Commutated relay spearheads new switching technique

By combining the long-life and non-arcing properties of semiconductors with the transient and high-current accommodation of relays, more reliable switching is achieved.

A HYBRID relay-semiconductor circuit fills a long-standing control systems need. It removes the inherent weaknesses of each switching element and possesses the desirable virtues of both.

Unlike the conventional relay-semiconductor combination, the commutated relay uses a solid-state switch as a full-load carrying element, but only for short periods. The semiconductor can thus carry loads far in excess of its rating because the load-carrying intervals only occur when the relay is opening or closing.

In the conventional system, the semiconductor's role is confined to buffering, suppressing, or such auxiliary functions as providing time-delays.

The relay's coil is also used in a different way in the commutated relay. It serves as a control mechanism in which the contacts are used both to gate the semiconductor and to carry the full load current for most of the operating cycle.

The commutated relay can thus switch motors and other power systems without the usual arcing or high noise. It is more reliable, has a high-power capability, longer operating life, and easily accommodates the transients generated. In one case this hybrid approach resulted in extending the operating life of the relay used from 50,000 cycles to over three million cycles.

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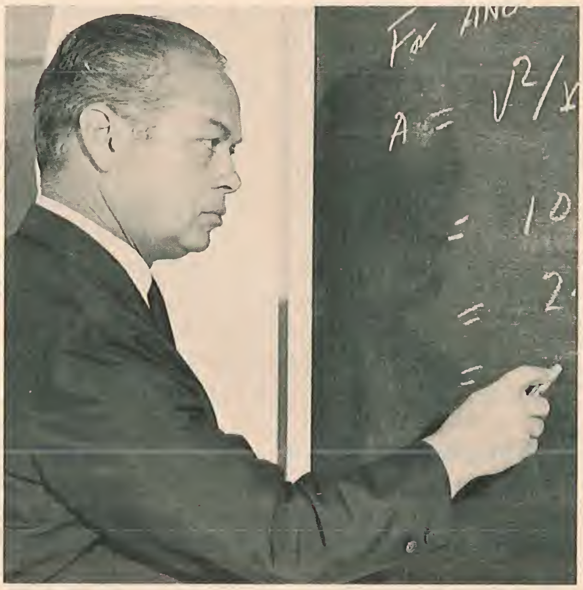
Weaknesses of the usual approach

What's wrong with the conventional approaches to relay or semiconductor switching? Both the relay and the semiconductor



Chalking up another hybrid switch? Author-inventor vonBrimer, working out the design of a future addition to the commutated relay device family.

possess certain shortcomings as switching devices. Their limitations result in high cost due to short life and low reliability.

The relay has the following weaknesses:

- Generation of mechanically induced noise into the system.
- Short life under high-current loads.
- Shortened life and limited reliability due to contact-arcing.
- Relatively slow switching speeds.
- Lengthened delay before reaching steady-state because of contact bounce.

Relay advantages for general switching applications are:

- Ability to withstand very high voltage and current transients.
- Very high steady-state load ratings.
- Circuit simplicity.

On the other hand, semiconductor limitations are:

- Comparatively low current ratings.
- Vulnerability to current and voltage transients.
- Relative circuit complexity.

It does possess the following desirable traits:

- Rapid switching speeds.
- Long (virtually infinite) life.
- Relatively quiet operation.
- Toleration of high magnitude, short-duration signals well beyond steady-state ratings.

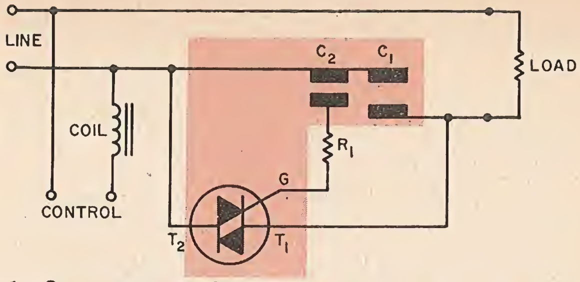
A description of commutated relay operation shows how the respective weaknesses are nullified and the strong points combined.

Operation of the commutated relay

The commutated relay (Fig. 1) functioning is keyed to the triode ac semiconductor switch (a five-layer diode also known as a Triac) and its arrangement with the delay contacts.

The Triac can be turned on by a signal of either polarity and will conduct in both directions.[1] The "gate" signal is supplied from the line voltage through dropping resistor R_1. In switching currents of 50 amps (at 125 vac), the controlling gate current is 50 ma at 3 volts, or, 0.15 watts. Thus, the dropping resistor R_1 need only have a 0.5 watt rating.

A single-pole, single-throw relay with auxiliary contact C_2 is used. The contacts have been pre-adjusted so as to achieve a sequential order of switching. The load contact C_1 has a wider gap than the auxiliary contact C_2. Thus, when the relay coil is energized, C_1 will close after C_2 has closed. Similarly, when the coil is de-energized, C_1 will open before C_2 does.



1. Commutator relay circuit features Triac switch and unique contact arrangement to achieve more reliable switching. This approach combines the desirable attributes of its semiconductor and relay components and overcomes the inherent limitations of each.

Operating sequence is as follows: As the coil circuit is energized, contact C_2 closes and turns on the Triac. This supplies current to the load through terminals T_1 and T_2. A very short interval later, load contact C_1 closes, and, by its shunt connection of low resistance, removes the load current from the Triac for the duration of the ON cycle.

When the coil circuit is de-energized, contact C_1 opens (while the Triac is still energized) and the load current transfers to terminals T_1-T_2 without any arcing. A very short interval later, contact C_2 opens, turning off the Triac. Typically, the time interval between the operation of the contacts C_1 and C_2 would be 2 msec for a relay with a total operation time of 5 msec.

In the commutated relay, a Triac with a continuous rating of six amperes will easily switch short-time transients of 1000% overload.[2] Note that the I^2t rating of the Triac is the governing design point. This means that switching may occur later in the cycle, so long as the higher magnitude current (borne by the Triac) has a proportionally reduced duration. Thus the control circuitry must be time-regulated to accommodate this limitation. The relay contacts will also conduct transient currents of this magnitude as long as the semiconductor performs the main switching function. For over-voltage transients, the Triac is only exposed for 2 msec per second of operation. Expressed as a ratio of OFF-time to ON-time, the duration of exposure to overvoltage or overcurrent is reduced by a factor of 500.

Commutated relay has high reliability

Reliability is usually the most important attribute to be considered. The major factors contributing to relay failure are contact arcing (on interruption) and contact bounce (on making contact). These negative factors are eliminated in the commutated relay.

Major factors in the failure of solid-state switches are either high current levels or short-time, high-voltage transients during operation. Since the relay contacts short-circuit the semiconductor for all but an infinitesimal part of the operating cycle, these problems are eliminated.

The bounce characteristics found in conventional relays are also reduced by the commutation system. The contact bounce of the gate-switching circuit (C_2) is electrically eliminated, as the initial contact gates the Triac switch on. The switching time consumes 20 μsec. The Triac will remain on without any further gate signal until a polarity reversal occurs at the half-cycle crossing of the load current. This reduces the current below the holding value for the Triac. For this reason, the load does not see any contact bounce at C_1 or C_2, even if it does occur.

The operating speed is also improved by the commutated relay. Moreover, there is much less variation in the switching times with load. In conventional relays, the bounce will vary with individual relays, adjustments and the nature of the load. With commutation, this variation, as well as the usual relay change in pull-in, drop-out, contact resistance, etc., (due to mechanical erosion and wear) are reduced.

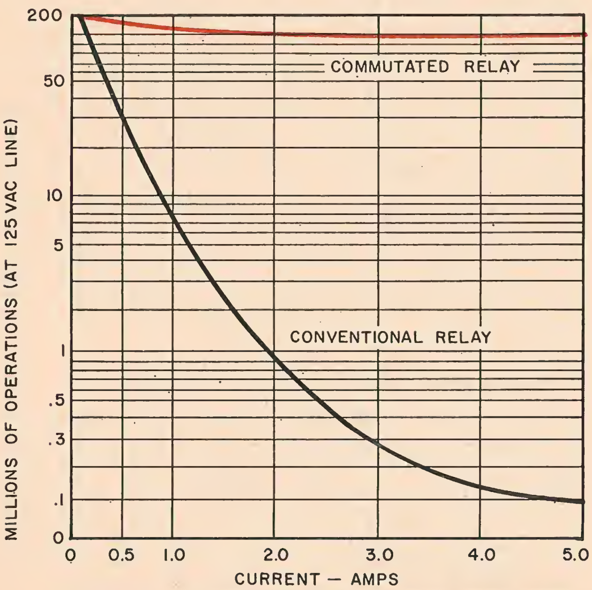
Low-level current flow and dry operation are both achieved with the desirable minimum contact drop of a relay. However, because of the switching function of the semiconductor, the failure tendency due to oxidized contact surfaces (a common occurrence with conventional relays) is decreased. Commutated relays are relatively free from unwanted switching due to voltage spikes or circuit transients. This is because the mechanical reaction-time of the relay is usually longer than the duration of the spike or transient. The Triac is isolated from these transients because the relay will not close on them; this adds greatly to the overall reliability of the unit.

In many applications, the commutated relay should be considered as a simple redundant system with the relay effectively paralleled by a solid-state switch. With this premise, it is evident that the relay's reliability and life are increased several hundred times by the elimination of arc damage to the contacts. The semiconductor has its reliability and life increased because of its isolation from circuit transients and its confined use (short duty-cycle). Together, the life and reliability of a commutated relay is thus much greater than that of a simple relay or solid-state switch when either is used independently (see Fig. 2).

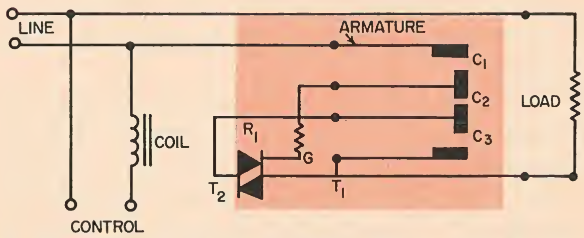
Extending the commutation principle

In some industrial applications, the line transients of overvoltage or high frequency (dv/dt effects) may cause some spurious switching with the circuit of Fig. 1. A slow-down RC filter placed across terminals T_1–T_2 will alleviate this problem. Overvoltage protection devices (such as suppressors) can also be used to eliminate this spurious switching effect.

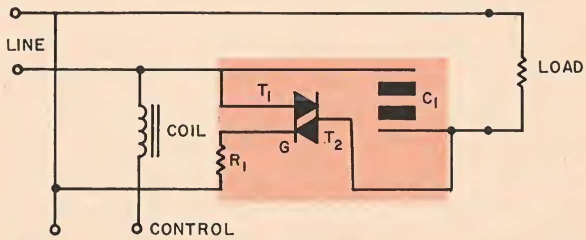
A cascaded contact arrangement can be used to isolate the semiconductor from the line transients (Fig. 3). The operating



2. **Increased lifetime is just one** of the benefits reaped by the commutated relay principle.



3. **Cascaded contact arrangement** on a circuit offshoot of the commutated relay isolates the semiconductor from line transients.



4. **Faster turn-on of the switching circuit** is provided when the Triac gate circuit is parallel to the relay coil. Current reaches the load in just 15 μsec.

sequence is similar to that of Fig. 1, the major difference being the isolation provided by the extra contact (note that complete isolation of the switch component is provided until contact C_2 is closed).

When the coil is first energized, contact C_2 gates the Triac switch ON to provide load current flow until contact C_3 closes and shorts out the Triac. On the release of the relay (de-energization) contact C_3 transfers the load to the Triac. Contact C_2 "de-gates" the Triac to OFF, thus opening the load current path. Contact C_2 is the last to open and it isolates the switching system. It is arranged to open slowly in order to give the Triac time to effect complete interruption of the load current. The purpose of contact C_1 is to always open or close under zero current conditions in the circuit.

For the faster turn-on of more substantial loads, a semiconductor switch can be gated on by the control circuit at the same time the relay coil is energized (see Fig. 4). Operation of the system is as follows: The Triac is turned on by its gate circuit at the same time the relay coil is energized. This permits current flow through the load in just 15 μsec. The relay contacts close about 5 msec later (333 times slower), and remove the load from the Triac by their parallel (short-circuit) resistance. For the duration of the ON time, the Triac does not see any load. The contacts, being closed, have a very high-current capability.

As the control switch is opened, the relay contacts open, but the Triac stays on until a current zero-point is reached. As this point is passed, the relay contacts have already established a small gap, thereby preventing the starting of an arc. Note that the Triac does not (in the absence of gate signal) remain ON past the zero current point.

Although this discussion was limited to an ac circuit using a Triac for relay commutation, this does not imply that the technique is limited exclusively to that combination. SCRs, transistors and many other solid-state devices may be similarly fitted into multiple-throw switches, deck switches, stepping relays, and many other electro-mechanical components to achieve commutated switching. The commutated relay may thus be viewed as the forerunner of many a novel, hybrid-type approach to control systems design. ■ ■

References

1. E. K. Howell, "Triac Control for AC Power." General Electric Application Note 200.35, May, 1964.

2. General Electric Data Sheet "Silicon Gate-Controlled AC Switch ZJ257/285 (Triac) 175. 10," Feb., 1964.