The electric railway. Part 2, What is electricity and how can it be made to drive trains?

THE ELECTRIC RAILWAY

Paul Russenberger

Part 2 – What is electricity and how can it be made to drive trains?

Brig BLS shed with Re4/4 174 and Ae8/8 272. ALL PHOTOS: *Paul Russenberger*

As Ernst Birchler, a Swiss rolling stock engineer, once said to me *"This electricity is dangerous stuff – you can't see it, you can't hear it, you can't smell it; you can feel it - but then it's too late!"* Whatever it is, electricity has to be kept in its place and in its place it can do powerful things as Swiss railways so ably demonstrate.

This is a rather technical article – but don't stop reading just yet unless you have 'O-level' Physics. In it I want to introduce some of the concepts which will have to be considered in this series if I am to meet the Editor's challenge of explaining the what-and-the-why of Swiss electrification.

Firstly, electricity is in everything. In some things it can be made to move easily, these are **conductors**, and in others it cannot, these are **insulators**. Conductors are often metals such as iron (and hence steel), copper and aluminium. Copper conducts electricity well, aluminium is not as good, but it is strong and very light, making the combination useful for overhead line. Carbon is both a reasonable conductor and a lubricator, making it useful for pantograph heads which have to rub against the contact wire. Typical insulators are ceramics such as porcelain, cloth such as cotton and plastic. The latter two make good material to cover cables because they are mechanically flexible and porcelain is mechanically stiff making it suitable for insulating and supporting overhead lines – keeping the electricity in.

For electricity to flow through a circuit, it has to go all the way round and back to its starting point. A good example of this is the simple circuit making up a torch. The electricity comes out of the battery, along a wire, through a switch, through the lamp, through more wire, back into the other end of the battery and through the battery to emerge again. If any part of the circuit is disconnected, the circuit is incomplete and the electricity does not flow. Taking the typical electrified railway, the electricity is generated (never mind how just yet), comes through the supply network, along the overhead line or conductor rail, through the traction equipment on the train, into the running rails, back to the supply network and so to the generating station.

The electricity is made to move by an **electromotive force, e.m.f.** for short. This can be developed by a chemical reaction in a battery, but it is limited. It is better done with a generator. These work by passing a conductor through a magnetic field. This induces an e.m.f. in the conductor and the electricity will try to move. How hard it tries depends on the strength of the magnetic field and how quickly the conductor moves through it; the harder it tries to move, the greater the e.m.f.

TOP: Hasle-Rüegsau on the EBT section of the Regional Mittelland. De4/4 235 propels in a single car while Te 26 stands in the siding.

BOTTOM: MOB BDe4/4 "Lenk" at the town of the same name in September 1990.

If the ends of the conductor are connected by a conducting material, the circuit is completed and the electric **current** flows. The **e.m.f.**, sometimes referred to as

TOP: Brünig line HGe4/4 101 965 stands at Brienz in August 1997.

BOTTOM:Brünig line Deh 1120 011 emerges from the tunnel at Brienz, August 1997.

the voltage, is measured in **volts** and the current in **ampères** or **amps**. How much current flows depends on the **resistance** of the whole circuit. It is a measure of how much the electricity is impeded as it flows round the circuit. It depends on the nature of the circuit, including the metal used in the cables, their cross section and length – the greater cross section, the lower the resistance and the greater the length, the greater the resistance. Resistance is measured in **ohms**.

The power flowing through any electrical circuit is found by multiplying the voltage by the current and is given in **watts.** For one of the 440 kilowatt BDe4/4 motor coaches of the MOB to deliver its full power, it has to draw 518 amps from the overhead line which is at 850 volts compared to the rail. (Work it out!)

It is time to introduce one of the Laws of Physics – Ohm's Law. It applies to all electrical circuits and to all individual parts of each circuit.

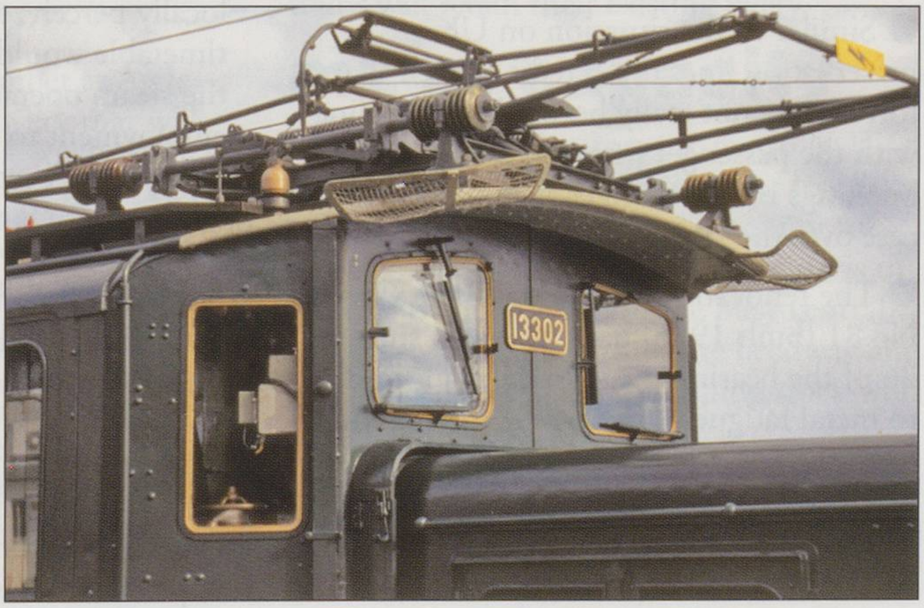
Electromotiveforce (e.m.f.) =
Current x Resistance
or
Volts = Amps x Ohms
(You can calculate that the BDe4/4 presents a resistance of 1.65 ohms at the supply.)

The electricity has to be driven from the power station through the supply system to the train. A voltage is needed at the train to force the electricity through it to drive the train. There will be some resistance in the supply system, so some of the voltage, and therefore power, will inevitably be lost before the electricity reaches the train. To keep the loss of voltage as low as possible, the current must be kept low and the power available at the train is given by the voltage between the overhead line (or the conductor rail) and the running rail multiplied by the current flowing.

As it was explained already when a conductor is moved through a magnetic field an e.m.f. is induced. The effect of the movement is to generate electricity. The process can also be made to work the other way round. If a conductor carrying an electric current is placed in a magnetic field, a mechanical force will act on the conductor and the conductor will try to move. Whenever an electric current flows, it creates a magnetic field around the conductor and the strength of the magnetic field is dependent on the current. The magnetic field produced by the current interacts with the other magnetic field in the same way as two magnets will interact with each other. The greater the current, the greater the force. So, to produce a large force in a motor, a large current has to flow. But in the paragraph above it was explained that the current flowing to the train has to be as low as possible.

This is the conflict. The voltage in the supply system must be as high as possible to keep the current and power loss down. The current in the train must be as high as possible to enable the motors to develop the force to drive along the track. The story continues…

Author's Note: This is a simplification as it should be more properly referred to as **'impedance'** *in order to apply to all circuits. I have used* **'resistance'**, *which is correct for direct current, to keep the nomenclature straightforward.*



TOP: RBDe4/4 2114 'Näfels-Mollis' at Le Bouveret. Electrification of the branch to St Gingolph in 1954 eliminated a pocket of steam working.

BOTTOM: The pantograph on Be6/8 13302 carries a warning against contact and has additional mesh screens to protect staff from inadvertent contact when entering the cab.