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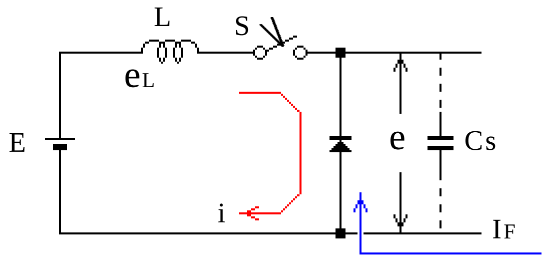
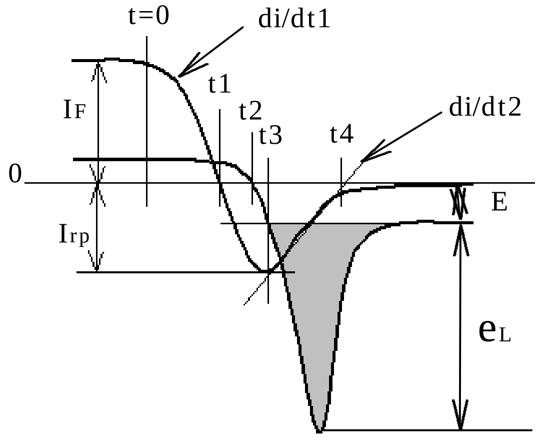
This month, we will describe how overvoltage occurs due to the hole accumulation effect of a diode device. This phenomenon takes place when a diode shifts from an on state to an off state by circuit operation (when in commutation). How this occurs is described using a circuit indicated below and a waveform that occurs when in commutation.



Equivalent circuit when in commutation



How overvoltage occurs

1) IF flows first in the forward direction of the diode.
2) Commutation starts at t = 0.
3) At this time, if the diode's forward voltage drop is ignored, the current declines at E/L, because $E = L\,{}^{di}\!/_{dt1}$. ---------- (1)
4) At t1 and later, a reverse recovery current flows due to the carrier accumulation effect of the diode.
5) At the point t2, the junction is restored and the diode starts restoring its bulk.
6) At t3, the reverse recovery current reaches its maximum, and the voltage applied to the diode becomes source voltage E.

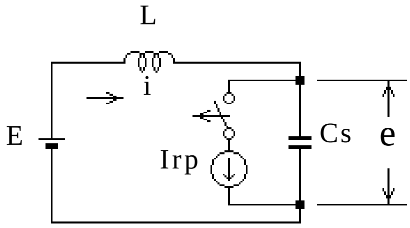
   Irp = maximum $\quad \therefore {}^{di}\!/_{dt1} = 0 \quad \because L\,{}^{di}\!/_{dt1} = 0 \quad \therefore e = E$

7) At t3 and later, the reverse recovery current attenuates due to the disappearance of carriers in the diode bulk. At this time, the diode is subjected to a commutation surge voltage of

   $e = E + e_L = E + L\,{}^{di}\!/_{dt2}$ ----------(2)

Calculating overvoltage

If the diode bulk recovery occurs quickly (that is, if the lag between t3 and t4 is short), L's energy ${}^{1}\!/_{2}\,LIrp^2$ changes quickly, so that an overvoltage of $L\,{}^{di}\!/_{dt2}$ occurs. In the calculation model in the right-hand figure, let Cs = Cj + Cs'. -------- (3) where Cj is junction capacity and Cs' is the floating capacity of wiring.



Overvoltage calculation model

At this time, Irp reaches the maximum reverse recovery current. Let t4 - t3 = 0, and the following holds:

$$E = L\frac{d^2q}{dt^2} + \frac{q}{Cs} \quad \text{---(4)}$$

$$q = CsE + A\cos\frac{t}{\sqrt{LCs}} + B\sin\frac{t}{\sqrt{LCs}} \quad \text{------------------(5)}$$

$$e = E + \frac{A}{Cs}\cos\frac{t}{\sqrt{LCs}} + \frac{B}{Cs}\sin\frac{t}{\sqrt{LCs}} \quad \text{------------------(6)}$$

$$i = \frac{dq}{dt} = -\frac{A}{\sqrt{LCs}}\sin\frac{t}{\sqrt{LCs}} + \frac{B}{\sqrt{LCs}}\cos\frac{t}{\sqrt{LCs}} \quad \text{-------(7)}$$

Under the initial conditions, and when t = 0,

$e = E \qquad i = Irp$

Therefore,

from Equation (6), A = 0. From Equation (7), $B = Irp\sqrt{LCs}$ holds.

Therefore, $$e = E + Irp\sqrt{\frac{L}{Cs}}\sin\frac{t}{\sqrt{LCs}} \quad \text{----------------------------(8)}$$

This means that the diode's maximum reverse voltage e becomes

$$e = E + Irp\sqrt{\frac{L}{Cs}} \quad \text{---(9)}$$

Since Cs is small (several pico-Farads to dozens of pico-Farads), surge voltage occurs when wiring inductance L is large.

Suppressing commutation surge voltage

1) Add capacitor C in parallel with the diode to absorb surge voltage. This capacitor C is called C between A and K.
2) Use an avalanche diode to absorb surge reverse power.

Next issue : IGBT's Dead Time