Arc Fault Protection System in Low-Voltage Installations for Protecting Installations and Persons

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Overcurrent protective devices are often not sufficient to protect installations and persons from the effects of arc faults. Fast active protective devices, which limit the arc duration to some milliseconds, provide significantly increased protection. This article deals with the design of and requirements on such an active protection system, which consists of an arc detection device and a short-circuiter. Both fixed installation and a mobile arrangement of the system will be presented.

Keywords: arc fault, arc detection, short-circuiter, protection of installations, live working

1 INTRODUCTION

Arcs resulting from insulation faults that have a wide range of causes can occur in electrical installations or also in on-board electrical power supplies with high operating voltages. The arcs produced in this way are undesirable and are generally known as arc faults. The level of current present in these arc faults can vary considerably, depending on the installation and the fault concerned. This prevents the overcurrent protective devices in the network from being tripped or causes them to be tripped only with a considerable delay. The amount of energy associated with the arc resulting from this uncertain or delayed tripping of the protective devices may cause severe damage to the installation or even injury to persons. Active protection measures assume that the arc fault will occur, and comprise arc detection and methods of disconnecting the arc fault [1]. A very reliable and yet often slower method of detection is generally implemented in lower power AC and DC networks. Existing switches of the installation are used here for the activation. In order to achieve under these cases a good protection, the time required for reliable detection may be several multiples of 10 ms. In high power networks such as in LV/MV systems, active arc fault protection measures must be effective within a few milliseconds (< 5 ms). In order to limit the effect [1] of the arc fault (e.g. pressure, radiation, sound, pyrolysis) as much as possible, it must be quenched before it reaches the peak current value. Limiting the duration of the arc fault not only limits the maximum effects produced but also drastically reduces their duration and thus the secondary effects of temperature, vapors, fire risk, as well as the migration of the arc. The energy of the arc must be limited to 100 kWs in order to achieve the aim of system protection. A limit of 50 kWs is even necessary in order to prevent serious injury to persons working on installations [2].

2 FIXED INSTALLATION

Arc fault currents of 30 to approx. 70 % of the prospective short-circuit current can occur in low-voltage systems [1, 2]. Although these currents therefore normally also trip the overcurrent protective devices, this is only possible with tripping delays several times longer than 10 ms, making the protection provided inadequate. To ensure rapid arc fault protection, an additional short-circuiter is often tripped with a delay of a few milliseconds. In this way, the arc fault is quenched considerably earlier than the disconnection provided by the overcurrent protective devices. In these kinds of systems, several criteria, such as light, current, pressure and sound, are used to detect the arc fault[1]. The combination of light and current has proven itself in LV systems. The effective spectral sensitivity is therefore generally in the visible range from blue to infra-red. The possibility to distinguish other light sources in this range is only limited. However, it must be ensured in these conditions that nuisance tripping caused by switching arcs resulting from switching during normal operation are prevented. The additional current measuring frequently needed normally makes use of the measuring equipment already provided in the system. When properly installed and maintained, the detection systems that are available enable detection times of < 1.5 ms or even < 1ms to be achieved already at arc currents below 10 kA. The system (Fig.1) consists of two short-circuiters which are mounted directly on the busbars between the phases.

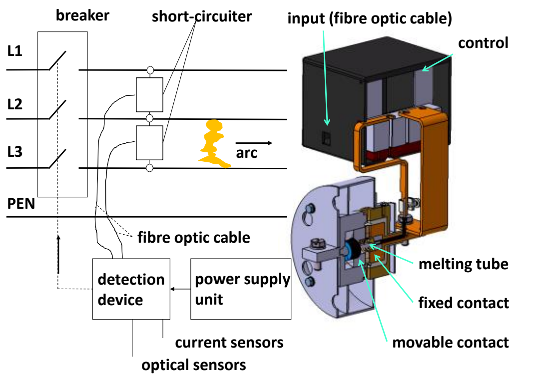

Fig.1: Arc fault protection system and short-circuiter

This arrangement for implementing a three-pole short-circuit is sufficient to ensure the reliable quenching of all normal arc faults and does not require any additional switch panel due to its small dimensions. A fiber optic connection is enough to activate the short-circuiter. The energy required for tripping the short-circuiter is provided from the residual voltage of the arc fault itself. The short-circuiter (Fig.1) has a fixed and a moving contact. After the signal is transmitted, a current flows through a melting tube, causing it to be rapidly destroyed adiabatically. The moving contact then moves towards the fixed contact, thus producing a bolted short-circuit.

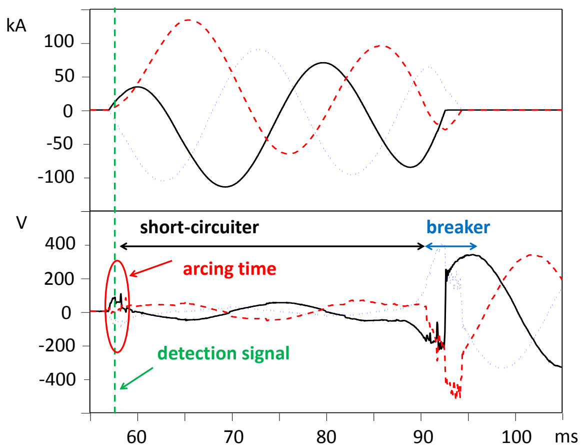

Fig.2: Function of short-circuiter in a three-phase system (230/400 V) with breaker

However, the commutation of the arc fault current and thus its quenching starts already when the current flows through this tube. Figure 2 shows an example of the quenching of an arc fault in a 230/400 V switchboard with this type of short-circuiter at a prospective current of 65 kA. The detection was implemented with optical point sensors only. The arc was detected after approx. 0.6 ms. The circuit-breaker of the switchboard was tripped at the same time as the short-circuiters. The commutation and the complete quenching of the arcs was completed after approx. 1.6 ms. The high-speed breaker interrupted the short-circuit current after approx. 40 ms. The energy of the arc fault was limited by the system to < 10 kJ.

3 SYSTEM FOR LIVE WORKING

The installation of arc fault protection systems with fixed short-circuiters is normally restricted to systems requiring a high level of availability combined with high short-circuit ratings. Only a small proportion of systems are therefore provided with an arc fault protection system for maintenance work that has to be carried out under live conditions. However, persons working here are directly exposed to risk, particularly with opened systems. The wearing of personal protective equipment (PPE) is prescribed for live working. This personal protective equipment is suitable for reducing the thermal effect of arc faults, so that a person does not suffer from second degree burns. IEC 61482-1-2 stipulates that protection against arc fault energy up to 318 kJ is ensured with PPE class 2. The additional use of a mobile short-circuiter to optimize personal protection during live working is useful in order to achieve a drastic reduction of the thermal effect and also the other effects of the arc fault in particular [3]. Live working requires mobile use of the protective system as much as possible. The installation of the protective system must be simple and should not cause any additional hazards. The system must have a high level of trip reliability in the event of an arc fault and a high resistance to nuisance tripping at the point of use. Live working is largely carried out in systems with a lower power rating compared to industrial systems.

In the public utility sector, 80% of the systems have prospective short-circuit currents in the 10 kA range. Fuses are generally used as overcurrent protective devices in these systems. During live working, the arc fault is frequently caused at the equipment of the switchboard and not directly at the busbars. The installation of current measuring devices and optical line sensors locally would thus cause a considerable hazard. The arc fault protection system therefore operates with purely optical arc fault detection using point sensors.

3.1 DETECTION SYSTEM

Spectral sensitivity is between approx. 300 and 850 nm. During live working, however, it cannot be assumed that the system is closed, but rather that extraneous light or even additional lighting is present. The withdrawing of fuses under load and normal operational switching may also be necessary during live working. This, however, will produce a visible switching arc amongst other things. To prevent nuisance tripping, a detection unit of the arc fault protection system evaluates a threshold value of illuminance for a fixed duration, as well as the relative change in illuminance (9000 lx /ms) at a specific gradient. A tripping signal is sent if an illuminance of 120,000 lx is reached without any other criteria. Tests in a realistic environment showed that this evaluation was sufficiently insensitive to disturbance from external light generated from construction lighting (halogen, xenon, fluorescent lights), normal flash lights, indirect sunlight. The switching arcs of modern switchgear as well as the withdrawing of fuses under load at currents even above > 1 kA likewise are not detected as arc faults [4]. During live working, the arc fault may be covered by sections of the system or by the person carrying out the work. Several point sensors can be provided here in order to ensure a high detection reliability despite this. Figure 3 shows an example of this kind of system. In this case, the system can be monitored fully and redundantly with three sensors (overlapping color areas) with a high detection reliability with arc faults of only 1 kA (arc lengths > 1 cm). This has been demonstrated in extensive tests using standing and crouching dummies. Fewer sensors are sufficient when the light intensity of the arc is higher or the working areas are defined.

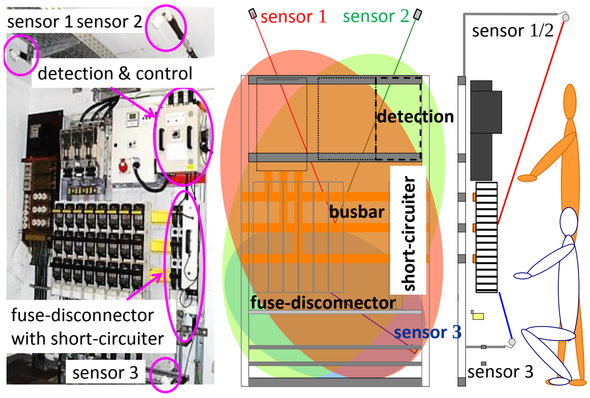

Fig.3: LV system with mobile arc fault protection

3.2 SHORT-CIRCUITER

The short-circuiter preferably consists of only two units, which are each arranged between the two phases. As shown in Figure 4, a special strip-type NH fuse switch-disconnector, which is also lockable, can be installed or provided in the system for higher short-circuit currents and higher incoming supplies of up to 630 kVA. Two short-circuiters with an NH design (Fig.4) as well as a disconnecting blade are inserted in this fuse-disconnector. The control unit as well as the detection unit can be arranged in a mobile box to which the optical point sensors are connected.

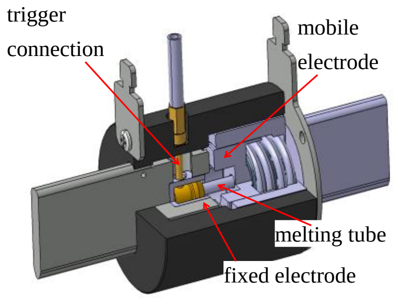

Fig.4: Short-circuiter with NH design

The fuse-disconnector can carry short-circuit currents of 25 kA (impulse 53 kA) for 1 s. The short-circuiters can also be arranged in the mobile box with the detection unit and the control unit for prospective short-circuit currents of approx. 10 kA. The box itself can also be provided with a battery for a stand-alone power supply and can house its connection cables and optical sensors. Figure 5 shows this type of arrangement installed in an LV system with two point sensors.

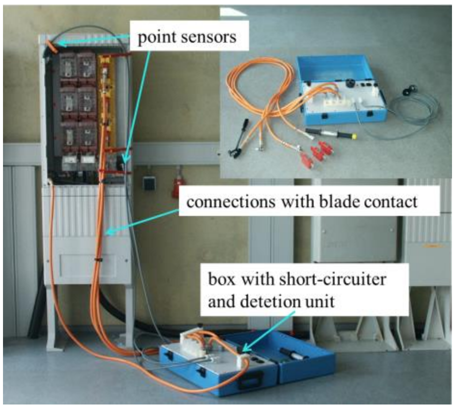

Fig.5: LV system with mobile arc fault protection

3.3 BENEFITS

The current can be severely limited by the arc fault. Even if the prospective short-circuit current is only limited by 50%, the disconnection time of a fuse can be drastically delayed.

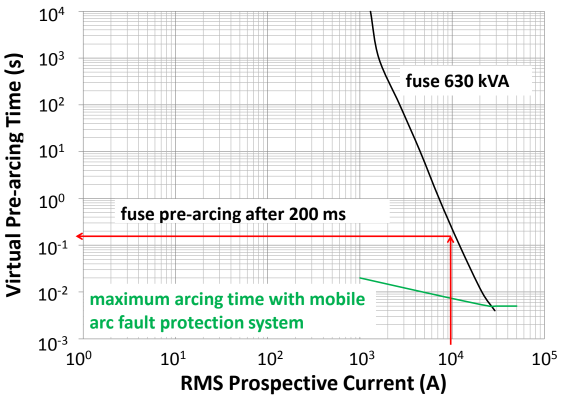

Fig.6: Time-current characteristics of fuse and the protection system

A system rated at 630 kVA typically have prospective short-circuit currents of between 16 and 23 kA, and are therefore equipped accordingly with NH 630 kVA-gTr fuses (Fig.6). The disconnection time at the prospective short-circuit current is only a few milliseconds. However, if the current is limited to 10 kA, this break time already increases to over 200 ms. The energy of an arc fault at approx. 200 V with over > 600 kJ exceeds the protection limit of the personal protection equipment. With an additional short-circuiter the duration of the current flow as well as the arcing time can be limited to only a few milliseconds as the fuse is loaded with almost the prospective short-circuit current after the system is activated. The short-circuiter system enables the maximum arcing times at currents of 1 kA and higher to be limited in less than 20 ms, currents of 25 kA and higher in less than 5 ms. With a three-phase short-circuit at 25 kA, the arc fault energy stays below 30 kJ and thus far within the thermal protection limit of personal protective equipment. The considerable time limitation of the arc fault also drastically reduced the radiation effect, the pressure wave, the sound, the metal vapor, the metal particles, the toxic gases and the pyrolysis. This therefore considerably improves the protection of the system and of persons carrying out live working.

4 CONCLUSIONS

Short-circuiters can considerably reduce the effect of arc faults in LV systems. The arc faults can be extinguished considerably earlier than the disconnection implemented by overcurrent protective devices such as circuit-breakers and fuses. This improved protection can be achieved particularly with permanently installed devices for systems with very high short-circuit ratings. Personnel protection is naturally also improved as well as system protection. A mobile system can be used to provide additional protection for low and medium power systems, which are normally not equipped with a permanently installed arc fault protection system. This is particularly useful for live working since personnel may be exposed directly. A sufficiently fast and reliable detection of arc faults can be achieved with little additional effort, even under special conditions of live working.

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