GUN POWER SOURCE FOR ELECTRON GUN OF 3MeV DC ACCELERATOR

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Abstract

In DC electron beam accelerator electron gun is situated at high voltage terminal which requires constant power irrespective of beam energy. Floating power source is required for gun. This paper describes the scheme of static gun power source derived from parallel coupled voltage multiplier column.

INTRODUCTION

A 3MeV, 10mA DC Electron Beam Accelerator based on the parallel-coupled voltage multiplier scheme in SF_6 gas at 6kg/cm^2 pressure is being developed at Electron Beam Centre, Kharghar, Navi Mumbai. The electron gun is situated at 3MV terminal. It requires 500W power for anode, filament and grid. Gun power source has been derived by suitably coupling the ac components present at the HV end of the multiplier column. A step down transformer rated for 50kV/600V/100kHz floating at 3MV to extract 500W power from HV column has been designed and developed. The transformer primary inductance was optimized to maintain voltage build up uniformity in the HV column.

POWER EXTRACTION ANALYSIS

3MV multiplier column has been analysed with Pspice simulator for power extraction. Fig.1 shows the schematic diagram of high voltage multiplier column used for the analysis of power extraction from HV multiplier itself. For a given RF input, V_{RF}, across RF electrode HV multiplier column acquires a stage voltage, V_s, through a capacitive coupling, which is given by

$$V_s = \frac{V_{RF}}{k} \qquad \text{------------ (1)}$$

Where k is the capacitive coupling factor which is given by

$$k = 1 + \frac{4\ C_{ac}}{C_{se}} \qquad \text{--------(2)}$$

Where Capacitances C_{ac} (4.5pF) and C_{se} (3.6pF) are geometrically configured between a pair of corona guards and RF electrode to corona guard respectively.

Due to last stage corona guard to HV dome capacitance, 50pF, an equivalent capacitance appearing across last stage HV column was estimated to 34pF. This causes non-linearity in voltage distribution in the multiplier stages which is compensated by putting a suitable value of inductance across last stage corona guard X-Y. The step down transformer with optimized value of primary winding inductance is connected across last corona guards (X-Y) of HV multiplier column at 3MV terminal. It acquires a stage voltage of 24kV, 100kHz from RF electrodes and convert it into 600V, 100kHz. It is rectified, filtered and supplied to the various SMPS based gun power supplies to get 5kV/15mA for anode, 15V/20A for filament and -3kV/5mA for grid of electron gun. For optimum value of primary winding inductance, the 3MV multiplier column was analyzed with Pspice simulator

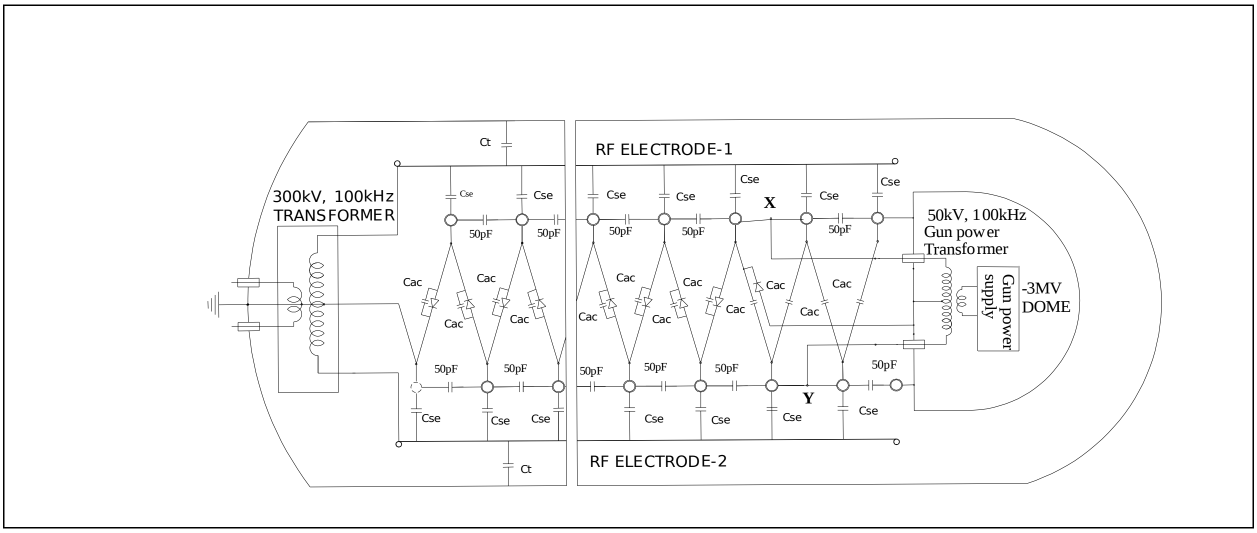

Figure 1: schematic diagram of high voltage multiplier column used for the analysis.

DESIGN CRITERIA

The voltage distribution in high voltage multiplier column with 300kV RF input at different values of transformer primary winding inductances has been analysed. Figure 2 shows the effect of inductance on last stage voltage towards HV end. The rated stage voltage is 57kV. Without inductance, last stage voltage estimated as 7.3kV. Resonance in HV column occurs at about 57mH inductance. Below this critical inductance, effective impedance across last stage is in inductive phase and above it, it is in capacitive phase. An increase in voltage is observed with loading in capacitive phase. Figure 3 shows the effect of inductance on multiplier stage voltage. Nonlinearity in the multiplier stage voltages at HV end is observed. With 80mH inductance, voltage build-up gets normalized in all stages in the range of 57.8kV to 23.48kV.

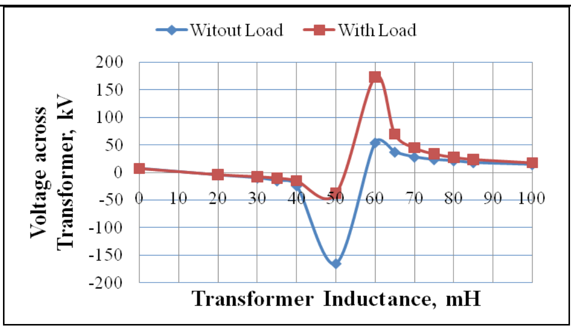

Figure 2: Effect of gun power transformer inductance.

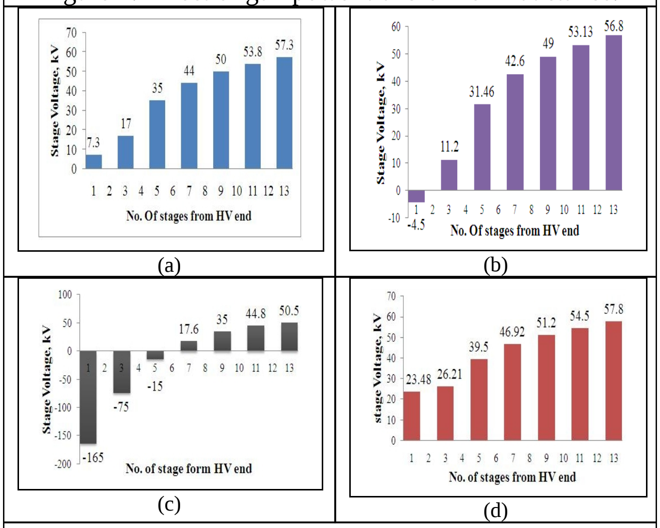

Figure 3: Multiplier stage voltage from HV end at 300kV RF input (a) with no inductor, with (b) 20mH, (c) 50mH and (d) 80mH primary winding inductance across last stage corona guard.

As the HV multiplier stage voltages are uniform till 63 stages, the graphs have been shown for 13 stages from HV end. Stage no.1 in the graph indicates the voltage across gun power transformer. Based on this analysis a transformer was designed and developed with 80mH primary winding inductance. An effective capacitance across last stage with this inductance was estimated to be 10.35pF.

DESIGN PARAMETERS

The transformer will be floating at 3MV terminal at 6kg/cm^2 SF_6 gas environment. It has to supply power to the gun through SMPS based gun power supplies from 1MeV to 3MeV energy. The design involves the optimization of various electrical parameters such as leakage inductances, distributed capacitance and coupling factor. For the given dimension of 3MV dome terminal, size and shape of transformer was finalized. From these considerations the design parameter has been finalised as shown in table-1.

Table 1: Design parameters of 50kV 100kHz Gun Power Transformer

Parameter	Value
Primary voltage	50kV$_P$
Secondary Voltage	150V-600V
Operating Frequency	100 – 120kHz
Primary circulating current	0.6 A$_{rms}$
Primary inductance	80mH
Secondary Inductance	400µH
Output power	500W
Secondary Current	1A-4A
Power Loss	~10W
Self resonant frequency (>2f$_O$)	> 200 kHz
Distributed Capacitance	<6pF
Operating environment	SF_6 gas @ 6 kg/cm^2

PERFORMANCE EVALUATION

The gun power transformer has been fabricated as per the design parameters. Transformer has been tested with dummy resistive load in actual condition at 3MV multiplier column to extract the power from multiplier column along with 50kW power oscillator and 10kV DC supply in open atmospheric condition. At 38kVp-0-38kVp, 103 kHz RF input, voltage across gun power transformer was 6kVp. The transformer has been successfully tested upto 400W extracted power from multiplier column. The extrapolated value of primary voltage for 300kV RF input is about 23.68kVp.

CONCLUSION

The transformer has been installed at 3MV dome terminal along with gun power supplies and operated upto 1MeV, 7mA of electron beam under 6kg/cm^2 of N_2 gas. It is also tested with 3kg/cm^2 SF_6 gas environment at 4mA, 1.5MeV of electron beam load. Further operation in SF_6 gas is in progress. The proposed method of gun power source floating at HV terminal is static in nature. It improves multiplier coupling efficiency for parallel coupled voltage multiplier.

REFERENCES

[1] K.Nanu et al, “Design of 3MV/10mA DC power source for E-Beam Accelerator” Proc. Indian Particle Accelerator Conference, Centre for Advanced Technology, Indore, Feb. 3–6 (2003), p-246.