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ELECTRICAL POWER ENGINEERING

Development of Trigger Drive Control System for Thyratron

Aye Ko Ko[#1], Myo Thein Kyaw[*2]
[#]*Department of Electrical Power Engineering, Defence Services Technological Academy*
Pyinoolwin, Myanmar
[1]AYEKOKO@yandex.ru
[2]myotheinkyaw@myanmar.net.mm

Abstract— **This paper describes the low cost pulse driver system for CO_2 pulsed laser project. Low cost driver board for three electrodes thyratron, microcontroller board and user interface program are implemented in this work. The effectiveness of the whole system is observed with simulation and experimental results. These results show that the proposed system is applicable to use in pulsed laser project.**

Keywords— **Driver board, Thyratron, Pulse transformer, Gate drive, Trigger drive**

I. Introduction

High power laser output is required in many applications in heavy industry such as iron cutting and the variation of pulse rate plays a vital role to produce high power laser output. Pulse forming network is essential part to produce laser and high energy switching elements are used to control the operation of that pulse forming network. Thyratron is used in this work because it has long been used in this field as a high energy switching element.

II. Proposed Design and Implementation

This work is decided for the implementation of the simple, low cost and applicable control system, which can change the pulse rate of laser below 100 Hz. The current existing CO_2 pulsed laser system can be used only for fixed pulse rate and our proposed idea that shown in Fig. 1 is to fulfil the weakness of the present system.

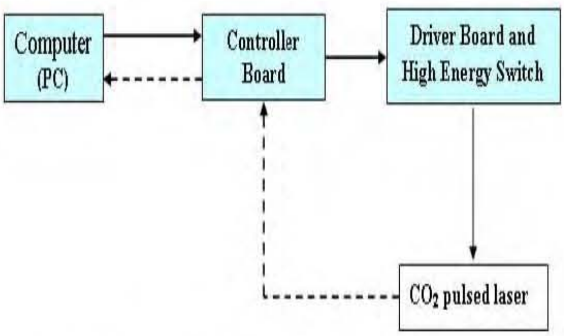

Fig. 1 Proposed system to control pulse rate of laser

In this approach, the desired pulse rate can be set on computer and then appropriate data will be sent to controller board. Finally, the controller board will trigger the driver board with desired pulse rate.

A. *Design Considerations for Driver Board*

To implement the driver board for thyratron, the trigger drive requirements of thyratron must be analysed. In Table 1, the basic trigger drive requirements of HY-3202 thyratron are shown [4]. This thyratron is medium power range switching element. The effectiveness of present development is observed with the trigger drive requirements of medium power range thyratrons listed in Table I.

TABLE I
TRIGGER DRIVE REQUIREMENTS OF HY-3202 THYRATRON

	Requirements	Min	Typ	Max
1	Peak Open Circuit Driver Voltage (Volts)	500	750	1500
2	Driver Pulse Rise Time (Nanoseconds)	-	100	150
3	Driver Pulse Width (Microseconds)	1	2	-
4	Peak Reverse Driver Voltage (Volts)	-	-	400

The pulse transformer is used in this work in order to get narrow width because it has low inductance and high voltage pulse with sufficient rise time. Moreover, there is electrical isolation between high voltage and low voltage side, and it needs only low input voltage to generate high voltage pulse [1]-[3]. The basic structure of pulse transformer based driver circuit is shown in Fig. 2.

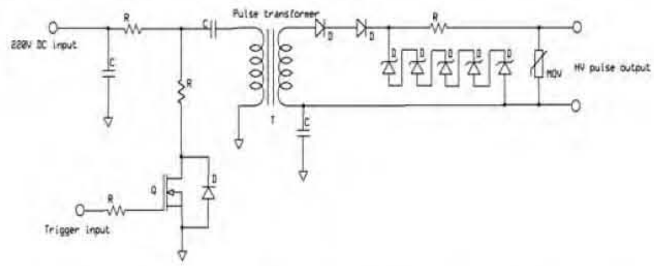

Fig. 2 Basic driver circuit

The storage capacitor on primary side of pulse transformer is charged in initial state. Output voltage generated by charging process is omitted in our approach. The high voltage trigger pulse will generate when capacitor on primary side of pulse transformer is in discharging process. In this process there will be three main components in the circuit to analyse the discharged current as shown in Fig. 3. The resistor in this circuit is for peak current limitation.

Voltage across primary winding:

$$V_p = L_m \frac{di}{dt} \tag{1}$$

where,

L_m = magnetizing inductance

i = magnetizing current

By ideal transformer equation, output voltage will be:

$$V_o = V_p \times \frac{N_1}{N_2} \tag{2}$$

where,

N_1 = no. of turns on primary side

N_2 = no. of turns on secondary side

By the equations (1) and (2), voltage output depends on magnetizing inductance L_m, rate of change of current $\frac{di}{dt}$ and turns ratio. To analyse the pulse width of discharge current, which is directly related to pulse width of output voltage, the discharge circuit is simplified as shown in Fig. 3.

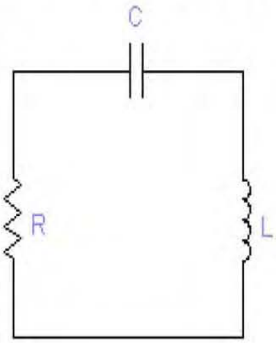

Fig. 3 Simplified discharge circuit

B. *Basic Characteristic of Series RLC Network*

By using Kirchhoff's voltage law in Fig. 3,

$$LI'(t) + RI(t) + \frac{1}{C}\int I(t)dt = 0 \tag{3}$$

$$I''(t) + \frac{R}{L}I'(t) + \frac{1}{LC}I(t) = 0 \tag{4}$$

The general solutions of above equation will be:

$$I(t) = c_1 e^{\lambda_1 t} + c_2 e^{\lambda_2 t} \tag{5}$$

$$I(t) = (c_1 + c_2 t)e^{-at/2} \tag{6}$$

$$I(t) = e^{-at/2}(A\cos wt + B\sin wt) \tag{7}$$

Based on above equation 4 and the following values of RLC, some results are obtained as shown in Fig. 4.

Suppose, initial voltage across capacitor V_c = 200 V

Case 1: R = 10Ω, C = 1 mF, L = 1 mH (Overdamping)

Case 2: R = 2Ω, C = 1 mF, L = 1 mH (Critical damping)

Case 3: R = 1Ω, C = 1 mF, L = 1 mH (Under damping)

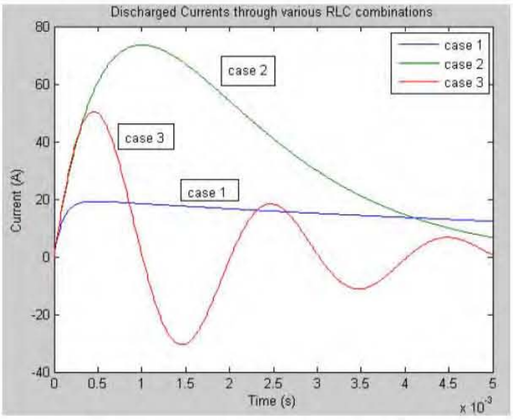

Fig. 4 The three basic nature of series RLC network

By analysing these results, low capacitance and resistance values tend to reduce the pulse width of discharge current. But undesired oscillation may occur. To obtain the desired pulse width and rise time, detail analysis is required and Matlab simulink is used for this purpose.

C. *Simulation by Matlab Simulink*

In practical, the effect of leakage inductance of pulse transformer cannot be omitted. The magnetizing inductance is also the main parameter to get required pulse width.

By constructing the simulink model in Matlab, the effect of leakage inductances and magnetizing inductance of pulse transformer are analysed based on simulink model.

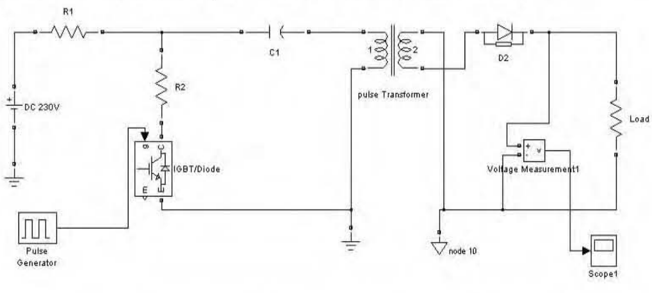

Fig. 5 Simple simulink model to analyze the pulse output

By observing the simulation results, the following crucial facts are obtained. The resistor value should be as low as possible until the minimum protection requirement of IGBT. Therefore R_2 is taken as fixed 1Ω and the values of C1, magnetizing inductance and leakage inductances are analysed. In general, to get the high voltage output the magnetizing inductance should be high. At that time the pulse width is increased. But in this work the requirement is not only the high voltage output but also the reducing of pulse width. To reduce the pulse width of output voltage, the magnetizing inductance is needed to reduce. To recover the voltage drop effect of reducing of magnetizing inductance, the leakage inductances have to be reduced as possible. The leakage inductances not only effect on the voltage drop and but also effect on the rise time of trigger pulse. The simulation result shown in Fig. 6 is obtained by using 5 μF C_1, 1μH magnetizing inductance, 100 nH leakage inductances on both side of pulse transformer and 50 Ω load.

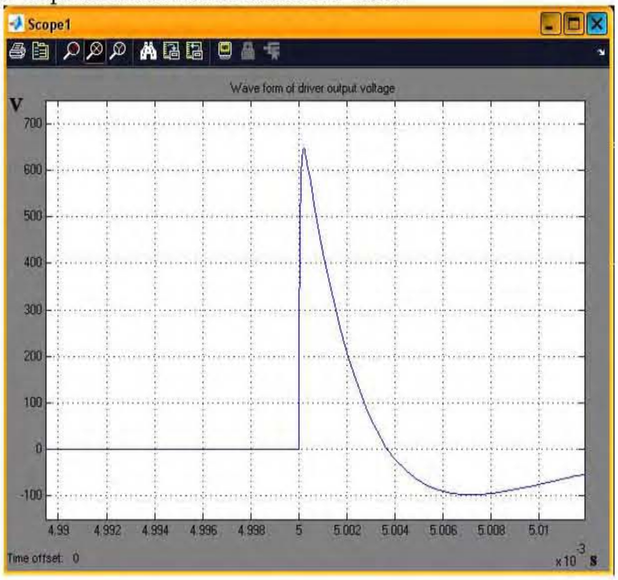

Fig. 6 Simulation result of driver board

D. Development of Driver Board

The pulse transformer is developed manually to obtain the required specifications and it has 1:5 turn ratios. Leakage inductances are reduced by proper winding configuration. Air gap in ferrite core is also used to protect saturation effect. It is necessary to measure some parameters of pulse transformer, such as magnetizing and leakage inductances. To obtain the desired result, trial and error method is used to develop the pulse transformer in this work.

Fig. 7 A simple low cost driver board for thyratron

E. Development of Controller Board

The main functions of controller board are: to receive data from computer via Universal Serial Bus (USB) or Universal Synchronous Asynchronous Receiver Transmitter (USART), to calculate the period of pulse according to received data and to generate trigger pulse to driver board via fibre optic cable. To fulfil these requirements, PIC18F4550 microcontroller is selected. This controller supports USB 2.0 and EUSART.

Fig. 8 Controller board

F. Implementation of Interface Program

The implementation of user interface program on PC is mainly considered on hardware interface. USB and serial port are used to connect with controller board. At present this program is only to set desired pulse rate of laser.

III. Results

The practical result measured by oscilloscope is shown in Fig. 9.

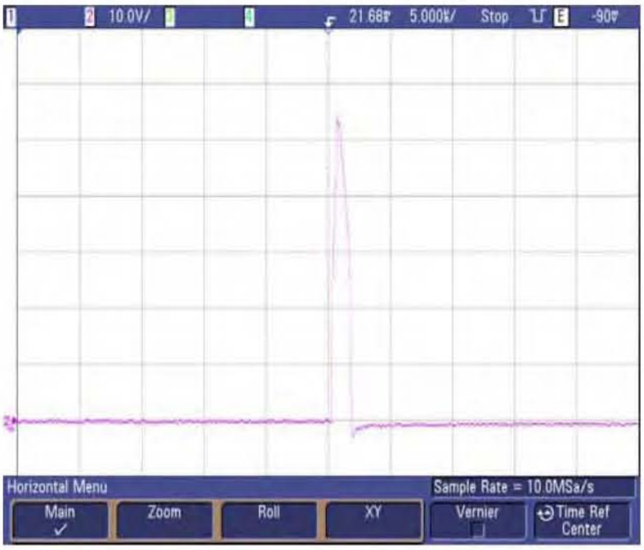

Fig. 9 Practical results of gate drive pulse

The comparison between the simulation result and practical result is shown in Fig. 10. These results show that simulation result is better than practical result because of the more leakage inductances of the pulse transformer which is used in this work.

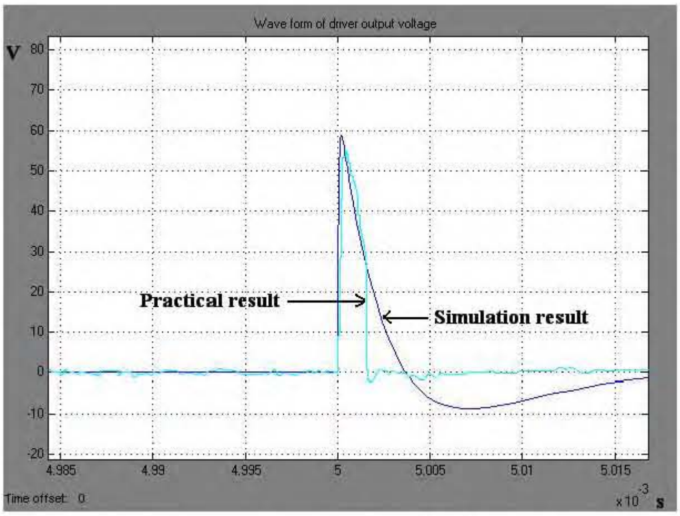

Fig. 10 Comparing the results of simulation and practical

The output voltages of driver board that shown in Fig. 9 and Fig. 10 are reduced ten times of real value because of the limitations of oscilloscopes. The 50Ω load is used to measure the output voltage. The pulse width is about 1.8μs and rise time is about 150 ns in the practical result. Although rise time does not reach perfect condition, this proposed system can be used in the pulsed laser project according to the specifications from Table I.

IV. Discussion and Conclusion

In this work, the three main parts are implemented. Overall system is developed with the low cost components, which are available in local market. By observing the practical results, this system can be used in the work of CO_2 pulsed laser system. But there are some weak points in our work, for example, rise time of trigger pulse. The appropriate design of pulse transformer, detail analysis of pulse forming network in driver board are still required to improve the performance of driver board.

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