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PROTECTIVE ARRANGEMENT FOR SEMICONDUCTOR RECTIFIERS

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Fig. 1

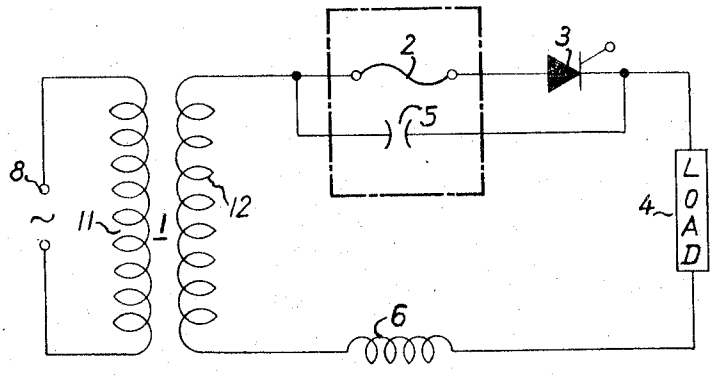
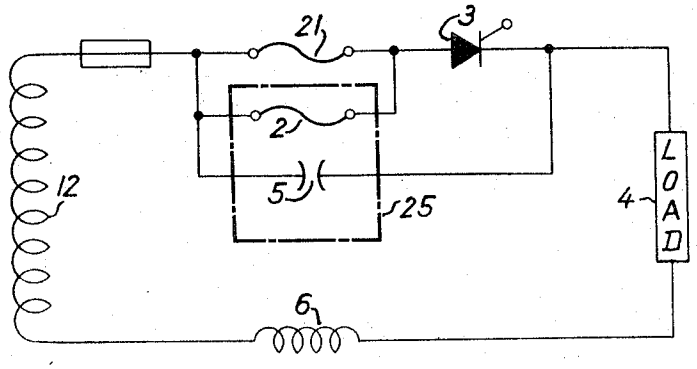


Fig. 2



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PROTECTIVE ARRANGEMENT FOR SEMICONDUCTOR RECTIFIERS

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The present invention relates to a protective arrangement for semiconductor elements such as rectifiers.

Utilization of semiconductor elements both as controlled rectifiers and as uncontrolled rectifiers requires the provision of protective means in order to prevent such heat sensitive semiconductor element, usually a germanium or silicon single crystal, from undue heating by overload or short-circuit currents. Usually, a fuse is connected in series with a semiconductor rectifier element or with a group of such elements. The fuse must meet particular requirements in order to provide for sufficient protection for the rectifier element or elements. One condition, of course, is that the response value for the fuse must be somewhat below the permissible current maximum of the semiconductor. Another requirement is that the arc voltage in the fuse after response thereof, is to be below the maximum voltage permissible for the other circuit elements of the network containing the rectifier.

The presently known fast acting fuses meet these requirements in case of low short-circuit currents and therefrom resulting long response time of the fuse. However, after the fusible conductor pertaining to the fuse element has melted down, there still remains an arc extending from and between the non-melting fuse electrodes whenever there are inductances or capacitances connected in the electric circuit rectifier network feeding stored energy as electric current into this fuse arc which current flows also through the semiconductor rectifier or rectifiers. This discharge current flows as long as there is electromagnetic or electrostatic energy stored in the inductances or capacitances respectively sufficient to maintain the fuse arc and until this energy permitted to be discharged has been converted into heat. This heat is developed partially in the arc, partially in the ohmic resistances of the network not being short-circuited and partially in the semiconductor rectifier body. Since the amount of heat necessary to melt the fusible conductor is constant, every additional energy is at least partially directly discharged into the semiconductor for conversion into heat therein, and the fuse then being in effect burnt out is powerless to prevent this resulting development of heat in the semiconductor body.

It is an object of the present invention to eliminate the heating up of semiconductor rectifiers in case of short-circuits after a fuse burns out.

It is another object of the present invention to provide for a new and improved protective arrangement for semiconductor rectifiers connected in circuit with inductances or capacitances.

According to one aspect of the invention in a preferred embodiment thereof, it is suggested to connect a fusible element directly in series with the semiconductor rectifier element to be protected and a spark gap means is shunted

across fusible element and rectifier element while being physically located in the vicinity of the fusible element. Whenever the fusible element melts because of a short-circuit or of an overload current, an arc is formed at the fuse ionizing the region between the electrodes pertaining to the spark gap means so as to fire the latter. Upon firing of the spark gap means, the still flowing electric current is commutated away from fuse and rectifier and flows now through the spark gap means.

While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter which is regarded as the invention, it is believed that the invention, the objects, and features of the invention and further objects, features and advantages thereof will be better understood from the following description taken in connection with the accompanying drawing in which:

FIGURE 1 illustrates a circuit network diagram of a first embodiment of the invention; and

FIGURE 2 illustrates a circuit network diagram of a second embodiment of the invention modified as compared with the first embodiment.

Proceeding now to the detailed description of the drawing, in FIGURE 1 there is illustrated a first embodiment of the invention.

A transformer 1 has a primary winding 11 connected to an A.C. voltage source such as the mains 8. A secondary winding 12 of transformer 1 provides for the necessary A.C. supply voltage level. There is provided in the circuit network for the secondary winding a semiconductor rectifier 3 preferably of the controlled type and being connected in series with a load 4 as well as with a fuse 2.

An inductance 6 illustrated as series connected circuit element is to represent inductivity of the circuit outside of the load itself. In particular inductance 6 represents that inductivity in the secondary transformer circuit, which will remain in series circuit connection with rectifier 3 in case of a short-circuit across the load 4.

The particular series circuit connection of fuse 2 and of rectifier 3 is shunted by a spark gap 5 dimensioned so as to fire whenever an arc appears in the fuse after the fuse element has melted. In particular, spark gap 5 is located in the vicinity of the fusible element of fuse 2 so that an arc in the fuse 2 ionizes the space between the electrodes pertaining to the spark gap 5 so that the latter can fire indeed.

During normal operation, the voltage drop across fuse 2 added to the voltage drop in forward direction across rectifier 3 is insufficient to fire spark gap 5. Also, the blocking voltage in case of normal operation across rectifier 3 is insufficient to fire spark gap 5. In either case no arc is being formed in fuse 2.

Now the case of short-circuit across the load 4 or any other overload current through semiconductor rectifier 3 is to be considered.

Upon occurrence of such short-circuit, the short-circuit or overload current will increase and fuse 2 will respond. In particular, the fusible element in fuse 2 is designed so as to respond at a current level above that of normal operation but below every conceivable and expectable short-circuit current value and particularly below the maximum current permitted to flow through rectifier 3.

The response of fuse 2 is carried out by melting of the meltable fuse conductor therein.

The melting of the fusible element of fuse 2 is determined by the so-called melt integral $\int i^2 dt$ which is the time integral over the square of the current values occurring during melting through the conductor and determining the amount of electric and heat energy required to melt the fusible element. This integral is approximately constant in the range of high short-circuit current values and short melting periods.

In order to develop more fully purpose and function of the inventive device it shall first be assumed that spark gap 5 were not employed.

After the fusible element or conductor has been melted so as to physically interrupt the conductive current path, of the rectifier network there still is stored electrical energy in inductance 6 which will discharge through the circuit and accordingly an arc will be formed across the otherwise interrupted current path in the fuse 2. This current will flow as long as there is sufficient energy stored to feed and maintain the arc in the fuse 2. Hence, the entire current passed through the electric circuit network results in an overall integral $\int i^2 dt$ well above the aforedefined melting integral. The melt integral is determined primarily by the properties of the fusible element, whereas the overall time integral over the square of the current is determined not only by the characteristics of the circuit elements employed but also by the initial short-circuit conditions and the amount of energy stored in and dischargeable from the circuit network inductances at the time when the short-circuit occurs.

This resulting overall integral value increases, of course, with the square of the current permitted to flow through the arc at the fuse and might have a multiple value as that of the melting integral. Also, the entire period of time during which a short-circuit and discharge current still flows across the fuse arc is much longer than that needed to melt the fusible element.

The semiconductor 3 is being passed through by this extended short-circuit and discharge current. The maximum permissible load for a semiconductor element itself is likewise determined by a particular integral $\int i^2 dt$ which is of approximately constant value as to the permissible maximum for periods of time below 10 ms.

It is thus apparent, that no problem exists, if there were no energy-storing inductances (or capacitances), so that the overall integral for the existing conditions then is equal to or only slightly above the melt integral, and both integral values remain well below the permissible semiconductor current integral value. The usual inductance 6 of such a rectifier network, however, is expected to produce an overall integral value well above the melt integral and thus possibly above the permissible semiconductor current integral value.

It is thus apparent that the fuse 2 alone as aforedescribed does not protect sufficiently the semiconductor rectifier 3, since the fuse, in fact, has no control over the extended current flow through an arc in the fuse, after fuse burn out which current flow extends the development of heat in the semiconductor rectifier in an uncontrolled manner. Moreover, the inductance 6 will discharge electric energy until all its energy has been converted into heat regardless what effect this has on the semiconductor. Some heat, of course, is produced and dissipated in the arc formed in the fuse, another sizable portion of heat, however, is developed in the rectifier body itself and this amount of heat depends primarily on the energy content stored in the inductance 6 and to be discharged fully therefrom.

The invention now provides for a spark gap 5 shunted across fuse 2 and rectifier 3 and in such physical vicinity of the fusible element in fuse 2, so that the spark gap fires whenever an arc develops across fuse 2. When spark gap 5 thus fires, the short-circuit current is commutated to now flow over spark gap 5 thus bypassing semiconductor rectifier element 3. The only current still flowing through semiconductor element 3 is that necessary to complete the melt integral so that the fuse 2 receives that amount of energy necessary to melt down the conductor therein completely, but no more electric current than that flows into the fuse and through rectifier 3.

It is apparent that with the provision according to the invention and before and after the aforedescribed current commutation takes place, the entire current flowing through semiconductor rectifier 3 in case of a short-circuit is only determined by the melt integral of fuse 2, which is well known and predeterminable for the fuse and will be maintained below the maximum permissible semiconductor integral. This is true regardless how large the short-circuit current is and how long it takes the inductance 6 to discharge its electromagnetic energy, since every extended current flow above that required to complete the fuse melt integral is being commutated across the spark gap 5. Thus, the semiconductor rectifier is now adequately protected jointly by the fuse 2 and the spark gap 5.

The spark gap 5 performs an additional function; namely, it fires also in case of voltage peaks in the secondary winding 12 which peaks are per se insufficient to cause fuse 2 to respond, but which peaks might break through the semiconductor.

FIGURE 2 illustrates a further embodiment of the invention. First there are provided the aforedescribed elements such as transformer secondary winding 12, inductance 6, load 4 and rectifier 3 interconnected also as aforedescribed. Connected in series with rectifiers is an ordinary fuse 21.

In addition, there is now provided a circuit element 25 composed of a spark gap 5 and of a meltable conductor 2 disposed in the vicinity of gap 5. The meltable conductor 2 is directly connected in parallel to fuse 21 so that elements 2 and 21 together could be considered as constituting one fuse with two parallel conductors. The spark gap 5 bridges all the elements 21, 2 and 3.

In this embodiment one can use an ordinary fuse 21 conveniently located in the apparatus right at the one output terminal of secondary winding 12, while element 25 is designed to have a fusible conductor 2 which in case of fuse response melts and forms an arc directly adjacent the electrodes forming the spark gap 5 so as to ionize the gap 5. Preferably, element 25 is cased into a housing common for conductor 2 as well as gap 5. Fuse 21 will have a slightly higher response current than conductor 2, so that conductor 2 will start to respond (fuse) thus increasing its resistance and shifting now some of the current to fuse 21 so that now the latter will also respond.

In both embodiments spark gap 5 is thus determined by the following requirements:

Spark gap 5 must not fire at the reverse or blocking voltage across rectifier 3 at normal operating voltage and current levels, nor must it be fired by the voltage drop when current flows in forward direction through rectifier 3 and fuse 2 (and/or 21).

The gap 5 must fire when an arc is being formed across fuse 2 which arc then ionizes the gap between the electrodes of spark gap 5. This firing must be more or less independent from the voltage drop across the arc of fuse 2 plus the voltage drop across rectifier 3 in case of a short-circuit current.

Finally, spark gap 5 should fire in case of temporary voltage peaks across secondary winding 12 insufficient to cause melting of the fuse 2.

It has been found advantageous to use silver as fusible conductor in fuse 2 and this fusible conductor is being placed at a distance from spark gap within the range of 0.5 to 3 mm., preferably 1 mm.

The invention is not limited to the embodiments described above but all changes and modifications thereof not constituting departures from the spirit and scope of

the invention are intended to be covered by the following claims:

What is claimed is:

Protective arrangement for semiconductor rectifiers connected between an A.C. voltage source and a load comprising: a fuse connected in series with the semiconductor rectifier, a fusible element connected parallel to said fuse and in series to said rectifier; and a spark gap means connected across said fusible element and said rectifier and being physically located near said fusible element so that an arc produced upon melting of said fusible element fires said spark gap means.

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