GUIDELINES FOR SELECTING TRIGGER CIRCUITS FOR THYRISTORS

BASIC REQUIREMENTS

For reliable triggering the gate current must be greater than the minimum dc value specified by the thyristor manufacturer at the lowest possible operating temperature. Assume this temperature to be -25°C for a 100A thyristor with a maximum gate current of 100mA at 25°C. The anticipated minimum gate current required for triggering all devices at this temperature is then about 160mA. To ensure reliable triggering, the gate current must never go below this value

However, if the thyristor is required to commutate the load current from another device in the case of a controlled rectifier or cycloverter, then due to the stored charge in the thyristor, the rate of rise of anode current can be very high. The same applies of course if a reasonably sized snubber network is placed across the device, which is needed to limit the transient voltage caused by the stored charge in the thyristor at turn-off. If the rated dc trigger current were applied to the gate then the device might fail after some time due to the limited speed with which the anode current spreads across the junction. At turn-on with high di/dt we find therefore that the area near the gate of the thyristor chip gets overloaded and thus damages the junction. For this reason it is necessary to ensure that the gate current rises very fast to a value well in excess of the rated trigger current to ensure that a bigger area becomes conductive when the fast rising anode current starts flowing. It is good engineering practice to choose a peak gate current of at least 4x the rated dc trigger current with a rise time of at least 1A/us. In the above case this would mean a current of at least 4 x 100 = 400mA. This current must be maintained until the device becomes conductive or during the maximum specified turn-on delay of the thyristor. In practice a time of 5 to 10us is chosen. It is important to note that the requirement for this peak gate current becomes less important as the anode voltage is lowered due to reduced heating on the gate periphery.

Consideration must also be given to the possibility of serious mains disturbances, which can terminate thyristor conduction. In such cases it is necessary to re-trigger the device as soon as the anode voltage turns positive again. It is therefore advisable to maintain the trigger current for the entire period during which conduction is required. This current should be not less than the minimum dc trigger current at the lowest possible operating temperature. In the above-mentioned case this would be 160mA.

Another important consideration is the latching current of the device. When for example highly inductive loads such as transformers are to be controlled, the anode current must have risen above the latching current of the device before the trigger current is removed while it is possible to control a rectifier with very short trigger pulses, it may cause serious difficulties with an ac controller. While it is preferable to maintain the trigger pulse during the required conduction period, it is possible to obtain a properly functioning system with a shorter trigger pulse provided the above is taken into account and the mains supply is clean.

Considering all the above aspects the Active Trigger Units are truly universal devices since they meet all the above aspects under all possible circuit and load configurations. Take for example the peak initial trigger current being greater than 1.3A rising faster than 1A/us for anode voltages above 100V can trigger any thyristor with a rated maximum dc gate current of 300mA. This covers the spectrum of most high power thyristors, because the very large devices rated at 3000A usually incorporate an amplifying gate structure which does not require such stringent triggering conditions (For unusual applications the present version can be extended to 2.5A) When looking at the necessity to maintain the trigger current during the required conduction period, the trigger unit performs this function perfectly provided the control input signal to the unit is maintained at 12mA. While the unit remains in the triggered mode, any fast rising anode voltage causes the thyristor to be triggered with the maximum gate current within less than 15us. The system reliably triggers unloaded mains transformers, controlled rectifiers, soft starters and very highly inductive magnet controllers. The concept has arisen from the need for a very compact universally applicable trigger circuit suitable for hostile industrial environments such as the mining and steel industry. A track record of many years of experience in many countries with all kinds of climatic conditions gives this product a high degree of confidence.

In order to understand some of the practical advantages of the Active Trigger Units, the design considerations using pulse transformers are discussed below.

PULSE TRANSFORMERS FOR CONTROLLED RECTIFIERS

It is possible to make a controlled rectifier using a small low cost pulse transformer, which will work under the proviso that the dc load has a very low inductance and the mains supply is very clean. This holds only for specific applications. If it is the intention to manufacture reliable equipment that works under all circumstances, then it must be assumed that the load can be inductive and that there are serious mains disturbances. It is therefore necessary to have a trigger pulse that is wide enough to ensure latching with inductive loads and which is continuously repeated with the smallest possible off time between the pulses. Furthermore while the pulse current must not be less than the specified dc trigger current at the lowest possible operating temperature, the initial gate current should be in the order 4x (rated dc trigger current at 25°C) for about 5-10us. If we have a thyristor with a rated dc trigger current of 100mA at 25°C then the transistor driver must handle a current of (4x100 + mag.current)mA, which is about 500mA. If the supply voltage for the driver is assumed to be 9V and the worst case gate voltage is 2V then the initial voltage available to generate a gate current is 9 - 2 = 7V provided the voltage ratio of the pulse transformer is 1:1. However in order to ensure resetting of the core in the pulse transformer we need a diode in series with the gate, due to the shorted emitter structure of the thyristor and this diode should be reasonably fast so that the forward recovery does not upset the fast rise time of the gate pulse. Also the driver transistor has a voltage drop of about 0,2V provided the device is properly overrated. Taking these factors into account, assuming the diode voltage drop to be not more than 0,8V we have 7 - 0,2 - 0,8 = 6V available for generating the 400mA and 160mA pulses. If the current is generated by a resistor, then the total circuit resistance including the pulse transformer must be less than 6/0,4 = 15Ω for the 400mA pulse and 6/0,16 = 38ohm for the 160mA pulse. Having a low cost pulse transformer with a 250uVs winding we get a maximum possible pulse width of 250/(max. gate voltage + diode voltage + IR drop of sec. winding) = 250/(2+0,8+0,5) = 75us. This determines the maximum allowable inductive load without multiple triggering, because the latching current must be reached before the end of this pulse. If the transformer has a leakage inductance of about 30uH then the L/R ratio for the 400mA pulse is 30/15 = 2us which is equivalent to a di/dt of about 0.18A/us. This value is too low for long-term reliability and therefore a much more expensive pulse transformer must be chosen. If it is desirable to meet VDE requirements as well, then such a transformer alone constitutes a price similar to the Active Trigger Unit.

In order to complete the picture, assuming that the gate current is generated by a resistor, the 400mA pulse must be obtained by bypassing the resistor with a capacitor in series with some resistance which is partly formed by the winding resistance of the transformer. Since we are dealing with considerable currents with short rise times it is sensible to decouple the gate drive circuit close to the pulse transformers to minimise interference with the remaining circuitry. If multiple triggering should happen due to very large inductive loads, it is not economic to solve the problem by increasing the snubber network, but rather to reduce the time between the trigger pulses. For this purpose the collector voltage of the driver transistor must be allowed to rise freely but with the restraint of not damaging the transistor, and therefore a clamping diode may be required.

The above design approach is based on current generation by means of a series resistor. A current source approach could also be considered, but would be more bulky due to the heat generated in the current source and is more sophisticated. The technical advantages of such an approach are minimal.

The last aspect to be looked at is the power supply. If the above circuit draws about 200mA from the 9V supply at a conduction angle of 120° then the steady state dissipation is 9 x 0,2 x 120/360 = 0,6W per thyristor. This brings the total dissipation for the trigger circuit to 6 x 0,6 = 3,6W. This power has to be paid for by a larger power supply and a bigger printed circuit board area over and above the requirements of the control circuit.

PULSE TRANSFORMERS FOR AC CONTROLLERS

For this application the pulse should be as long as possible to ensure reliable triggering with heavy inductive loads. This requires a large μVs value for the pulse transformer, which unfortunately also causes the leakage inductance to increase. With a large leakage inductance the gate rise time will be slow which could be acceptable for small thyristors with small snubber capacitors. For medium size and large systems the pulse transformer could be used as an energy transfer device and the gate current pulse shaping could be done on the secondary side of the transformer. This is not an elegant solution and would be better approached by choosing a much larger pulse transformer using the same approach as for the controlled rectifier above.

With ac controllers one of the anti-parallel thyristors has a reverse voltage applied to it while the other device is conducting. Therefore during triggering the reverse biased thyristor only sees the forward voltage of the conducting thyristor across its terminals. Because of this both thyristors can be triggered simultaneously provided the trigger pulse is carefully chosen. The pulse transformer must then have two separate secondary windings, one for each thyristor, and a series resistor with each gate to make sure that both gates receive a more or less equal trigger current. This again increases the size of the transformer slightly, because of the larger μVs required while still maintaining a low leakage inductance. With all the other conditions remaining the same the cost savings are not 50% as anticipated at first glance, because the bigger transformer together with larger ratings for components due to parallel triggering, offsets this ideal. Care must be taken in the control circuitry to avoid undesirable triggering of the next half cycle during low conduction angle operation. Therefore this system is not ideal for hostile environments, where sudden mains voltage changes associated with rapid phase angle changes can occur.

The AT401 trigger unit, which is designed for triggering two anti-parallel thyristors with a single trigger pulse. This allows for a similar cost advantage as the single pulse transformer version described above.

THE QUESTION OF COST

The cost of the conventional trigger circuit consists of the pulse transformer and all associated circuitry, the additional size of the power supply, the additional printed circuit board area, acquisition costs, inventory costs and labour. Adding all this and comparing the Active Trigger Unit with a system of equivalent performance for a 400 - 690V ac line, then the cost factor becomes relevant specially when considering low leakage inductance high performance pulse transformers. A further advantage is gained when a 1200V unit can be used.

A factor often overlooked is the implication of simplicity of a design and the possibility of using the same design for a multitude of purposes. It is convenient to know that the Active Trigger Unit performs perfectly well in all possible applications ranging from a few kilowatts up to more than 2 megawatts. A standardised design has many practical advantages over non-standardised systems, which lead to indirect not easily measurable cost savings.

THE QUESTION OF SIZE

For equal performance, the Active Trigger Unit saves at least 50% of space in comparison with standard pulse transformer technology. This space saving takes into consideration the practical layout of the board where minimum track separation for conformance to VDE standards is observed. In addition the increased size of the power supply and all the drive circuitry adds to the space. Power resistors or hot power transistors must be kept at some distance from other components. With Active Trigger Units it is possible to design a complete soft starter or a controlled rectifier including its own power supply on a single 100x160mm Eurocard. This becomes particularly impressive when one considers that the same card can control a small 5KW rectifier or a 2MW soft starter. From a practical point of view, size is important, because a smaller unit has much greater mounting flexibility than a large unit thus having indirect favourable cost implications. An aesthetic construction, which is facilitated by the Active Trigger Unit, makes the product more attractive to the customer.