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This issue presents snubber circuits, which are almost always required in power switching devices.

The snubber circuit is a circuit inserted to protect a switching device from overvoltage due to accumulated energy in the wiring inductance of the circuit when the switching device is turned off. Snubber circuits generally come in two types: a non-polarized type consisting of capacitors (Cs) and resistors (Rs) and a polarized type with Cs and Rs plus a diode. IGBT uses a polarized type, which effectively suppresses surge voltage.
(The snubber circuit is also described in the IGBT Total Module Catalog No. EC-E704P. If necessary, please refer to this material.)

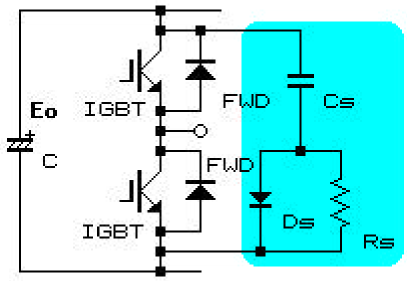

Fig.1 P-N Snubber Circuit

1) Snubber circuit operation

A typical P-N snubber circuit is described above Fig. 1.
Fig. 2 represents a circuit in the overvoltage occurrence mode of a bottom-arm IGBT at the time of turning off. Fig. 3 represents an equivalent circuit in a transient state at the same time.

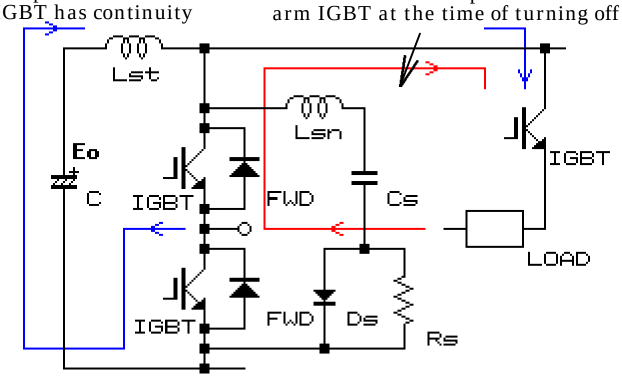

Fig.2 Turn-off mode of bottom arm IGBT

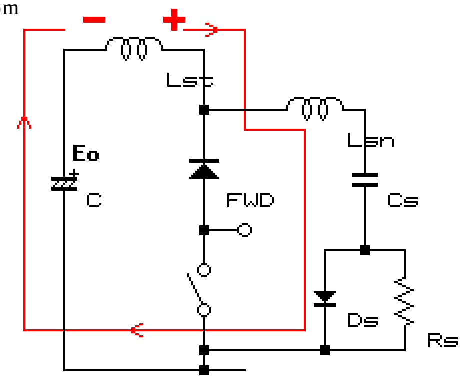

Fig. 3 Equivalent circuit when the circuit indicated in the left-hand figure is in a transient state

Fig. 2 represents changes in the current pass when the bottom IGBT, which was on, is turned off. When the bottom arm IGBT is turned off, the load current passes through the FWD at the top arm and is refluxed. Discharge of energy accumulated in the Lst is applied to the bottom arm IGBT as an overvoltage because the absence of a snubber circuit results in the loss of a discharge destination. Installing a snubber circuit results in Lst energy passing through the snubber circuit and being refluxed, as shown in Fig. 3. This allows overvoltage suppression. However, in reality, the snubber circuit also has wiring inductance Lsn, which may cause overvoltage.

How can Lst and Lsn be reduced? The key is to choose the right components and lay them out appropriately.

2) Current and voltage waveforms when a snubber circuit is involved

Let us consider current and voltage waveforms in the circuit indicated in Fig. 2, when the IGBT is turned off.

Fig. 4 represents current and voltage waveforms of the IGBT device when turned off. Use of a snubber circuit inhibits surge voltage stemming from wiring inductance Lst to Eo + Δ Vf.

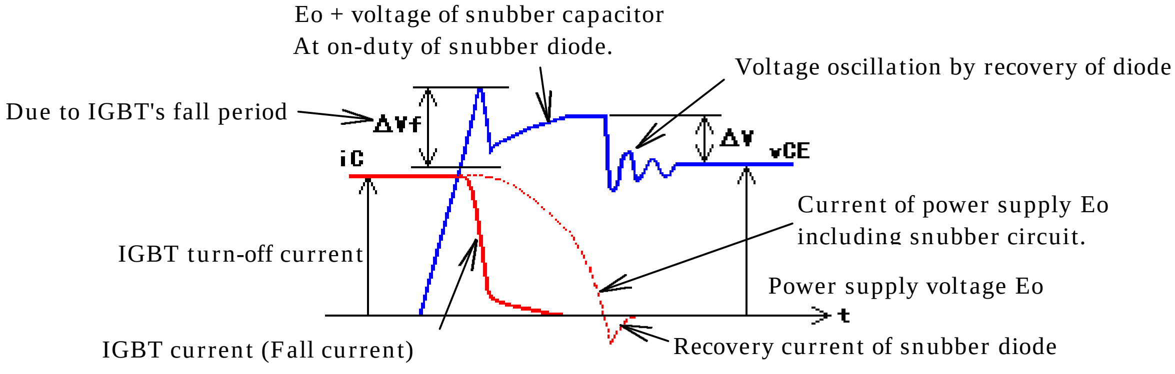

Fig.4 IGBT current iC & voltage vCE at snubeer circuit operation.

Fig. 5 represents current and voltage waveforms of the snubber diode Ds when the snubber circuit functions. The items can be determined with the following equations:

$$TS = \frac{2p\sqrt{Lst \times Cs}}{4}$$ ----------Equation (1)

$$\Delta V = Ic \times \sqrt{\frac{Lst}{Cs}}$$ -------------Equation (2)

Ic is an IGBT turn-off current

$$DVf = Lsn' \, dic/dt + Vfr$$ ---Equation (3)

where Lsn is the snubber circuit inductance as viewed from IGBT's collector and emitter terminals, and Vfr is about 50 V. The dic/dt is the current change ratio in IGBT's fall period.

$$TN = 3 \times Cs \times Rs$$ -------------Equation (4)

where TN is a time required to discharge 95% of the overcharge voltage of the Cs. Rs must be set to such a value that makes Ts + Tn < 1/fc.

In the above equation, in the case of a three-phase circuit, the Ts in Equation (1) becomes $\sqrt{3}$ times, and the Δ V in Equation (2) becomes $1/\sqrt{3}$.

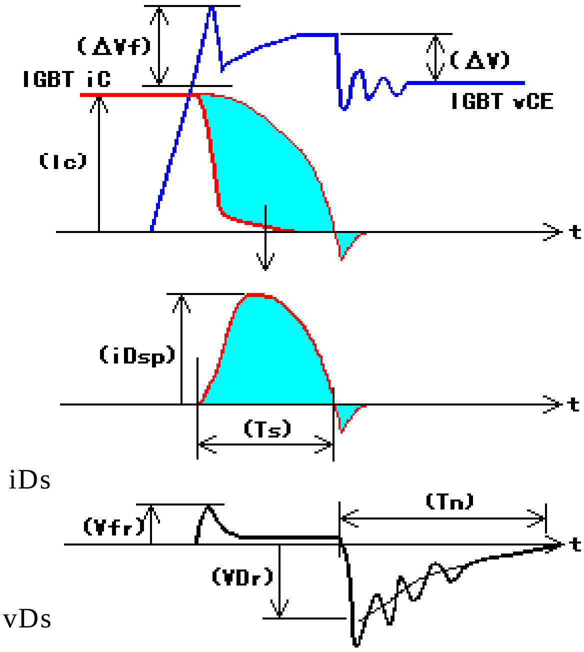

Fig.5 Each portion of snubber circuit.

Because of space limitations, the constants for each IGBT current class will be described in the next issue.

Next issue :1) Snubber circuit constants of IGBT 2) How surge voltage occurs of diode