Article for ELECTRO-SYSTEMS

Protecting semiconductor electronic elements with modern fuse links with Ultra-Quick characteristics manufactured by ETI - Polam

The correct selection of the fuse cut-out for the purpose of the semiconductors elements of electronic device protection involves the both exact system analysis, and given catalogue acquaintances of semiconductor elements and their safeties (time-current and energy characteristics, run-downs etc.) and their co-relations.
Main target of the present article is the explanation to users of devices some concerning doubts of the technique of protecting semi-conductors with fuse links. Such doubts, author of the article meets often during thematic conferences, trade fairs or ETI-Polam products presentations.

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The temperature of the p-n thyristor junction during his charge is relative to the values of conducted current. At the surcharge of such semiconductor element the temperature of the junction increases, so decreases thyristor blocking ability. The gate can lose the ability to steering thyristor. Too large increase of the temperature of the junction, causes the immediate thyristor damage. The reason of the big increases of the current conducted by thyristor can be his internal disturbances eg. loss of blocking abilities, and external disturbances, eg. the short-circuit or the surcharge on exit relay connectors (Fig. 1).

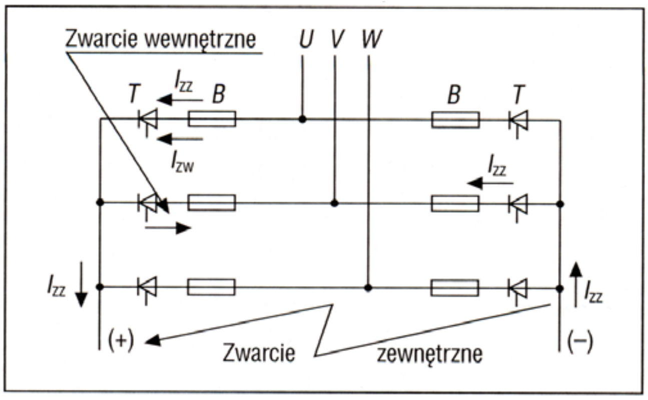


Fig.1

During the thyristor loss blocking abilities occurs, phase short-circuit on the secondary side of the transformer system. Takes place the very fast increase of the thyristor conduction current, limited only by the dispersion reactance of the transformer. The protection against the thyristor destruction in the second phase, by which also short-circuit current is conducted, defines limitations of this current in the course one semi-period (0, 01 s).
Accordingly, serially with thyristors are coupled fuses with ultra-quick characteristics gR and not fully range characteristics aR. In systems containing several or a dozen or so thyristors coupled parallel, complies individual fuses for every thyristor. This permits to enlarge reliability of operation, because in the time of one thyristor damage his fuse will cause the break of the short-circuit current, and this will make possible the further system operation. Through the thyristors coupled in the second pole also short-circuit current is conducted, but fuses will not get down to work because disappearance of this current on the greater number of parallel connections. However, most difficult system working conditions will appear in situation, when all thyristors in the branch simultaneously will lose the blocking ability. Ultra-quick fuses should then limit short-circuit current, that do not allow to the damage of the remaining thyristors, as result of the sharp increase of the junction temperature. The system protection against external short-circuits can also assure usage of quick switches coupled on the side of the direct current. However, it is important to remember about the suitable co-ordination of protections, well-chosen into such manner, that external disturbances do not cause getting down to work of fuse cut-outs. This can be obtained by the adaptation characteristics of each elements of surcharge protection to the characteristics protected thyristors and their suitable coordination.

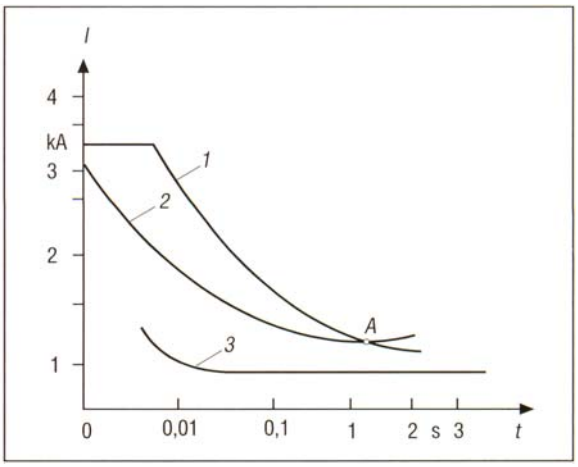


Fig. 2

Fig. 2 shows thyristor, fuse and switch current-time characteristics. The curve 1, which states the overload thyristor capacity in the function of time, is generated on the ground of given catalogue data. The curve 2 states current-time characteristics of getting down to work of the ultra-quick fuse. The efficient thyristor protection against short-circuits is obtained in situation, when discussed fuse characteristics runs below current characteristics of the thyristor. To make possible the full imposition of thyristors within the rated currents range, it is necessary to choose ultra-quick fuses with possibly large rated currents values. A rule is, that ultra-quick fuses do not assure good thyristors protection at smaller, but longer lasting surcharges, what illustrates course of curve No 2 over the curve 1 from the right side of the cross-cuts point A of curves. The curve 3 illustrates the characteristics of getting down to work the quick switch. At the longer time of surcharges curve runs horizontally, but quickly raises at the steeply growing current of the surcharge. The characteristics of getting down to work of the quick switch should take place {run} in the large range below characterizations of fuses, because protects this safeties before getting down to work during external (eg. earthing, short-circuits etc.) disturbances.
The fuse link with ultra-quick characteristics is built from:

- The fuse element made from the silver- tape; it has small heat capacity and the high density of conducted current;
- Copper or brass silvered external contact points, to which is connected fuse element; they serve directly to the joining of the insertion with the external circuit, and indirectly also for cooling fuse element;
- Ceramic (steatite) body, where the fuse element is situated;
- Quartz sand($SiO2$) acting as the hermetic filler of the arched space; he has specifically chemical composition and a permissive granulation on the obtainment of the sufficient value of the Joule's integral (And 2s) and short-circuit ability of switching off.
- Indicator of getting down to work (burn-through) of the fuse link - situated on the upper metal- cover or on the side- part ceramic body. (The least voltage of getting down to work indicator of the burn-through - 10 V.)

In view of the responsible part of ultra-quick fuses, their start up should be controlled. To this can serve micro-disconector (eg. NVS 5, or AMK manufactured by ETI-Polam) placed on the catch of the fuse cover, or on metal- brackets on the insertion with the side- indicator, started by the rising of the tin plate after the burn-through of the fuse link. Basic ultra-quick fuses parameters are presented in Table 1.

Fuse type (aR, gR)	DO	D	WT-NH U, U-N	WT-NH H,G,S
Short-circuit ability, kA	~50/-8	~50/-8	~50/-8	~50/-8
Max. rated voltage. V	~400/-250	500	~690/-440	~690/-440
Voltaic arc voltage, V	600 - 850	500	850 - 1250	850 - 1250
Rated current. A	Switching off values of the Joule's integral, A^2s			
2	6,3	5,8	-	-
4	13	11	-	-
6	20	18	18	-
10	65	60	60	-
16	200	180	180	140
20	275	250	250	230
25	480	470	460	400
32	-	-	750	650
35	1000	980	1000	835
50	1800	1750	1500	1030
63	2500	2500	3000	2680
80	-	5300	5300	5550
100	-	9000	9000	8350
125	-	16000	16000	11800
160	-	24000	24000	19300
200	-	40000	40000	27800
250	-	-	65000	45000
315	-	-	175000	85600
400	-	-	441000	160000
450	-	-	510000	-
500	-	-	620000	257000
560	-	-	740000	332000
630	-	-	850000	407000
710	-	-	-	653000
800	-	-	-	835000
1000	-	-	-	1060000
1250	-	-	-	1500000

Table No 1.

Heat Joule's integral switching off the fuse $\int (i^2dt)_{BC}$ has a constant value for a given type of fuse and is equal to the sum of heat integrals for the before-arc period and arc period. .Let postulate, that :

$$\int (i^2dt)_{BC} \equiv 3\text{-}5 \int (i^2dt)_{BO}$$

Where $\int (i^2dt)_{BO}$ is the heat Joule's integral of the before-arc period.

During short-circuit, fuse link element is burned and short-circuit current is limited.

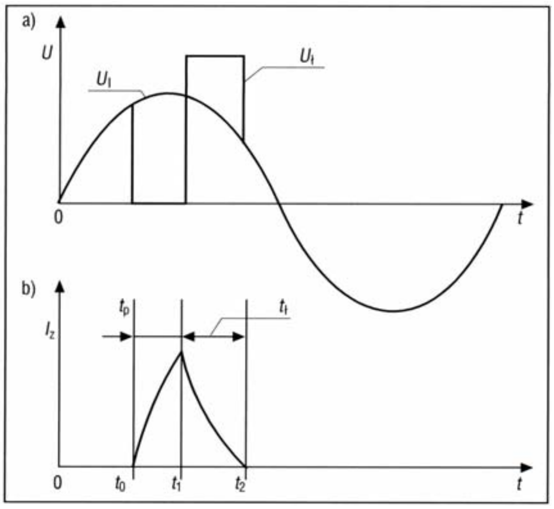
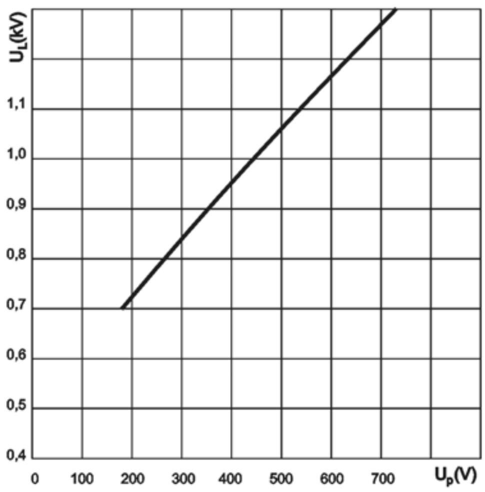


Fig. 3

On Fig. 3 shown the course of the increasing short-circuit current until the time t_1, whenas lights the voltaic arc in the fuse arched chamber. Hence short-circuit current grows smaller in the function of the arc voltage U_L which in case of ultra-quick fuses is stabilized. Besides the arc voltage U_L must be higher than the supply thyristor voltage, so that short-circuit current can remained reduced to the zero in the enough short time in the range t_1 - t_2 . The voltage in the circuit higher than the rated voltage of the fuse can cause extinguishing of the voltaic arc in fuse chamber, with so large delay that the thyristor protection will become not efficient. It is also important to remember, that the electric arc voltage can not exceeds the thyristor voltage class. The arc voltage between fuse electrodes is a sum of the anode voltage and cathodic voltage and the fall of voltage in plasma, which burns between electrodes. The value of the fall of voltage in plasma depends on the length of the arc, his temperatures and the current. This means, that the voltaic arc is shorter, the more stable arc voltage. The characteristic of the electric arc voltage U_L (kV) = f(Up) of the fuse link WT-NH 00C - 4a is shown on the Fig. 6.



Rys. 6

ETI - Polam in Pułtusk offers the full family of fuse links with ultra-quick characteristics in following sizes TO, Dll, Dlll, DlV, DV, WT-NH 00C, 00, 1, 2, 3 (type U-N - for fastening in the standard fuse base , and the type U - for fastening on helical clamps {connectors}. Lately, for the purpose of the facilitation of the selection and ensure semiconductor elements users good protection level, EPI POLAM introduced to the production new types and sizes of fuse links gR and the aR. This are fuse links of the type G, G - M, M - for fastening in the standard fuse base , S - for fastening on helical clamps {connectors}, in following sizes WT-1 In = 32 - 400A, WT-2 In = 160 - 630A, WT-3 In = 315 - 1250A.

Fig. 4

The fuse link type G (Fig.4) is not equipped with contact- knives. It has thread directed along the longitudinal axis of the insertion, for the purpose to screw the fuse between rails. G-M type (Fig. 5) of the fuse link is additionally equipped with the side damage indicator and brackets for fastening micro-disconector AMK serving of the remote signaling.

Fig. 5

For correct choosing fuse links Edith ultra-quick characteristics aR or gR for thyristor protecting, should be taken following precautions and co-relations:

- Fuse rated current should be comply following formula:

$$I_{BN} \leq I_{T(AV)\psi} \sqrt{2}\ \pi/\psi$$

Where $I_{T(AV)}$ – average value of the thyristor conduction current (for one period run, whereat conducting angle $\psi = \pi$, in the three-phase- system $\psi = 2\pi/3$.
It is important to remember, that the fuse current is definite as effective value , while the thyristor conduction current by a average value. If in system there is no separate surcharge thyristors protection (eg. in the form of quick switches), then the fuse rated current should be smaller, so his time-current characteristics ran below surcharge thyristor characteristics. Thyristors are then overloaded with relation to of their charge, what is uneconomical solution.

· UBN fuse rated voltage cannot be higher from the voltage of the protected circuit UBN < U2.

· Voltages: repeatable peak - reverse URRM and repeatable peak blockings UDRM thyristor should be higher than the maximum arc voltage of the electric fuse URRM > Uł and UDRM > Uł.

· The Joule′s integral of switching off the fuse $\int (i^2dt)_{BC}$ must be smaller than limitary Joule′s integral of thyristor $\int (i^2dt)$, so

$$\int (i^2dt)_{BC} < \int (i^2dt)$$

· The maximum prospective short-circuit current Ip which can appear in the circuit, should be smaller than rated short-circuit fuse ability of switching off Ik : $Ip < Ik$

· Short-circuit limited current of the fuse Iogr should be smaller than the thyristor unrepeatable peak conduction current ITSM :

$$Iogr < ITSM$$

The efficiency of the thyristor protection through ultra quick fuse links should be estimated comparing their time-current characteristics..

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