DEVELOPMENT OF HIGH PERFORMANCE THYRATRON DRIVER

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Abstract

To meet high performance injection requirements in INDUS-I and INDUS-II, the extraction and injection kickers of INDUS facility, must deliver current pulses with stringent time jitter. The excessive jitter in current pulse of the extraction and injection kickers with respect to respective master triggers, will lead to poor injection efficiency. To prevent this situation, a very low jitter & fast rise, thyratron trigger was designed. The trigger was designed to be reliable against thyratron arc down to the trigger grid. This thyratron driver is capable of producing very small time jitter and fast rise time of thyratron drive pulse, using low cost power MOSFET and transformer wound with coaxial cable. The driver delivers a 1μs/1500 V pulse with a rise time of ~70ns and jitter less than ±1ns. This thyratron trigger unit is being used in a number of pulsed power supplies in INDUS synchrotron facility. The paper presents the trigger circuit design, waveforms and the measured performance.

1. INTRODUCTION

Thyratron is a switching device which can withstands very high voltage (tens of kilo Volts) & can conduct high current (several hundred Amperes). To achieve this high voltage, high current switching capability, a robust Thyratron Driver is required. The performance of the Thyratron driver has great influence on the Thyratron tube's switching characteristics and its lifetime. Three major driver features will strongly affect the switching performance. They are (a) Trigger rise time (b) Trigger Jitter (c) Trigger output delay time. To meet these specifications an isolated Thyratron driver topology is proposed and fabricated.

2. DESIGN PRINCIPLE

The major requirement of the Thyratron driver is to deliver high quality trigger pulse with adequate voltage and current to turn on the Thyratron tube. To meet these requirements, selection of fast switching power MOSFET with small Ciss (the gate input capacitance of MOSFET), & Qg values and fast power MOSFET driver are the two most important factors. With careful design the Thyratron driver would meet the specification of trigger output pulse rise time of 70ns and jitter less than ±1nS. Smaller Ciss and Qg values coupled with enhanced driving capability of the MOSFET driver reduces the rise time of the output pulse. Besides the rise-time and jitter issue, trigger input and output signal isolation is also important factor to be considered in this design. High-speed opto-isolator is used to provide necessary isolation between the TTL -level input trigger signal from the control unit and the high voltage signal. So that these two sub-circuit systems will not interact with each other and hence improve the jitter performance of trigger output. Because of the fast rise time of the trigger pulse, oscillations might occur due to the parasitic capacitance and inductance in the circuit. To overcome this, RCD snubber circuit was used in the power MOSFET output stage. It was experimentally determined that 500nS trigger pulse is sufficient to fire the thyratron for fast current pulses. On the basis of said experiment, trigger pulse width was optimized. It fixed the transformer volts second and ensured low leakage inductance which is very important for output trigger pulse rise time. The schematic Thyratron Trigger is shown in Figure 1.

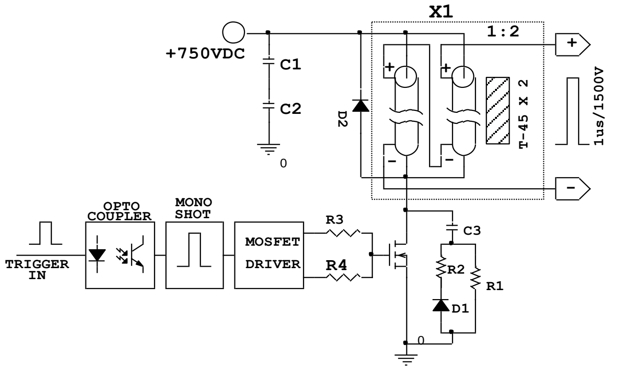

Figure 1: Thyratron Trigger Schematic

Capacitors C1, C2 discharge only about 10% during a pulse. The capacitor C1 and C2 charge by a voltage doubler circuit which is not shown in Fig. 1 and neither are the thyratron trigger negative bias voltage and the thyratron DC priming current. These thyratron auxiliary supplies are derived on a separate card. Thyratron arc down transients are somewhat clamped by the transient voltage suppressor. Most of the design effort was in component selection, circuit board layout and noise immunity. Detailed discussions of all the major components are as follows.

2.1 MOSFET Switch

One of the main component , a MOSFET switch IRFPG50 from International Rectifier, has a voltage breakdown rating of 1000 V, and average current rating of 6.1A. The drain–source voltage fall and rise times are approximately 35ns and at a price of approximately Rs.200, it is a very economical solution in comparison to other ultrafast MOSFETs having the same rating with drain–source voltage fall and rise times of approximately 10ns and a price of $200. IRFPG50 has a measured voltage fall time (90%–10%) of ~50ns in our circuit. In initial prototyping, IRF460 which has a voltage breakdown rating of 500 V, with an average current rating

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of 18.4A, was used with 1:3 pulse transformer. The measured drain– source voltage fall time with this FET was 40ns & output pulse rise time of ~100ns. To reduce the leakage inductance, another 1:2 pulse transformer was designed with primary side voltage of 750 V. MOSFET IRFPG50 is selected in the final design. The maximum transient voltage across the mosfet switch is 900V, which is limited by inverse diode across the transformer primary and the very low inductance of the primary capacitor. The drive circuit for the MOSFET was also a substantial design effort. A very fast FET driver from Unitrode, the UC3709, was chosen for this purpose. Two drivers in this package are paralleled to drive peak currents of ~ 3A. The layout of all the drive components was done to minimize inductance.

2.2 Pulse Transformers

Pulse transformer X1 shown in Fig 1 is specially constructed for low leakage inductance. This transformer provide step up ratio of 1:2 & isolate the thyratron high voltage surges during the pulse. The use of transformer also allows some effective clamping components to be used at secondary side. X1 is constructed with two parallel 1 m lengths, RG174 coaxial cable with 10 turns wound on 2 pieces of T-45 toroidal core. An off-the-shelf ferrite core T-45 was selected to fit in the available space on the PC board. The center conductor of both the cable is paralleled to be used as a primary & outer shields are connected in series to double the amplitude of output pulse. The advantage of this construction was to reduce the leakage inductance of the pulse transformer. In order to shield the 750V DC voltage on the cable and for personnel safety also, the center conductor is the primary and the outer conductor is the secondary.

Figure 2: Internal arrangement of Thyratron Driver

The used cable RG-174 has a breakdown voltage of 1500V, whereas T-45 toroidal core is CEL make HP3C grade, which has an effective length of 110mm & cross sectional area of approximately 92 mm^2. The total leakage inductance of the transformer is less than 100 nH.

3. TESTING & RESULTS

The measured rise time (10% - 90%) on the thyratron trigger grid is approximately 70 ns, as captured with a Tektronix TPS2024 scope and P5100 probe. Fig. 3 shows the measured jitter from the TTL trigger signal to the output thyratron trigger pulse. The maximum jitter after 5 hours and 36,000 pulses is less than ±1ns. The oscilloscope contributes approximately 200ps of jitter. The test was conducted at 2 Hz with a sample size of 36,000 shots. A 24-hrs run test resulted in a timing drift of less than 2 ns.

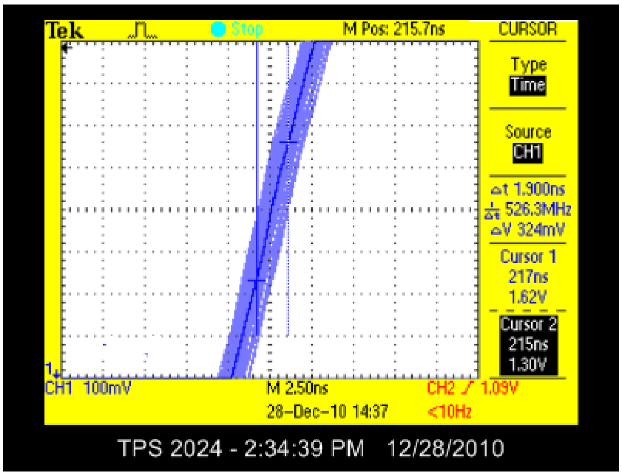

Figure 3 :Measured jitter of the O/P pulse

4. CONCLUSION

The Thyratron Driver has been fully tested and proven to be successful in delivering the adequate trigger pulses to drive the Thyratron tubes in injection and extraction kicker systems in the booster and storage rings at INDUS facility. This thyratron driver have been economically built and operated since 2005. In several years of operation, these drivers have contributed to the pulse timing stability and proven to be very reliable.

5. ACKNOWKEDGEMENT

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