KICKER PULSER CHARGER *

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Abstract

A highly regulated Pulsed Charging power supply was developed for the SLC damping ring kickers system to provide a kicker pulse amplitude stability of better than 0.01%. This unique supply charges the kickers cables, with capacitance of 4800 pF to 80 kV (15 J), in less than 40 usec. Operation is unaffected by intermittent kicker operation or changes in reputation rate up to the rated 180 Hz. The Charger utilizes a commercial dc regulated supply and a single SCR switch. There are three layers of regulators to insure high pulsed charging voltage stability.

Background

The SLAC, SLC requires a very will regulated damping ring kicker magnet pulse, both pulse to pulse and long term of approximately one part in ten thousand. In addition the pulsed current rise time must be less than 20 nanoseconds. This fast rise time requires a high gas pressure in the kicker pulser thyratrons which in turn infers the need to pulse charge the kicker pulser lines to avoid thyratron voltage breakdown.

Standard resonance charging of the kicker pulser line, which was first employed on the kickers, resulted in an unacceptable pulse rise time. In addition regulation of resonant charging was inadequate and irregular pulsing intervals only aggravated the regulation problems. Regulation and stability of the resonance charging system even after several improvement attempts was not better than one part in a thousand pulse to pulse and long term.

Solution

To address the rise time and regulation stability problems a pulsed charger was developed which improved the amplitude stability even with irregular pulsing intervals and repetition rates to 0.01%. and allowed for high gas pressures on the pulser thyratrons.

The design incorporates several novel approaches to achieve the desired performance. There are several items which effect the stability of charging the kicker pulser lines. as follows:

1) Impedance (capacitance) changes of the pulser line vs time related to temperature changes.

The pulser line impedance change was addressed by building a pulse charger with a low source impedance with minimal resonance charging. The source impedance of the charger is approximately 1/10 of the load impedance which results in a reduction of a factor of ten in voltage variation due to line impedance changes. The line impedance change is less than 0.1% with a water cooled line resulting in a charge voltage change of less than 0.005%.

2) Residual voltage (charge) on the pulser line resulting from reflections, leakage currents, and thyrtron turnoff variations.

The residual voltage is addressed by precharging the line to a low fixed highly regulated voltage. This voltage is less than 2% of the maximum charge voltage with a stability of 0.1% which results in less than 0.002% due to residual charge on the line.

3) Power line changes both fast and short term.

Power line changes were regulated by three layers of regulated. The first was a commercial switchmode power supply regulated to approximately 0.1%. Second a post regulator using a "bang bang" control to improve the regulation to 0.01% and Third a type of deQing circuit to proved an additional factor of two in regulation.

4) Thermal changes in monitory and control systems.

Changes in the monitory were addressed by using a low impedance temperature compensated voltage monitor directly connected to the pulser output. Because the charging is pulsed the monitor impedance could be 100 Kilohms terminated into 50 ohms which required no additional compensation to achieve the monitoring stability of 0.01% over the operation range.

The pulse charging was design to charge the 15 Joules of the pulser line in less than 40 microseconds (0.4 megawatts peak power). (Figure 1) This charging rate was fast enough to allow for the need increase in gas presser on the thyratron and at the same time slow enough to be able to reliably monitory and control the pulse amplitude to 1/10,000 and simple solid state devices.

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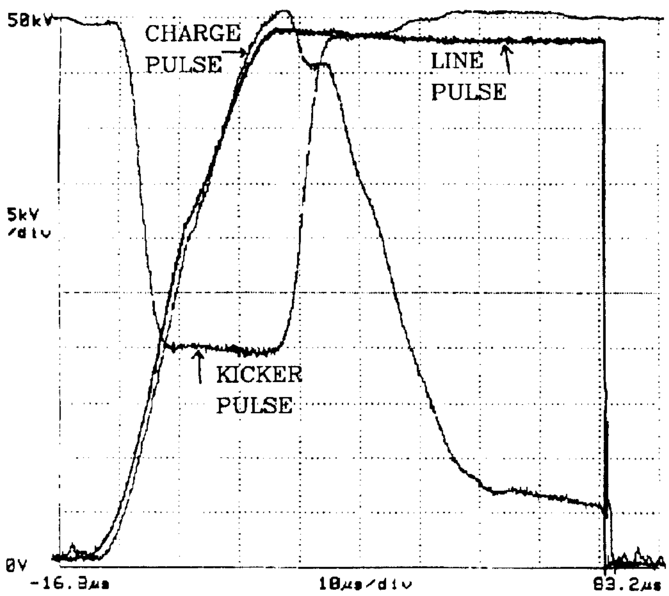

Figure 1
Pulse Charger Waveforms

Operation

The design incorporates several novel features. (Figure 2) Power is supplied by a voltage adjustable 5 kilowatt commercial switchmode power supply with a maximum voltage of 1000 Volts. The supply is connected to an energy storage capacitor C3 whose voltage changes by less than 7% during the pulse. This small voltage change allows the switching supply time to recharge the bank in the interpulse interval of 8 msec to approximately 0.5%. A shunt FET with series resistor is used as the second regulator to improve the regulation of the energy storage bank to better than 0.01% by switching on if the voltage on the capacitor is to high and off when the capacitor voltage is low. In addition to the energy storage capacitor the much smaller pulsing capacitor C7 is charge to the same voltage as the energy storage capacitor. At the pulse charging time SCR Q2 is turned on which discharges capacitor C7 through inductor L3. The system is not damped so that the discharge capacitor recharges in the opposite direction. The pulse transformer T1 which is connected between C7 and C3 steps up the voltage and generates the charging voltage for the pulser. The line capacitance reflects through the pulse transformer change the effective capacitance of the undamped ringing circuit. The negative ringing of the discharge capacitor C7 reverse biases the SCR Q2 turning it off. (Figure 3) The discharge capacitor C7 continues to ring positive again and then recharges by way of the energy storage capacitor C3. The magnetizing current of the pulse transformer helps recharge C7 to a limited voltage (approximately 50 volts) over C3 voltage determined by the flyback diodes CR1, the turns ration of T1 and the energy storage capacitor voltage. In addition to insure that the SCR is not overvoltaged diode

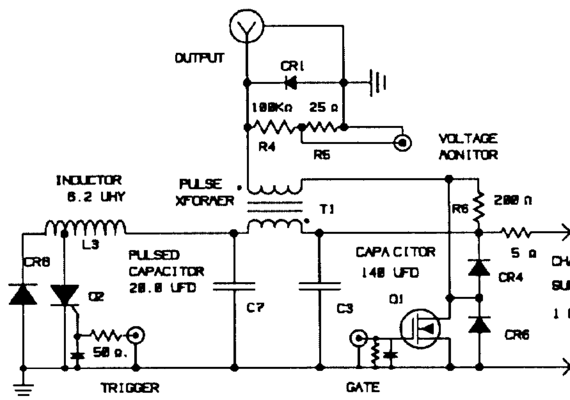

Figure 2
Simplified Schematic Diagram

CR11 forward voltage drop is used to insure that an overcharge of not more than 75 volts dose not occur. Precharging of the pulser line is accomplished by resistor R6 which connect a energy storage capacitor line to low side of the pulse transformer thereby precharging the pulser line to the regulated energy storage capacitor voltage.

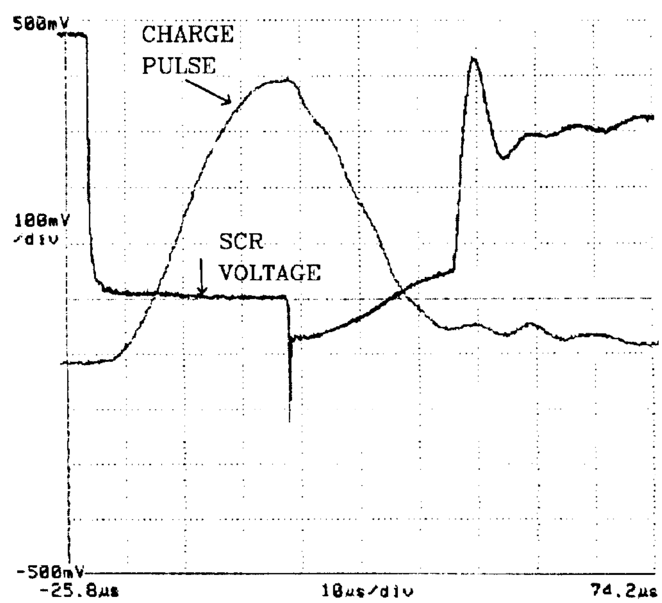

Figure 3
SCR Voltage and Charge Voltage

The final stage of regulation is accomplished by use of the FET which is connected to the low end of the pulse transformer with diodes CR4 and CR6 insuring that the voltage dose not exceed the power supply voltage. As the line is charging diode CR6 conducts caring all of the charging current. however when the charging current is less than the power supply voltage divided by R6 the current diverts to R6 and the voltage on the FET will rise in the final 1% of the charging of the line. By turning on the FET the voltage available to charge the line is reduces by approximately 0.5%. By monitoring the peak charge voltage with the voltage divider R1 and R2 and turning on the FET the final stage of regulation is implemented. Due to the leakage inductance of the pulse transformer this last stage of regulation can only provide for pulse to pulse stability and provides only a factor of two improvement in performance. Figure 4

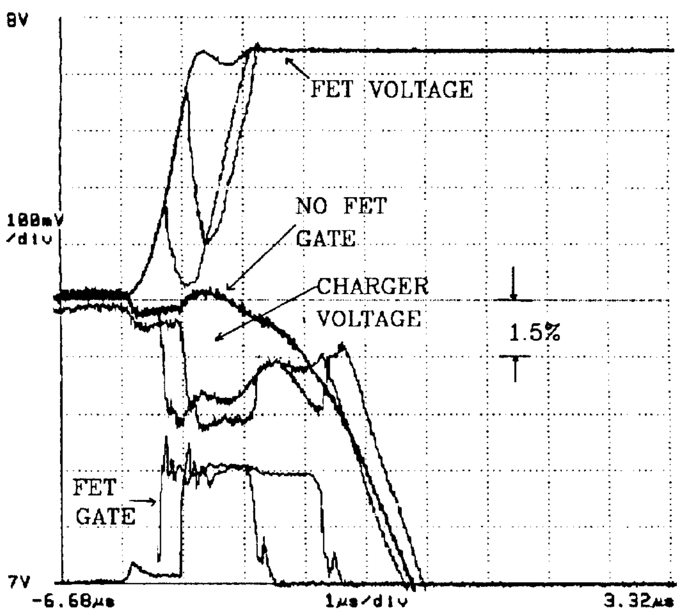

Figure 4
Final Stage Regulation

Conclusions:

A pulse charger for the SLC Damping Ring was produced which by use of several unusually technics was able to provide pulse charging regulated to 0.01% in a simple and inexpensively manor.

References

[1] F. Bulos, et al., "Some Fast Beam Kicker Magnet Systems at SLAC", Proceedings of the 1987 IEEE Particle Accelerator Conference, p. 1884.

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[3] T. Mattison, et al., "Status of the SLC Damping Ring Kickers Systems", elsewhere in these Proceedings.