Low Energy Spread RF Linac Variometer Pulse Forming Line

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Abstract

Variometer pulse forming line (VPFL) for low energy spread RF electron accelerator is described. VPFL modulator pulse power is up to 15 MW, pulse voltage is up to 55kV, pulse duration is 9 mcs, pulse repetition rate is 600 pulses per second. Pulse top unflatness is 0.1-0.15%.

Computer simulation indicates that pulse top unflatness of 8-cell VPFL with inversed winding can be reduced to 0.01%.

1 INTRODUCTION

Linear modulators are usually used for low top deviation high voltage pulses generation. Pulse top unflatness (pulse rise revoltage, ripple, top fall) is defined by forming line and pulse transformer parameters. Ripple voltage depends upon the quantity of FL cells. Top unflatness can be diminished by increasing the quantity of FL cells or by means of RLC correction circuit. Cell coils regulated magnetic coupling also would decrease ripple as well as unflatness[1,2]. Magnetic cells coupling can be realized in double FL winding as well as in ordinary winding. Double winding VPFL consists of capacitors connected one to another by means of coil and the second coil that is magnetically coupled to the first coil and connects the next pair of capacitors. Ordinary winding VPFL consists of several capacitors connected by means of magnetically coupled coils. Pulse top correction is realized by coil self- and mutual inductance variation that is due to movable electromagnetic screens.

Variometer pulse forming line with plate electromagnetic screens or with short-turn screens generates pulses with top unflatness 0.3-0.5% for 8-10 cell forming lines. Electromagnetic screens are movable and their driving corrects pulse length and top unflatness. The progress was reached by first cell winding magnetic axis inversion that have decreased top unflatness to 0.1-0.15%.

2 VARIOMETER FORMING LINE

2.1 Magnetic field inversion of variometer forming line.

Pulse top ripple is due to linear modulator forming line discreteness. Ripple can be decreased by cells quantity increase or by RLC correction circuit. Additional coil will decrease top ripple if placed in series with FL , but as coil inductance increases the pulse rise time increases and modulator efficiency diminishes.

FL winding magnetic coupling reduces top ripple due to decreasing cell frequency . On the other hand one can vary the pulse shape by cell coil self and mutual inductance variation.

Computer simulation of 8-10 cell VPFL presents top unflatness up to 0.1% ,and pulse rise time is 10-15% of pulse duration. Further increase of pulse rise time would diminish modulator efficiency.

We carried out computer simulation of 20 Om 8-cell VPFL discharge on resistor load. Computer model had an additional coil in series with FL first cell coil. Magnetic coupling coefficient is 0.15, except the last cell that is 0.12. First cell winding magnetic field is inversed, magnetic coupling coefficient is 0.06. We have carried out pulse top correction by cell inductance variation and additional coil inductance variation. Pulse top unflatness was less than 0.01% for pulse duration 8 mcs (0.9 pulse voltage), pulse rise time 1.1mcs (0.1-0.9 pulse voltage). Pulse duration of 0.01% unflatness is 6mcs.

2.2High power modulator forming line.

Forming line consists of 10 LC-cells connected in series, each cell capacitance is 0.02 mcF. Windings are winded upon cylindric stock. Cell winding inductance is 15 mcH. Electromagnetic screens are made of two coaxial short turns placed inside the winding. Short turns are divorced and driven by dielectric bar that is in perpendicular to the winding axis. Bar rotation moves screen magnetic axis from 0 up to 180 degree from that of the winding.

As screen moves, coil inductance changes from 15.5 mcH up to 10 mcH and coils mutual inductance from 2 mcH up to 1.8 mcH. Relative self and mutual winding inductance depends upon a screen angle as you can see in figure 1.

VPFL impedance varies from 26 Om to 22 Om and depends upon a screen angle.

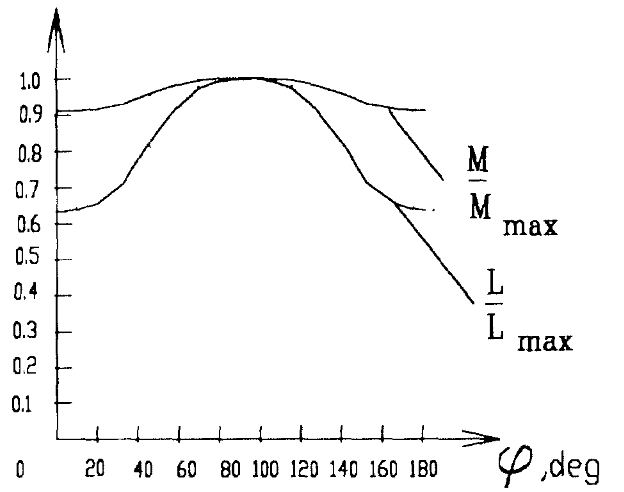

Figure 1. Relative self and mutual winding inductance dependence upon screen angle.

Eddy currents are induced in screens placed in winding magnetic field. FL winding cooling is realized by two air fans which power equals to 280 cube meters per hour each. Fans are installed at the FL winding top and bottom.

The potential of electromagnetic screen is equal to that of the winding.

We have tested VPFL modulator that was loaded by klystron. VPFL is switched by hydrogen thyratron TGI1-5000/50 on primary of the pulse transformer with turns ratio 1:3. Charging voltage of VPFL is up to 36kV, modulator pulse repetition rate is up to 600 pulses per second. The pulse top was corrected by cell winding inductance adjustment that was realized by the rotation of electromagnetic screen driven by low velocity motors(Figure 2).

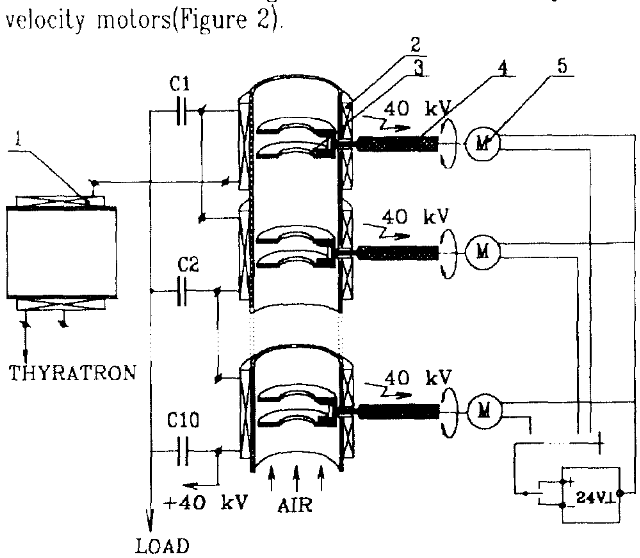

Figure2. VPFL schematic diagram.
1 – additional coil, 2 – first cell coil, 3 – electromagnetic screen, 4 – insulating bar, 5-motor.

In the result of adjustment 0.3-0.4% pulse top unflatness was reached that can be reduced by increasing of additional coil inductance, but in this case pulse rise time will increase and modulator efficiency diminishes.

FL leakage inductance changed pulse top ripple no more than screen adjustment did. High frequency waves in the cable connecting modulator with pulse transformer were dumped by RC-circuit that is in parallel with pulse transformer primary. Pulse top ripple that is due to pulse transformer leakage inductance and capacitance was also reduced by screen adjustment.

First cell winding magnetic axis inversion caused real progress of the pulse quality. FL first cell coil was rewinded, so first to second coil mutual inductance became negative. Screen readjustment decreased pulse top unflatness up to 0.1-0.15% without the increase of pulse rise time.

3 CONCLUSIONS

VPFL first cell winding inversion decreases linear modulator pulse top unflatness . Pulse top unflatness up to 0.1% can be reached on 8-10cell VPFL. We hope the future progress can be obtained by increasing the quantity of VPFL cells.

According to the results of computer simulation pulse top unflatness for 8-10-cell VPFL could be reduced to 0.01%.

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5 REFERENCES

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