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Design of Snubber Circuit for Thyristors using Pspice

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Abstract— In normal cases switching a power electronic devices causes a sudden abrupt transients across the device which is undesirable for its perfect operation. So snubber circuits are necessary to maintain the safe function and long life of power switches. These circuits provide better efficiency and increase the possible switching speed and reduce the EMI. This paper deals with the designing of RC snubber circuit for thyristors. RC snubber circuits are normally connected across a switching device to limit the rate of rise of voltage (dv/dt). To analyse the performance of the circuit inductive load switching is simulated. Simulations are done in Pspice.

Keywords— EMI, Inductive load switching, snubber circuit.

I. INTRODUCTION

Snubbers are indispensible in power electronics. Snubbers are small networks of parts in the power switching circuits whose function is to control the effects of circuit reactance. Snubbers are an essential part of power electronics.

Snubbers are any of several simple energy absorbing circuits used to eliminate voltage spikes caused by circuit inductance when a switch is either mechanical or semi-conductor—opens. The objective of the snubber is to eliminate the voltage transient and ringing that occurs when the switch opens by providing an alternate path for the current flowing through the circuit's intrinsic leakage inductance. Snubbers in switch mode power supplies provide valuable functions:

- Reduces or eliminates voltage or current spikes.
- Limit di/dt or dv/dt.
- Shape the load line to keep it within the safe operating area.
- Transfer power dissipation from the switch to a resistor or a useful load.
- Reduce total losses due to switching the devices.
- Reduce EMI by damping voltage and current ringing.

Snubber circuits enhance the performance of the switching circuits and result in higher reliability, higher efficiency, higher switching frequency, smaller size, lower weight, and lower EMI. The basic intent of a snubber is to absorb energy from the reactive elements in the circuit. The benefits of this may include circuit damping, controlling the rate of change of voltage or current or clamping voltage overshoot. In performing these functions, a snubber limits the amount of stress which the switch must endure and this increases the reliability of the switch.

When a snubber is properly designed and implemented the switch will have low average power dissipation, low peak power dissipation, low peak operating voltage and low peak operating current.

In real world a switched load appears as impedance. So when these loads are switched, there are unwanted voltage transients or surge currents which have a negative effect on switching elements and also the controlling circuit. These effects can have immediate or time delayed consequences which can lead to the malfunctioning or even defects of the switching elements and the controlling circuit. If snubber circuits are well designed, they can reduce or even eliminate these effects. Therefore it is necessary to use snubber circuits with relay contacts because electric arcs can be reduced and a longer life of the contacts can be achieved. In addition the number of switching cycles can be increased which will allow savings in material and maintenance costs. If SCRs are used snubber circuits are necessary to control the rise of the voltage along the anode to cathode track. If this voltage rises at faster rate it can lead to unwanted turn-on of the device. If this happens, a faultless action of the device can't be guaranteed anymore and it could fail. The snubber circuit absorbs the energy which is stored in the load. To keep the switching device within its safe operating range, it is necessary to protect the switch. If the load is inductive, the switch-off can be problematic because the self-induction wants to maintain the current flow which leads to voltage transients which can be in the range of kilo to megawatts.

II. PRINCIPLE OF OPERATION

A RC snubber circuit consists of a series combination of resistance Rs and capacitance Cs in parallel with the thyristor. Capacitor Cs in parallel with the device is sufficient to prevent unwanted dv/dt triggering of the SCR. When switch S is closed, a sudden voltage appears across the circuit. Capacitor Cs behaves like a short circuit, therefore voltage across SCR is zero. With the passage of time, voltage across Cs builds up at a slow rate such that dv/dt across Cs and therefore across SCR is less than specified maximum dv/dt rating of the device.

Before SCR is fired by gate pulse, Cs charges to full voltage Vs. when the SCR is turned ON, capacitor discharges through the SCR and sends a current equal to Vs. as this resistance is quite low, the turn ON di/dt will tend to be excessive and as a result, SCR may be destroyed. In order to limit the magnitude of discharge current, a resistance Rs is inserted in series with Cs. Now when SCR is turned ON, initial discharge current Vs/Rs is relatively small and turn ON di/dt is reduced.

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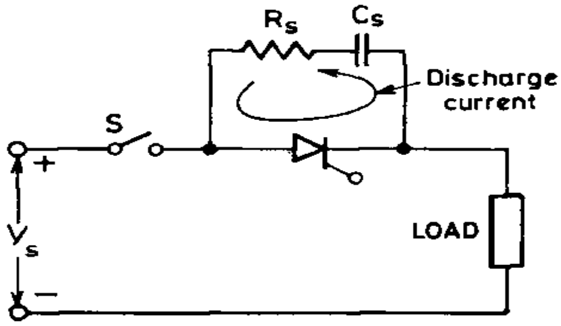

Fig.1 Equivalent circuit for SCR

In actual practice; Rs, Cs and the load circuit parameters should be such that dv/dt across Cs during its charging is less than the specified dv/dt rating of the SCR and discharge current at the turn ON of SCR is within reasonable limits. Normally, Rs, Cs and load circuit parameters form an undamped circuit so that dv/dt is limited to acceptable values.

The design of snubber circuit parameters is quite complex. Practically, designed snubber parameters are adjusted up or down so as to obtain a satisfactory performance of the power electronic system.

III. PLACEMENT OF SNUBBER

For the placement of the snubber, the type of load must be known. Because of the fact, that the protection circuit has to be designed according to the load, it is impossible to design a universal protection circuit.

For an inductive load, the snubber must be connected either in parallel to the switch, or in parallel to the load as shown in fig.2(a). A simple snubber consists of a resistor and a capacitor. If the snubber is connected in parallel to the switch, the current flows through the protection circuit at switch-off and then decays. Because of the connection in parallel to the switch, there is a constant current flow through the snubber when the switch is open. To keep this current flow to an acceptable level, a well designed circuit is needed.

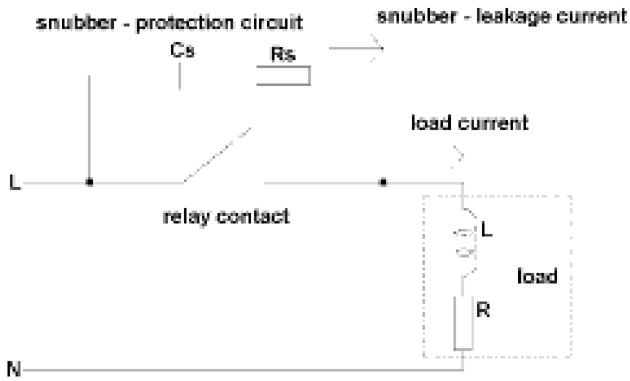

Fig.2(a) Position of snubber across switch

If the snubber is connected in parallel to the load as shown in fig.2(b), the current flow is also stopped through the switch and the snubber circuit becomes active. In contrast to the first method there is no current flow when the switch is open but there is a leakage current when the switch is closed. In this arrangement the current flow caused by transient voltages cannot flow over the neutral wire which can lead to improved EMI.

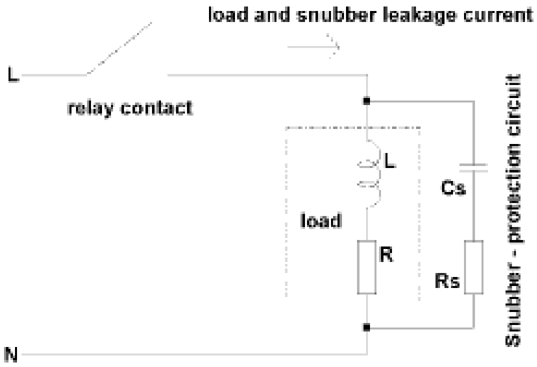

Fig.2(b) Position of snubber across load

IV. DESIGN OF SNUBBER CIRCUIT

A. Derivation of Snubber components

From the fig.1 it can be written as

$$V_s = i(R_s + R_l) + \frac{di}{dt}$$

Taking Laplace Transform

$$\frac{V_s}{S} = (R_s + R_l)I(S) + LSI(S)$$

$$I(S) = \frac{V_s}{L}\left[\frac{1}{S} \cdot \frac{1}{S + \frac{R_l + R_s}{L}}\right]$$

Its solution gives, $i = I(1 - e^{-t/\tau})$

Where

$$I = \frac{V_s}{R_l + R_s} \;;$$

$$\tau = \frac{L}{R_l + R_s}$$

't' is the time in seconds measured from the instant of closing the switch.

$$\frac{di}{dt} = I.e^{-t/\tau}.\frac{1}{\tau}$$

$$= \frac{V_s}{L} e^{-t/\tau}$$

The value of di/dt is maximum when t=0

$$\frac{di}{dt} = \frac{V_s}{L}$$

$$L = \frac{V_s}{\frac{di}{dt}}$$

The voltage across SCR is given by,

$$V_a = R_s . i$$

$$\frac{dV_a}{dt} = R_s . i$$

$$R_s = \frac{L}{V_s}\left[\frac{dV_a}{dt}\right]$$

$$C_s = L\left(\frac{2\xi}{R_s}\right)^2$$

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Where **ξ** is the damping factor (or damping ratio). Inorder to limit the peak voltage overshoot across thyristor to a safe value, damping factor in the range of 0.5 to 1is usually used. The snubber circuit design depends on the damping factor (ξ).

When ξ decreases, the snubber resistor and capacitor values decrease but the peak voltage and snubber circuit discharge current increase. Maximum instantaneous dv/dt OFF occurs at a time later than t = 0 when ξ is lower than 0.5.

When ξ increases, the snubber resistor and capacitor values increase and the voltage overshoot decreases. The maximum instantaneous dv/dt OFF occurs at t = 0 when ξ is higher than 0.5

B. Design Procedure

Here the circuit is analysed based on two approaches:

1. Without snubber circuit
2. With snubber circuit

Steps considered for without Snubber circuit is discussed below:

i. Considered the case when an inductive load switching is provided; there will transient across the device.
ii. Corresponding values of dv/dt and di/dt is measured from the plots shown in fig.3 (a), 3(b).

Steps considered for with Snubber circuit is discussed below:

i. Obtained values from the plot shown in fig.3 (a), 3(b) are substituted in the derived snubber components(R and C).
ii. With these values plots obtained is shown in fig.4 (a), 4(b) and came to a conclusion that the transients was completely reduced.

V. SIMULATION RESULTS

A. Without Snubber Circuits

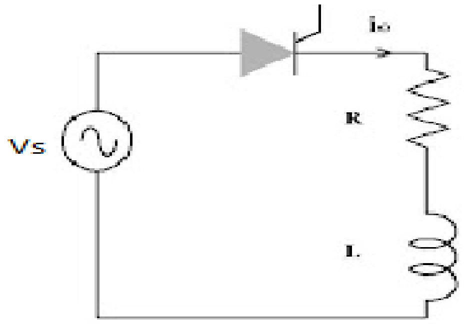

Fig.3 Equivalent circuit without snubber

Specifications:

Table 1: Parameters used without snubber circuit

Parameters	*Specifications*
Input voltage, V_s	230V
Inductance, L	1.004H
Resistance, R	0.5Ω

Plots Obtained:

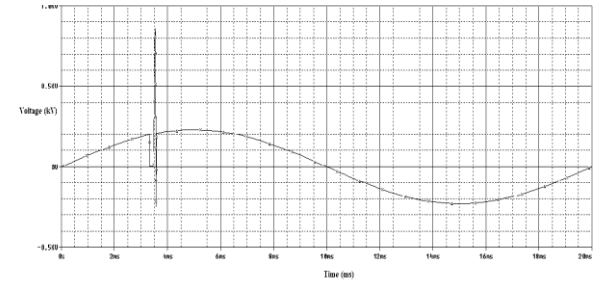

Fig.3(a) Voltage across SCR

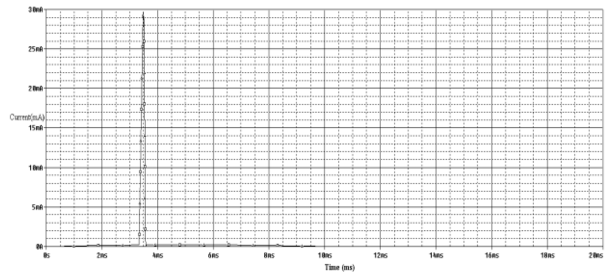

Fig.3(b) Current through SCR

From the above plots ,
dv/dt = 250V/ms
di/dt = 10A/ms

B. With Snubber Circuits

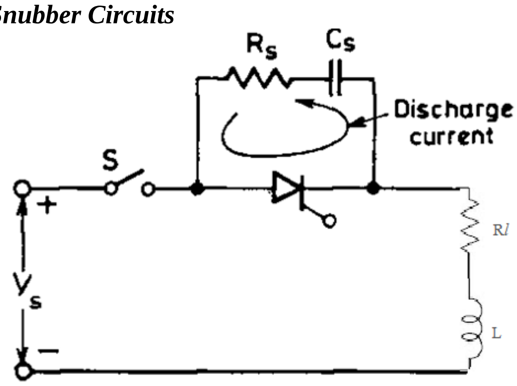

Fig.4 With snubber

Specifications:

Table 2: Parameters used with snubber circuit

Parameters	*Specifications*
Input voltage, V_s	230V
Inductance, L	0.023H
Capacitance, C_s	0.07F
Resistance, R_s	25mΩ

Plots Obtained:

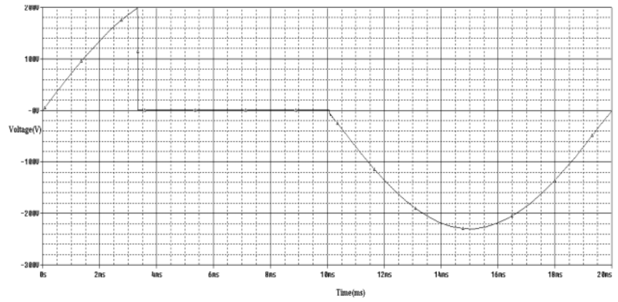

Fig.4 (a) Voltage across SCR

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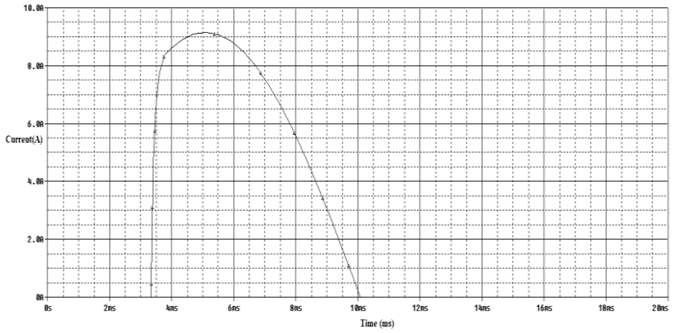

Fig.4 (b) Current through SCR

VI. CONCLUSION

On comparing the output results obtained in the absence of snubber circuit as well as by using snubber circuit; the transient found to be reduced in the snubber. This was simulated in Pspice A/D platform and results are obtained.

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