HVDC 송전용 광구동 사이리스터(LTT)를 위한 소자특성 및 응용의 요구

장창리, 김상철, 김은동, 서길수, 김형우, 방 욱, 청콴유, 김남균
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Device Feature and Application Status for Light Triggering Thyristor(LTT) in HVDC Transmission

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Abstract

The design concept for 8kV light triggering thyristor (LTT) with integrated BOD was discussed here in detail. The trade-off between light triggering input source againsthigh dV/dt limitation has been treated via grooved P-base for gate design. The main application point used for high voltage DC transmission (HVDC) was represented.

Key Words : light, thyristor, high voltage DC transmission (HVDC)

1. Introduction

Recently HVDC transmission is a hottest topic for international HVDC network linking in between Korea, China and Russia. Therefore, LTT is one of power device to be considered for upcoming project in the application used in the HVDC linked in between East Asia and Korean Peninsula.

Historically, high voltage DC transmission (HVDC) has been developed by usual electrically triggering thyristors (ETT) in the early 1980s. In order to improve the reliability of whole HVDC system with reduced electronic elements adopted in thyristor valve, ETT has been replaced by light triggering thyristors (LTT) in the 90th. In 1995, 8-kV 3.5-kA LTT was developed in Hitachi for Back to Back (BTB) system. At the same time, Siemens has developed 8.5kV LTT with the integrated break-over diode. In 2002, Siemens has transferred all of process technology of LTT to Xi'an PERI in China upon the cooperation project for 500kV HVDC transmission linked from Guizhou to Guangzhou in China. LTT can be also used for the power system stabilization by static Var compensation (SVC) installed on thermal power station. Fig.1 shows the 300MVA HVDC valves applying LTT in Japan. And Table 1 lists major component to be applied in this equipment.

The design concept for 8kV LTT is introduced in this paper. The important point for applying LTT into the HVDC valve has been discussed, too.

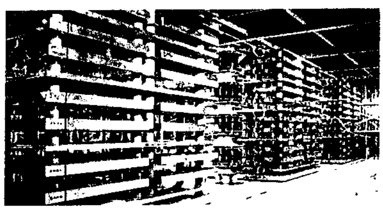

Fig. 1. HVDC valves applying 6.6kV LTT.

Table 1. Major component in HVDC valve.

Table.Specification of major component

Item		Specification
Capacity		300MW
DC Voltage		250kV
DC Current		1,200A
Light Triggered Thyristor Valve	Capacity	300MW
	Insulation	Air Insulation
	Cooling	Deionized water(pt) circulated Cooling
	Thyristor	Light triggered 6.6kV-1.2kA
Control and Protection		Digital type, Dual system

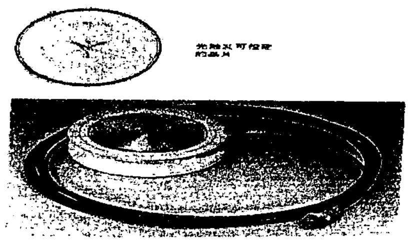

Fig. 2. Si wafer with house attached the light fiber for LTT.

2. Discussion

2.1 Features of LTT device

In principle, the basic fundamental and fabrication technology of LTT is similar to ETT (Electrical Triggering Thyristors). Fig.2 shows the silicon wafer and its house for 8kV, 3.5kA LTT. However, the triggering mechanism and method is quite different with that of ETT. For LTT, light is directly triggered to the gate of LTT via the optical fiber. The carriers activated by light in the Pbase light sensing area will turn on the four-layer of PNPN switch shown in Fig.3. And for ETT, the gate current is needed to fire the four-layer of PNPN switch by positive gate pulse. Due to this difference, the switch performance and process technology for two devices has been affectedsignificantly. In LTT, very slightly light signal is needed for directly light drive. Moreover the energy of light for gate trigger is only one to several tenth of electrical energy for ETT. Therefore, how to improve the light sensitivity against sacrificing dv/dt are the major objectives to LTT's design.

2.2 Light triggering against dV/dt

As mentioned above, the gate triggering power or gate current is significantly relevant to switching characteristics of device for instance turn-on time, delay time, di/dt performance etc. The triggering power in ETT should either be large enough to meet so called "heavy triggering"or be strong enough for light power in LTT. From other hand, the output power of currently light source i.e. LED in the today's available market is little low, so the specified structure receiving light in Si with highest sensitivity is adopted in LTT. In this case it can be obtained light triggering input power less than 10mw(see Fig. 4) if the mentioned specified structure is applied. This means that the area of light sensitive structure in central part of LTT should be as small as possible. Otherwise the failure features carried out by dV/dt capablity i.e the capable of the thyristor to withstand voltage ramps of several kV/s without being triggered by the resulting displacement current, would suffer. The small structure requires particular protection measure against the onrush of the turn-on current. This is usually done by means of multistage amplifying gates [1].

2.3 Self-protection via BOD

The novel LTT integrates the both light triggering and over-voltage protection function into a single wafer in order to simplify the drive unit and controlling unit assembled in the stack of thyristors valve. From up -to -date technology, it is possible to integrate the over-voltage protection function into the inner of device. But in reality the break-over voltage by (see Fig.5) integrated built-in break-over diode (BOD) should be larger than the minimum voltage that is applied DC voltage in the circuit (VD). Additionally this voltage range should not be so big i.e. it lies in some narrow range, which upper limit (VBOD) should be smaller than the forward blocking voltage (VDSM) of main device in adequately. To realize this target, the common way is to have chemical or laser etching Si to form recessive structure. However the stability of BOD voltage still be a questionable.

To improve its inherent stability, non-uniformity doping or curved PN junction (etching off the thin layer for B-Al pre-deposit) was adopted in LTT.

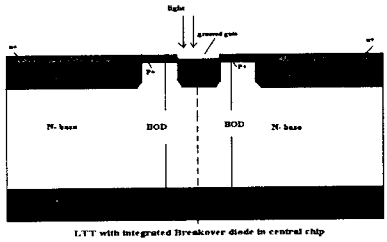

Fig. 3. LTT structure with integrated BOD.

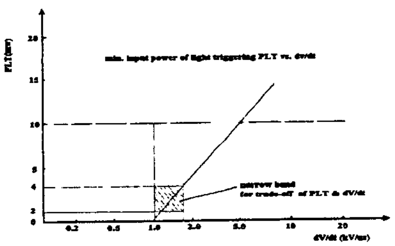

Fig. 4. relation of input power of light triggering PLT and dv/dt.

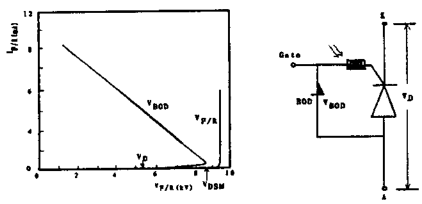

Fig. 5. I-V curve of a BOD protected 8kV LTT thyristor .

2.4 Self-protection against dV/dt

LTT should be withstanding to instantaneously inrush high dv/dt at several kV/s. If this dV/dt ability is too low then destruction will be resulted from " re-triggering" in the thyristor. In terms of LTT, dv/dt limitation is very important parameter. However dv/dt and light triggering sensitivity are contradictory parameters, so the compromise is necessary.

As stated in Fig.4 dv/dt becomes low if light sensitivity in the light sense area of LTT is high, and the visa verse. Since LTT requires very high in the light sensitivity, the dv/dt limitation will be, therefore, sacrificed. Together with all these items, it is necessary to adjust the doping profile of P- base and its circumscription. In addition to adjust the amplifying gate (AG) and cathode design ensures its nominal dv/dt limitation. This procedure is so complicated that difficult to be controlled in properly technology by designer.

2.5 Application point of HVDC valve

Although HVDC system is very complicated and complex system, but thyristor valve and value base electronics (VBE) is the important core in the HVDC whole system. The thyristor valve is mainly composed of elements of thyristor and anode saturation reactor.

Many thyristors connected in series were composed of HVDC thyristorvalve, but the potential of all thyristors is differently. Since the elements are controlled by a controlling system which is connected to a common base to the ground i.e. VBE (Value Base Electronics). Therefore the communication between the controlling system and elements of thyristor must be isolated in electrical potential. The different system so called magnetic coupling circuit i.e. optical system via lens mirror to realize this communication has been developed in the past. But today's main design method is to use signal transmission system adopted by optical fiber.

The requirement for optical fire pulse e.g. FP (triggering pulse) to be used in triggering thyristors is that it should be ensured to triggering thyristors from blocking state to conductionstate. It can be done directly by light triggering thyristor or by transmitting optical pulse to electric pulse via thyristor controlling unit (TCU) such that to obtain electric pulse to fire the electrical triggering thyristors (ETT). Generally TCU includes the protection circuit such as over voltage protection and forward recovering protection as well as working monitor for ETT. However, compared to ETT, TCU for LTT can be simplified considerably since the light coupler is only added to each thyristors assembly.

Therefore, TCU has following common features:

Triggering in protection of HV-Thyristors when over-voltage happed. This is omitted in LTT system.

Triggering in protection for high dv/dt at intervals of recovery. This is unnecessary in LTT, too.

Indication of triggering in protection for TCU

Indication of thyristor failure (short circuit case)

Replace of ETT by LTT does not imply the neglect all electronics devices based on thyristor bases, however, monitoring system to be capable of detecting fault element is still necessary. Therefore adopting LTT in the reality operation of high voltage-DC valve does not means the simply neglect the electronics units and devices to be electrically connected to each thyristor. In HVDC transmission, the total results of LTT replace of ETT have been observed to greatly improvement in total reliability because of omitted protection for both BOD and RP (recovery protection).

It is important to separate the control and protection for each thyristor to thyristor in other position such that to obtain the residencies in all position of the valve as well as to avoid the unnecessary failure of commutation. The state information of thyristor is fed back to VBE. These indication pulses are binary and contained the state information for turn-on and turn-off of thyristors. Moreover, the equivalent information will be transmitted to controlling system via optical fiber whilst thyristor was triggered by protected triggering system. As the failed elements are equal to the elements in residencies, then converter will be tripping operation. Otherwise all thyristors will be failed in this situation.

3. Conclusion

The design principle for LTT applying in HVDC system has been given in this paper. The light triggering againstdv/dt for integrated BOD has been optimised in our design. The main application note for HVDC valve has been mentioned finally.

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