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Early Experiments

by A.E.Hauser-Gubser

Introduction

In the course of the last few years, a few railway companies in Switzerland have introduced the converter locomotive. In view of the excellent results obtained, orders for further engines have been placed by other lines with the industry and to the observer of the scene the start of a new era in locomotive design is self evident. It is therefore of considerable interest to understand the reasons for this development.

Of necessity I have used many technical terms which may be unfamiliar to some members and so this series will conclude with a glossary which will give an explanation of the English technical terms employed and, at the Editor's request, their German equivalents.

The Problem

During the sixties and seventies, both the technical and commercial departments of the Swiss Federal Railways had come to realise that the conventional locomotive had reached its technical limits. In addition the challenge of future high speed lines and the probable construction of the Gotthard Base tunnel were recognised in outline. For these routes an engine capable of a top speed of 230-250 km/h, in the power range of 6000-7000 kW (8160-9250 hp), with a tractive effort of 250-300 kN was essential to obtain a substantial reduction of running times. Designed for universal use, it should be capable of hauling heavier goods trains than before over the Gotthard route. For so ambitious a project the then available modern locomotive classes, Re4/4 II, Re4/4 III and Re6/6, had to be regarded as technically obsolete, the more as this type of engine has numerous shortcomings inherent in a system first adopted during the opening years of the century. Some of the problems lie in the use of series wound commutator motors, which need collectors and brushes. Powerful motors of tis type are bulky and massive; the Re6/6 motor, for example, with a power rating of 1350 kW, weighs 3.9 tonnes. Such a weight influences the bogie design and the forces developed at higher speeds by a bogie of more than 20 tonnes limit the admissible top speed. Another shortcoming of the conventional locomotive is the method of speed control by tap changers. The voltage surges during the step-by-step switching during the acceleration phase are the cause of a jerky increase of the motor power, which in turn impairs the adhesion with a subsequent partial loss of tractive power. In addition, the pulsing torque with a frequency of 33 1/3 cycles per second (cps), that is to say, double the supply frequency, increases the tendency to slip, notably in the macro skid range. An infinitely variable control, such as is possible with the rectifier locomotive, is therefore one of the main requirements.

The conventional locomotive consumes a relatively high amount of energy in the form of single phase alternating current, at 15000 Volts 16 2/3 cps, due to the share of idle power supplied in addition to the true power. To obtain a good energy balance, an efficient regenerative brake is needed. Finally, the new engine should not generate harmonic waves to avoid any interference with signal and telecommunication circuits. Only the converter locomotive meets all requirements. The second best solution, the rectifier locomotive, despite a substantially better use of available adhesion, still needs a motor with commutators and brushes and has the disadvantages of consuming even higher amounts of idle power and generating more harmonic waves of different frequencies.

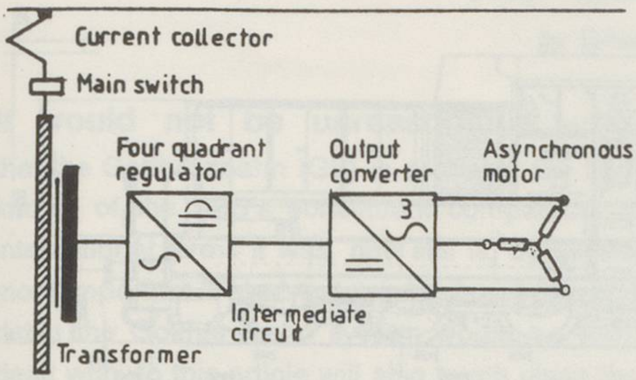


Figure 1 Schematic diagram of converter loco.

The Solution

The theoretical solution consists of a radically new circuit which opened the door to the use of the extremely robust and considerably lighter asynchronous motor. Contrary to the conventional or direct motor locomotive, where the transformed current is fed directly to the motors, the current in the converter locomotive is converted twice. First the transformed alternating current is fed to a four quadrant regulator, where conversion to direct current takes place. The latter is then smoothed in the intermediate circuit from whence it flows to the DC/AC converter which finally produces a three phase alternating current of infinitely variable voltage, frequency and amplitude. The beauty of this solution is the possibility of generating power with the traction motors during the braking phases, which then flows back to the catenary without the necessity of costly additional electric or electronic equipment, as is the case with the Re classes. Figure 1 shows the basic circuit.

The First Trials

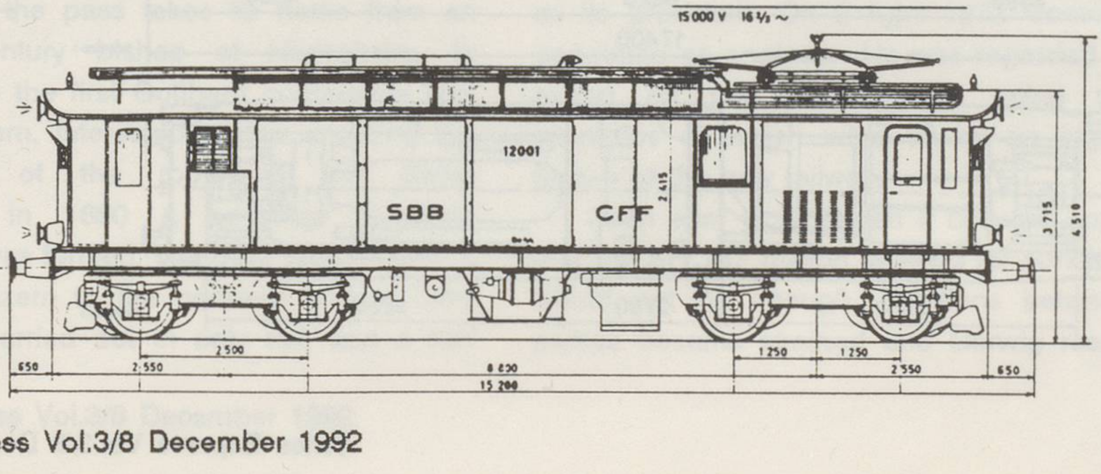
In 1972 an inconspicuous vehicle appeared without the usual publicity show on the Luzern-Beinwil-Lenzburg-Wildegg line, Be4/4 No.12001 (Figure 2), a conversion of the motor baggage car De4/4 No.1685. This small locomotive was put into service to acquire the necessary know-how for the development of future converter engines.

The shortcomings of this experimental locomotive were to be brutally exposed, confirming once again that only the very best of components are good enough for the rigourous demands of railway service. There are still locomotive engineers who remember vividly the frustrations they endured trying to get Be4/4 No.12001 back in motion, mostly in vain. But an excellent learning process was provided and on the whole the tests confirmed the theoretical superiority of the converter locomotive.

There was however one important technical shortcoming, at this time all converter locomotives had to be equipped with static converters, that is to say the thyristors could be turned on, but could not be turned off. This feature had to be carried out by an array of complex circuits with the help on many electronic devices which were not only heavy, but took up a great deal of space.

Confident in the success of converter technology, the SBB had already ordered in 1971, six Am6/6 shunting locomotives, Nos.18521 - 18526 (Figure 3), which were delivered to various marshalling yards in 1973. Their design profited considerably from the

Figure 2 Be4/4 No.12001 Courtesy SBB



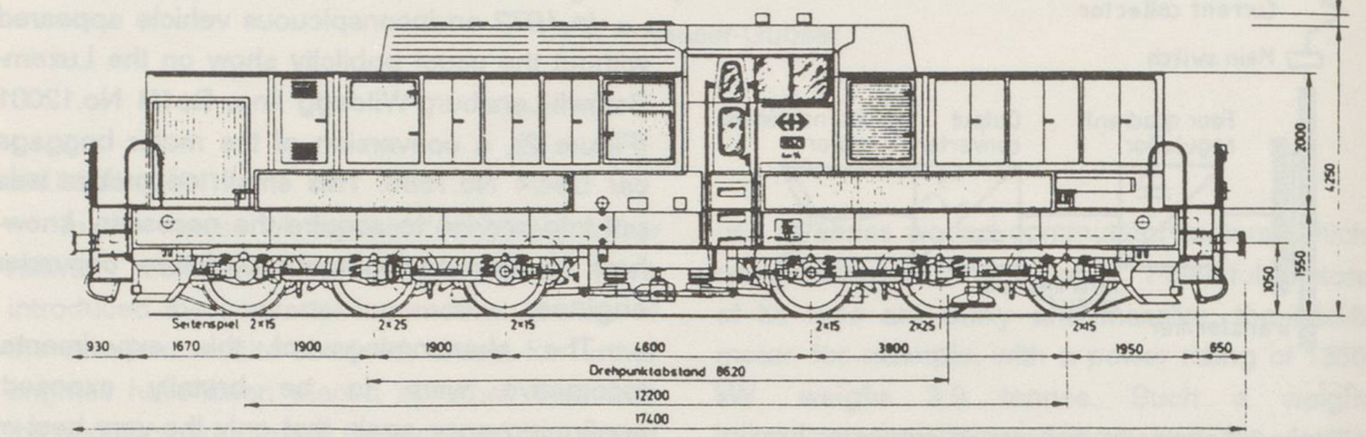


Figure 3 Am6/6 Courtesy SBB

experience gained with 12001 and confirmed the substantial increase in tractive power possible with converter technology.

Encouraged by the results, the SBB then ordered ten Ee6/6II shunting locomotives, Nos.16811 - 16820 (Figure 4), which were delivered in 1976. With these locomotives all electrical components could be rigourously tested under the strenuous conditions of a marshalling yard. The results provided invaluable know-how.

A line locomotive of 5000 kW with static converters now appeared to be possible. Such a locomotive the E120 of the DB, built by BBC Mannheim, a subsidiary of BBC Baden, underwent trials on the Lötschberg route. The results were somewhat inconclusive as she hauled only a slightly higher tonnage than the much cheaper BLS Re4/4 No.161. The powerful regenerative brake did however make a deep impression, as did the far better energy balance.

To be continued

Figure 4 Ee6/6 II Courtesy SLM