THE ELECTRIC RAILWAY

Paul Russenberger

Part 5 - The Chosen System

The previous article described how a decision was taken in 1915 to use alternating current at a voltage of 15,000 and a frequency of 16 2/3 cycles per second (or Hertz, abbreviated to Hz) for the mainline electrification of the Swiss Federal Railways. While it was logical in that it would simplify working with the BLS, Austria and Germany, there were very sound technical reasons for its choice.

The electrical power transmitted to a train is found by multiplying the voltage by the current[1]. The power lost in any part of the supply network is proportional to the square of the current (the current multiplied by itself). So, to minimise the losses in the supply network, the aim is to have the highest possible supply voltage so as to minimise the current drawn for any given power output. The force developed by a series wound[2] traction motor to drive the train is proportional to the square of the current drawn and the power delivered is proportional to the current. So, to develop a high torque to start a train and keep it going, the current drawn should be as high as possible, but as explained in the third article, this current must be controlled when the motor is started if it is to be large enough to deliver power at speed. The traction engineer's dream is the supply engineer's nightmare – and vice versa!

The key to solving the problem is the transformer. This is a device which enables the voltage in an electric circuit to be altered. For a (theoretical) perfectly efficient transformer, the product of the input voltage and current is the same as the product of the output voltage and current.

Voltage in x Current in = Voltage out x Current out

Supplying the train with electricity at a high voltage enables the current actually flowing to the train to be kept down, keeping the inevitable losses at an acceptable value. On the train a transformer reduces the voltage to one which the motors can accept and at the same time increases the current to one which will drive the train along.

While this has essentially solved the supply problem, a difficulty remains. Transformers only work on alternating current. The series wound motor, whose characteristics of a high starting torque and an ability to run at varying speed are so useful for railway traction, excellent as it is on direct current, does not work well on alternating current. The technology to rectify alternating current on a train, without incurring an unacceptable size and weight penalty, did not exist in the early decades of the 20th century. The solution was to reduce the frequency of the electrical system below the 50 Hz being used by local electricity companies to 16 2/3 Hz. The transformers in the supply network and on the trains would be less efficient, but the motors would work satisfactorily, even though they would not be as efficient as their direct current counterparts. As part of the compromise, motors powerful enough to lift a train to the Gotthard Tunnel would be large and this would influence the design of the locomotives.

Reducing the system voltage to one suitable for the traction motors and rectifying the current in trackside installations would have required much more fixed equipment. It would have also required a special electricity main to supply the substations which would have been placed about 16km apart. Where such systems were introduced, the substations were usually permanently staffed. These two issues made a direct current system unsuitable for use on railways across the Swiss Alps.

Acting on the decision of 16th February 1916, the electrification started with work on the conversion of the Gotthard line, though the first main line section of the SBB to be electrified was from Bern to Thun where it connected with the BLS electrification. The section of the Gotthard line through the tunnel from Göschenen to Ambri-Piotta was opened on 13th September 1920, extended to Erstfeld in October and to Biasca in December. Bellinzona was reached in May 1921 and Chiasso in February 1922. Extensions at the northern end brought the wires to Luzern the following May and to Zürich in February 1923.

Operational experience showed that the system worked well and reduced operating costs. On 4th May 1923 the SBB Board approved the 'Accelerated Electrification Programme' which had been put forward by a Motion in the Council of States on 4th February 1919. By the summer of 1927 the main lines from Genève to Rorschach, Luzern to Basel and Vallorbe to Brig were electrified. By the close of 1928 the first stage was complete as the Yverdon to Olten route was converted and the wires reached Chur and Schaffhausen. The SBB had now electrified 1,681 route kilometres or 55.3% of the system.

By the outbreak of the Second World War a further 510 route kilometres had been added bringing the proportion to 73.6%. Electrification continued during the war so that by 1950 some 2807 route kilometres or approximately 95% of the system was electrically worked[3]. The wartime electrification included the only narrow gauge SBB route – the Brünig from Luzern to Interlaken Ost – which was the only narrow gauge line supplied at 15kV until the LSE was re-electrified in 1964. Two sections of line were electrified for the French National Railways (SNCF) – Genève Cornavin to La Plaine in 1956 at 1500 V dc and Basel CFF to St Louis in 1957 at 25kV ac 50Hz. The final sections to complete the electrification were the branches from Oberglatt to Niederweningen, now part of the Zürich S-Bahn, and from Cadenazzo to Luino in 1960.

At the end of WW2 the annual average demand for power was 101 Megawatts. It was clear at the start of electrification that the railway would have to generate most of the electricity needed, some being purchased from, or generated jointly with, other concerns. A railway owned grid was built to distribute the power from hydro-electric power stations at Amsteg, Göschenen and Ritom on the Gotthard line, at

Barberine, Trient, Vernayaz and Massaboden in the Rhône valley and at Seebach in northern Switzerland. Jointly owned power stations are at Etzel and Rupperswil. Power is also purchased from privately owned stations at Mieville in the Rhône valley, Varzon (in Italy), Mühleberg (between Kerzers and Bern), Gösgen (near Rupperswil), Küblis (in Graubunden), Lungern and Spiez. A 132kV power line runs from Vernayaz to Rupperswil. Most of the remainder are linked by 66kV lines.

The next article in this series is intended to provide an overview of the locomotives built to haul the trains during the first two decades of electric operation.

[1] This is correct for a direct current circuit. For an alternating current circuit it has to be multiplied by the 'power factor'. This arises because in an ac circuit the maximum voltage and current do usually not occur simultaneously, difference depending on the nature of the circuit. For a traction system the power factor is typically 0.8.

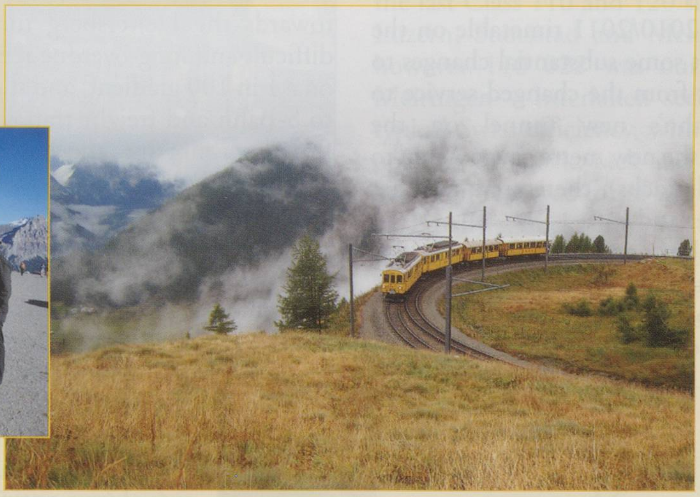
[2] A motor in which the current is passed though the fixed coils which produce a magnetic field and then through the armature or rotating part of the motor.

[3] For the exact dates of electrification the reader is referred to 'Schienennetz Schweiz', published by the SBB.

BERNINA CENTENARY FIRST DAY COVERS

Michael Farr

An alpenhorn group playing while a train halts at Alp Grum on the second day in very different conditions from the first day.



Disappointingly dismal weather at Alp Grum on the first day (Saturday)

ALL PHOTOS: Maurice Criddle

Getting down to it! Yet another photograph is taken of an Allegra (in Pontresina depot)

In SE 103, P 21, we have already reported and illustrated the special CHF100 stamp issued by Swiss Post to mark the Bernina line centenary. This featured one of the new Allegra units. During a visit to Pontresina for the Bernina line centenary celebrations member Maurice Criddle not only found first day covers on sale with the Swiss stamps but also envelopes carrying a stamp issued by the Italian Post Office. A cover with €0.65 Italian stamp is illustrated. It is cancelled at 23037 Tirano (SO) with a special postmark which reads: *Patrimonio mondiale dell'Unesco - Ferrovia Retica dell'Albula e del Bernina.* The Giorno di emissione (First day of issue) was the same as the Swiss stamp - 6.5.2010. Maurice's two Swiss FDCs with the Allegra stamp were both postmarked 7743 Brusio. One of the envelopes carried an old black and white photo of a train on the spiral viaduct and the other with a colour shot of two restored railcars in Berninabahn yellow livery.