power source can be evaluated dynamically and also statically through an arc simulator. The arc simulator is developed to simulate the arc load of short circuit and arc and return power to the line.

1. INTRODUCTION

Welding performances of arc welding power source used to be evaluated qualitatively by welder rather than quantitatively through instruments. Categories of welder's evaluation may be arc strike, metal transfer, arc stability and spatter. Now arc stability indexes based on dynamic measurements of welding parameter have been suggested [1] .
But those kinds of the arc stability index can not be applied to evaluate the welding performances of the arc welding power source due to lack of arc load reproductivity and difficulty in isolating power source parameters from arc welding process parameter such as filler metal or shielding gas.

Now owing to the recent development of power electronic, dynamic loads of welding arc can be applied to the output terminal of welding power source instead of welding torch [2,3] . Furthermore power delivered to so called arc simulator from the power source can be recovered and returned to the line source.

2. CIRCUIT MODEL OF WELDING PROCESS

Welding power source consists of transformer, reactor, rectifying unit and power control unit such as SCR bridge or inverter unit. The circuit of power source may be modeled through no-load voltage Vo, inductance L and internal resistance R_i.
Transformer lowers input voltage of 220V or 440V to the no-load voltage Vo which is usually set around 80V. High no-load voltage give rise to the easy arc strike while to the high possibility electrical shock and burnback. Inductor L is designed to 150~600 μH. for MAG welding. Higher inductor reduces number of short circuits and increases fluidity of molten metal. Internal resistance is given from internal circuit elements or power bus and the value of internal resistance is varying around 0.08Ω. Welding arc load can be characterized by voltage drop due to arc and voltage drop due to external resistance. The external resistance is the resistance from the cable resistance between power source teminal and welding torch and from the wire resistance between contact tube and molten drop at the wire tip. The external resistance is varying around 0.05Ω.
Circuit model for welding process specially for Metal Active Gas(MAG)welding, can be represented by eqn(1) based on the model shown on Fig.1

$$L\frac{di}{dt} + (Ri+Re)i = Vo - Vac - Gz ---- (1)$$

where Vac = voltage drop of anode film and cathode film
Gz = voltage drop along the arc column of length z.
Vz=Voltage drop from arc

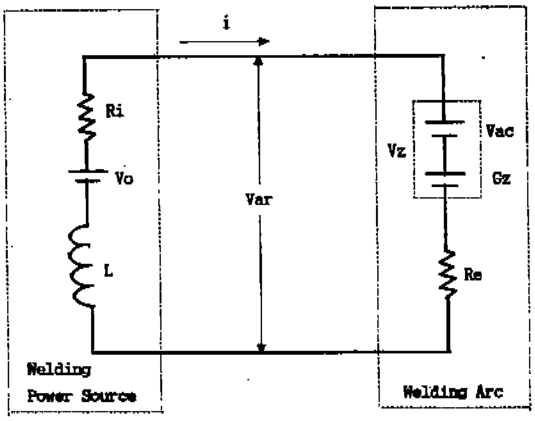

Fig 1. Electrical circuit model for welding power source and arc load.

Voltage drops at the surface of molten drop(drop at the anode film)and also voltage drops at the molten metal on the parent metal(drop at the cathode film). Voltage drops 5~10V at the anode film and cathode film respectively. Sum of these two drops is represented by V_{ac} which is zero during the metal transfer of short circuit. Gz is varying along the length of arc column and is zero during short circuit. Linear equation of lumped system of eqn(1) can be solved for arcing phase and short circuit phase.
Mode Ⅱ and mode Ⅰ represent arcing phase and short circuit phase respectively as shown on the Fig. 2

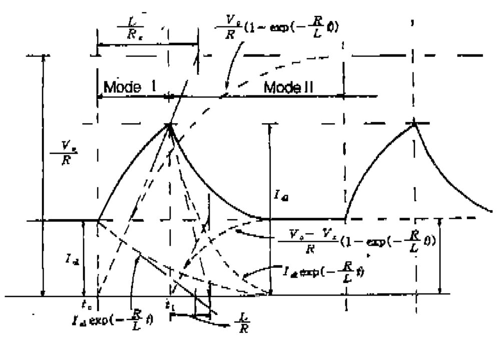

Fig.2 Output of arc mode and short circuit mode

3. DESIGN OF ARC SIMULATOR

From eqn(1) parameters of arc load are varying along the mode Ⅰ and mode Ⅱ while parameters such as L and R_i of power source keep constant. Arc simulator consists of short circuit unit, booster unit and recovery unit (converter). Short circuit mode can be implemented by short circuit unit as shown on Fig. 3. while arc mode can be implemented by switching off IGBT in the short circuit unit.
Booster unit is used to raise the average voltage of short circuit and arc (28V for 280amp of welding current) to the level of 220V otherwise voltage difference across converter is too high and as a result arc simulator can not return power to the line source. Booster unit of chopper consists of inductor L and switching element IGBT. By changing duty cycle(on-off time ratio) voltage can be raised from 28V to 220V.
Switching frequency of chopper is 3kHz and inductance is 3mH.
Recovery unit(converter) is used to convert dc power of welding power source output into power of 3∅ sinusoidal ac [4] .
Arc simulator consisting of short circuit unit, booster and converter is shown on Fig 3.

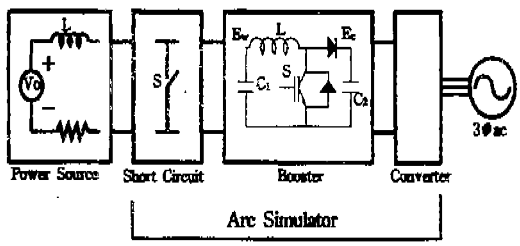

Fig 3. Power source-Arc simulator-Line source

Principal requirements of converter are sinusoidal wave of voltage and current, and in phase(100% of power facactor) between them. These requirements can be achieved through PWM control and reactor as shown on Fig 4.

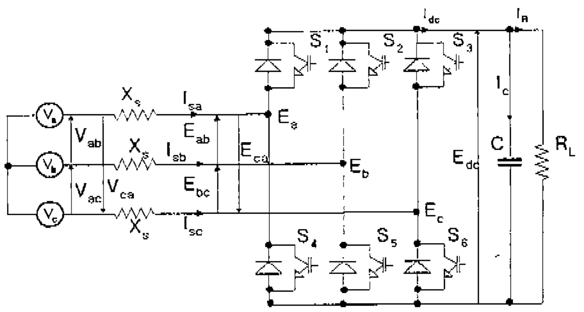

Fig 4. Power circuit of recovery unit

Circuit equation for the converter unit on Fig 4. is

$$V = I \cdot X + E ------ (2)$$

where $\cos\alpha$ is phase angle between V and E.
By controlling $\cos\alpha$, power can be returned(recovered)from dc side of PWM converter to the power line keeping $E\cos\alpha > V$. Vector E can be determined from the modulation factor r

$$E = r \times Edc ----- (3)$$

where **r** = modulation factor
Edc=dc voltage which is output of chopper

Phase angle $\cos\alpha$ between V and E can be determined from eqn(2) and eqn(3). The control of $\cos\alpha$ and modulation r is done through DSP(ADSP2105).

4. FUNDAMENTAL EXPERIMENTS OF ARC SIMULATOR

Voltage and current are measured at the short circuit unit as shown on Fig 5. Duration of short circuit and arc time is respectively 3ms and 9ms. Due to the inverter frequency from the inverter type welding power source, voltage fluctuates between 23V and 37V during arc time.

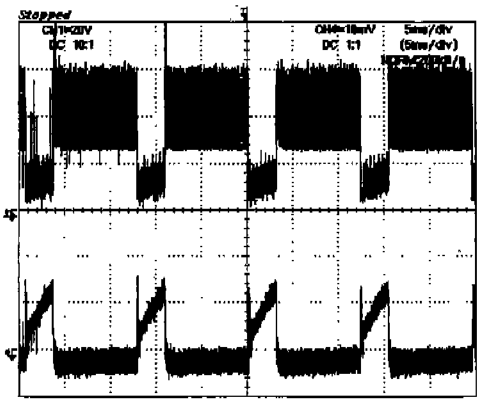

Fig 5. Voltage and current during short circuit mode and arc mode.

Fig 6 shows voltage boost of chopper output by regulating on-off time ratio. The ratio is 0.84 which gives 1/(1-0.84)=6.25X boosting of voltage.

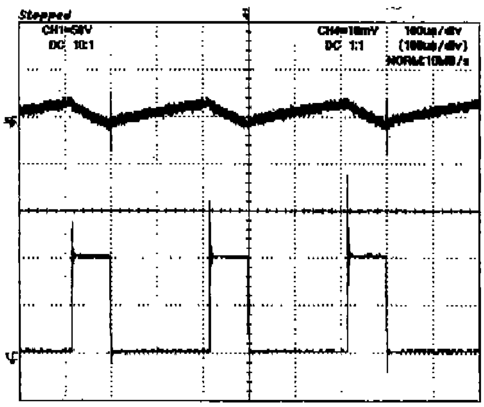

Fig 6. Output of chopper and on-off time ratio

Voltage and current are measured at the converter as shown on Fig 7. Phase between voltage and current is 180 ° which means power recovery from welding power source to the line.

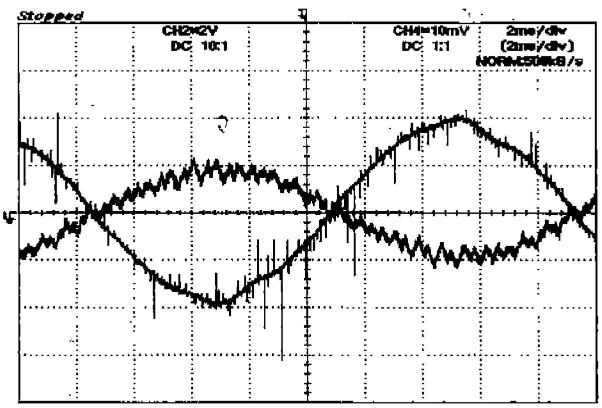

Fig 7. Voltage and current of 75amp at the reactor.

During recovery sinusoidal current is modulated through PWM control as shown on Fig 8.

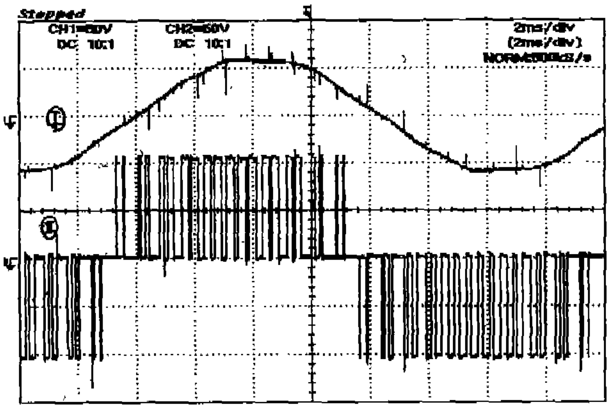

Fig 8. Sinusoidal wave of PWM modulation.

5. Conclusion

Arc simulator is developed to simulate arc load dynamically. The arc simulator is designed to return power from welding power source into the line. The load of short circuit and arc is applied to the output terminal of welding power source. From the simulated load rather than actual welding load, reproducibility of experimental evaluation of power source can be obtained.
Furthermore output characteristic of welding power source would be examined to give quantitative evaluation of power source performance by analyzing output signal to the various welding load.

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