THE ELECTRIC RAILWAY

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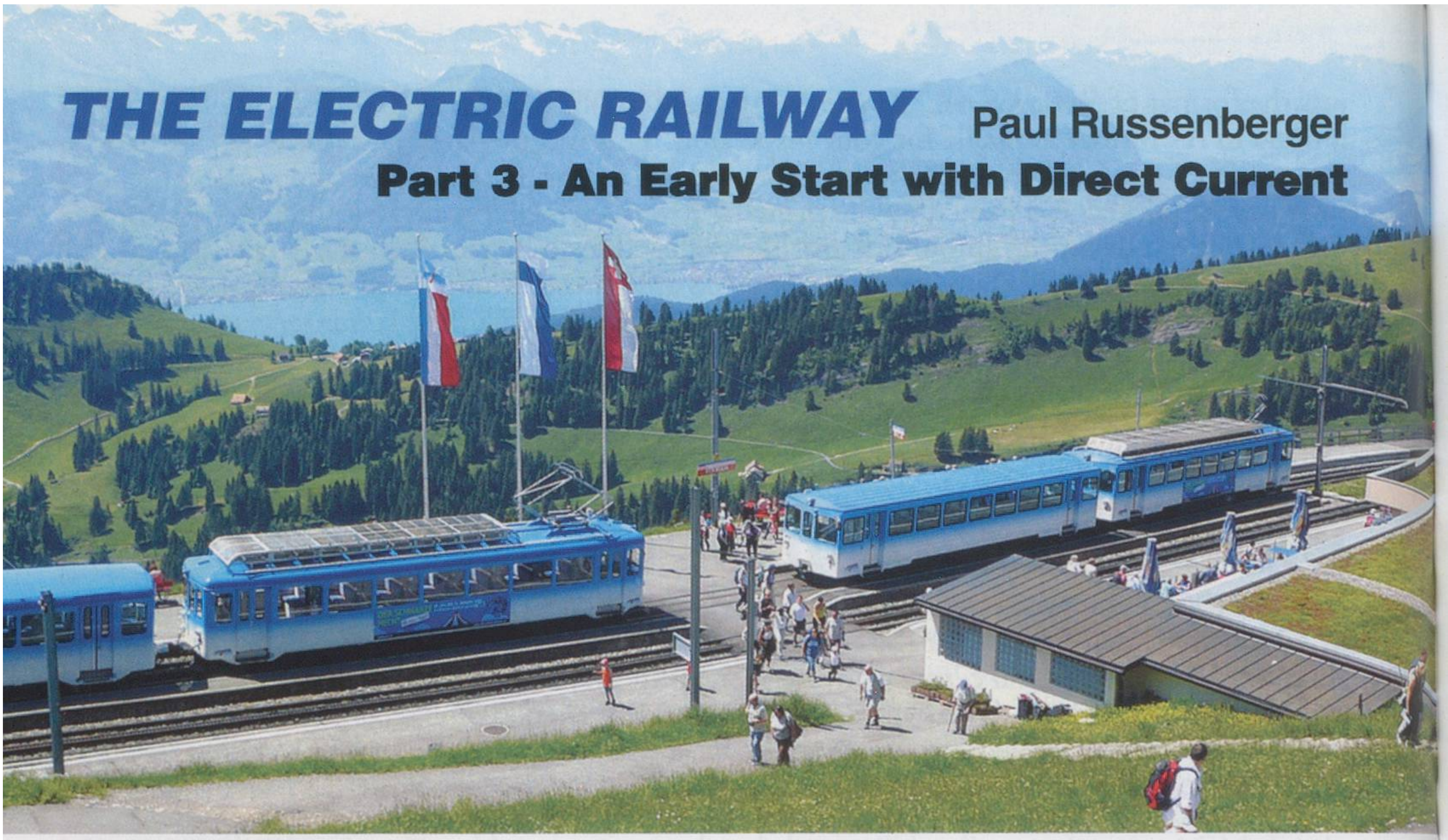
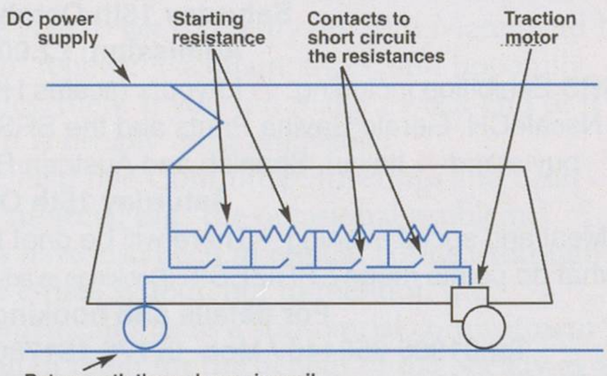
Part 3 - An Early Start with Direct Current



Arth Rigi Bahn trains wait at the top of the "Queen of Mountains". PHOTO: *Phil Emond.*

In 1879 Werner von Siemens demonstrated an electric train at the Berlin Exhibition. A locomotive hauled some trucks with seats round a narrow gauge track. Direct current was delivered to the train by a central third rail and returned to its source through the wheels and running rails. It was very much an electric equivalent of Richard Trevithick's 'Catch Me Who Can' which ran in London in 1808. A replica of von Siemens' train is displayed in the Berlin Transport Museum. His equipment was very simple, yet its principles were to remain unaltered for dc electrification for 100-years. This very simplicity, together with the effectiveness of the dc series motor for rail traction, enabled dc railway electrification to be used worldwide.

In a dc system, the train picks up current from a third rail or overhead wire and passes it to the motors. In dc motors a magnetic field is created by the electricity as it passes through two coils - the field coils - in the outer, stationary part of the motor. The coils are opposite each other so that the magnetic field passes across the centre of the motor. After going through the field coils, the current is passed into coils in the rotating part of the motor, known as the 'rotor' or 'armature'. The field coils and armature are said to be 'in series' with each other, hence the term 'series motor'. As previously explained, when an electric current is passed through a magnetic field it experiences a force which acts at right angles to both the magnetic field and the flow of the current. This force acts on the armature and the motor turns. To reverse the direction in which the motor rotates, the flow of current through the field coils is reversed. The direction of the magnetic field is consequently reversed and so is the direction of the force on the rotor.



When the motor is running, the interaction of the armature coils with the stationary magnetic field causes an electro-

1. Two trains pass at the intermediate station of Winteregg on the BLM. PHOTO: *Michael R Wild.*

2. A BLM train leaves Grütschalp at the top of the cable-car from Lauterbrunnen for its journey to Mürren. PHOTO: *Mark Barber.*

3. CEV Te 2/2 No 82 stands on the MOB siding at Gstaad. PHOTO: *David Edwards.*

motive force to be developed which opposes, and therefore naturally limits, the current flowing through the motor. When the motor is stationary, this 'back e.m.f.' is not present. If the full voltage of the overhead line were applied to the stationary motor, an excessive current would flow, possibly causing the motor to spin violently and overheating it electrically.

To control the motor on starting, the current is limited by passing it through resistances which absorb some of the voltage applied to the train so that the motors do not receive the full supply voltage. As the motor turns, the back e.m.f. is generated and the current is reduced. Some of the resistances are eliminated, the voltage applied to the motor, and therefore also the current, rises and the traction force developed by the motor is increased turning the motor faster and also increasing the back e.m.f.. This process continues until all the resistances have been eliminated from the circuit. Because of the heating effect caused by absorbing the voltage, the train can only run for a limited time before all the resistances have to be eliminated to avoid overheating.

The system is shown in simplified form in the accompanying diagram.

Nine years after von Siemens' demonstration, the first electric tramway in Switzerland was opened from Vevey to Chillon in 1888. The trams themselves were thoroughly conventional. Electricity was supplied at 500 volts through a pair of overhead wires. A trolley ran along the top of them to collect and return the current. This was probably prone to 'derailment' as it was replaced by conventional bow collectors in 1913 when the system voltage was also increased to 600 V.

In 1891 two more new routes were opened using electric traction – a tramway connecting Sissach with Gelterkinden (which closed in 1916 - see P10) and the Grütschalp to Mürren section of the BLM. This was the first Swiss railway, as opposed to tramway, to use electric traction and still uses the original 550 volt system.

The Zürich Electric Tramway (Elektrische Strassenbahn Zürich) and its constituents opened their system in stages from 1894 to 1907, generally using dc electricity from the start, though some real horse power was used until 1900. It was in Genève that the first tramway was electrified in 1894, though horse power remained in use there until 1903, and steam until 1911. Also in 1894, the Orbe –

1. An MOB train waits in the snow at Château-d'Oex. PHOTO: Nigel Harper.

2. A wintry scene on the Nyon-St Cergue. PHOTO: David Edwards.

3. Ee2/2 No 2 of the Orbe-Chavornay line. PHOTO: Mark Barber.

4. Trogenerbahn Bde 4/8 No 22 waits at the terminus at St Gallen. PHOTO: Mark Barber.

Chavornay line was opened and became the first electrified standard gauge line.

The success of these schemes prompted the inauguration of short lines across Switzerland. By the mid-1900s, hardly a city or large town was without an electric tramway. Interurban lines such as the Schaffhausen – Schleitheim Strassenbahn and the Trogenerbahn appeared, making use of the newly proven technology. The most ambitious advance was the decision of the Montreux – Oberland – Bernois railway to use electric traction. This was the first Swiss long distance railway not to be powered by steam, the section from Montreux to Les Avants opening in December 1901.

The electrification of mountain railways began with the Arth-Rigi-Bahn in 1907 at the increased overhead line voltage of 1500. This became the highest dc voltage used in Switzerland with the exception of the Nyon-St. Cergue line, which opened in 1916 using 2200 volts.

By the close of the First World War, a significant proportion of the smaller Swiss railways such as the Berner Oberland Bahn or the Schöllenenbahn were electrified. With very few exceptions, they used direct current supplied at a voltage between 750 and 1500 volts. In contrast, very few of the main lines were using electric traction, the most significant exception being the BLS.

While the dc system is extremely simple, it suffers the disadvantage that the maximum voltage of the supply is limited to that which can be accepted by the motors. Since the power consumed is equal to the voltage multiplied by the current, a large current has to be passed to the train. Voltage is lost driving this current down the overhead wire to the train. One way round this is to reduce the distance between supply points. But the equipment needed is expensive and in a country like Switzerland access to numerous locations at the trackside can be difficult. If the Swiss railways were to be electrified a solution to the problem of reducing the number of supply points had to be found.