Experimental study of the effect of circuit inductance on pinch- time in plasma focus MTPF2.5 KJ

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Abstract

This paper investigates the effect of circuit inductance on pinch-time of plasma focus. One way to increase the gain and optimization of pulsed plasma systems is to reduce the inductance of the circuit. For this purpose, we investigate the effect of different values of total circuit inductance on pinch formation time. Experimental and simulation results are compared. the proposed system shows a decent functionality that if the inductance is reduced, the efficiency of the system will increase.
Keywords: inductance, plasma focus, circuit.

Introduction

In recent years, there has been an increasing interest in small plasma focus (PF) devices. PF produces a pulse plasma discharge. A large burst of current is applied to a dilute gas inside the tube. This current initially ionizes the gas into a plasma. One of the most important issues to increase the focal plasma gain is to reduce the inductance of the whole circuit, and thus this issue is very effective in designing and manufacturing small focal plasma with low energies. Experimental study of the inductance effect during pinch formation is an important issue that has been less discussed. In this paper, the simulation and experimental results of the inductance effect of the total plasma circuit at the time of pinch formation are studied [1,2].

Simulation

First of all, an electric discharge circuit and the effect of circuit inductance on the physical plasma pinch process are simulated in MATLAB SIMULINK.
The equivalent circuit of the system is $L=L_0+L_P(t)$ that as shown in figure 1.

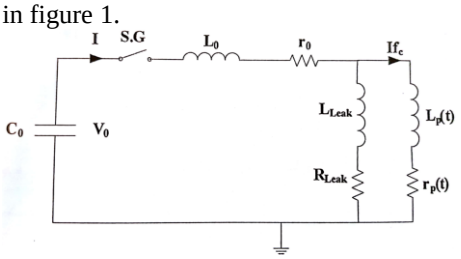

Figure1. the equivalent circuit of the system

In this equation, L_p is plasma inductance that is variable and L_0 is power supply circuit inductance includes capacitor inductance, connection cable, spark gap switch that is constant. where C_0=16.8μF. L_0 and r_0 are initial resistance and inductance, respectively.

Which have been obtained experimentally. L_{leak} and R_{leak} are leakage inductance and resistance. The discharge voltage is 14kV. Total inductance and resistance are 105nH and 17.1mΩ respectively.
In order to optimize the circuit, we must reduce the cable length and the number of connections in the transmission circuit as much as possible to reduce the inductance. For this purpose, it is better to design and build the transmission system in an integrated manner.

Results and discussion

In-circuit simulations for different inductances, the pinch formation times were evaluated. Three different inductances were visible in terms of the practical operation of this device. The inductance is from a minimum of 90 nH for an integrated system and a maximum of 130 nH for a system with a longer cable. As shown in figure 2, in systems with lower inductance, the current rises up to peak faster and the pinch forms faster near the peak current.

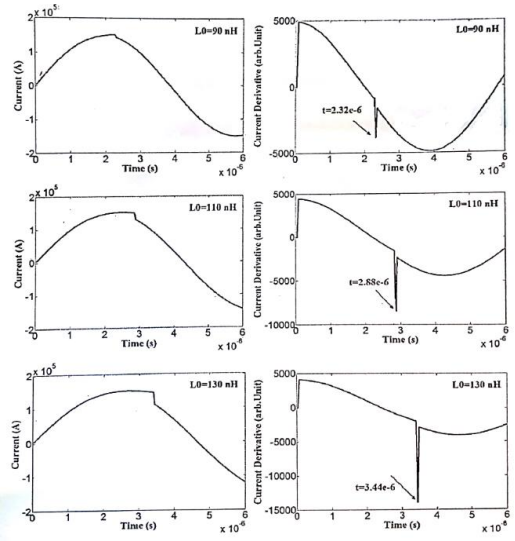

Figure 2. the discharge current and current derivative waveform

for instance, pinch time is $2.32e^{-6}$ for L0=90nH and is $2.88e^{-6}$ for L0=110nH and $3.44e^{-6}$ for L0=130nH. Accordingly, fewer inductance results in a stronger pinch, which indicates an improvement in system performance. Using the results of experimental studies and simulations of others, we considered the plasma inductance values to be 0.22nH and 0.56nH.[1,2,3]. Increasing L_P at the time of the formation of the pinch causes a sudden decrease in the discharge current and deeper fractures in the derivative current are shown in figure 3.

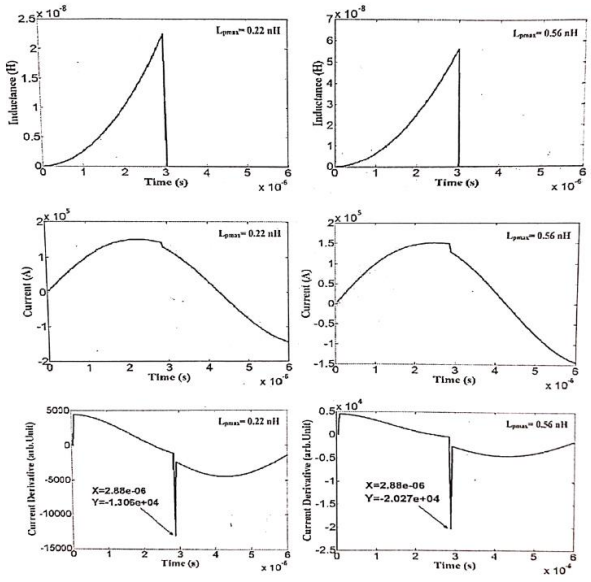

Figure 3. the discharge current and current derive for Lp=0.22nH and Lp=0.56nH and L0=110nH

So it produces a stronger pinch. If the plasma inductance increase, the magnetic field pressure on the pinch rises. experimentally, the plasma focus was improved by removing the cable and reducing the electrical connections, and changing the capacitor bank to one capacitor as a result the circuit's inductance was decreased from 100 nH to 27 nH. The improved device performance is showen in figure 4.

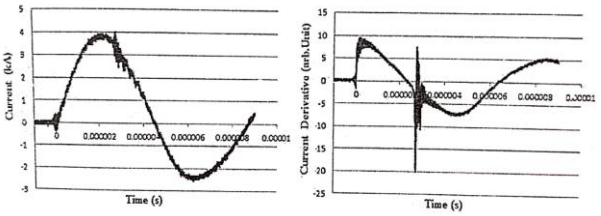

Figure 4. the current and current derive in discharge voltage 14kV (by Rogowski coil)

measurement with the Rogowsky prob shows that the discharge period is 8.3 μs, and the pinch formation time is in 2.7 μs is formed at approximately 0.63 microseconds after the maximum current. If we compare it with a similar device with more connections and higher inductance it proves that the pinch happens faster than the other plasma focus.

Conclusions

In this paper, the effect of inductance on pinch formation time has been studied by MATLAB SIMULINK and experimental study on plasma focus; we conclude that by reducing the inductance of the transmission system and losses, the pinch is formed in faster time at a point close to the maximum current, which indicates an improvement in device performance.

References

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