



Suitable protection for motor drives

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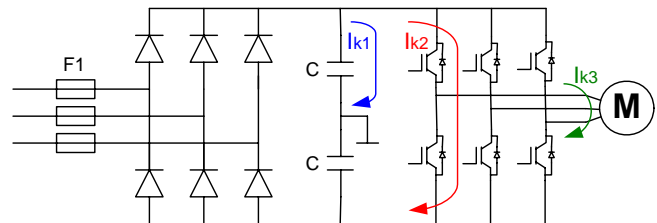
In today's industry avoiding "down-time" can be the same as creating income.

The upper statement ever more reflects the current conditions in the industry. Reliability of production systems is becoming more and more important and will even more do so in the future. We all wish for our production devices to be functioning normally. But if a malfunction appears, it should be fixed as soon as possible, for every hour of down-time presents a loss of income. Despite many designers' opinion that one can protect motor drives using only miniature circuit breakers, experiences show that internal part of frequency converter remains unprotected from short-circuiting.

Keywords: soft starter, frequency converter, IGBT, semiconductor protection fuses

Ever since soft starters and frequency converters entered the contemporary production operation, mostly to decrease production costs (electricity, maintenance), there has been a great confusion on the market regarding proper electrical protection of these devices. Such a situation leaves a lot of motor drives unprotected. Unfortunately all designers, maintenance teams and even users are not familiar with the advantages of protection with semiconductor protection fuses.

Years ago soft starters and even frequency converters had built-in semiconductor protection fuses. But as these devices were becoming ever smaller, their producers decided to leave suitable protection up to the end user to decide upon, and provided corresponding instructions and recommendations on which fuses or protection to use. This became an established praxis in the field of soft starters (with few exceptions), but not in the field of frequency converters. In this field, designers usually hold to a general rule that protection with MCBs (characteristic C) is sufficient. Suitable protection of motor drives and testing of this protection is covered by **IEC 61800-5** standard (Semiconductor power converters for variable-frequency drives).



Picture 1: Block scheme of frequency converter

Some say that electronic protection, placed between frequency converter and motor, should suffice. But latest experience shows, this might not be so, since the internal part of the frequency converter is not properly protected from short-circuiting.

When it comes to frequency converters, we can encounter at least three types of malfunction:

1. Motor blockage
2. uncontrol of exit IGBT transistors
3. short-circuiting on the capacitor – DC part

Motor blockage (Ik3): Difficult operating conditions often cause motor blockage for various reasons (temperature, bearings, mechanic barriers, breakages). This causes the current, running through the inductor, to increase, which the frequency converter detects and interrupts the current through the inductor. Yet this electronic protection, on account of cable overvoltages and other reasons, does not represent a 100% protection. Also, as time passes, degradations occur, which even lessen its reliability.

Uncontrol of IGBT transistors (Ik2): Frequency converter is an electronic device and as such sensitive to environment disturbance. Such a disturbance, which usually enters the converter through the cable, can cause izkrmiljenje of exit transistors, which could lead to two open transistors at the same time and consequently short-circuiting.

Short-circuiting on the capacitor (Ik1): Capacitor in the DC part of frequency converter is most subdued to the process of ageing. After cca 5-8 years its capacitance falls down to 2/3 of its original worth – if used under normal conditions ($T_{amb} = \max 40^{\circ}\text{C}$). For every 10°C added, its life expectancy divides into halves. Capacitor is also becoming more and more mechanically deformed, which could also lead to short-circuiting.



Picture 2: Short-circuiting on the capacitor

Recent frequency converters are built modularly. Feeder part and exit part are encapsulated with compound, which makes any kind of repair or replacement of damaged parts impossible. Usually we have to replace the entire frequency converter.

This can be avoided only by use of properly dimensioned line fuse-links for semiconductor protection, which will protect your frequency converter from short-circuiting both on the outside as well as on the inside of the frequency converter.

Is the IEC 61800-5 safety demand fulfilled by use of gG fuse-links for protection of drives?

An argument in favor of use of gG fuse-links (or MCBs) goes something like this:

“If a malfunction appears inside of a device, something must be damaged despite the fact that we are using quick fuse-links for semiconductor protection. Therefore we can change the drive at anytime. Even if use of gG fuse-links causes more damage, there is no great difference between use of gG and gR fuse-links”.

As long as the selection of gG fuse-links relies on I^2t value (10ms) regarding to semiconductor component, which does not cause a serious explosion, and as long as we’re 100% sure that we will not replace the fuse-link until we repair the malfunction, this argument is in theory acceptable. We must not forget that the 61800-5 standards demands “always testing for one malfunction”.

But what happens, if the fuse-link is replaced and all available energy concentrates at the point of malfunction on the semiconductor element? In hundreds, even thousands of factories this is an everyday occurrence.

And what if the fuse-link, which was used to replace the destroyed one, is NOT a semiconductor protection fuse-link, such as was primarily installed? Most people say “gG fuse is a gG fuse”, meaning that these fuse-links are all the same, since they are all manufactured and tested according to the same standard and also not too exact when it comes to determining the let through energy I^2t .

This is far from the truth, because gG fuses actually differ severely from one another. This means that the energy (if we conclude that all fuse-links have been replaced and the drive is restarted, since there was no malfunction to be found by visual check up) could be far greater. And what

happens next? Drive manufacturers insist that you “always use the same fuse-links as those recommended in technical instructions”. Most maintenance personnel accept the “gG fuse is a gG fuse” rule and consequently use what they keep in store or what they can buy in the nearby shop. But, if the argument in favor of use of gG fuse-links is the availability of spare parts, what then is the advantage of using gG fuse-links, considering that original spare parts should be used according to manufacturer’s instructions?

Worst-case scenario – and unfortunately not far from everyday – happens, when maintenance team overbreak safety components in the drive (fuse-links) and leave the door of the drive open, against all recommendations of drives’ manufacturers (usually to make sure that everything is functioning properly). This is something that happens every day, all over the world.

After a few internal malfunctions, which the drive “survives” without consequences, many decide to replace them in order to see if they are still functioning normally. If you don’t do so, the energy keeps escalating with each malfunction. And if the maintenance team leaves the door open, we witness an additional danger to this team (not only to the equipment) in case of thyristor or IGBT transistor explosion.



Picture 3: Consequence of IGBT transistor explosion

Suggested fuses for V/f frequency inverter

Input side external fuse type (without 3-phase choke)	Input side external fuse type (with 3-phase choke)	230 VAC Class 1 (kW)	230 VAC Class 2 (kW)	400 VAC Class 1 (kW)	400 VAC Class 2 (kW)	460 VAC Class 1 (HP)	460 VAC Class 2 (HP)
CH14UQ/10A/690V (D2)	CH14UQ/10A/690V (D2)	0,37	0,37	0,75	0,75	1	0,75
CH14UQ/10A/690V (D2)	CH14UQ/10A/690V (D2)	0,75	0,75	1,5	1,5	2	1,5
CH14UQ/16A/690V (D2)	CH14UQ/10A/690V (D2)	1,1	1,1	2,2	2,2	3	2
CH14UQ/16A/690V (D2)	CH14UQ/16A/690V (D2)	1,5	1,5	3	3	3	3
CH14UQ/20A/690V (D2)	CH14UQ/16A/690V (D2)	2,2	2,2	4	4	5	5
CH14UQ/25A/690V (D2)	CH14UQ/20A/690V (D2)	3,3	3,3	5,5	5,5	7,5	7,5
CH22UQ/40A/690V (D3)	CH14UQ/25A/690V (D2)	4,4	4,4	7,5	7,5	10	10
CH22UQ/40A/690V (D3)	CH22UQ/40A/690V (D3)	5,5	5,5	11	11	15	15
CH22UQ/50A/690V (D3)	CH22UQ/50A/690V (D3)	7,5	7,5	15	15	20	20
/	CH22UQ/50A/690V (D3)	11	11	22	22	30	25
/	CH22UQ/50A/690V (D3)	11	11	22	22	30	25
/	S00UQ1/80/80A/690V	18,5	15	30	30	40	30
/	S00UQ1/80/100A/690V	22	18,5	37	37	50	40
/	S00UQ1/80/160A/690V	22	22	45	45	60	50
/	S00UQ1/80/160A/690V	30	30	55	55	75	60
/	S1UQ1/110/250A/690V	37	37	75	55	100	75
/	S1UQ1/110/250A/690V	55	45	90	90	125	100
/	S2UQ1/110/400A/690V	55	55	110	90	150	125
/	S2UQ1/110/400A/690V	75	55	132	110	150	150
/	S2UQ1/110/400A/690V	90	90	160	160	200	200

Class 1 = continuous duty according to the IEC 146 norm
 Class 2 = 150% overload for 60 seconds according to the IEC 146 norm

Suggested fuses for **AC Vector inverter**

Input side external fuse type (without 3-phase choke)	Input side external fuse type (with 3-phase choke)	External fuse for a DC connection common DC power supply	230 VAC Class 1 (kW)	230 VAC Class 2 (kW)	400 VAC Class 1 (kW)	400 VAC Class 2 (kW)	460 VAC Class 1 (HP)	460 VAC Class 2 (HP)
CH14UQ/10A/690V (D2)	CH14UQ/10A/690V (D2)	AQS14UQ/6A/690V	0,37	0,37	0,75	0,75	1	0,75
CH14UQ/10A/690V (D2)	CH14UQ/10A/690V (D2)	CH14UQ/10A/690V	0,75	0,75	1,5	1,5	2	1,5
CH14UQ/16A/690V (D2)	CH14UQ/10A/690V (D2)	CH14UQ/10A/690V	1,1	1,1	2,2	2,2	3	2
CH14UQ/16A/690V (D2)	CH14UQ/16A/690V (D2)	CH14UQ/16A/690V	1,5	1,5	3	3	3	3
CH14UQ/20A/690V (D2)	CH14UQ/16A/690V (D2)	CH14UQ/16A/690V	2,2	2,2	4	4	5	5
CH14UQ/25A/690V (D2)	CH14UQ/20A/690V (D2)	CH14UQ/20A/690V	3,3	3,3	5,5	5,5	7,5	7,5
CH22UQ/40A/690V (D3)	CH14UQ/25A/690V (D2)	CH14UQ/32A/690V	4	4	7,5	7,5	10	10
CH22UQ/40A/690V (D3)	CH22UQ/40A/690V (D3)	CH14UQ/40A/690V	5,5	5,5	11	11	15	15
CH22UQ/50A/690V (D3)	CH22UQ/50A/690V (D3)	CH22UQ/63A/690V	7,5	7,5	15	15	20	20
/	CH22UQ/50A/690V (D3)	S00UQ1/80/80A/690V	11	11	22	22	30	25
/	S00UQ1/80/80A/690V	S00UQ1/80/100A/690V	18,5	15	30	30	40	30
/	S00UQ1/80/100A/690V	S00UQ1/80/125A/690V	22	18,5	37	37	50	40
/	S00UQ1/80/160A/690V	S00UQ1/80/160A/690V	22	22	45	45	60	50
/	S00UQ1/80/160A/690V	S00UQ1/80/200A/690V	30	30	55	55	75	60
/	S1UQ1/110/250A/690V	S1UQ1/110/250A/690V	37	37	75	55	100	75
/	S1UQ1/110/250A/690V	S1UQ1/110/315A/690V	55	45	90	90	125	100
/	S2UQ1/110/400A/690V	S2UQ1/110/400A/690V	55	55	110	90	150	125
/	S2UQ1/110/400A/690V	S2UQ1/110/500A/690V	75	55	132	110	150	150
/	S2UQ1/110/400A/690V	S2UQ1/110/500A/690V	90	90	160	160	200	200
/	S2UQ1/110/630A/690V	S2UQ1/110/630A/690V	/	/	250	200	350	300
/	S2UQ1/110/630A/690V	S2UQ1/110/630A/690V	/	/	315	250	450	

Class 1 = continuous duty according to the IEC 146 norm

Class 2 = 150% overload for 60 seconds according to the IEC 146 norm

Prices of typical frequency converter with power of 5 kW range up to a few thousand euros. Cost for suitable protection with fuse-links for semiconductor protection is on the other hand (when using low price cylindrical fuse-links) in the range of few euros (depending on rated current).

To prevent unforeseen damage we should build semiconductor protection fuse-links in during the installation of the system, not later, when we find out that without them we cannot provide proper protection of the device and when certain damage has already been done.

Recent views in the field of maintenance have already come to demand proper protection for the equipment. If fulfilling this demand, you may even get certain discounts at making maintenance contracts. In anyway, fulfilling this demand strengthens your negotiating position.

To all those, who wish to know more on the subject, I recommend the article “**Short circuit protection of Variable Speed drives**” by Per Reinholdt.

Literature:

- ETI d.d.'s internal material
- Short circuit protection of variable Speed drives, Per Reinholdt

<http://www.trafomo.com/pdf/No%2013%20Short%20Circuit%20Protection%20of%20Variable%20Speed%20Drives.pdf>