

Spark Gap Surge Protectors For Lv Mains

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Introduction

In the last year or so spark gap surge protectors have appeared in the Australian market place. There is now at least one Australian manufacturer of these spark gap devices whose design is based upon a German design.

This paper discusses the merits and drawbacks of spark gap surge protectors and concludes that for all but possibly the most exposed sites MOV based surge protectors provide excellent protection with no adverse effects upon the AC mains.

Background

Traditional spark gap devices have been around for many years, and are used as lightning protection by electric utilities for high voltage applications (primary side of the transformer).

Traditional spark gaps, sometimes called air gaps, are simply a gap of air separated by two electrodes. When a high enough voltage (difference in potential) occurs between the two electrodes, the air gap sparks over and creates a short circuit for current to flow.

One reason arc gap technology has historically not been used on the secondary side of the transformer is because of the difficulty in extinguishing the arc.

The arc, once created by the impulse voltage is sustained as “follow on” current, AC current that flows through the arc plasma. Effectively the arc appears as a short circuit across the AC mains. This results in a short circuit on the system that will trip upstream circuit protection devices therefore limiting the reliability of the system.

For this reason spark gaps have largely been overtaken by zinc oxide varistors on HV lines. It was natural for these varistor devices to find application in LV surge protection also. Indeed the vast majority of LV surge arresters currently in use are metal oxide varistor types.



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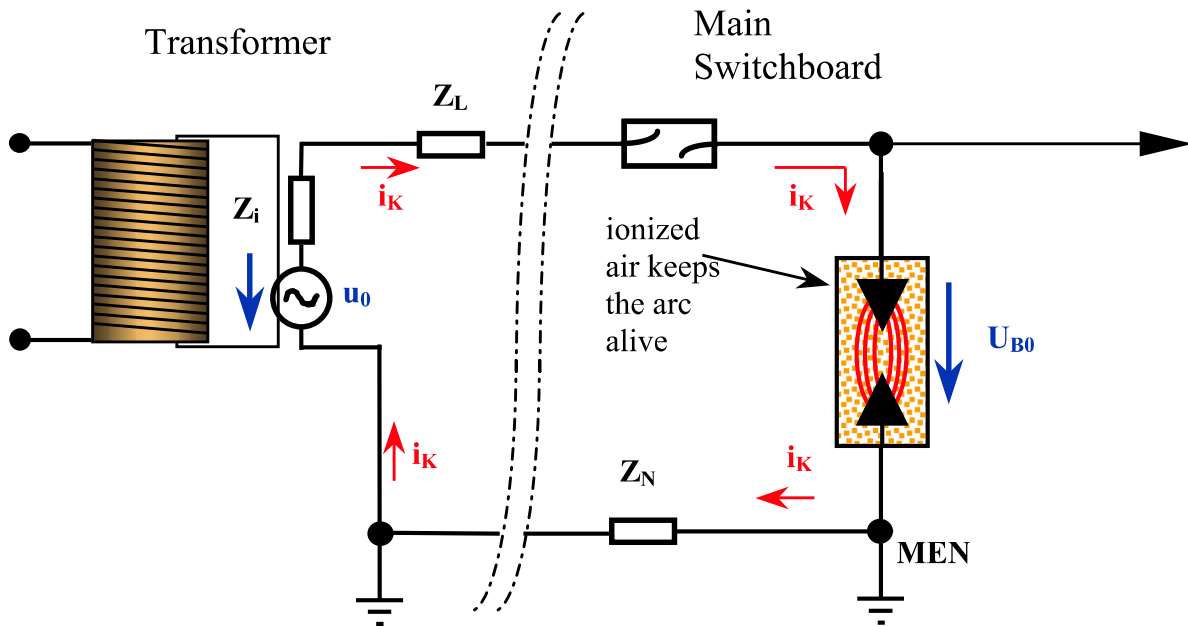
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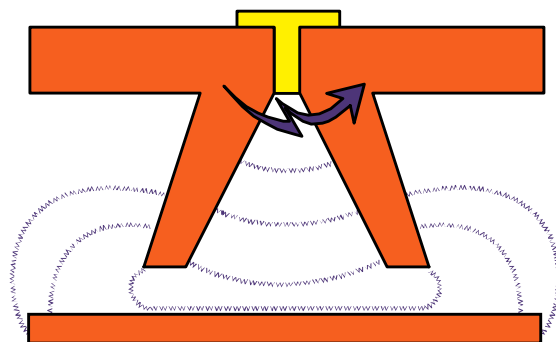
The figure below shows a spark gap surge diverter connected between line and neutral of a main switchboard. AS4070 specifies how surge diverters shall be connected. They are connected between line and neutral, not line and earth.



Once the spark gap fires the follow on current is only limited by the source impedance of the supply transformer and the impedance of the supply leads, $Z_i + Z_L + Z_N$. The current that will flow could be equal to the short circuit rating of the switchboard. If the arc does not extinguish the upstream supply fuse or circuit breaker will operate thereby disconnecting the supply.

Recent developments

More recently LV spark gap arresters have appeared on the market with a number of useful features. The first and most important feature is the construction of arc chutes which allow the arc to extinguish. Other manufacturers have different arrangements to aid in extinguishing the arc. A typical construction is shown below.



The two electrodes are top left and right. Ignition occurs and the arc bridges the distance between the electrodes. The arc is pushed outwards and downwards. The arc then strikes



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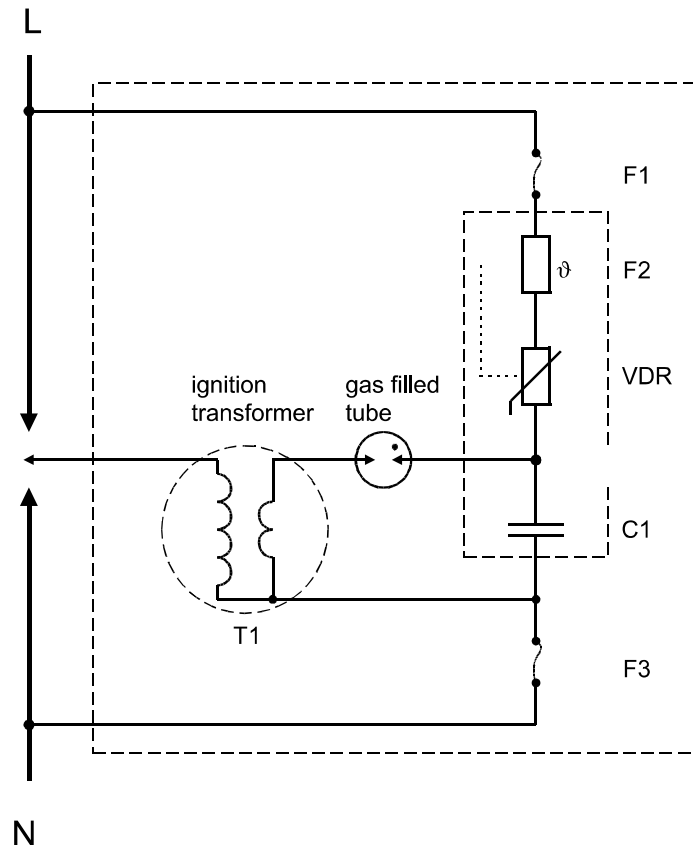
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the crash plate below and finally breaks into partial arcs, which aid in the extinguishing process.

Spark gap surge diverters with this type of construction typically have impulse firing voltages of 4-5kV.

Another recent development has been the triggered spark gap. A third triggering electrode is introduced which creates an arc to trigger the main arc. The design of these triggering circuits is quite simple. A typical circuit is shown below.



A voltage divider comprising the MOV, VDR, and capacitor, C1, connects across the line and neutral terminals. The capacitor works as an energy storage device. Once the voltage on the capacitor reaches the impulse firing voltage of the gas filled arrester the arrester fires and the capacitor charge is dumped into the pulse transformer, T1. The transformer produces a 4-5kV output at its secondary thereby firing the spark gap.

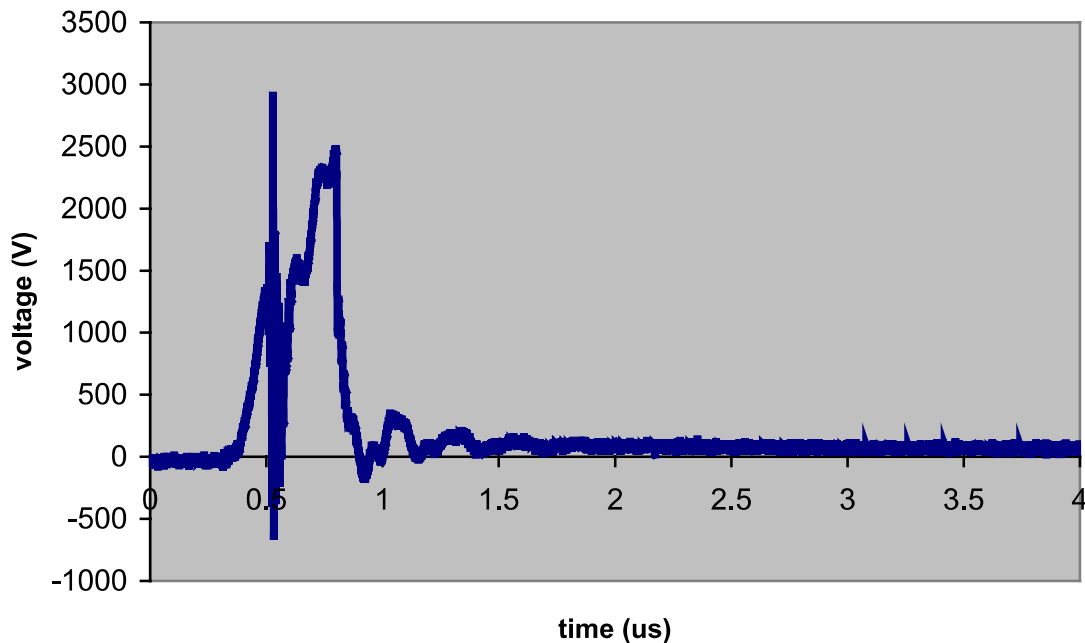
Such triggered spark gap diverters are rated at typically 900V or 1.5kV. If a slowly increasing AC voltage is applied to the diverter the firing voltage is indeed 900V or 1.5kV. However if an impulse is applied the firing voltage is more like 2.5-3kV. The figure below shows the impulse firing voltage of a 900V triggered spark gap. So a spark gap diverter must be followed by a secondary stage. It cannot be used alone to protect a whole facility.



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Application

Spark gap diverters have very high surge ratings and based upon the premise that bigger must be better they should be the answer to all surge protection problems. Unfortunately this is not always the case.

Spark gap diverters originated in Germany where the emphasis is on cheap domestic protectors. The largest MOV based protectors typically available from the European manufacturers is 40kA. So something inexpensive was needed which had a high surge rating.

The situation in the US and Australia is different. These countries have developed high energy MOV based surge diverters and the use of spark gaps has been almost unknown. For example Novaris manufactures its MULTIMOV diverters in ratings up to 200kA per phase.

The major difficulty with spark gap protectors is the impulse firing voltage, which for triggered spark gaps is still high as the figure above shows. The second difficulty still remains with the “follow on” current. Performance graphs in brochures look very attractive but a little interpretation is needed. Below is the performance of a triggered spark gap tested with a 6kV 1.2us, 3kA 8/20us combination waveform superimposed on the positive peak of a 240V 50Hz supply.

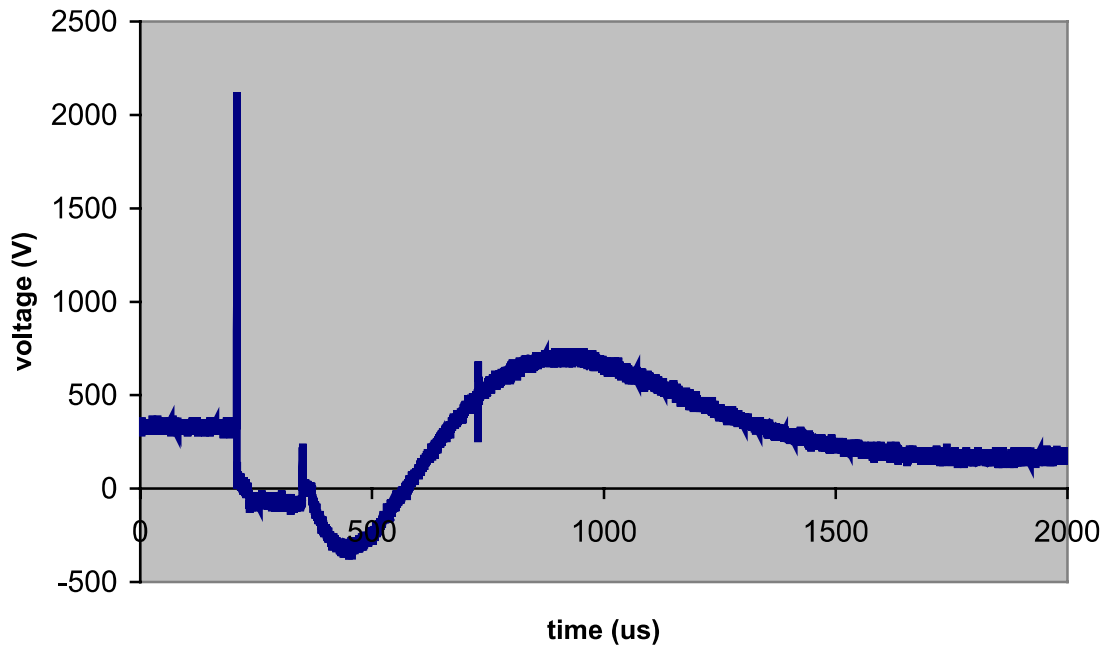
The trace on the left shows the mains peak, 340V, followed by the impulse and the spark gap operation. The mains voltage then drops to zero as the spark gap conducts and the follow on current flows. This is because the test generator and its isolation network has relatively high source impedance. In a real installation the follow on current will flow until the next mains zero crossing.



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In order to fully test spark gap diverters it is necessary to apply an impulse and activate the spark gap with an AC supply whose potential short circuit current is equal to the installation in which the diverter will be installed. This can be done as follows:

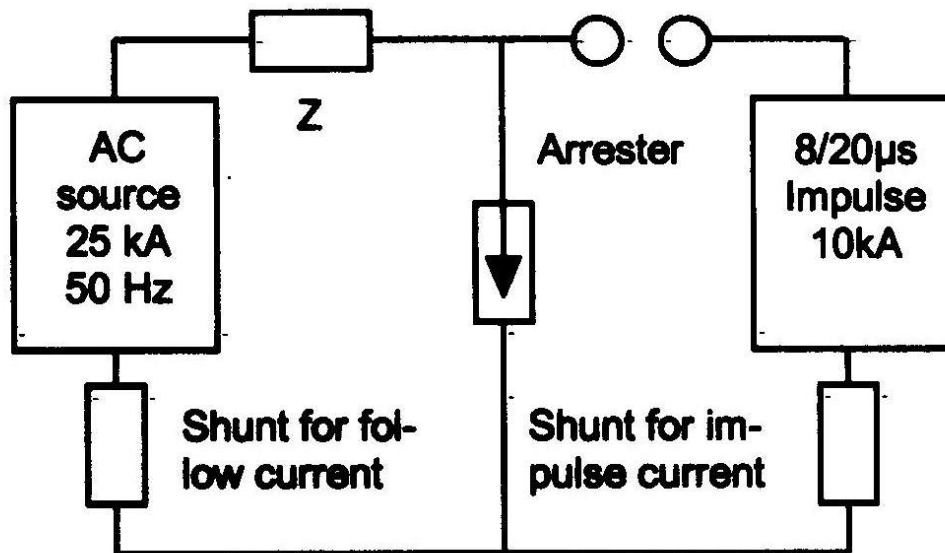


Fig.7 Principle test arrangement for combined testing of gap arresters with surge current and follow current.

The results of such a test are shown below (ref 1):



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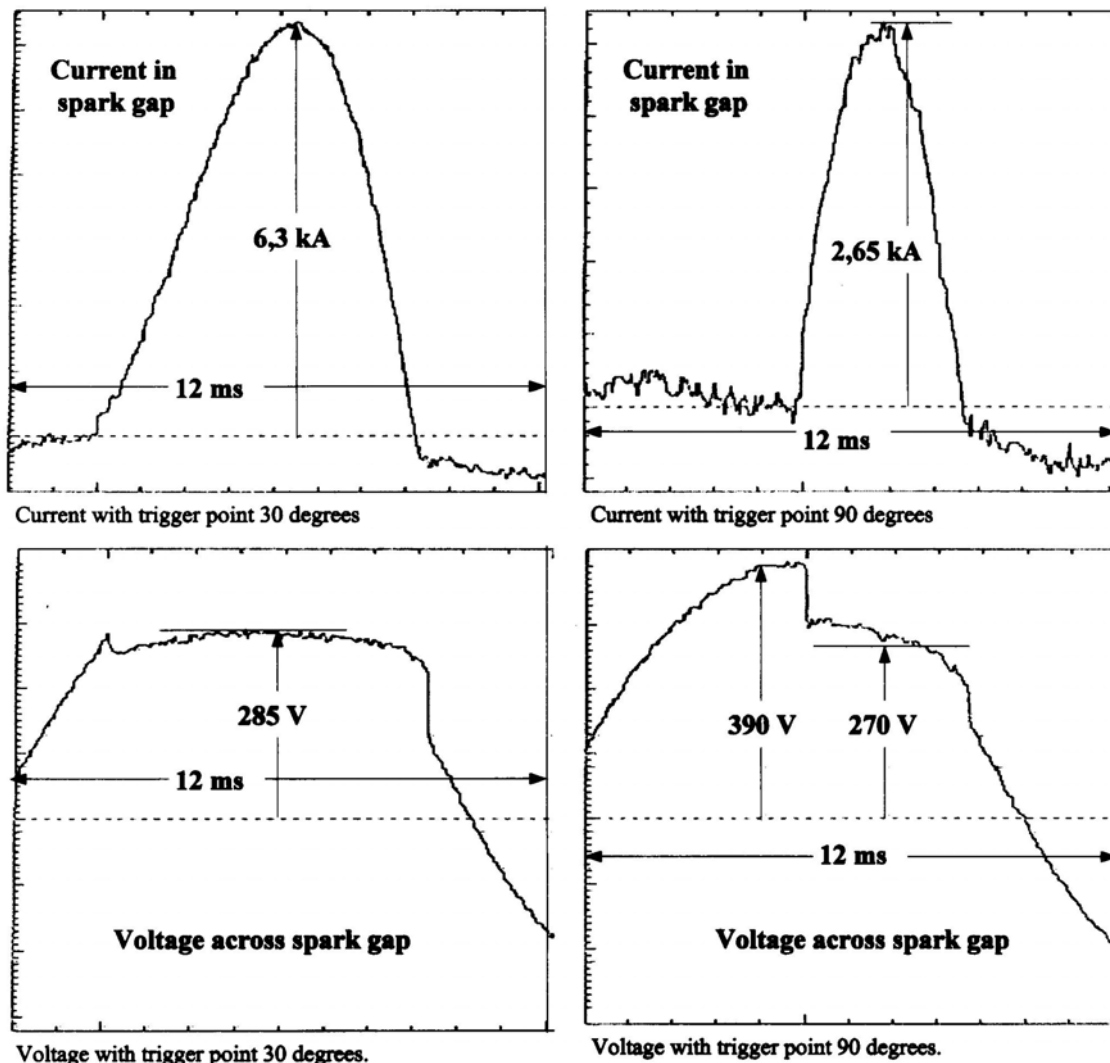
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These tests show:

1. The follow on current is large and depends upon the available short circuit current from the supply.
2. The follow on current distorts the mains voltage waveform.
3. The magnitude of the follow on current depends upon where in the mains cycle the spark gap is triggered.
4. The follow on current will continue until the next mains zero crossing.

The potential for tripping upstream circuit breakers is obvious. The 6.3kA graph has an I^2t of approximately 140,000. A 160A HRC fuse may just survive. For main switchboards rated less than 160A per phase there will always be a possibility of the follow on current tripping the main supply. For this reason spark gap surge diverters must be fused to prevent upstream line fuses or circuit breakers tripping.



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Spark gap surge diverters must be chosen with an AC fault current rating equal to or greater than the potential fault current of the installation. If not there is no guarantee that the arc will be extinguished at the next zero crossing. For example many of the German domestic types have fault currents ranging from 4kA to 17.5kA and are unsuitable for main switchboard installation.

Conclusion

Spark gap surge diverters have high energy ratings and therefore could find use in highly exposed sites.

Let through voltage even with the triggered types is high prior to the spark gap firing. This means they must be followed by secondary protection to limit the let through voltage.

Spark gap protectors have an AC follow on current, which depends upon the source impedance of supply. This AC follow on current may trip upstream service fuses and circuit breakers particularly in main switchboard installation of less than 125A per phase.

MOV type diverters have no follow on current since they clamp the voltage above the mains peak. They have proven effective and reliable over many years. There seems little reason to change to spark gaps and until such time as that reason appears Novaris will continue to recommend MOV type protection for main switchboard installations. Novaris is able to supply spark gap protectors but will not recommend such devices unless there is a compelling reason and so long as the customer is well aware of the potential pitfalls.

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References:

1. "Lightning Arresters with Spark Gaps. Requirements and Future Trends of Development and Application" Meppelink, Drilling, Droidner, Jordan and Trinkwald. Presented at ICLP Rhodes September 2000.

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