Selection Of SCRs For Parallel Operation

Application Note

Replaces September 2000 version AN5369-2.0

AN5369-2.1 July 2002

Selection of Thyristors (and Diodes) for Parallel Operation with non-reactor/resistor sharing.

When thyristors are intended to be used in parallel without the use of reactors or resistors to force current sharing then the thyristors must be chosen in such a way that they will share the current in relation to their forward voltage drop at the operating current.

This Application Note gives a simple way of doing this from the data presented in the device data sheet, based on a number of simplifying assumptions. The problems of differing turn-on performance, finger voltage etc. have not been considered here but are addressed in Application Note AN4999 "Turn-on Performance of Thyristors in Parallel". The treatise below is presented in terms of the fully turned on phase of a thyristor conduction cycle. The methodology can equally be applied to rectifier diodes in parallel.

Dynex Semiconductor will append a 4 digit selection number to the device type to specify your particular sharing criteria.

Consider the case of two thyristors in parallel with voltage V_2 across them. In this situation the total current is divided between the two SCRs such that SCR_1 is carrying I_2 and SCR_2 is carrying I_1. At the current I_1 SCR_1 has a forward voltage drop of V_1.

It is assumed here that all the variation in Forward Voltage Drop between the thyristors is due to variation in the slope resistance and that the knee voltage V_0 is the same for both thyristors.

SCR_2 is assumed to be the data book limit case device and V_0, rt_2 are the figures printed in the data book.

Now $V_2 = V_0 + I_1.rt_2$ for SCR_2

and $V_2 = V_0 + I_2.rt_1$ for SCR_1

i.e. $I_1.rt_2 = I_2.rt_1$

or $rt_1 = I_1.rt_2/I_2$ ....(1)

At the current I_1 we have:

$V_1 = V_0 + I_1.rt_1$

$V_2 = V_0 + I_1.rt_2$

$\therefore V_2 - V_1 = I_1.(rt_2 - rt_1)$

Substituting for rt_1 from (1) we have

$V_2 - V_1 = I_1.(rt_2 - I_1.rt_2/I_2)$

i.e. $\Delta V = I_1.rt_2.(1 - I_1/I_2)$...(2)

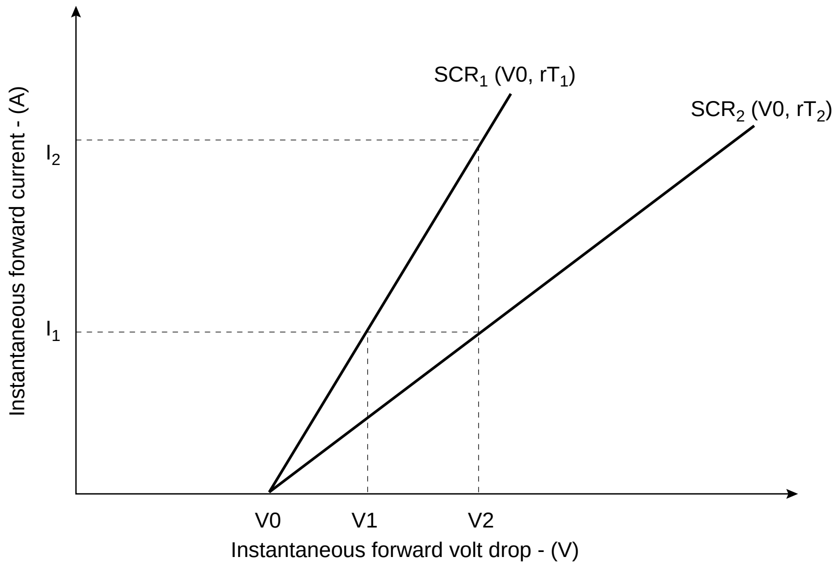

Fig. 1 Total current is divided between the two SCRs

Suppose that there is a situation whereby N SCRs are connected in parallel and are required to conduct a current I_{tot} amps with a given cooling system.

- In the worst case N-1 SCRs will conduct current I_1 and the remaining SCR will conduct

  $I_2 = I_{tot} - (N-1).I_1$ …………………….......................………(3)

- Define a mis-sharing factor (x) such that

  $I_2 = (1+ x).I_1$...……………………………………………….....(4)

Note that different people define mis-sharing in different ways. Some people would say that a 20% mis-sharing results in the current in two devices dividing 80/120. In the above definition this would be a mis-sharing factor of 0.5 because 120 = (1 + 0.5)*80 !

- $I_{tot} = I_1.(N-1) + (1+x).I_1$

  i.e. $I_1 = I_{tot}/(N + x)$ which is the lower current level.........(5)

- The maximum current I_2 is $I_{tot} - (N-1).I_1$

- This will be carried by the SCR with slightly higher losses because the voltage across all devices is the same, so the device with the higher current has the higher losses. If the conduction losses of the data book device calculated at I_2 are within those that the cooling system can disperse then the design is feasible.

- Substituting for I_1/I_2 from (4) into (2) and for I_1 from (5) we get

  $\Delta V = I_{tot}.rt_2.\ (x /((1+x)*(N+x))$ at I_1…………….........……(6)

  Note that the value of ΔV can be scaled by the factor I_{test}/I_1 to the value of ΔV at any test current point on the linear part of the forward volt drop curve.

If ΔV is too tight compared to the production spread indicated in the data sheet then the mis-sharing factor will have to be increased and hence the number of devices in parallel will have to increase.

Example 1 :

Consider 2 DCR1673SZ28 thyristors in parallel which are required to conduct a total of 40kA peak and share current to within ± 20% of the average i.e. one thyristor can take 24kA while the other takes 16kA.

For the DCR1673 rt is 0.093mW

To find the mis-sharing factor x : 24kA=(1+x)*16kA i.e. x = 0.5

From equation (6)

$\Delta V = 40x10^3 * 0.093x10^{-3} * 0.5/[(1+0.5)*(2+0.5)] = 496mV$ @ 16kA

The production test point for the DCR1673 is 3kA

So ΔV =496 * 3/16 = 93mV @ 3kA

Example 2 :

Consider running a number of DCR803SG12 thyristors in parallel to conduct a total of 1200A **average** current half wave with a heat sink that gives a thermal resistance, junction to ambient, of 0.155˚CW per device. The ambient temperature is 40˚C and the desired junction temperature is 100˚C .

Data sheet gives V0= 0.85V

rt = 0.38mohms

The maximum power that may be dissipated is (100-40)/0.155 = 387 Watts.

From the dissipation curves in the data sheet 387W is equivalent to 320A average 1/2 wave. This is the maximum current.

Assuming a mis-sharing factor of 0.2, the current in the other semiconductors is given by equation 4,

namely, 320 = (1+0.2) * I_1 i.e. I_1 = 320/1.2 or 267A

Number of devices required in parallel for 1200A is given by equation 3 i.e. 320 = 1200 – (N–1) * 267 or N = 880/267 or 4.29

Therefore 5 devices are needed in parallel for a mis-sharing factor of 0.2.

Because we have to use 5 thyristors instead of 4.29, the minimum current, given by equation equation 3, will therefore <u>actually</u> be: I_1 = (1200-320)/4 = 220A

i.e. a mis-sharing factor (x) of (1-220/320) = 0.3125 not 0.2 as originally.

Therefore equation (6) gives

$\Delta V = 1200*\sqrt{2}*0\ .00038*(0.3125/(1.3125*5.3125)) = 0.0289$ Volts or 29mV @ I_1= 267A average or 377A peak.

The datasheet V_F curve shows that the total spread of V_F at 377A for the DCR803 is ~50mV so that selecting devices to a 29mV band is reasonable and the use of two bands would utilise 100% of the production spread.

If we reduce the number of devices in parallel from 5 to 4,the lower current level would be (1200-320)/3 = 293.33 A

The mis-sharing factor (x) is therefore 1–(293.33/320) = 0.0833 and therefore ΔV = 12mV

i.e. to use the whole distribution, 4 bands would be required.

Using multiple Vf bands can cause problems with the supply of replacement devices and should be recognised before opting for the solution with the least devices in parallel.

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We offer an extensive range of air and liquid cooled assemblies covering the full range of circuit designs in general use today. The Assembly group offers high quality engineering support dedicated to designing new units to satisfy the growing needs of our customers.

Using the latest CAD methods our team of design and applications engineers aim to provide the Power Assembly Complete Solution (PACs).

HEATSINKS

The Power Assembly group has its own proprietary range of extruded aluminium heatsinks which have been designed to optimise the performance of Dynex semiconductors. Data with respect to air natural, forced air and liquid cooling (with flow rates) is available on request.

For further information on device clamps, heatsinks and assemblies, please contact your nearest sales representative or Customer Services.

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Target Information: This is the most tentative form of information and represents a very preliminary specification. No actual design work on the product has been started.

Preliminary Information: The product is in design and development. The datasheet represents the product as it is understood but details may change.

Advance Information: The product design is complete and final characterisation for volume production is well in hand.

No Annotation: The product parameters are fixed and the product is available to datasheet specification.