

TECHNICAL NEWS

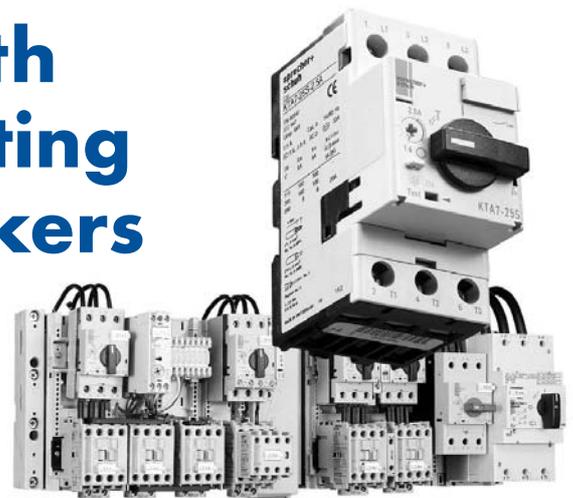
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Controlling high short circuit currents with current limiting circuit breakers

By J Paulke



Modern industrial power systems have to be able to meet peak load without difficulty. The corresponding capacity or "spinning reserves" means that in the event of a fault, the short circuit current rises rapidly. One solution is to use circuit breakers that are capable of limiting the fault current to a lower level minimising the thermal and mechanical stress on the plant and its components.

How do current limiting circuit breakers work?

The steady increase in the size and power of electricity distribution systems not only makes more power available to the consumer in normal operations, it also raises the short circuit level. It is therefore extremely important to adequately protect an electrical plant against overload, to handle high short circuit currents and to selectively isolate the affected section of the power system in case of a fault.

In the case of a short circuit the stress on the switchgear as well as on other system components can be reduced substantially, however, if the short circuit current can be cut off before it

has a chance to reach a high level. The standard AS3439 (Low voltage switchgear and controlgear assemblies) takes this into account by not specifying any verification of short circuit withstand for let-through currents lower than 15kA. The current flowing in the event of a short circuit can be limited by a rapid build-up of an arc voltage to oppose the system voltage driving it. Current limiting circuit breakers operate according to this principle.

Design and operation of current limiting circuit breakers

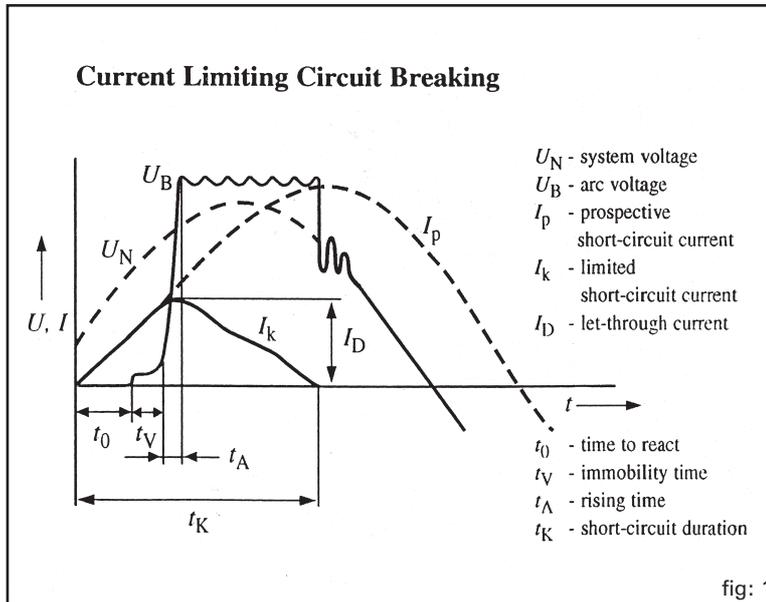
A short circuit can only be effectively limited by a circuit breaker, if the arc voltage can be made to increase to a sufficiently high level in the shortest possible time. Since an arc cannot ignite, and no arc voltage can build up until the contacts separate, the short circuit increases during the time the circuit breaker takes to react (Fig. 1).

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The periods are essentially

- separation of the contacts and ignition of the arc,
- arc motion and arc lengthening and
- splitting up the arc

(See Fig. 2)

Immediately after the arc ignites, the arc roots on the surface of the contacts remain stationary for an instant. During this immobility time, the increase in an arc voltage is brought about solely by the lengthening of the arc due to the opening of the contacts.

A worthwhile increase in arc voltage during this period can only be achieved by a high operating speed, which is only possible with a high-precision mechanism having moving parts with very low masses. As previously mentioned, by proper design of the mechanism and the current path, the electromagnetic forces of the short circuit current itself can be used to accelerate the

Therefore the short circuit trip on the circuit breaker must trip the contact with as little delay as possible to ignite the arc. By appropriately designing a circuit breaker, it is possible to use the electromagnetic forces of the short circuit current to support the opening of the contacts. Thus the contact opening is assisted by a hammer armature that is accelerated by the field of a coil conducting the fault current and knocks the contacts apart.

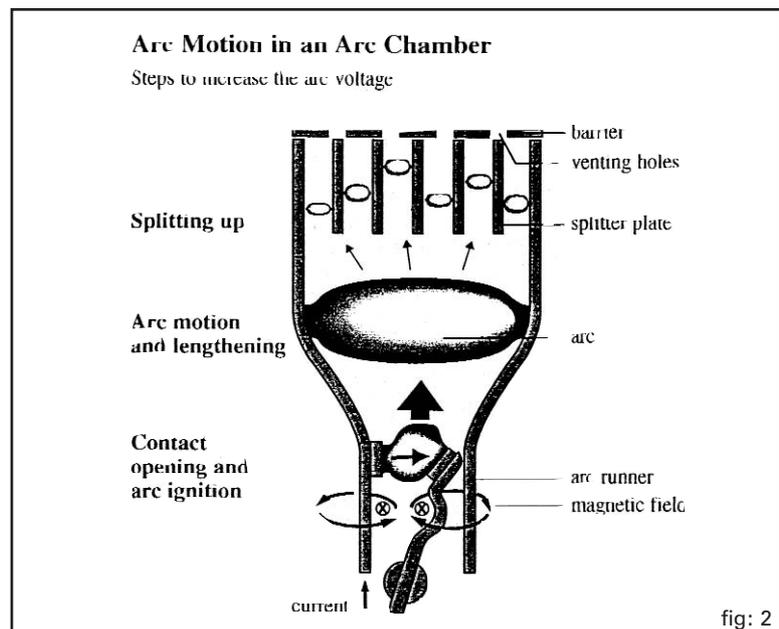
achieved mainly by,

- lengthening the arc,
- cooling the arc and
- splitting the arc up into several series of arcs.

The build-up of a high arc voltage in an arc chamber can be divided into a number of periods during which the above techniques are applied to increase the arc voltage.

Controlling the arc

As the contacts open, the surface area making contact quickly becomes smaller and current density as well as contact resistance increase, until finally the metal at the last point of contact vaporises explosively - that is the moment of arc ignition. The main task now is to increase the arc voltage in the shortest possible time and with it, its power conversion. This is



opening of the contacts.

To further increase the arc voltage, the arc must be driven off the contact points. For this purpose, the current path in the region of the contacts must be arranged so the resulting magnetic fields exert a force on the plasma of the arc to move it away from the contact points towards the arc splitter plates (Fig. 2). While it is moving through the arc chamber, the arc also has to be extended to enable it to be forced properly into the stack of splitter plates. Those splitter plates have the effect of splitting the arc up into a number of series of arcs which contributes to yet another considerable increase in the overall arc voltage.

Temperature, pressure and flow in the arc chamber

The processes while tripping a short circuit described above are generally accompanied by extreme temperature and pressure gradients. While immediately after the arc has passed a given point in the arc chamber, temperatures of a few thousand Kelvin can still be measured, the temperatures in the core of the arc are between 10000 K and 20000K.

The explosive vaporisation of the metallic melting bridge in the moment of arc ignition generates a shock wave that is propagated through the arc chamber and is reflected several times from its walls. Other pressure waves result from the movement of the arc through the arc chamber.

Their magnitude depends on the current. The pressure reached ranges from a few bar in the case of small circuit breakers to tens of bar in large circuit breakers. While the characteristics of the arc plasma are such that a high pressure contributes to increasing the arc voltage, the shock waves do subject the circuit breaker to considerable mechanical stress. Since a pressure wave forms in front of the moving arc which resists and slows its movement and can delay or prevent the arc from being pushed into the stack of splitter plates, pressure waves also directly influence the behaviour of the arc and therefore the breaking characteristics of the circuit breaker. The arc chamber therefore has venting holes that provide for a controlled reduction of the pressure waves. (Fig. 2) The high pressure and temperature gradients, the magnetic forces acting on the current conducting plasma and the fast arc motion also cause flows of plasma in the arc chamber that influence the breaking operation of the circuit breaker.

Reducing costs by limiting the current

Understanding and being able to control these complex processes are the basis for achieving an improvement in circuit breaker performance.

Years of experience, ongoing research and development and the application of modern digital computing techniques

are essential to take advantage of the complex interaction between chamber geometry, magnetic field distribution, pressure and temperature distribution, arc motion and plasma flow in the arc chamber. The results of these efforts are evident in Sprecher + Schuh's KT7 series of circuit breakers of the Advanced Control System (ACS) which exhibits a marked improvement on the already impressive performance of its predecessor the KTA3-25.

Limiting the short circuit current values to far below the prospective fault current of the system and the resulting reduction in the thermal and dynamic stress on the circuit breaker and primary plant obviates in most cases any necessity to achieve reliability by deliberately oversizing components, eg. contactors for motor starters to achieve type "2" co-ordination. Appreciably reducing the short-circuit current is thus the key to constructing more compact and therefore cheaper switchgear installations, especially at high fault current levels.

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Short circuit co-ordination KT 7

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