

Mains power supply and circuit protection

(Fuses and circuit breakers)

Lyle Whyatt VK5ZNB.

This article relates to domestic type installations, as industrial installations will have other criteria. The fuses and circuit breakers (CBs) under discussion are the circuit fuses at the switchboard, not the fuses which may be installed in any apparatus.

Operation of fuses and circuit breakers

Wire fuses

Wire fuses are heat/temperature sensing devices. In normal operation, at loads up to its rated capacity, the fuse will heat up as a resistor in the circuit (which it is). Under overload conditions the temperature rises to the melting (fusing) point of the wire element, and the fuse opens the circuit. Under typical conditions, with tinned copper wire, the actual fusing current will correspond to about twice the rated current. Figure 1 shows a common porcelain fuse-holder and also a modern CB which can replace its re-wireable wedge.

If the fuse is subject to a short circuit, the temperature rise will be almost instantaneous and the wire will vaporize, causing an arc within its holder, and leave only coppery black flash residue. Some re-wireable fuse wedges have a torturous wire path to help extinguish the arc. As the size of street supply mains and consumer circuit wiring is increased, there is a possibility that the

lower impedance of the mains will allow sufficient current to flow to maintain the arc, which continues until some other protection feature operates. In extreme cases, a fire may ensue, especially in multi-phase installations.

HRC Fuses

High Rupturing Capacity (HRC) fuse elements are typically silver wire or foil and are contained in a ceramic tubular container with metal end caps. The space within the tube is filled with a sand-like substance. These fuses act in the same way as wire fuses with respect to overload conditions, and typically will not operate until about three times the rated current is exceeded for some time. Under short circuit conditions, the vaporization of the element and any arcing is contained within the ceramic tube and is not likely to cause a fire. Figure 2 shows a typical HRC fuse cartridge with both base and top of its fuse-holder.

Fuse and CB ratings

The rating of fuses and CBs includes three parameters:

- Voltage of circuit
- Current rating. Normal/continuous operation.
- Rupture capacity. The effective capacity to interrupt an instantaneous fault current up to thousands of amps without mechanical failure (blowing up or destroying itself!)

Wire fuses have a very low rupture capacity under fault current. Typical HRC fuses have a rupture capacity of 80 to 100 kA and offer the highest protection, but with the added expense, if you have to replace them. Wire fuses should never be used to replace HRC fuses. Replacement fuses should always match the existing fuse rating but could have a higher rupture capacity.

Circuit breakers

Circuit breakers (CBs) are essentially a spring-loaded switch with the contact release mechanism being both temperature (normal load current) and magnetically (fault current) controlled. The separating contact system will be located within an arc-chute to stretch

Glossary of terms

Fuse: A device placed in the active line of a circuit, which provides protection through the fusing of a wire or similar element. This device requires replacement of the fusible element before the circuit is restored.

Circuit breaker: A device, which through heating and/or magnetic effect causes a spring loaded contact to be opened. This device can be simply re-set to restore supply after the fault/overload is removed.

Overload fault: A circuit which is electrically overloaded beyond the designed limit, although the excess current is not caused by any faulty appliance, e.g. a stalled motor.

Short circuit fault (temporary): A live circuit where the active and neutral are brought together in an intermittent contact.

Short circuit fault (bolted): A circuit, initially dead (switched off), which has the active and neutral effectively bolted together through

some fault, and then the switch is closed. This fault always results in very high current flow.

Mains supply fuse: The fuse (or circuit breaker) installed by the power authority, normally at the service point for the consumer.

Fault current level: The instantaneous fault current which is caused in the power mains at the service point and switchboard location. Its magnitude depends on the distance from the power station, on the voltages used, and on the differing conductor sizes in the street supply circuits. Values of 6 kA to 50 kA are typical.

Mains supply alternatives: There are many different forms of mains supply and these may require different fusing criteria when considering fault current. Typical forms are:

- Bare mains mounted on poles/cross-arms, with insulated separate service wires to

the house and then (service) fused at the eaves or in the meter box.

- Bare mains mounted on poles/cross-arms, with insulated neutral screened cable (concentric stranded neutral around the central active core/s) and then (service) fused in the meter box.
- Bare or insulated mains mounted on poles/cross-arms, with a service fuse box mounted on the pole, supplying the consumer via an underground connection.
- Underground mains with service fuse pits/pillars at the boundary of the property. This is further divided between houses on the mains side of the road (with maximum fault current) and those fed across the road with the longer, smaller sized service cable.

and extinguish the arc around the moving contact within the body of the CB. Figure 1 shows a typical domestic CB which may replace the old porcelain re-wired wedge.

As a fully engineered device, a CB will be able to control over-current heating (time curves are published) and instantaneous faults according to the details of the design. Typical modern rail-type switchboard CBs may have a fault rating of 4.5 kA to 8 kA. If you are installing or replacing CBs use the 6 kA or 8 kA types when your fault current is high (How far away is your supply transformer?).

Plug-in CBs

Many older switchboards used wire fuses with porcelain bodies. There are plug-in CBs available which plug into the fuse base in place of the wire fuse holder. Typically these have a 5 to 20 amp rating to match the old fuses. These CBs provide much better fault protection than wire fuses and do not need to be replaced after an operation. After checking and clearing the fault, just switch 'off' to reload the spring contact assembly and then switch 'on'. They normally have a 1.5 kA to 3 kA fault rating which is better than a wire fuse, but not necessarily good enough for your fault current condition. Always look for the 3 kA variety. Do not replace a HRC fuse with an old-design porcelain type fuse base just so that you can use one of these CB's. Your HRC fuse was put there to provide high fault current protection.

Power supply system

In older areas with bare overhead copper mains, the conductors may be small (up to just adequate!) in size and these mains will provide a comparatively high impedance to fault current. This, combined with the service run from pole to house, will limit the available fault current at the switchboard such that 1.5 to 3 kA CBs should be able to handle it OK. However if you are connected to the mains at the actual transformer pole, or only one span away, your fault current could be significant, and higher rating CBs should be used.

In newer areas with larger bare/insulated overhead aluminium mains, the impedance will be less and significant fault current may be possible. The service wiring could be 10 mm² copper



Figure 1: Porcelain wire fuse and CB replacement

and this is able to carry significant fault current to the switchboard. In these conditions wire fuses should not be used and only HRC fuses or 4.5 kA CBs, minimum, should be considered.

In modern areas, the underground street mains cables will be large, typically 150 mm² aluminium, and the smaller tee-off service cables to the other side of the road will be 35 mm² aluminium. These cables can carry substantial fault current and only HRC fuses or 6 kA CBs are recommended. In no circumstances should wire fuses be used.

A call to your power supplier should

be able to establish the fault current at your location, or at least at your supply transformer.

All modern supply service fuses will be HRC type, whether located in a pole service box, in a service pillar/pit or on the switchboard. In areas remote from the city, the service fuse may be replaced with a high rupture CB with an external operating lever. This enables a consumer to reset the CB after an incident without the necessity to call out a power company technician who has to travel many kilometres just to restore supply.

ar



Figure 2: HRC fuse cartridge and holder