The International Standard on Solid-State Relays (IEC 62314, Ed. 1)

Critical Review

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Subject and Scope

1.1. In this section I focus on the scope of the standard. According to the standard the scope is limited to solid-state relays with rated voltages of up to 750V and AC currents up to 160A. In the remarks it is noted that requirements for solid-state relays with DC output circuits are under consideration. These remarks are a little bewildering: what is the necessity to release a standard on the solid-state relays that covers only a small fraction of the solid-state relays that are available in the market today? In fact, many types of solid-state relays with the output element in the form of two powerful MOSFET transistors can switch both AC and a DC current, Fig. 1. The absurdity of the situation becomes apparent when one considers that only half of such relay (AC) is covered by standard IEC 62314, while the other half of the same relay (DC) is not covered.

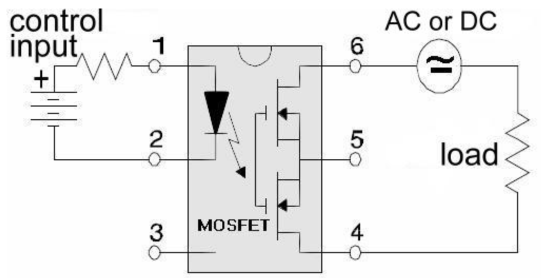

Fig. 1. Solid-state relay rated for both AC and DC loads

Even the standard itself (in note to Section 3.1.8) recognizes that “the same solid-state relay may be … rated for both a.c. and d.c.”

Also it is not clear of what current and voltage values it’s speaking, usually for semiconductor devices the peak values are specified while for electromechanical relays the r.m.s values are specified. Such ambiguities in the international standard are, in my opinion, inadmissible.

1.2. Again in the Scope it is noted that the “solid-state relays are components (not stand alone devices) and, as such, do not perform a direct function. Therefore, no EMC requirements are included in this standard.” In my opinion, this is rather debatable. First, very often solid-state relays are used for direct switching of electric motors, solenoids, heating elements, lighting lamps, etc., in which case all control equipment consists of this relay only, without any additional electronic control circuits, and as such it is a stand alone electronic device incorporated into power equipment which does not contain any other low signal electronic elements. Electromagnetic compatibility (EMC) of such power equipment is determined completely by the solid-state relay only. The consumer has to know about the EMC of the equipment (solid-state relays in this example).

Secondly, in itself even the simplest solid-state relay contains many complex built-in electronic components: light emission diodes (LEDs), photo diodes or phototransistors, electronic

amplifiers and triggers, synch circuits with a network voltage, elements of overvoltage protection, etc., that characterizes it more as a complex electronic “device”, and not a simple “element”.
Thirdly, today in the market there are so-called "intelligent" solid-state relays with expanded functions, supplied by complex electronics, and sometimes even a built-in microprocessor.

For the above reasons, the EMC requirements should of necessity be included in the standard of such rather complex electronic devices as solid-state relays. It is not only our opinion. In [1] introduces research results for influence of voltage harmonics and EMC on solid-state relays in industrial applications. From the test results, it is can be generally concluded that the effect of harmonics and random high frequency distortion would lead to a delayed opening and closing of the solid-state relays. Any discontinuity or line disturbance that interferes with the triggering and latching process can cause the solid-state relays to mistrigger by dropping out half-cycles.

1.3. According to standard “solid-state switching device with monolithic structures fall within the scope … and are not covered in this standard”, however it does not explain what is exactly “the monolithic structure”.

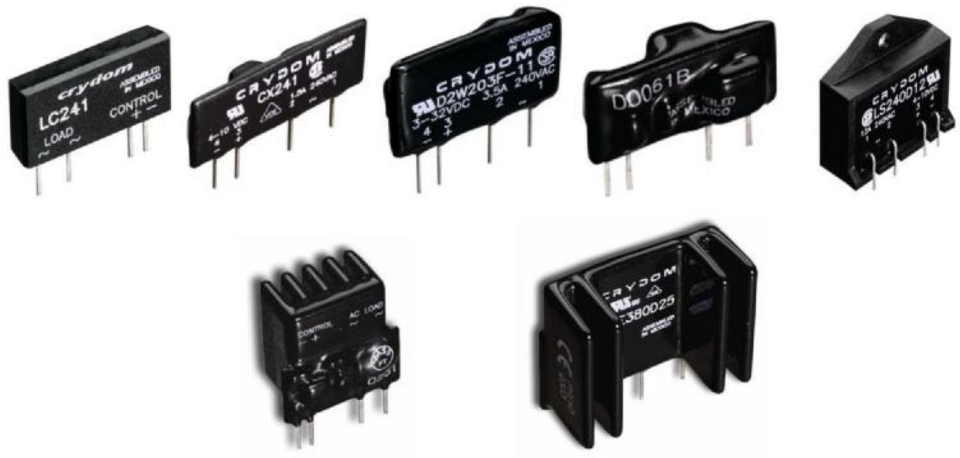

Fig. 2. Solid-state relays from Crydom with monolithic structures embedded in epoxy resin and integrated with a heat sink

Besides the definition for “the solid-state relay” given in Section 3.1.1 (the analysis of this definition is given later in this article) does not expel presence of the monolithic structure in the solid-state relay. In fact, the terms "solid-state" and "monolithic" are almost synonymous! Such absolutely non-valid restriction of a scope is, in our opinion, inadmissible. For example, it is possible to buy solid-state relays from a widely known company, Crydom, with many years of specializing in the production of such relays, Fig. 2, which represent monolithic structures, embedded in plastic or filled with epoxy resin. In some cases, as a uniform monolith it is integrated as well with a heat sink. According to standard IEC 62314 it is claimed that these relays fall within the scope only because they filled by epoxy resin? What logic is in this is not clear!

1.4. The standard states that semiconductor contactors fall within the scope, but does not give any definition to the term “contactor”. However, without precise definitions of the differences between the “relay” and the “contactor” it is impossible to understand precisely what devices fall within the scope.

Analysis that we have performed has shown that today there are no precise boundary lines between the “contactor” and the “relay” and no precise definitions allowing referring to this or that concrete switching device as a “contactor” or as a “relay” univocally.

Fig. 3. Solid-state contactors for low currents and solid-state relays for high currents (produced by ABB)

The opposite is more true, in the technical literature today there is complete arbitrariness in the assignment of names "relay" or "contactor". By what criterion, for example, has the world leader in the field of electrical equipment, ABB, used when referring to some of its solid-state switching devices as a "relay" class, and others as a "contactor" class, Fig. 3?

The single basic difference that we have detected by analyzing the technical parameters of these two products “classes” is that contactors are equipped with the heat sink, and the relay not. Of course this doesn’t prevent a relay’s user from adding a heat sink to the relay at switching current more than 5 – 10 A, in this case does it “magically” become a contactor? We think not, a solid-state contactor is the exactly the same as a solid-state relay, but installed on a heat sink?! We have even seen an Internet Web site where this was acknowledged. However, adoption of such a criterion as the absence or the presence of a heat sink for differentiating between “relay” or “contactor” for a switching device is patently absurd, Fig. 4. Besides we have to keep in view that at rated currents of 10 and more amperes any semi-conductor switching device (both the “contactor” and the “relay”) demands a heat sink. Without a heat sink these devices are capable of carrying only a small percentage of rated current.

Fig.4. The absence or the presence of a heat sink for differentiating between “relay” or “contactor” for a same switching device is seems as patently absurd

Thus, with the absence of a clear boundary between "contactor" and "relay", it remains absolutely not clear what product is covered by standard, and what products fall within the standard as the upper limit of currents established in the standard (160A) characterizes. It seems to be that it is more likely to be power contactors rather than the relays. If such boundary is not established, it is obviously impossible that the given section should restrict the scope of the standard, and this should be removed as absolutely not correct.

Terms and Definitions

2.1. In Section 3.1.1 the definition for the term “solid-state relay” is given. According to the standard it is an “electrical relay in which the intended response is produced by electronic, magnetic, optical or other component without mechanical motion”. What is the “intended response” in this definition? We understand this as “the response upon an input value”.

Generally, any electric relay has an input sensing element that “responds upon an input value”, and an output element that performs the switching in an external circuit. In a typical electromechanical relay these elements are a coil with magnetic system and contacts.

Apparently, from the definition given in the standard, the principle of construction of an input control circuit stipulates only that it should not contain any moving components, while the output power switching circuit is not characterized in any way. Therefore, under the definition given in the standard, any solid-state relay may be a suitable device that consist semi-conductor input sensing transducer (optocoupler, for example), the semi-conductor amplifier and the output electromagnetic relay. On the other hand, well-known relay design in which it is embedded epoxy resin, includes a semi-conductor output switching element (the thyristor, the transistor) controlled by a reed switch. The control coil of the reed switch forms a magnetic control circuit of the relay. The relays based on this well-known principle are widely used [2, 3]. But the reed switch contains internal moving components, so, such a device cannot be referred to as a “the solid-state relay” in spite of the fact that it meets to all requirements of standard IEC 62314 except the definition of the term: “the solid-state relay”. Another example is a unit containing two back-to-back connected power thyristors (the natural solid-state switch) controlled by external push button, Fig. 5, is this a “solid-state relay” or not?

In our opinion definition of the term “solid-state relay” presented in IEC 62314 is not correct and requires revision with an orientation to the "solid-state" character of the output element that is carrying out switching of an external circuit (load) instead of to the design of a control circuit.

2.2. In Section 3.1.4 of the standard “rated insulating voltage” is defined as the “value of voltage to which dielectric tests and creepage distances are referred”.

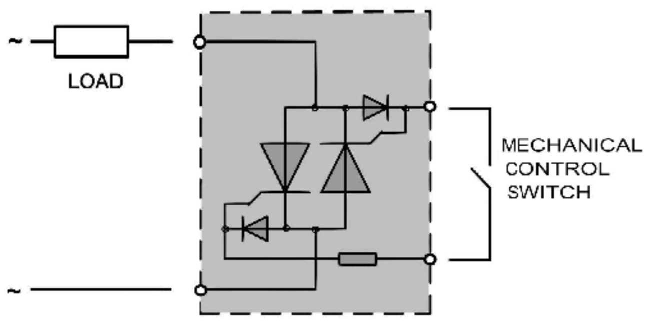

Fig. 5. Solid-state relay controlled by mechanical switch (push button, for example)

In our opinion, it is rather strange and is not, per se, a defining formulation. The definition of the “rated insulating voltage” should be absolutely precise and circuits to which this voltage refers (apply) must be clearly stipulated. For a solid-state relay it is usually accepted to use terms such as “withstand voltage” or “dielectric strength” to relate the connection between the internal input control element and the output switching element connected into external load circuit, and also between a metal plate on the relay body (intended for contact with the heat sink) and all other current-carrying terminals of the relay. In our opinion, these would be a more correct definition for the term under consideration in that they are more precise and widely used in technology. In addition the standard has to stipulate parameters of the “voltage” as r.m.s. or peak value, AC or DC, time interval for voltage applying. Without of all these, it is impossible to understand and to use term “rated insulating voltage”.

2.3. In Section 3.1.5 the definition of the term “rated impulse withstand voltage” is given as “peak value of an impulse voltage of prescribed form and polarity which the solid-state relay is capable of withstanding without failure under specified conditions of test and to which the values of the clearances are referred”.

And again, as well as in the previous case, it is not certain to which circuits of the relay the term is to be applied. The question is that in the solid-state relay there are some independent circuits isolated from each other to which the term a “rated impulse withstand voltage” can be applied, and these circuits have essentially different levels of insulation, and, hence, and withstanding voltages, leading to uncertainty in the use of this term. For example, in the solid-state relay of type R111/25 (with a nominal operating voltage 280 V AC) the withstanding peak voltage across terminals of the switching element can reach 650V, and between an input control circuit and an output circuit of the switching element – 4000 V. In the low-power solid-state relay H11D1 type the withstanding peak voltage across the terminals of the switching element can reach 300 V, and between an input control circuit and an output circuit of the switching element – 7500 V. So, what is the “rated impulse withstand voltage” in these examples?

2.4. In Section 3.1.6 “rated operational current” is defined as “normal operating current when solid-state relay is in the ON-state and takes into account the rated operating voltage, the rated frequency (4.3), the load category (4.4) and the overload characteristics at 40 °C ambient temperature unless otherwise specified”.

In this definition, first it is not clear what is "normal" current, and what is "abnormal" current? Normally, the current carried through an ON-state relay is fully dependent on the load and may change over a broad range in accordance with how the load changes. So, what is the “normal” current?

Secondly, what is the relation to the current carried through ON-state relay, that is, with the output switching element being in a full conductive condition, is it also the “rated operating voltage” which has been applied to an output circuit of the relay before switching to the ON-state? In fact after the relay switches ON, any operating voltage cannot be applied to an output circuit of the relay as in the ON-state there remains only a small voltage drop (shares or units of Volt), depending on the current carried on the switching element.

Thirdly, as is known from the theory of the power solid-state devices, the unique criterion, limited to a carried current, is the temperature of its internal semiconductor structure which strongly depends on the presence or absence of a heat sink, and type of cooling (natural, air compulsory, water, etc.), frequency of load switching, power factor, and the duty cycle.

In connection with the above, the definition “rated operational current” must be changed to a more correct form: “the maximal effective value of a current carried through output switching element of solid-state relay in stationary mode for a long time period, when the temperature of its internal structure does not exceed maximal admissible temperature for the given kind and a material of semi-conductor structure, for the specific type of a heat sink and cooling conditions at 40 °C ambient temperature”.

2.5. In connection with the above, it is definitely not clear what the “rated uninterrupted current” the solid-state relay is. It is defined in Section 3.1.7 as the “value of current stated by the manufacturer, which the solid-state relay can carry in uninterrupted duty”. If this is so, can’t the “rated operating current” (from Section 3.1.6) of the relay also carry current in an “uninterrupted duty”? What is a difference between these two currents?

2.6. The new concept is introduced into Section 3.1.11 of the standard: “rated conditional short-circuit current”, which is treated as the “value of prospective current, stated by manufacturer, which the solid-state relay, protected by a short-circuit protective device specified by the manufacturer, can withstand satisfactorily for the operating time of the device under the test conditions specified in the relevant product standard”.

We make no further comments, it is simply impossible to understand the definition.

2.7. The definition for “leakage current” is presented in Section 3.1.12 as the “r.m.s. value of maximum current, stated by the manufacturer, which solid-state relay can carry in OFF-state condition”.

As the leakage current strongly depends on the voltage applied to the output switching element of the relay, and also on its temperatures, in our opinion, it would be necessary to add the words: “… at the maximum operating voltage and the maximum admissible temperature of solid-state structure” to this definition.

2.8. The definition of the term “ON-state voltage drop” is treated in Section 3.1.13 as the “peak value of voltage, stated by manufacturer, between solid-state relay terminals in the ON-state condition”, demands additions and refinement.

First, it is not clear why the ON-state voltage drop is to be characterized by the “peak value”. As is well known, the ON-state voltage drop characterizes the power dissipation and heating of the solid-state elements in conductive mode. Why must the power dissipation be characterized by a peak value and not by an effective value?

Secondly, actually the solid-state relay has both terminals of an input control circuit and terminals of output switching elements. In most types of solid-state relays both input and output circuits contain semiconductor elements: LED in input and thyristor or transistor in output. Both of these elements are characterized with ON-state voltage drops. So the question arises, about which “terminals” is the standard talking?

Thirdly, if the standard means the output switching element, a voltage drop on it is determined not only by physical properties of this switching element, but also by the current passing through it. Unfortunately, in the definition given above the connection of voltage drop with a current for which this voltage drops is missing. All these make the term absolutely indeterminate and unsuitable for practical use.

2.9. In Sections 3.2.3 and 3.2.5 “Terms and Definitions” two terms are defined: “Functional Insulation” and “Basic Insulation” are defined and are further used throughout the standard. According to IEC 61810-1 "Functional Insulation" is the insulation necessary only for the proper functioning of the relay and the insulation protected from the electric shock is defined as "Basic Insulation". As an explanation of the difference between these two kinds of insulation, in remarks to tables 10 (h) and 11(e) an instance of "functional" insulation is given as the insulation between contacts of the relay, necessary (as affirmed in the standard) only for the proper functioning of the relay. It is impossible to agree with this assertion, for it is abundantly clear that the same insulation can be “basic” or “functional” depending on the application of the relay. For example, if contacts of the relay make switching in the electric circuits inaccessible to a contact by the person, the insulation between contacts of the relay really is clearly functional, but if contacts of the relay disconnect a voltage source of a part of the electrical installation to which there is an access of a person (direct or mediated, through other electric circuits) this is already “basic” insulation. On the other hand, the relay is often used for galvanic decoupling circuits with the different potential in the equipment, thus insulation between the coil and contacts of the relay has no relation to safety of the person and is cleanly functional, whereas in other cases of relay application it is “basic”. Thus, it can be asked how can the insulation marking in the relay be generally defined, that is, without a connecting it to the concrete application? To establish various demands to electric strength of insulation of the relay only by these definitions determined in advance is impossible. So what is the necessity for defining these terms in general?

2.10. In Section 3.2.4 the term: “solid insulation” is given and defined as: “a solid insulating material interposed between two conductive parts”.

First, the LED on an input of solid-state relay and photodetective diode, connected in control circuit of the output switching element are each encased in plastic, i.e., not conductive. Despite this, sometimes optical clear insulation material is interposed between these two elements enclosed in dielectric cases to increase the dielectric strength. So, the definition is not suitable for this situation.

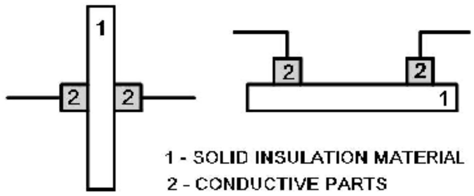

Fig. 6. Examples with different properties for same insulation material which bosh suitable for the “solid insulation” definition

Secondly, both examples shown in Fig. 6 are suitable for the “solid insulation” definition but the properties of this insulation for the same insulating materials and same conditions are absolutely different. It is not clear what the necessity was to introduce this term into the standard and to give it a special interpretation. In our opinion, the term and the definition are absolutely unnecessary in a standard on solid-state relays.

2.11. In conclusion of our review of the “Terms and Definitions” section we feel it necessary to emphasize that there are many special terms and definitions, including some newly invented and not always correct, in which the standard terms currently in wide use in semiconductor industry and characteristics are not applied. These include such terms, as maximum repetitive OFF-state voltage; maximum non-repetitive OFF-state voltage; critical rate-of-rise of ON-state current; critical rate-of-rise of OFF-state voltage; surge (non-repetitive) ON-state current; holding current; peak pulse current; maximum rms; ON-state current; control current; control voltage, turn-ON time; turn-OFF time, minimal load current, etc.

There is nothing that justifies “invention” of new terms while totally ignoring the widely used terms. This does not do honour to the authors of this section of the standard, and only bring bewilderment and disappointment.

Characteristics of the solid-state relay

3.1. In this section rather than repeat what we’ve already written we shall address only new terms and the new characteristics of solid-state relays offered in the standard. Thus, in section 4.4 of the standard an absolutely new system of classes for the electric loads has been introduced. These classes have not existed before and are intended for use only in the given standard. The existing system of load classification, known widely as the Utilization Categories and embracing all possible types of electric loadings, is completely ignored in the standard. In our opinion, such an approach when for each new standard a new system of classifications is invented completely ignoring existing systems is not justifiable and consequently the standard, in this part, should be completely rewritten and incorporate the terms currently employed throughout the industry.

3.2. The term, “overload current profile”, introduced in Section 4.3 is treated in Section 3.1.9 as “current-time coordinates for the controlled overload current”, and in Section 4.3 overload current treated as “a multiple of rated operational current (Table 4) and represents the maximum value of operating current under operational overload conditions. Deliberate overcurrents not exceeding ten cycles of the power-line frequency which may exceed the stated values of Table 4 are disregarded for the overload current profile”. It is difficult to understand the meaning of these sentences and all the more so difficult to use them in practice. At the end of Table 4 “Minimum requirements for overload capability test conditions” is introduced for load categories that have been specially “invented” (Table 1) for the standard and not used anywhere else in the technical literature. These categories and terms (as mentioned previously) are filled with ambiguities which have no place in an international standard. For example, load category “LC A” is described as “resistive or slightly inductive loads”. How much is “slightly”? Is the term “slightly inductive” is suitable for a standard? Instead of all these convoluted, unconvincing and unintelligible word-combinations in the engineering specifications on solid-state switching devices there exist precise, clear parameters that are widely used and usual for technical specialist’s parameters:

I_T(RMS) – max. continuous ON–state current (rms);
I_{TM} – max. peak repetitive ON-state current (for half cycle);
I_{TSM} – max. peak non-repetitive surge ON-state current (for half cycle);
I^2t – max. surge non-repetitive ON-state fusing current

In our opinion, only these four parameters should be used in the standard instead of all the tables and all new parameters, invented for characterizing of the load and overload capacity of a solid-state relays.

3.3. Section 4.5 introduces such parameters as “rated control circuit voltage” and “rated control supply voltage”. In the clarification of these terms it is given that the difference between these two voltages can occur owing to the transformer, rectifier etc., elements built-in in an internal control circuit of the relay, on which an additional voltage drop can be created. The introduction of the two different “voltages” and the explanation given for this result in bewilderment only: who and with what purpose needs to know about voltage differences between internal elements and internal circuits inside the solid-state relay?! In our opinion, this information is absolutely senseless and even harmful as it only confuses the consumers.

3.4. In the same section (4.5) such terms as “switch-on voltage” and “switch-off voltage” are introduced. In actual specifications of solid-state relays appearing on the market, the “control voltage” characteristic is specified as the interval of control voltages provided proper relay functioning, for example, 3 – 12 V DC. This is simple and absolutely clear. What purpose is served for inventing specially for this standard two new and unclear terms? For example, what is “switch-off voltage”? In the standard no definition or explanation for this term appears!

Marking and the Documentation

Table 2 of of the “Marking and Documentation” section lists the technical parameters required of the producer for indicating the relay directly, or referring to it in the technical specifications.

This table contains a set of parameters that we have already criticized above and does not contain any important parameters that we have not also addressed. There is, however, one new parameter (No. 3d) that attracts attention: “safety maximum load integral i^2t between 1 ms and 10 ms”, which appears in the standard for the first time and has not been included in Section 3 (Terms and Definitions) and nor in Section 4 (Characteristics of Solid-State Relay). The requirement for inserting the parameter in the technical specifications which has not been mentioned at all in the standard, seems to us as not admissible.

Construction requirements

In Section 7.1 the requirement for the materials used in the relay is formulated as follows: “The maximum permissible temperature of incorporated materials used in solid-state relays shall not exceed their operating limits, which shall be verified by testing according to 7.3 …” The given formulation, in our opinion, is erroneous. It should be written: “The maximum *operating* temperature of incorporated materials used in solid-state relays shall not exceed their *permissible* temperature, which shall be verified by testing according to 7.3 …”, thus giving the formulation the opposite sense.

Tests

In Section 8.2.1 a), 2) it is emphasized (by underlining) that the overload capacity the solid-state relay “utilizing a current-controlled cut-out device in addition to an overcurrent protection … shall be tested with the cut-out device in place”. In other words, if the solid-state relay is used in a concrete electrical installation together with the protective automatic circuit breaker, it should be tested for overload capacity together with this circuit breaker. So, what are we testing in this case: the solid-state relay or circuit breaker? According to standard requirement it is the circuit breaker.
We already noted above that standard requirements connected to testing solid-state relays by voltage higher than the rated level do not specify concrete points (circuits) between which the test voltages should to be applied. It is incorrect and should be corrected, also for Section 8.4 Insulation tests. However, this will be only a partial solution of the problem. More complex is the problem of test withstanding the voltage of the output switching element of the solid-state relay.

The problem arises because many constructions of solid-state relays contain built-in internal structures for overvoltage protection (more often, varistors) which, naturally, have lower pickup thresholds than the installation protected by them (that is, the solid-state switching element of the solid-state relay). Thus, short-term, step-up pulses of a voltage on the relay terminals at tests will lead to pickups of this protective element. The long duration, for example, approximately one minute, of the step-up voltage during the tests will lead to the destruction of a protective element. Thus, it is impossible to perform normal withstanding voltage tests for many solid-state relays constructions.

The problem may be solved by changing a principle of connection of a protective element to output relay terminals at which this protective element could be disconnected from the terminals for the period of tests due to removal of external links, Fig. 7. Such a change in the design of the solid-state relay would allow solving a problem of tests and should, in our opinion, be introduced into the standard as the obligatory requirement to construction of the solid-state relays.

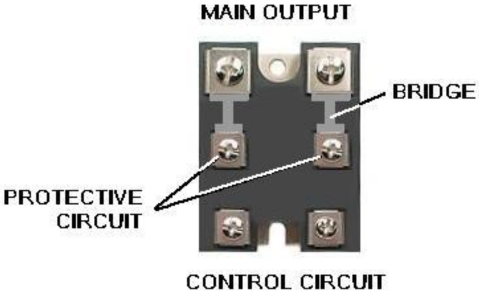

Fig. 7. Solid-state relay with incorporated protective element which can be disconnected from the main terminals for the period of tests due to removal of external links (bridge).

Conclusions

1. Power semiconductor devices and solid-state relays have appeared long before standard IEC 62314 was issued and existed in the market any more than ten years. During this time precise and clear terms and definitions were developed that are widely used by all specialists and manufacturers. Trying to completely ignore the existing set of terms and introduce a new set of terms and definitions connected only with the unique new standard is, in our opinion, absolutely unjustified and harmful.

2. The considerable number of mistakes, unintelligible definitions and the absence of connections with terms currently used in practice make, in our opinion, it impossible to use standard IEC 62314 in its existing form.

3. Standard IEC 62314 requires complete rewriting in view of the analysis brought in given paper.

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