In situ determination of the static inductance and resistance of a plasma focus capacitor bank

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The static (unloaded) electrical parameters of a capacitor bank are of utmost importance for the purpose of modeling the system as a whole when the capacitor bank is discharged into its dynamic electromagnetic load. Using a physical short circuit across the electromagnetic load is usually technically difficult and is unnecessary. The discharge can be operated at the highest pressure permissible in order to minimize current sheet motion, thus simulating zero dynamic load, to enable bank parameters, static inductance L_0, and resistance r_0 to be obtained using lightly damped sinusoid equations given the bank capacitance C_0. However, for a plasma focus, even at the highest permissible pressure it is found that there is significant residual motion, so that the assumption of a zero dynamic load introduces unacceptable errors into the determination of the circuit parameters. To overcome this problem, the Lee model code is used to fit the computed current trace to the measured current waveform. Hence the dynamics is incorporated into the solution and the capacitor bank parameters are computed using the Lee model code, and more accurate static bank parameters are obtained. © *2010 American Institute of Physics.* [doi:10.1063/1.3429207]

I. INTRODUCTION

To model any electromagnetic device, among the input parameters are the static bank parameters. For example for any modeling of a plasma focus discharge (see Fig. 1), among the input parameters are the static inductance L_0 and resistance r_0, given the bank capacitance C_0. The word static is used here in preference to the phrase "short circuit" as the former conveys the more accurate meaning that these parameters are the relevant parameters when there is no dynamic electromagnetic load. Moreover static also implies *in situ*; that everything remains the same except that there is no motion attributed to the current distribution. The term short circuit is not sufficiently accurate in this context, as the position and design of the short circuit are subject to sometimes arbitrary definition which would give unreliable results.

A simple approximate method is to operate the plasma focus at high pressures, say 20 Torr neon; so that there is little current sheet motion. Then the discharge current approximates a lightly damped L_0-C_0-r_0 oscillation where C_0 is the bank capacitance and L_0 and r_0 are the static inductance and resistance of the bank, respectively. Analysis of two or three cycles of the current waveform then yield approximate values of L_0 and r_0, given that C_0 is known.

However it turns out that even at 20 Torr neon, there is usually significant motion of the current sheet which affects the current waveform, as this motion introduces an additional time-varying inductance into the circuit; even though at such high pressures the axial motion is not fast enough to reach the end of the anode at the end of the first half cycle drive. So there is no focus (radial) phase (see Fig. 1). Nevertheless, because of the axial motion, the estimated static inductance will be too high. Therefore an analysis of the current waveform including the small but significant current sheet dynamics is necessary in order to obtain a true measure of L_0. In this paper we discuss the estimate of capacitor parameters using a high pressure discharge first using damped L_0-C_0-r_0 analysis, assuming no current sheet dynamics. Then we show that actually there is significant current sheet motion. Finally we use a plasma focus code, with included dynamics to analyze the measured current waveform, thus separating the L_0 and the additional amount of inductance due to motion.

II. EXPERIMENTAL PROCEDURES AND RESULTS

A. Estimate of capacitor bank static parameters from a high pressure discharge

An example is given here, using the INTI-PF, which is one of the plasma focus machines developed from the UNU/ICTP PFF.[1,2] The capacitor bank has a capacitance of $C_0 = 30\ \mu$F. The plasma focus is filled with neon at 20 Torr. The capacitor bank is charged up to 10 kV and discharged. The current trace is monitored with a current transformer. The discharge current waveform is as shown in Fig. 2.

Assuming that the discharge current waveform is that from a lightly damped L_0-C_0-r_0 circuit, the waveform may be treated as sinusoid with period T; the following approximate equations[3] hold:

$$L_0 = T^2/(4\pi^2 C_0), \quad (1)$$

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