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Autor: Russenberger, Paul

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Paul Russenberger

RAILWAY ELECTRIFICATION IN SWITZERLAND

Our illustrious Chairman switches on a new series about the wires on Swiss railways.

PART 1: SOME PRINCIPLES AND PROBLEMS

There is only one reason for electrifying a railway: to improve its balance sheet – to enable it to make more money! This can be achieved by any of the following, examples being taken from Switzerland as far as possible:

- Increase in speed to increase ridership (main lines)
- Reduction in journey time through rapid acceleration of frequent stopping services (suburban services, notably around conurbations such as Zürich)
- Reduced fuel cost at point of use (schemes started around World War I as a result of difficulty in importing coal)
- Reduced cost of locomotive maintenance (all schemes)
- Elimination of a pocket of steam or diesel traction causing operational inflexibility and avoidable local costs (final SBB electrification of branches)
- Tunnel working necessitating exhaust-free traction (Jungfraubahn, Zürich S-Bahn)
- Increased environmental compatibility (urban tramways)

In reality, lines are usually electrified for a combination of these reasons. Because there is always the high capital cost of installing the fixed power supply equipment, together with additional civil engineering work, there must be an improved financial performance to service the capital invested. Since an electric locomotive is cheaper to build and maintain than the equivalent diesel, electrification schemes are usually implemented as an alternative to the construction of new diesel units.

Another advantage of electricity over diesel fuel as the prime mover is that the electric locomotive can draw upon a larger power supply than that available to a diesel. While diesel engines can be made to operate for limited periods at higher power outputs than their continuous rating, diesel engines fitted to locomotives are controlled so that their continuous power rating cannot be exceeded. It is much easier to construct an electric locomotive that can be permitted to exceed its continuous rating for short periods. In each case the limit lies in the production of heat which can be dissipated from an electric engine much more easily.

Perhaps uniquely, this was never really the situation in Switzerland where the development of electric traction was driven by the need to replace steam. In Switzerland steam traction had two significant disadvantages: it used imported fuel and a single new steam locomotive delivered a lower power output than an electric locomotive of similar date. The advantage of electric traction is enhanced by the weight of a steam locomotive and tender being more than the equivalent electric locomotive; less power is absorbed in moving the traction unit and so more is available to haul the money making payload.

Although a variety of reasons usually support electrification, the system actually chosen

OPPOSITE PAGE:

ABOVE: Swiss electrification as it is so well known - a train of lightweight coaches hauled by a standardised locomotive. A cross-country express enters Olten behind Re4/4ᴵᴵ 11266 in September 1990.

BELOW:

Relatively short distance, local electrification schemes often employ a dc supply, usually at 1500 volt. Here a BOB ABeh 4/4 arrives at Lauterbrunnen in September 1976. On the right the shorter mountain Wengernalpbahn, also electrified at 1500-volt dc can be seen.

ALL PHOTOGRAPHS BY THE AUTHOR

is almost always a compromise because there is a fundamental problem inherent in the nature of electricity. Electricity which is suitable for transmission from the generating station to a train is not suitable for driving its motors and vice versa. The thrust of technological development in electrification has been to reduce the unwanted effects of the compromise. Before embarking on a discussion of railway electrification in Switzerland, it will be useful to remind ourselves of how electricity "works", starting at the point of use – the motor.

When electricity is passed along a conductor, a magnetic field is created around the conductor. Everyday experience shows us that a magnetic field exerts a force on iron and other magnets; it also exerts a force on other magnetic fields. In the direct current (d.c.) motor the

Electrification of tramways has assisted in keeping streets clear and the urban air cleaner. A classic Swiss tram in Basel by the Spalenturn in July 1975.

current passes through fixed coils of copper wire wound round iron cores at the periphery of the motor to produce static magnetic fields; the current is then passed into the central, rotating part of the motor where it creates another set of fields. These fields react against the static ones and turn the motor. The greater the current, the greater the magnetic fields and the greater the turning force (or "torque") produced. The motor is reversed simply by changing the direction of the current flow in the fixed fields; this reverses the direction of the magnetic field and hence the direction of the force on the rotating part of the motor. This type of motor will also operate on alternating current (a.c.), but it needs to be low frequency a.c. and the resulting motor is larger, heavier and less efficient. The rotating part is known as the "armature" or "rotor."

Electricity will flow through a conductor when an "electromotive force" (e.m.f.) or "electrical potential difference" is applied to it. Whenever an e.m.f. appears, electricity will attempt to flow. An e.m.f. is measured in volts and is often referred to as "voltage": it is sometimes described as "tension", which is also the French word for voltage. An e.m.f. will be produced when a conductor is passed through a magnetic field – this principle is used in the generation of electricity. The coils turning in a motor are passing through the magnetic field created by the outer, fixed coils. Thus an e.m.f. is generated in the armature and opposes the flow of current; it is known as the "back e.m.f.". As the motor turns faster, the e.m.f. builds up and it is necessary to increase the applied voltage to maintain the current passing through it and the torque produced.

This effect enables a motor to be used as a generator and thus be made to act as a brake absorbing energy in the movement of the train and changing it into electrical energy. However, the voltage applied to a stationary motor has to be limited because the back e.m.f. is not present.

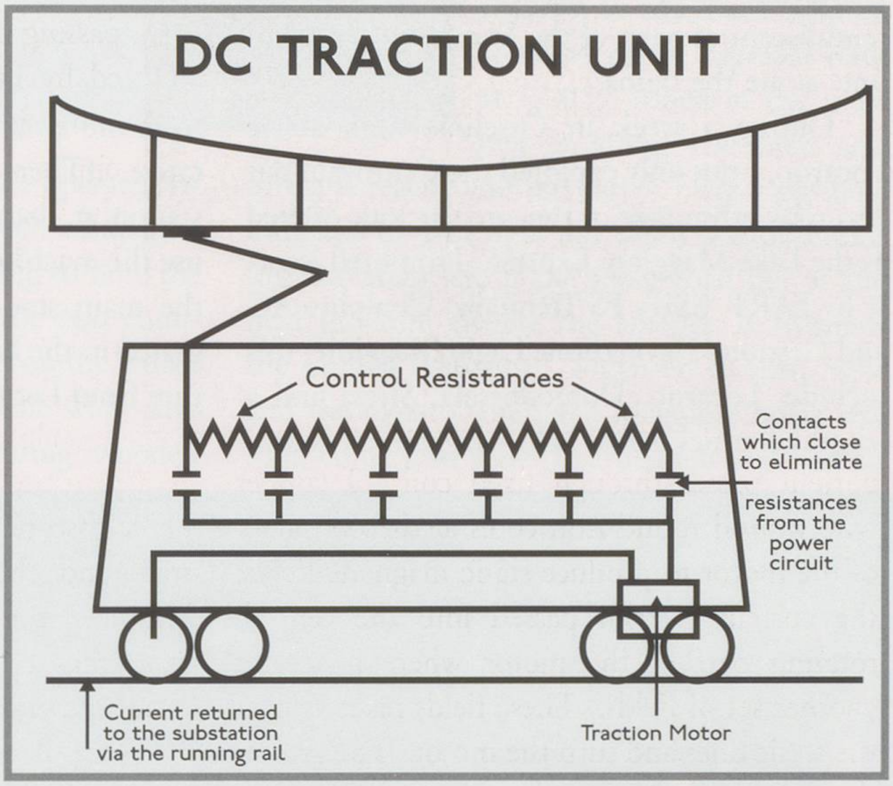
Regardless of how good a conductor is at passing electricity, it will resist the flow of electricity and in doing so absorb the voltage. The greater the current flowing, the greater the loss of voltage and the loss of power available to drive the train as it is used up forcing the electricity through the supply system. Simply putting more power into the system is not a solution, because this power used get the electricity to the train will rapidly exceed the power available at the train and will have to be paid for as well! Since the power delivered to the train is related to the current multiplied by the voltage, by transmitting electricity at high voltage less current is needed for a given power output and the power lost in transmission is reduced. In power terms this is better still, because doubling the voltage and halving the current passed will reduce the loss by three-quarters.

So here is the essential difficulty: electricity is best transmitted at high voltage and low current, whilst it has to be used in motors at low voltage and high current.

The feature of resisting the flow of current can be used to control a d.c. motor. By passing the electricity through "resistances" after the train picks it up and before it reaches the motors, the voltage at the motor can be reduced. As the motor begins to turn the back e.m.f is built up and the current drops. This means that the torque produced will drop, so the controlling resistance is reduced by closing switches, or contacts, so that the electric current can avoid passing through some of the resistances. The current will literally "take the path of least resistance." This is sometimes referred to as "short circuiting" or "shorting out" the resistances, which are themselves sometimes known as "resistance grids" or, simply "grids." The resistances are simply metal conductors, usually of iron or steel, shaped to allow air to pass through them easily. This air flow is needed because the energy that has been used driving the electric current through them has to go somewhere and it appears as heat. In Switzerland, they are often mounted on the roofs of motor coaches.

This heating effect unfortunately has another result. The rate at which the resistance grids can be cooled is limited by the air flow over them, so a rise in temperature is unavoidable as heat builds up faster than it can be dissipated. This means that a train has to be designed to accelerate sufficiently for an adequate back e.m.f. to be generated to enable all the resistances to be short circuited before they get too hot. (In B.R. Southern Region days this was known as "getting off the grids.")

It was explained above that a motor can be used as a generator and thus act as a brake for a train. This will only work if the generated electricity can go somewhere and a solution to this is to pass it through the resistances which have been used to control the motors. The resistances get hot and so absorb the energy from the motion of the train. That is why shimmering air can often be seen above the resistance banks on the motor coaches just after they have stopped.



In very simplified form, the electrical layout of a d.c. power unit is shown in the figure. The current is drawn from the overhead line, passed through the control resistances, then the motor and back to the substation through the running rail.

This system is used in Switzerland, largely on relatively short railways. Why this is so and why the Swiss chose to the low frequency a.c. system operating at 15,000 volt for main line electrification will be discussed in subsequent articles. *(TO BE CONTINUED)*