CONSTRUCTION & TESTING OF 50kW/120kHz OSCILLATOR FOR 3MeV, 30kW DC ACCELERATOR

S.K. Srivastava, R.I. Bakhtsingh, P.C. Saroj, S. Dewangan, M.K. Pandey, K. Nanu, K.C. Mittal, K.V. Nagesh and R.C. Sethi

Accelerator & Pulse Power Division, Bhabha Atomic Research Centre, Mumbai – 400 085.

INTRODUCTION

A 50kW, 120kHz push pull oscillator has been designed and developed as an input source for 3MeV/30kW dc accelerator being developed at EBC, Kharghar. The oscillator drives the 3MV voltage multiplier column through a coupled circuit consisting of secondary tuned air core transformer and the capacitance formed by the feeder electrodes to the multiplier. A pure sine wave of 120kHz at 12kV is required at the RF transformer primary terminals. The oscillator has been commissioned and tested. The construction details of this oscillator and test results are presented here.

SCHEME OF OSCILLATOR

Fig.1 shows the circuit diagram of the oscillator. It is based on triode vacuum tubes in push-pull Colpitts configuration operating in class-C mode for better efficiency. It has the following advantages of; (i) self adjustment with varying loads by grid-leak bias, (ii) immunity to high voltage surges, (iii) natural elimination of even harmonics, (iv) higher voltage output and hence ease of matching with RF transformer. The triode & associated circuit components like Filament transformer, RF chokes, blocking capacitors, grid-leak resistor and cooling water column coils are enclosed inside a shielded cabinet whereas the tank circuit is located inside the accelerator tank.

A variable high voltage dc is inverted by the triodes to get 12kV ac at 120kHz. This voltage is stepped up to 150kV-0-150kV in resonance condition at the secondary of RF transformer. A fraction of this output is fed back to the grid circuits (180° out of phase with respect to plate circuits) by a capacitive voltage divider. In order to maximize the efficiency, losses in the triodes and circuit components have been minimized by proper selection of operating conditions & high Q-factors. Output energy of the accelerator can be adjusted by varying the DC input voltage to the oscillator. Electronic interlocks have been incorporated for protection of the system and operators safety.

CONSTRUCTION OF OSCILLATOR

Water-cooled triodes rated for 10kV, 6.5Adc have been assembled inside a RF shielded cabinet having shielding effectiveness of 80dB for E-field and 30dB for H-field at 120kHz. Low conductivity water at a flow rate of 15LPM serves to cool the plates of triodes. Spiraled nylon braided PVC pipe with 1kV/m has been chosen to isolate 10kV dc plate voltage from ground. Plate RF chokes (10mH, 10kV, 10A, 200Q) and grid RF chokes (10mH, 1kV, 1A, 200Q) have been designed and fabricated using Litz wire to minimize the eddy current losses. The distributed capacitances in the RF chokes were minimized by sectionalized winding and perforated insulators. This enabled to keep the self-resonance frequency > 500kHz. The chokes are oriented at right angles to each other to minimize interference. EMI filters are provided in the 230V ac power line to minimize RFI. The unloaded Q-factor of the secondary winding of the RFT has been selected > 1500.

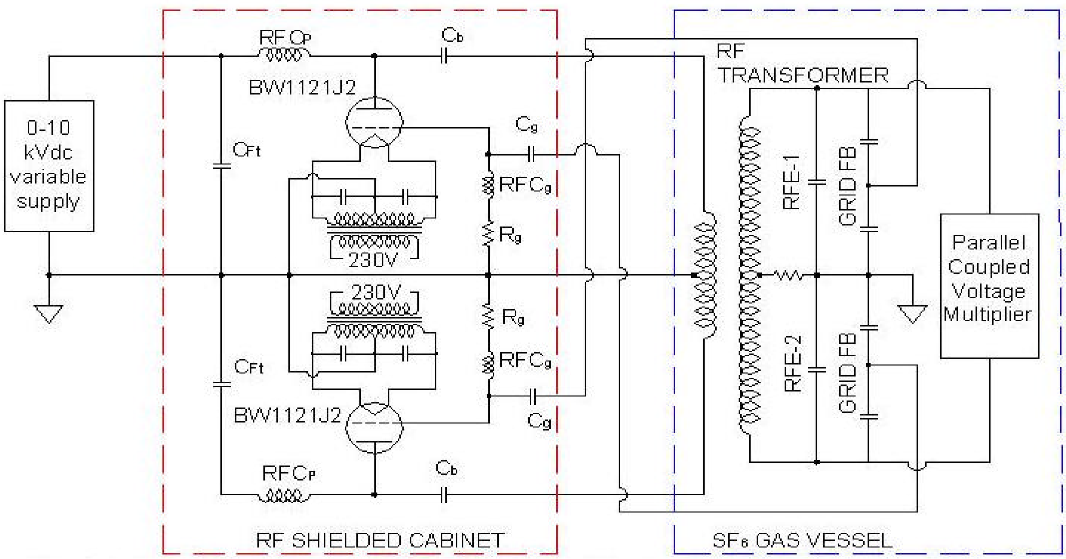

Fig.1. Schematic circuit diagram of 50 kW, 120kHz Push-Pull Power Oscillator

The tank circuit is made up of the secondary inductance of RF transformer and capacitance formed between RF electrodes (RFE-1 & RFE-2). The connection from the oscillator cabinet to tank circuit located inside the accelerator tank is through shielded co-axial cables. The photograph of oscillator assembly is shown in Fig.2.

Fig.2 Assembly view of 50kW/120kHz push-pull oscillator

In the power oscillator, the triode is the critical device to be protected in the event of abnormal operating conditions. The startup sequence of the high voltage power supply is interlocked by the use of timers & relays. Interlocks have been provided for doors of RF cabinet, water flow, airflow, thermal fuse of triode & over voltage condition. The power oscillator is self adjusting to transient loading conditions of the voltage multiplier column by grid-leak bias. Tripping mechanism has been incorporated in the HVDC control system for over voltage & over current. The safety interlocks have been tested for high voltage operation of Triode oscillator.

TEST SETUP AND RESULTS

The performance of oscillator was evaluated in two stages. First, a Hartley based tank circuit has been constructed for evaluating the oscillator integrity independently. For this a tank inductor with ratings of 110µH, Q=885, 10kV, and 50A has been fabricated using Litz wire. The tank capacitance of 15.4nF has been built using 7 Nos. of 2200pF/ 18kV ceramic high-Q capacitors in parallel. The output of oscillator has been rectified using high frequency rectifier rated for 24kV PIV and 30A in bridge configuration. Dummy load resistor rated for 2.5kΩ, 10kV, and 20kW has been assembled using 20 Nos. of 50kΩ, 1kW wire wound resistors. Photograph of the test setup is shown in Fig.3.

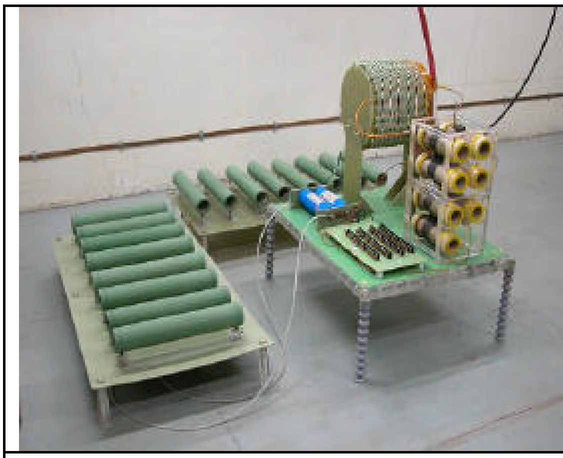

Fig.3 Test setup for evaluating the oscillator

This test has been conducted in the single ended mode instead of push-pull mode for simplicity. The triode was energized and tested up to the maximum rating of 10kV in open circuit condition. Thereafter the dummy load was connected and tested up to 14kW at plate voltage of 6kV limited by the test setup. In both open and loaded conditions the frequency was observed to be constant at 105kHz with pure sine-wave.

To evaluate the power oscillator with RF transformer in required Colpitts mode, a simulated tank circuit was made. It comprises the secondary inductance of the RF transformer and ceramic high-Q capacitors connected in series combination rated for withstanding 80kV. The Grid feedback was derived from a capacitive voltage divider across the tank capacitance. The ac output was rectified using HF rectifier stacks in full-wave mode and filtered to enable loading on wire wound resistor load rated for 1.25MΩ/50kV. The oscillator has generated a sine-wave of 105.5 kHz in this configuration. It has been loaded up to 900W at 36kV DC with an input voltage of 2kV at the oscillator anode. Since the RF transformer is kept in air medium, the test was restricted to 80kV peak.

Extrapolation of data obtained from the above dummy load tests ensures satisfactory performance of the oscillator in the accelerator system from the load impedance consideration. Further testing will be conducted in the actual conditions along with RF electrodes and voltage multiplier shortly.

REFERENCES

[1] R.I.Bakhtsingh, et.al "Design of 50kW, 300kV RF Source for 3MeV, 10mA Industrial Electron Accelerator" InPAC-2003, Feb, 2003, pp-447.

[2] E.May, Industrial High Frequency Electric Power p.42-156.