AN307
APPLICATION NOTE

USE OF TRIACS ON INDUCTIVE LOADS

INTRODUCTION

Although triac circuits are now well known by designers. The use of these components for inductive loads requires certain precautions which should not be neglected of optimum use is to be made of them. That is the purpose of this article which reviews the various triac control modes and recalls the principles which guarantee its correct operation.

Phenomena Occurring when the Circuit is Closed

The triac is known as a component which is essential in controlling power from an AC source (mains). In most cases, the circuit has an inductive component: either because of the nature of the load itself: motors, transformers, ballast inductance; or because of the source impedance: utilization of the secondary of a transformer, length of the supply line, etc. On inductive loads, the operating conditions vary considerably, when closing the circuit, depending on the control mode (gate current, polarity and width) and synchronization of the firing. In order to build an optimal control circuit it is indispensable to analyse the various possibilities.

FIRING

Control Signal

The triac is fired by a gate current $I_g > I_{gt}$ whose duration should enable the main current to reach the triac holding current value (I_L). The width of the control signal is determined by the rate of increase of the main current (di/dt), limited by the load inductance and by the choice of the firing quadrant. The loading current, I_L, is highest in the second quadrant (A_2 positive with respect to A_1, I_g negative): (see Figure 1-a).

The rate of rise of the main current, di/dt, is proportional to the amplitude of the power supply voltage at the moment of firing (di/dt = V/L). The width of the firing signal required is less when firing occurs near the peak of the mains voltage than when its occurs around zero of that voltage (see Figure 1-b).

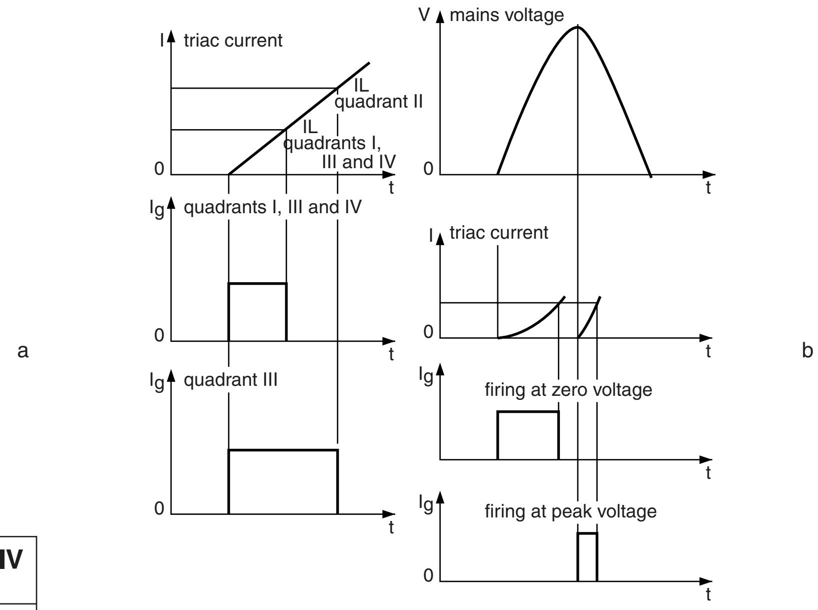
To fire the triac and to ensure conduction in continuous operation, we can compare various types of control circuits.

Gate Current Control by Single Pulse

To ensure correct operation, the gate pulse should be synchronized with the triac current zero point and should be long enough to enable the main current to reach the latching current I_L level (see Figure 2-a).

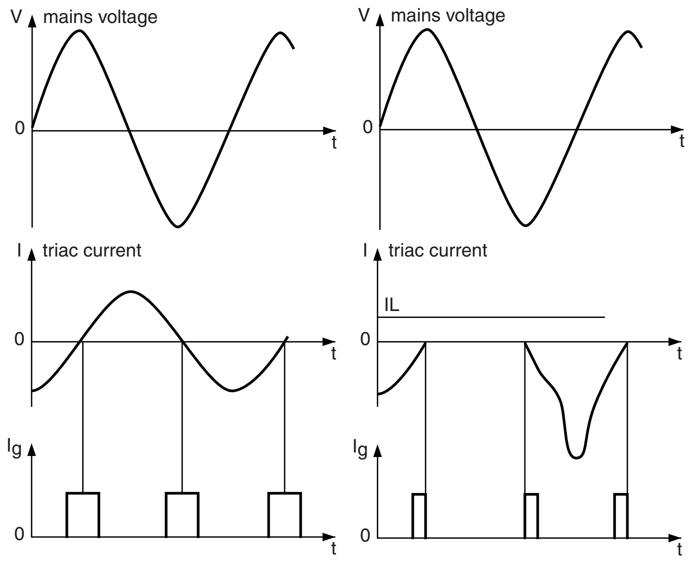
In case the pulse occurs before the triac current reaches its zero point (incorrect synchronization) or if its duration is too short to allow the main current to exceed the latching current I_L, the triac conducts only during alternate half-cycles. The high DC component thus introduced in the load can produce considerable overloads due to saturation of magnetic materials.

Figure 1. Width of Control Signal Required as a Function of the Firing Quadrant (a); width of Control Signal Required as a Function of the Moment of Firing (b)



Quadrants Polarity	I	II	III	IV
A2	+	+	–	–
G	+	–	–	+
with respect to A1				

Figure 2. Gate Control by a Single Pulse Synchronized with Zero Current (a); in Case of a Single Pulse whose Duration is too Short, the Triac only Conducts during Alternate Half-cycles (b)



Gate Control by Pulse Train

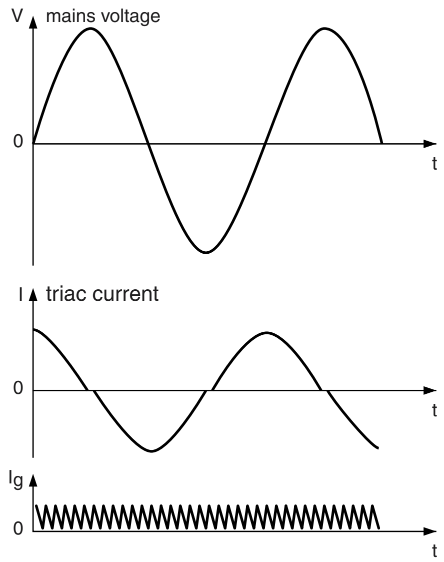
The control by gate pulse train eliminates problems of synchronization on the current. A recurrence frequency of several kilohertz guarantees correct operation of this type of control (see Figure 3).

This procedure, whose results are satisfactory, is often used for controlling triacs in inductive circuits. A variant of this principle consists in making use of a circuit which monitors firing and which delivers pulses to the gate as long as the voltage across the triac is higher than a threshold, usually fixed at about 10 volts (see Figure 4). This type of circuit enables delivering just the amount of gate current required for firing.

Gate Control by DC Current

Gate control by DC guarantees ideal firing but has the disadvantage of high consumption, specially when the control power supply is provided by the mains. In this case, it is preferable to use a negative current for the gate control (quadrants II and III).

Figure 3. Gate Control by Pulse Train



TRANSIENT PHENOMENA DURING TRIGGERING

Principles

During continuous operation, the magnetic field H, proportional to the current in the coil, varies with respect to the induction B, with a delay as shown by the hysteresis cycle in Figure 5. In transient operation, the induction can follow a different path and reach the saturation value BS for which the magnetic field H (according to the coil current) increases very rapidly (see Figure 8).

In the circuits controlled by a triac, opening occurs when the current is at zero. The induction thus has a remanent value Br, corresponding to H = 0 (see Figure 5). When the triac begins to conduct, the transients depend on the instant of synchronization of the control signal with respect to the mains voltage.

Figure 4. Firing Monitoring Circuit: the Control Signal is repeated until Firing

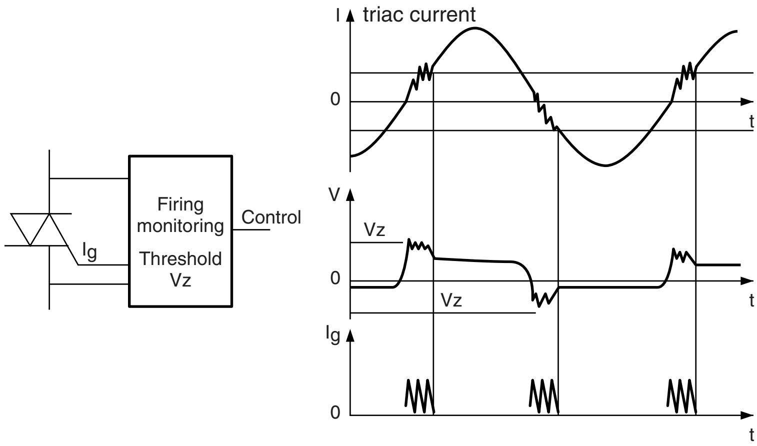


Figure 5. Magnetic Field H with Respect to Induction B in Continuous Sinusoidal Phase

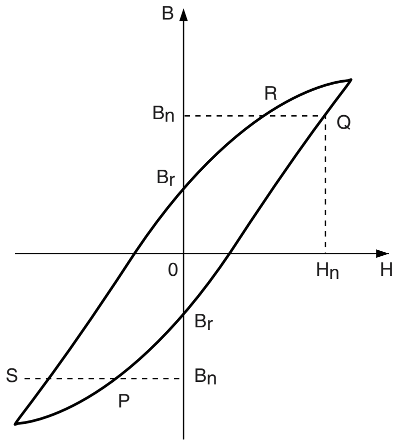
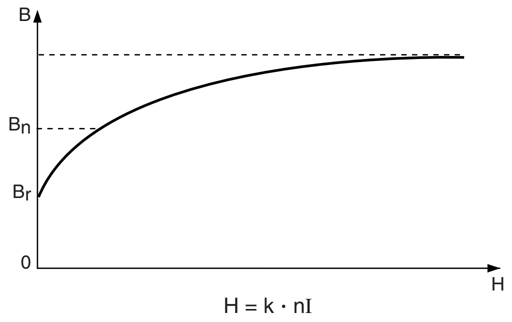


Figure 6. Induction Bs Versus Field H Variation



FIRING AT ZERO MAINS VOLTAGE

Peak induction tends to the value:

$B_{max} = 2\ B_n + B_r$,

thus in most cases reaching saturation induction B_s.

The amplitude of the current proportional to the magnetic field H becomes very high; this type of control produces the highest transient overloads (See Figure 7-a).

In order to limit the over current during firing at zero voltage, control must be done by complete periods. Since the triac allows an integral number of half-cycles to pass, the polarity of the mains voltage at the moment of firing is the reverse of that at the moment the circuit is opened.

Peak induction thus reaches the value:

$B_{max} = 2\ B_n - B_r$, because B rises between P and Q on the hysteresis cycle.

The overload is lower than previously but still remains high (See Figure 7-b).

FIRING AT PEAK MAINS VOLTAGE

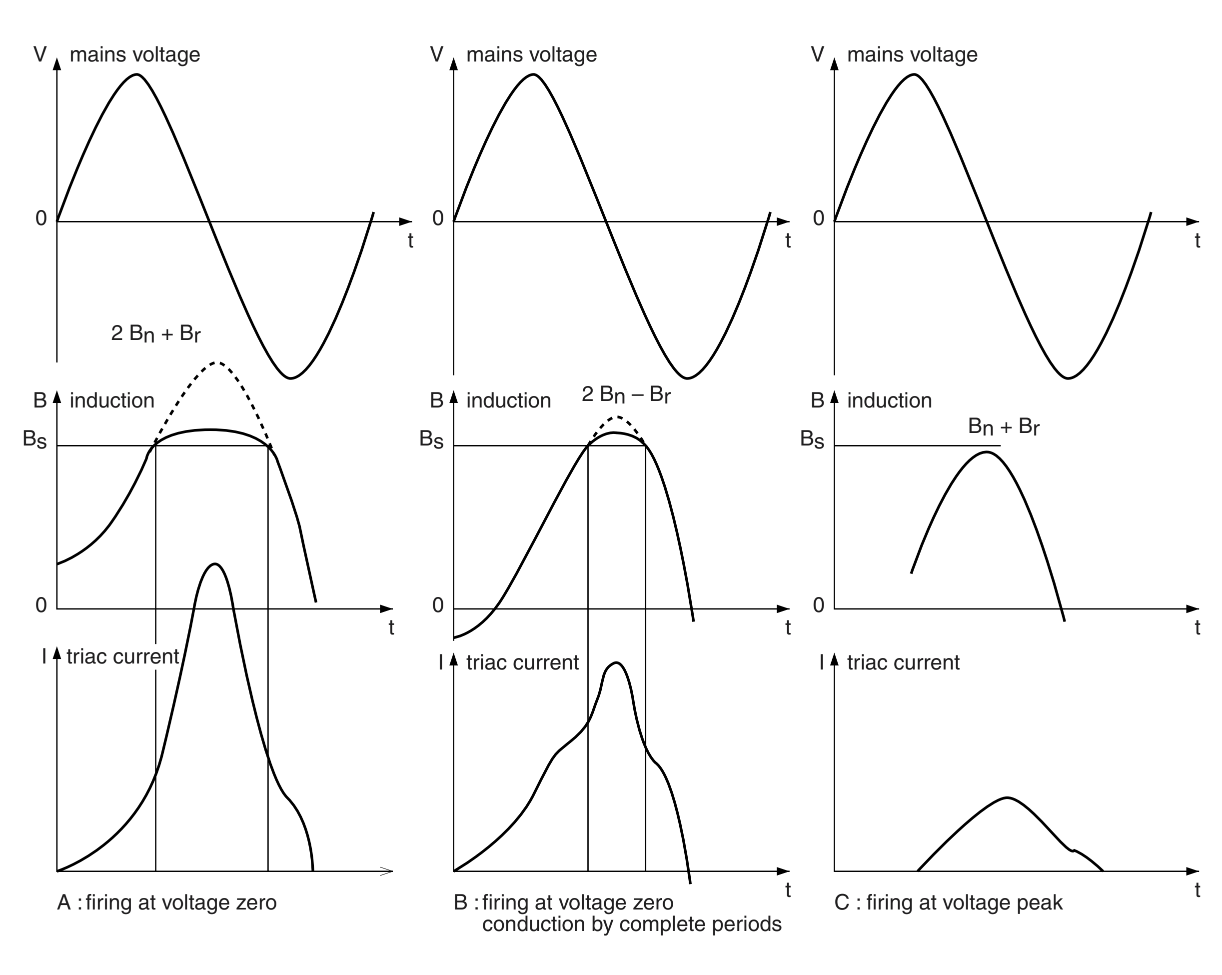
Peak induction takes the value:

$B_{max} = B_n + B_r$.

In general, the threshold of saturation B_s is not reached and amplitude of the current remains within acceptable limits (See Figure 7-c).

This type of synchronization is simple and efficient and should be adopted whenever possible on loads composed of materials which can be saturated.

Figure 7. Transient Induction and Current at Beginning of Conduction



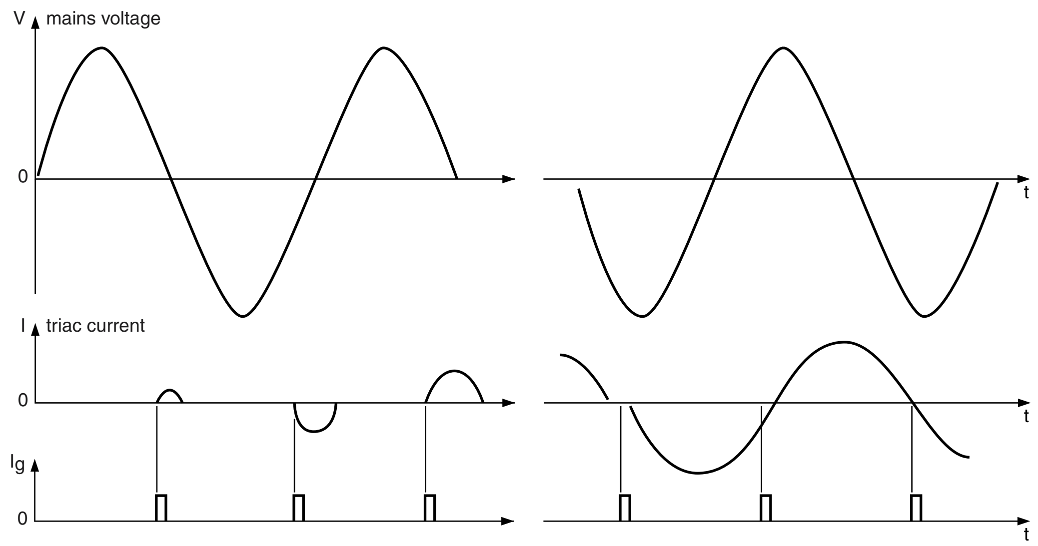
FIRING AT INDUCTANCE PHASE SHIFT WITH CONDUCTION BY COMPLETE PERIODS

Firing at the real inductance phase shift with conduction by complete periods places the magnetic field and the induction on the hysteresis cycle of continuous operation: consequently, transients are eliminated. However, the design of the control circuit for this firing mode is complex and consequently it is reserved for special applications.

FIRING BY PHASE SWEEP

The triac is first fired at the end of a half-cycle. Then progressively the difference of phase between the voltage zero and the instant of firing decreases until total conduction. With a sufficiently low sweep speed, any transient overload is thus avoided (see Figure 8). This procedure is widely used and gives very good results.

Figure 8. Firing by Phase Sweep



SPURIOUS FIRING

The control circuit plays an important role in normal operation. However, in case of spurious firing, the triac may have to withstand an accidental overload. The peak amplitude of the current which could flow through the triac should be known to select its rating: the maximum current which could flow through the circuit should not be higher than the accidental overload capacity of the triac (ITSM). In this care the triac is oversized.

CONCLUSION

We have seen the essential points guaranteeing correct operation of a triac. If the circuit is closed on an inductive load, you need to:

Fire the triac: With a sufficiently wide gate control signal, in the chosen quadrants (depending on whether higher sensitivity or a low latching current is required).

Avoid transient overloads: By synchronizing the control signal with respect to the mains at the moment of firing (firing of the triac at zero voltage should be avoided).

Keep the triac in conduction: By selection of the type of control (avoid gate control by a single short pulse).

REVISION HISTORY

Table 1. Revision History

Date	Revision	Description of Changes
February-1989	1	First Issue
31-Mar-2004	2	Stylesheet update. No content change.