SIMULATION OF KICKER PULSER WITH MATLAB SIMULINK

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Abstract

The pulser system of kicker magnet in Synchrotron Radiation Research Center (SRRC) is a 25 kV in-house-designed high voltage system which generates a pulse current to steer the injected beam from booster ring into storage ring. The injection efficiency is strongly influenced by the performance of this pulser. It is very difficult and dangerous to measure and modify the circuit inside of pulser because of high voltage environment. Before any performance improvement, simulation of circuitry of this pulser with MATLAB Simulink is a safe way to understand the behavior of every component. Model of such system will be demonstrated and modification of such system will become easier for future applications.

1 INTRODUCTION

Figure 1 shows the circuitry of pulser system of kicker magnet, it's so simple for the first look. But the whole system is operated at high voltage (25kV) and high current (about 6000 amperes pulsed), so it's so dangerous for human to operate and maintain. There must be a special protection on the circuitry that is operated at high voltage environment. So the whole pulser system is sinked in oil tank except the charging power supply.
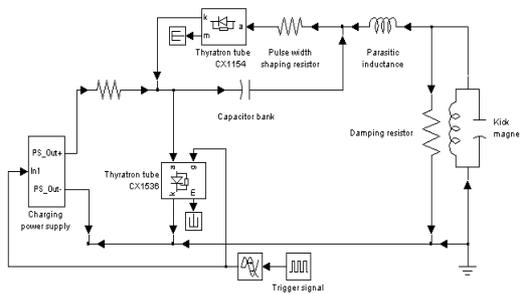

Figure 1. Circuitry of pulser system.

Maintenance of pulser system of kicker magnet is a laborious, dangerous and dirty work, no more to say to modify the circuitry of pulser system.

MATLAB Simulink is a software package for modeling, simulating and analyzing dynamical system include power electronics. The libraries of power system blockset of Simulink contain models of most typical power equipment, so everyone can easily build models from scratch, or take an existing model and add to it. Simulations are interactive, so parameters can be changed 'on the fly' and immediately see what happens. No matter what how high voltage is the pulser system working on, with Simulink it is just a click-and-drag procedure, this encourage us to try things out.

After the model of pulser system was built, the characteristics of components of pulser system could be better understood and the performance of this system might be modified.

2 PERFORMANCE OF PULSER SYSTEM

When thyratron switch is triggered on, the energy stored at charging capacitor will discharge a half sine current waveform through kicker magnet. This trigger timing of pulser system of kicker magnet is synchronized with 10Hz booster ring injection cycle, so every 0.1 second it most generate a pulse current to steer the injected beam from booster ring into storage ring. Figure 2 shows this pulse current waveform.

Ideally the magnitude of every cycle pulse current is the same to steadily steer electron beam to storage ring, but there is no such ideal power supply.

When the injection procedure is ready to start, the high voltage power supply have been set at specified setting for a little while so charging capacitor is already fully charged and the waveform of pulse current is only determined by kicker magnet and charging capacitor. But the 10Hz trigger signal continues to trigger thyratron switch, so charging power supply must periodically charge the charging capacitor with 10 Hz. The period is just about 0.1 second, so the charged voltage on charging capacitor is dependent on dynamic characteristic of charging power supply.

Figure 2 shows commercial A and commercial B power supplies used as charging power supply. In order to get same second pulse current (5600A peak), commercial A power supply is set at 22kV and commercial B power is 25kV.
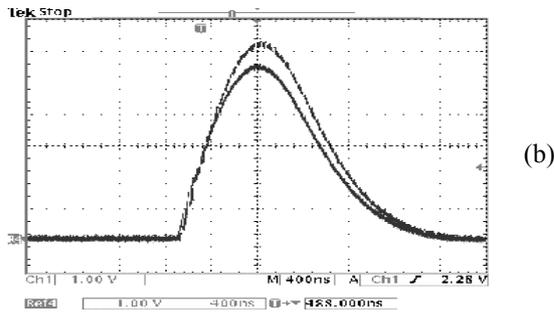

(a)

(b)
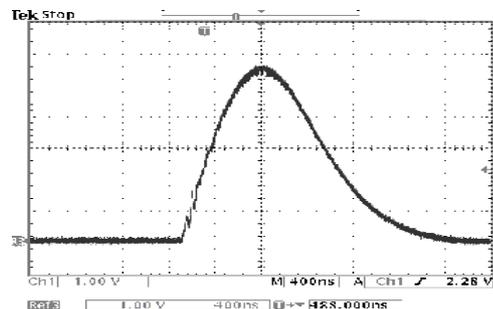
Figure 2. First and second pulse current waveforms (a) commercial A (b)commercial B power supply used as charging power supply.

Figure 2(a) shows the peak of first pulse current is 5540A and second is 5600A when commercial A is used as charging power supply, there is about 60A different and the electron beam is smoothly injected. Figure 2(b) shows there is a big difference between first and second pulse currents, the peak of first pulse current is 6400A and second is 5600A; while injection such difference will kick stored beam of storage ring out and inject beam from zero.

Now the charging power supply used at pulser system of kicker magnet is commercial A power supply, so there is no problem on normal operation, but based on experience, the MTBF of commercial A power supply is shorter than that of commercial B power supply. For the point of view of maintenance, replacement of commercial A power supply with commercial B power supply is a better choice but the injection efficiency is necessary to solve.

Simulating the behavior of pulser system of kicker magnet with commercial B power supply as a charging power supply with MATLAB Simulink and to figure out the models of pulser system and commercial B power supply might find a way to improve the performance and reach less laborious maintenance.

3 MODELLING OF KICKER PULSER SYSTEM

There are three active devices in the pulser system,, commercial B power supply, thyratron CX1154 and thyratron CX1536. Thyratron CX1154 is used as a diode in the pulser system, so the behavior of thyratron CX1154 could be modeled with diode supplied with Simulink. commercial B power supply and thyratron CX1536 are a little complicate but still could be modeled.

3.1 Modeling of Thyratron CX1536

The function of thyratron CX1536 in the circuitry of pulser system is to be a switch., 10Hz pulse trigger signal turn on CX1536 to let charge stored on charging capacitor discharge through kicker magnet and CX1536, and CX1536 will turn off automatically when discharging current reach zero. The behavior of thyratron CX1536 is very similar to that of thyristor, so the model of detailed

thyrsistor is used to simulating thyratron. The parameter dialog block is list below, and the latching Il is set to zero.
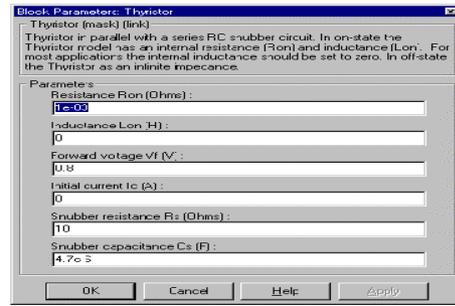

Figure 3. Parameter dialog block of detailed thyristor.

3.2 Modeling of commercial B Power Supply

Based on the specification of commercial B power supply, there are two characteristic is related with dynamic performance, one is the maximum 100mA output current and the other is 50ms time constant of output voltage.

For the maximum 100mA output current limitation, we can just take a little calculation to see this parameter is or isn't the issue to restrict 10Hz operation of commercial B power supply.

.12μf (charging capacitor)* 100mA * T (time)
  = 25kV (setting of commercial B power supply)
⇨ T = 0.03 second

The time need to charge 0.12μf is 0.03 second is much less than 0.1 second charging period, so the maximum 100mA output current must not the main restriction.

As well known theory, a system should take about 4~5 time constant to reach it's stable output; so the time for output voltage of commercial B power supply to reach 25kV setting value must take 200ms~250ms. Comparing 200ms~250ms with 100ms charging period, there seems not enough time for commercial B power supply to output the setting 25kV. With this 50ms time constant parameter, the model of commercial B power supply is built as figure 4.
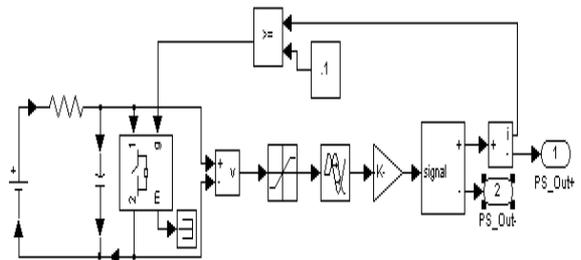

Figure 4. Model of commercial B power supply.

When thyratron CX1536 is turned on, the output current of commercial B power supply is latched to 100mA and output voltage is almost zero, so the parameter of 50ms time constant will influence the rising waveform of output voltage.

Figure 5(a) shows voltage waveform on the charging capacitor at thyratron CX1536 turn-off period, it is very obvious voltage can not reach the 25kV setting. Figure 5(b) shows first and second pulse current waveforms, they are very match the real pulse current waveforms, the first is about 6400A and second is about 5600A.
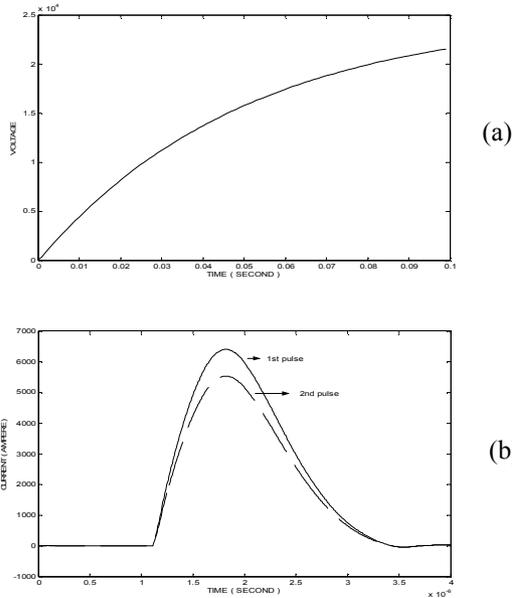
(a)

(b)

Figure 5 (a) Voltage waveform on the charging capacitor at charging period. (b) First and second pulse current waveforms.

Based on the result of simulation, it is to say the model of pulser system of kicker magnet built with MATLAB Simulink behave very close to the real circuitry. If there is something to be modified, we could just play on PC till better performance of is reached and then to start the real work.

4 CONCLUSION

Making use of the powerful simulation ability of MATLAB Simulink, the behavior of pulser system of kicker magnet is exactly simulated and the model is created.

With the model of pulser system of kicker magnet, any modification on this system could be easily constructed on personal computer without labor and danger that will save a lot of time to find a way to get better performance of pulser system of kicker magnet.

5 REFERENCES

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