A Gate Driver for High Voltage Thyristor Diode Switch

W. H. Kim, I. Kang, J. S. Kim, H. J. Ryoo, G. H. Rim
Korea Electrotechnology Research Institute
28-1, Sung-Ju Dong, Chang-Won, Kyung-Nam, Korea 641-120
E – mail : whkim@keri.re.kr

M. H. Cho, J. H. Nam, J. W. Kim
Korea Heavy Industries & Construction Co., Ltd.

Abstract - **Many semiconductive switches are operated in series for high voltage operation. The same number of gate drivers are needed to control all the switches, hence, the drivers cause high cost and system complexity.**

In this study, a simple and low cost gate driver for high voltage thyristor diode switches is investigated. This gate driver can operate several high voltage thyristor diode switches at the same time.

1. Introduction

This paper describes the gate driver for high voltage thyristor diode switch (hereafter, TDS) which is simple but very effective on cost reduction. The high voltage thyristor and diode that is connected in inversely parallel to thyristor form a TDS module. Several numbers of modules are connected in series and stacked to form a switch and the numbers of modules depend on the rated voltage of the control object. When connecting several TDS in series, the numbers of TDS are determined by the maximum applied voltage at both ends of whole modules that shall be connected in series.

The TDS controller is composed of two parts: one is the control circuit which generates on and off signals and the other is the circuit which insulates and finally transfers the on and off signals to the thyristor gate. The control circuit and on and off signals can be driven by $\pm$15V. But high voltage (maximum 2kv) is applied at both ends of TDS. If this control signal is used for driving signal, the control circuit shall be damaged by the invasion of high voltage serge or high current into the control circuit when TDS was broken during switching. It is therefore necessary to insulate the control circuit and TDS to protect the control circuit.

Fiber optics is currently widely used for gate drives for insulation. This requires independent gate driver for each switching element and is expensive to manufacture. Therefore the manufacturing cost shall increase as many TDS are required to control a high voltage.

Another method is to use high voltage insulating pulse transformer to compose gate driver. The primary windings of high voltage insulating pulse transformer are connected in series and the second windings are connected to TDS gate and anode terminal in parallel. In this case, the pulse transformer also requires as many as TDS. Also, the size and weight of all gate drivers are the problems.

This paper describes the circuit that solved all the above problems and can drive several switches with one pulse transformer driver by using the signals from the control circuit.

2. Gate driver for TDS

Fig.1 shows the construction of TDS. If the electric potential at A is high, then the current flows from A to B through SCR when SCR is on. But the current flows from B to A through diode and SCR is not on but off when the electric potential at B is high than A. If we properly set the outer circuit so that the electric potential becomes high at A and B in turns, the current flows from A to B when the electric potential at A is high and SCR is on. When the electric potential at B is high, the SCR is off by the reverse voltage and the current flows from B to A through the diode.

Fig.2 shows a gate driver for TDS. This circuit is composed of LED(Light emission diode) for trouble detection, snubber circuit for preventing voltage spark, and insulating transformer, etc. If the number of TDS increases, then the same numbers of gate driver like as fig.2 are required. But if we connect several gate drivers like as fig.2 to the secondary part of the round core, one gate driver can control several switches.

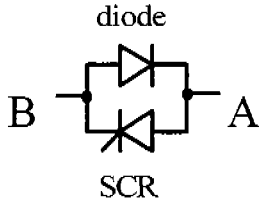

Fig.1 Thyristor Diode Module

3. Construction of TDS

In the application of the suggested gate driver in this paper, the following example shall be explained. A high voltage TDS stacked and connected in series is composed of k numbers of modules and each module contains m numbers of TDS. The size and price of overall gate driver and the volume and weight of high voltage electric equipment which requires this switch are drastically reduced by driving m numbers of switch element with one high voltage insulating pulse transformer.

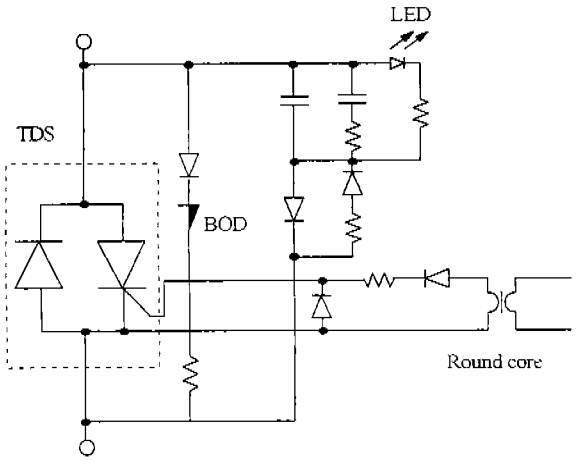

Fig.2 Gate driver for TDS

High voltage insulating pulse transformer is a round core type. The m numbers of TDS included in k numbers of modules require m numbers of primary and secondary windings in high voltage insulating pulse transformer to operate it. The size of high voltage insulating pulse transformer is dependent on the size of insulating voltage on the primary and secondary windings. The m numbers of TDS included in each module shall change depending on the insulation between the secondary windings of high voltage insulating pulse transformer and the insulation between each TDS. But the effect is not great. Assume that the maximum rated voltage of thyristor is 1 kV. four or five elements of TDS module are enough for the rated electric power. Therefore the numbers of high voltage insulating transformer and gate driver can be reduced to one fourth or one fifth and the weight and size can also be reduced to one third and one fourth.

Fig.3 shows overall construction of proposed gate driver for high voltage thyristor diode switch. One example is given in this figure that one thyristor (T1) and diode (D1) connected in inversely parallel to T1 compose one TDS and four TDS compose one TDS module. If the voltage controlling all switch modules is 80kv and the rated voltage of one TDS is 1kV, then more than eighty TDS should be connected in series. In this case, more than twenty high voltage insulating pulse transformers are needed. As shown in fig.3, the V_{gate}, the primary both ends controlling signal voltage of high voltage insulating pulse transformer, shall be distributed to k numbers of modules so that the primary voltage of module is V_{gate}/k.

Fig.4 shows the construction of the primary windings of high voltage insulating pulse transformer.

As shown in fig.4, the size of high voltage insulating pulse transformer is dependent on the size of insulating voltage of the primary and secondary windings. The m numbers of TDS included in each k module depend on the insulation between the secondary windings of high voltage insulating pulse transformer and insulation between each TDS. As referred, its effect is not serious. The gate driver, therefore, can be optimized if the insulation distance was kept optimum in each component.

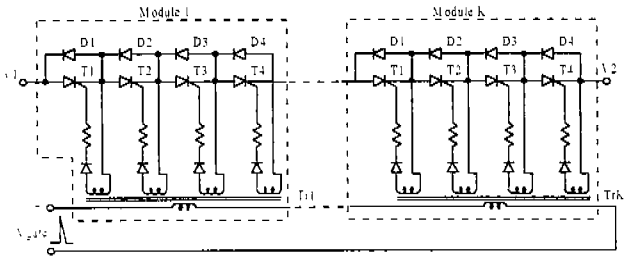

Fig.3 Overall construction of gate driver for high voltage thyristor diode switch

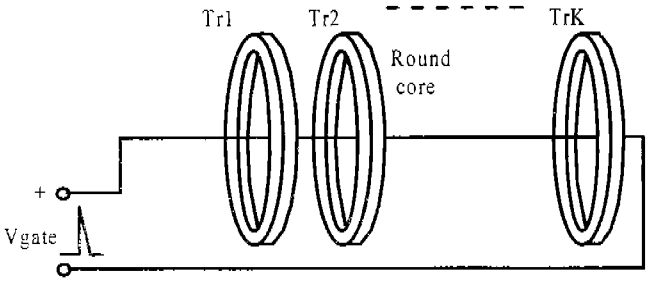

Fig.4 The construction of the primary windings of high voltage insulating pulse transformer

Fig.5 shows the construction of the secondary windings of high voltage insulating pulse transformer. As shown in this fig.5, the numbers of secondary coils are four and the voltage (V_{out}) applied at both ends is equal to $V_{gate}\ n_2/Kn_1$, where n1 and n2 are the numbers of turn in the primary and secondary windings in high voltage insulating pulse transformer respectively.

Fig. 5 is a simplified drawing to explain the structures of secondary windings. In order to get an identical output voltage on the secondary windings, m numbers of secondary windings shall be wound from the start to the finish parts. Before winding, four windings should be packed into one bundle.

The numbers of turns in primary and secondary windings

in fig.4 and fig.5 are determined by the size of voltage in primary and secondary voltage of high voltage insulating pulse transformer. As m numbers of switch element included in k numbers of modules depend on the required rated electric power, the m numbers of switch element can be controlled depending on the high voltage insulating pulse transformer design.

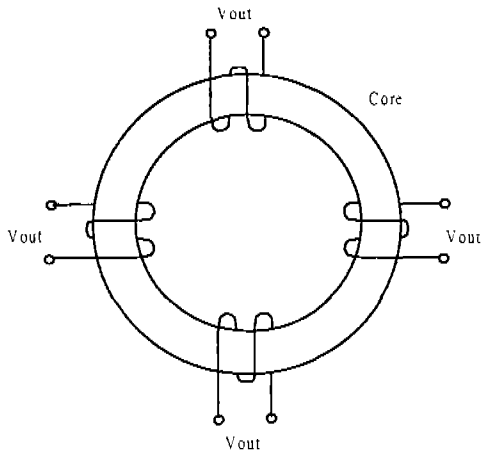

Fig.5 The construction of the secondary windings of high voltage insulating pulse transformer

Fig.6 shows the comparison ficture of one TDS driving type (right) and four TDS driving type (left) circuits. The gate driver for four TDS is about twice as big as that for one TDS. But a large amount of cost reduction is possible if the volume of the system is reduced by connecting many switches.

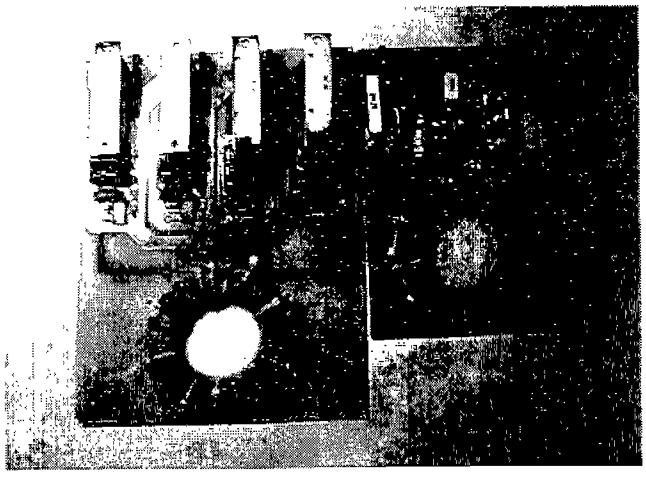

Fig.6 Comparison of gate drivers

Fig.7 and fig.8 shows pulse voltage waveforms that are obtained from the actual test of one and four TDS gate drivers. Upper and lower parts are pulse voltage and pulse current waveforms respectively. This shows that a series driving normally operates and there is no problem in four TDS gate driver.

4. Conclusions

This paper described simple but cost-effective gate driver for high voltage thyristor diode switch. It consists of k numbers of modules in which m numbers of TDS in each module were connected in series. A drastic reduction of price, volume, and weight were achieved by driving m numbers of switch element with one high voltage insulating pulse driving transformer. High voltage insulating pulse transformer is a round core type. As m numbers of switch element included in each k numbers of module are dependent on the rated electric power of the element, the numbers of switch element can be increased depending on the design of high voltage insulating pulse transformer. The size of high voltage insulating pulse transformer is proportionally increased but the reduction of size, weight and price of gate driver is bigger than that.

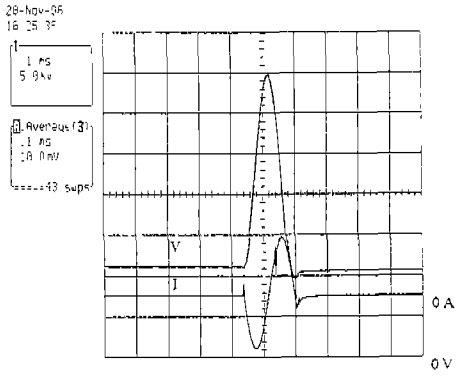

Fig.7. Voltage and current waveforms generated by conventional gate driver(5kV/div, 20A/div)

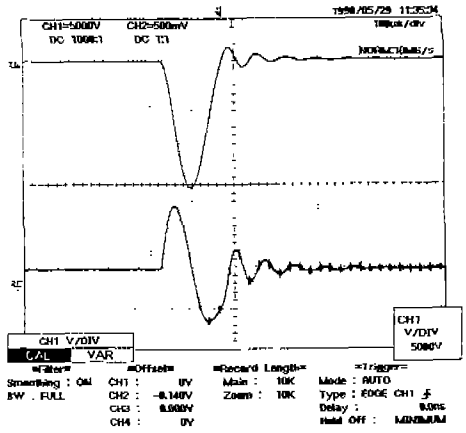

Fig.8. Voltage and current waveforms generated by conventional gate driver(5kV/div, 20A/div)

References

[1] R.M. Fhrlich, et al, "AC Electrostatic Precipitation", IEEE Massachussetts Institute of Technology, Bambridge, MA, pp1211-1214, 1984

[2] G. H. Rim, W. H. Kim, J. S. Kim, et al, "Investigations of Flow and Collection Efficiency in Wide-Duct Electrostatic Precipitator", in IEEE ICPE '95 Conf. Rec., pp720-724., 1995

[3] G. H. Rim, W. H. Kim, J. S. Kim, et al, "A Semi-Pulse Power Supply for Wide-Pitch EP on a 500MW Power Plant", in IEEE ICPE '95 Conf. Rec., pp610-615., 1995

[4] J. P. Strakey, R. R. Santore, et al, "Status of Retrofit Projects for U. S. Clean Coal Technology Program", Coal & Newclear Power Plant, vol. 41, no. 10, pp1273-1285, 1995

[5] United States Patent No. 4,061,961(Dec. 6. 1977)

[6] United States Patent No. 4,311,491(Jan. 19. 1982)

[7] United States Patent No. 4,558,404(Dec. 10. 1985)

[8] United States Patent No. 4,567,541(Jan. 28. 1986)