Continuity of Protective Conductors

Resistance

Resistance can be defined as:

"… that component of a circuit which produces or generates opposition to the free movement of electrons".

George Simon Ohm expressed resistance in his law which states that "The current in a circuit (resistive) is directly proportional to the voltage and inversely proportional to the resistance. This is expressed in the following formula:

$$I = \frac{V}{R}$$

When we take a look at a normal circuit, we think of the load as being the only present resistance, as indicated below:

In truth, the actual circuit conductors themselves contain a resistance so when we look at the circuit above, we should take this into account as below:
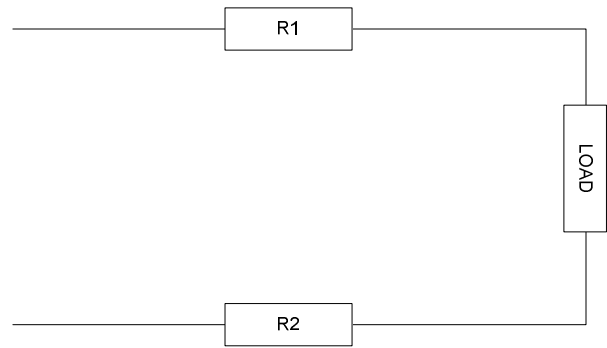
Resistance and the Conductor

Resistance is directly proportional to length and inversely proportional to c.s.a.

This means that

- More length = more resistance
- Less length = less resistance
- The greater the c.s.a. the less the resistance
- The smaller the c.s.a. the greater the resistance.

This relates directly to our cabling in that if a cable is too small (i.e. c.s.a. of 1 mm^2) to carry the current of the circuit we simply choose a larger c.s.a. cable (say 1.5 mm^2) so that the current is carried through the cable which has a lower resistance.

So it is worth realising that cables that possess resistance will directly affect the efficient working of our circuits. The other factors that affect the resistance of our cable are:

1. Heat (e.g. in the case of Ambient temperature
2. The actual material the cable is made from

Heat or Ambient Temperature

Heat has a direct effect on resistance and a cable (or any material) will be said to have a (temperature coefficient). If materials like copper and aluminium, that have a positive temperature coefficient, get hotter their resistance increases. If materials like carbon get hotter their resistance decreases and they are said to have a negative temperature coefficient.

So temperature is vitally important when considering cables as it directly affects a cables resistance and therefore its current carrying capacity. This is obviously linked to the correction factors we apply especially grouping and ambient temperature and thermal conditions.

The Actual Material

As all materials possess resistance scientists took samples in the form of cubes of every material and produced resistivity values for each material. Resistivity simply means the resistance of a "sample portion" of material, and in a similar way to resistance its value is measured in Ohms. The size of the sample usually in cubic cm or cubic mm means that its resistivity value is very small and coppers value for instance is given as 17µΩ/mm. This sample value is of course put into a formula which uses it and magnifies it by multiplying the cables complete length by the samples value.

There is a formula that relates the factors like length, c.s.a. and resistivity. This is:

$$R = \frac{\rho l}{a}$$

R= Resistance measured in Ω
ρ = the resistivity measured in µΩ/mm (Greek symbol Rho)
l = the length is the cable
a = the surface area of the cable

The c.p.c.

We know that the job of the c.p.c. is to safely, speedily and adequately carry the fault current through the "earth path" and as it will possess resistance this must be as low as is possible to ensure effective operation of the circuits protective device whether fuse or m.c.b.

It is because of this, that the formula:

$$S = \frac{\sqrt{I^2 t}}{k}$$

is employed to check the effective size of the c.p.c. If it is shown as too small, a larger c.p.c. must be installed. Alternatively, BS7671 provides a table detaling acceptable conductor sizes.

Conductor Resistance and Insulation Resistance

When carrying out an insulation resistance test on a consumer unit it

is often easy to forget that all circuits basically are connected across live and neutral whatever they are, e.g. ring circuits, lighting circuits, showers, etc. This fact means that when all of these circuits are connected together and an insulation resistance test is done, the overall reading may well be unacceptable. Why, because the circuits all possess resistance and resistors in parallel have the effect of reducing the overall value. The diagram below shows 4 circuits each with a 'healthy' insulation resistance value of 2 MΩ.

The result of this is that 4 x 2 MΩ circuits give a total value of 0.5 MΩ (Fig 1). This is the lowest value we can accept and it is easy to see that any more circuits connected in parallel to them would mean an unacceptable value of insulation resistance.

The regulations (BS7671) allow us to sub-divide these circuits to get around this problem but it is a fact that often goes unrecognised that cables and resistances behave in this way.

We must not forget that the basic facts of Ohms Law, although having different names (cables, lights, elements, etc.) still produce the same results in our sometimes complicated installation. We need to remember the "ground rules" which hopefully will help us appreciate more fully, what we do and why we do it. So whether we are calculating the resistance of a lamp or interpreting the resistance of test result (i.e. a high current continuity tester) we must keep our fundamental principles in mind.
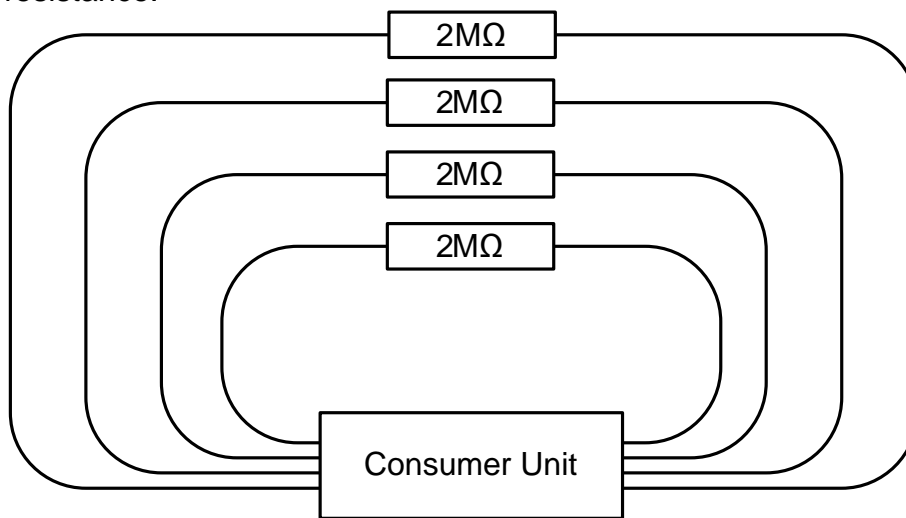

Fig 1. Resistances in parallel