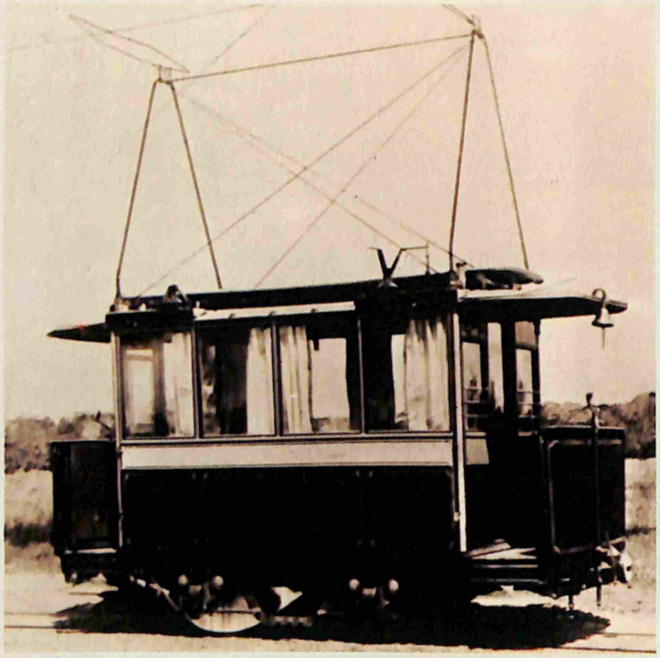
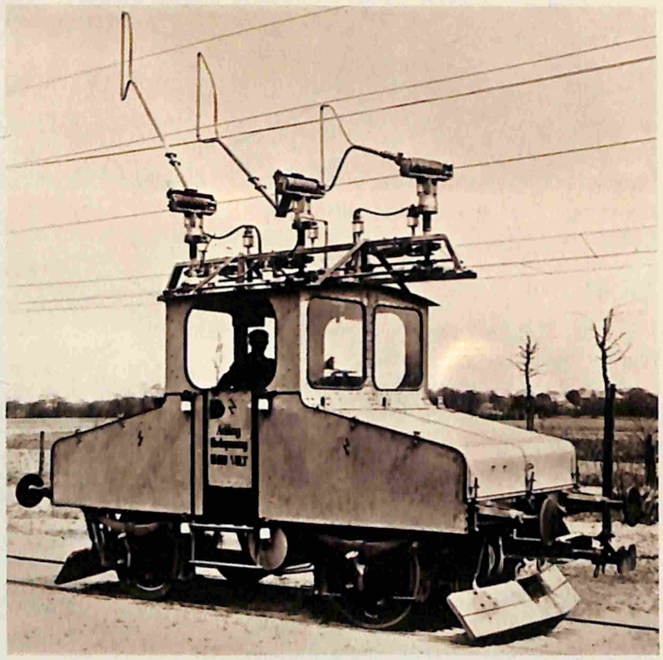
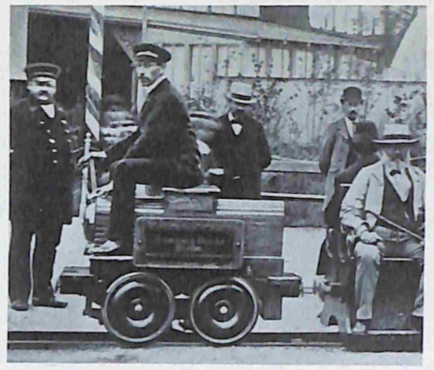
SIEMENS

Milestones in the Development of Electric Traction







The first electric locomotive, constructed by Werner von Siemens 1879

After Werner von Siemens had discovered the dynamo-electric principle in 1866 and was thus able to produce electric power economically, he began to think of ways and means of using electric power for drive purposes. He was looking for possible applications for electric motors.

On February 14, 1879 Werner von Siemens informed his brother Carl that he intended to set up a railway in Berlin with an electric locomotive. On May 31, the world's first electric locomotive was operating at the Berlin Trade Fair. It hauled three small exhibition cars on a circular track 300 m long. The locomotive had a rating of 2.2 kW at 150 V d.c. and reached a speed of 7 km/h. The current was collected from a centre rail.

1880

The first electric locomotive is introduced as an attraction in Brussels, and then displayed in various major cities of Europe.
Werner von Siemens proposes the construction of an elevated railroad in Berlin.

1881

For the first public electric tramcar in Lichterfelde near Berlin, the direct current is supplied through the rails. The tramcar travels at a speed of 30 kilometres per hour and already carries more than 12,000 passengers in the first three months.

1882

The first electric pit locomotive is delivered for the Zaukerode bituminous coal mine in Saxony and remains in service there until 1927.

1889

Walter Reichel designs the current-collector bow, with which current is taken from the catenary.

1891

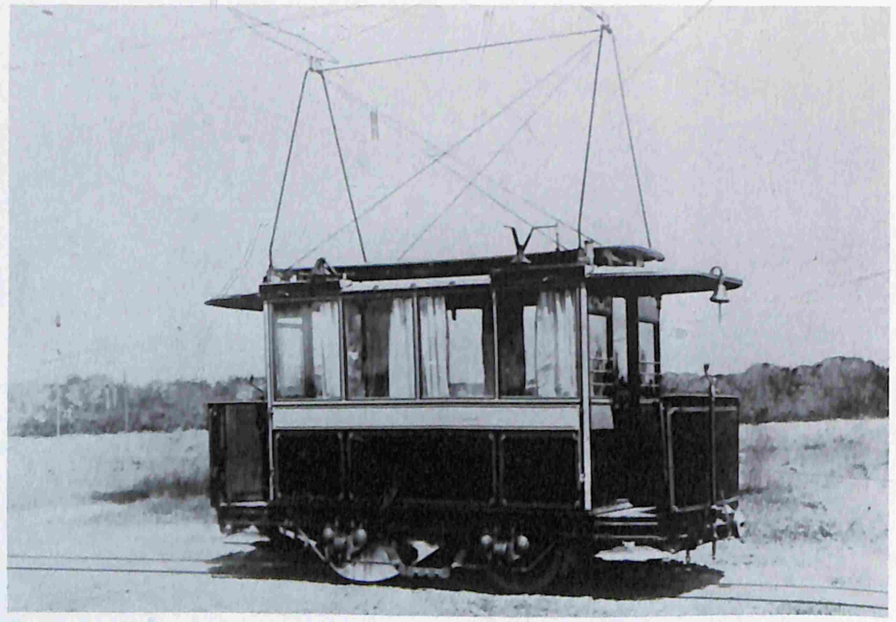
The first electric switch-motor is installed by Siemens & Halske of Vienna at Vienna's West station.

1892

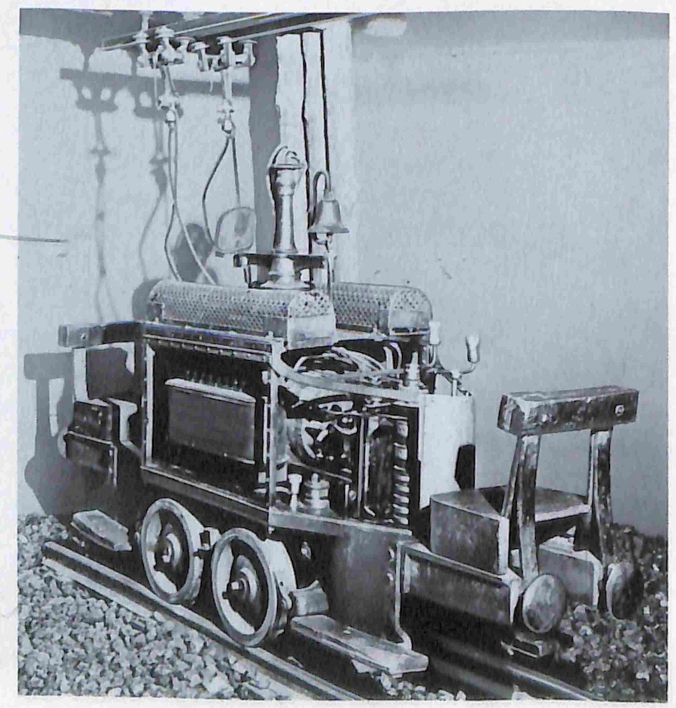
Direct current with voltages up to 600 volts is well-proven for railway service in urban transit systems and in mines. Higher voltages are required for transportation of heavy loads over greater distances. Direct-current motors cannot yet be built for this purpose, however, because commutator difficulties arise in the case of higher ratings. Additionally, the transmission of direct current over greater distances would be extremely inefficient because of the low voltage and the related line losses.

At the instigation of Wilhelm von Siemens, experiments thus begin at Siemens & Halske in the grounds of the Charlottenburg factory to use alternating current for traction purposes, after an appropriate patent had already been applied for on January 18, 1886. Accordingly, it was planned ". . . to mount a Volta induction coil on a vehicle electrically moved by means of an alternating-current motor, in order that current of a low voltage can be supplied, while a current of high voltage circulates in the supply lines . . .".

Two phases of the alternating current are supplied to the motor via two wires, and the third phase via the grounded rails. The voltage is 550 volts. This motor is displayed at the Chicago World Fair in 1893.



The first electric tramcar with pantograph 1889



Pit locomotive for the Zaukerode bituminous mine (Saxony) 1882

1894

The first electromechanical Siemens signal box becomes operational in Prerau (Moravia) on the Franz-Ferdinand Northern Railway. This signal box developed by Robert Pfeil improves efficiency in that the electric motors replace human effort. Two years later, signal boxes follow in Berlin and Munich.

1896

In Budapest, Siemens & Halske of Vienna builds the first subway on the European continent and opens it for service. The current is supplied by means of insulated rails on the tunnel ceiling, and the voltage is 300 volt.

1897

The experiments with high-voltage alternating current, begun in 1892 and interrupted because of official misgivings, were resumed at the instigation of Wilhelm von Siemens.

Following the successful completion of these experiments in 1900, the knowledge is gained that electrical energy can be supplied to a locomotive by means of high voltage directly or through transformers.

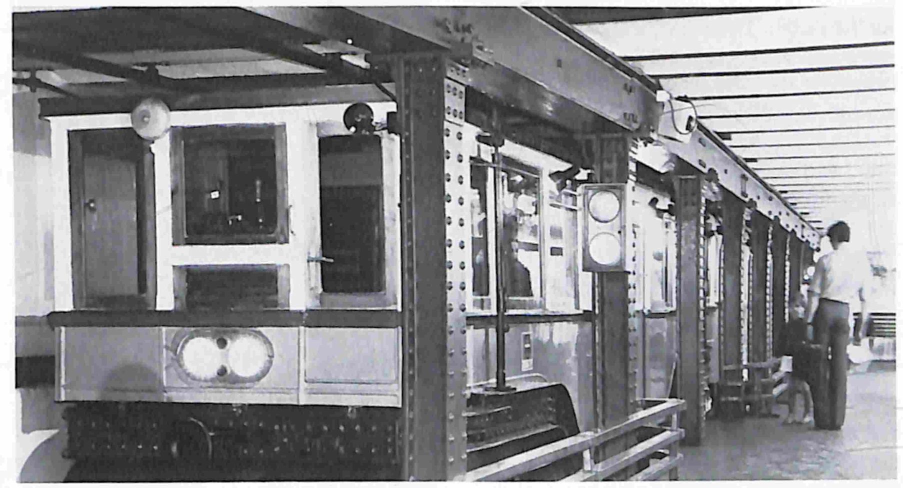
1898

The Studiengesellschaft für elektrische Schnellbahnen (Research Association for Electric High-Speed Railroads), to which leading companies belong, is founded for further trials of high-speed trains.

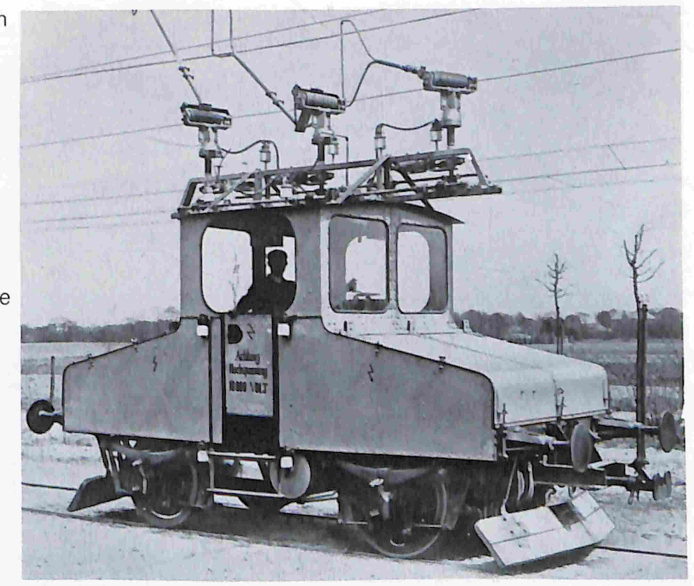
1900

On the Wannsee Railway in Berlin, tests are conducted with a trial service to determine under which conditions electric traction with direct voltages of 600 to 750 volt can replace steam operation on main lines. The contact rail is located adjacent to the track. When trial service ends in 1902, it is established that on suburban lines, heavy trains can be electrically driven with direct current.

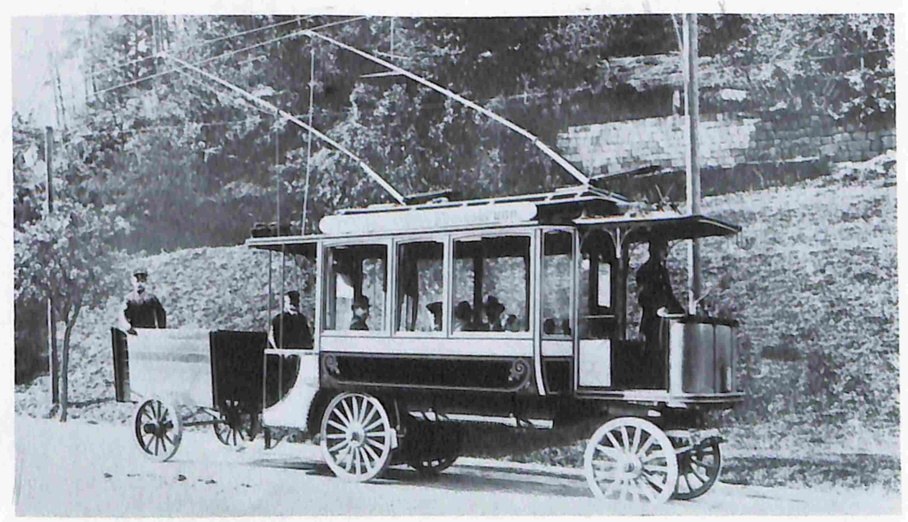
Intensive development work begins which has as its goal the introduction of electric locomotives. Because favourable experience has been gathered with the railcar systems – for example, with tramcars, with elevated lines and subways, with urban and suburban lines, as well as with short main lines – it is believed initially that electric traction as a whole can be resolved with these railcar systems. It is now seen, however, that efficient operation of long-distance passenger and freight traffic is more easily accomplished with locomotives. Also the first trolley-bus was developed in this year.



The first electric driven subway motor-car in Europe for the Budapest Metro 1896



Three-phase a.c. research locomotive 1897 with hight voltage power supply



Trolley-bus, constructed by Siemens & Halske 1901

1902

Running trials are begun on the Marienfelde-Zossen military railway line near Berlin. The locomotive is equipped for the first time with four three-phase induction motors, which are fed with 10,000 volt, 50 hertz three-phase alternating current. It travels at 105 kilometres per hour.

1903

The high-speed railcar of Siemens & Halske reaches a speed of 210 kilometres per hour on November 25 – a sensation for the public, because such high speeds were as yet unimaginable. It is realized, however, that the three catenaries suspended above each other next to the track are very problematic. Moreover, the three-phase induction motor is not well suited for traction service due to the close relationship between the input frequency and the running speed. New possibilities in this area first become available with semiconductor technology nearly seven decades later.

1906

For the first single-phase alternating-current locomotive, the Siemens-Schuckertwerke design a series motor. Using this locomotive, electric service begins on February 19 on the Murnau-Oberammergau line, with an alternating voltage of 5000 volt and a frequency of 16 hertz. This electrification with low-frequency alternating voltage initiates a new era in the development of electric traction.

1908

The first electric operation of urban and suburban railways with 6000 volt alternating-voltage and 25 hertz begins in Hamburg between Blankenese and Ohlsdorf.

1909

On July 28, the Prussian State Parliament approves the funds for the electrification of the Dessau-Bitterfeld line. It is decided to use 10,000 volt alternating voltage, 15 hertz. The frequency is soon changed to 16 2/3 hertz, because the statewide mains frequency is raised from 45 to 50 hertz.

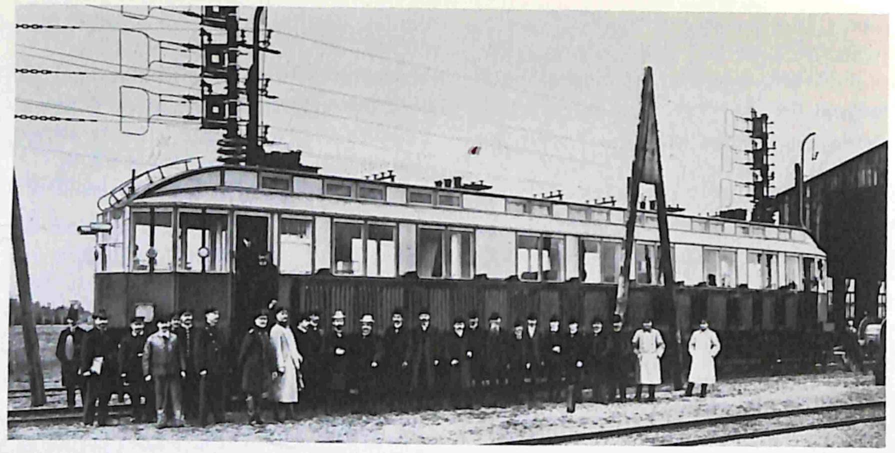
1911

Electric railway service begins on January 18 on the Dessau-Bitterfeld line. On November 25, one of the electric locomotives equipped by the Siemens-Schuckertwerke reaches a speed of 135 kilometres per hour.

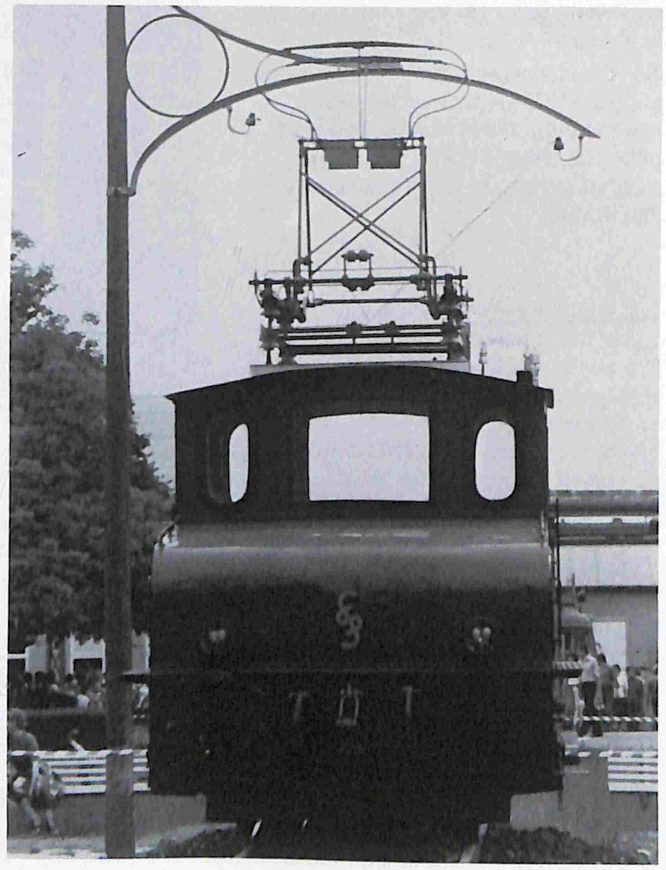
1912

The advantages of high-voltage single-phase alternating current at low frequency are confirmed on the Dessau-Bitterfeld line. For this reason, several of the various German state railroads unite in an agreement to standardize the use of single-phase alternating current at 15,000 volt, 16 2/3 hertz for "electric traction" in the future.

An electric sequence-interlocking frame with mechanical interlocking and electromagnetic lever collars for routing and signal levers is commissioned in a form still used today.

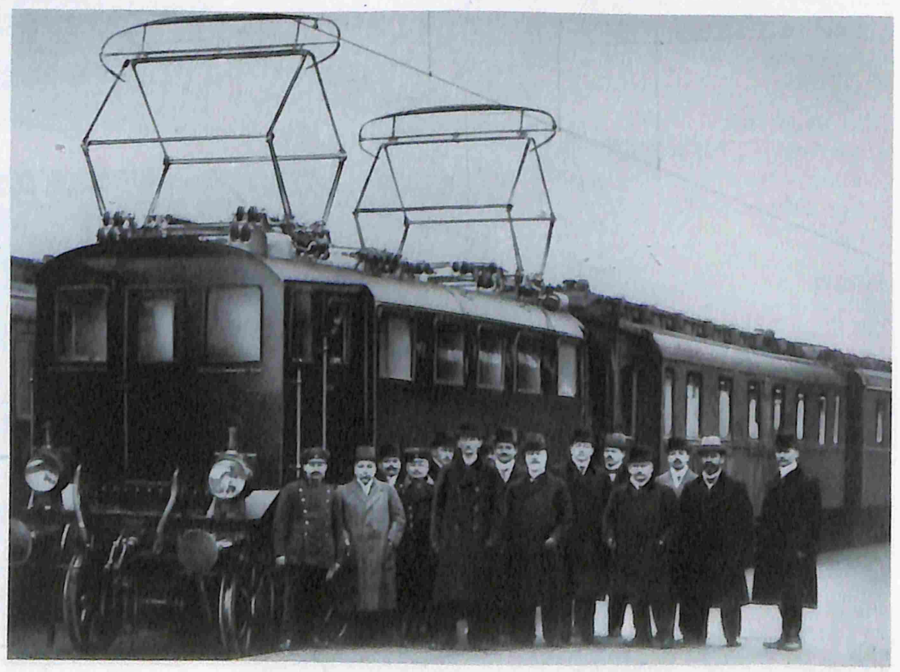


High-speed railcar of Siemens & Halske reaches a speed of 210 km/h on November 25, 1903



First single-phase a.c. locomotive with series-wound motor 1906, in operation on the Murnau-Oberammergau railway up to 50 years.

Inauguration of electric service on the Dessau-Bitterfeld line in Germany 1911



1914

For transporting ore in the far north of Sweden, from Kiruna to Riksgränsen, the most powerful freight locomotives to date, (3200 kilowatt) are placed in service; they prove exceptionally sucessful under very severe operating conditions. The Riksgränsen line is long recognized as a masterpiece of engineering and convinces many critics of the advantages of electric traction.

1916

With the railway automatic dialling system (called Basa in German), long-distance telephone connections can be made by dialling two or three-digit numbers; with the railroad, such a system is thus realized seven years earlier than in the public network of the Reichspost (German Post Office).

1918

280 kilometres of the long-distance railway lines in Germany are electrified.

1920

By means of an agreement between the government of the Reich and the eight German states having railways, the railway networks are brought together under a unified management. Bavaria retains an extensive measure of independence. A total of 92 electric locomotives are in service.

1925

The Deutsche Reichsbahn (German Railways) begins efforts to drive the axles of electric locomotives individually, whereas until this time two or more axles were commonly driven by one motor using rods and cranks.

Thus, Borsig and the Siemens-Schuckertwerke receive the contract to build the E 16^5 with individually-driven axles in the form of nose-suspended drives.

1927

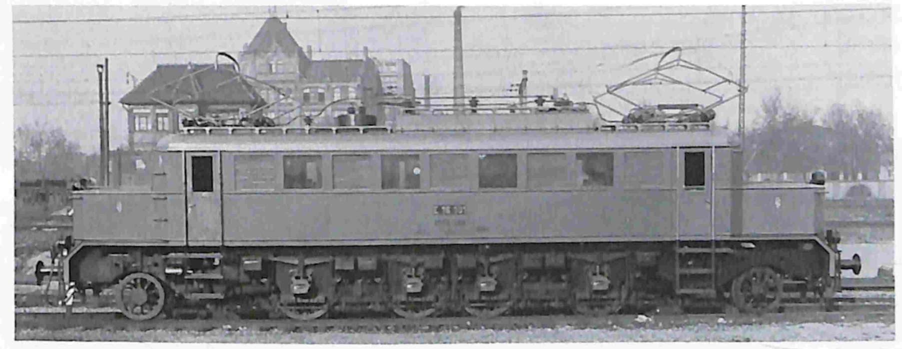
Automatic train control (INDUSI), for monitoring proper operation of trains, is introduced on the lines Berlin-Hamburg and Berlin-Stettin; beginning in 1932 with the three-frequency resonance system.

1930

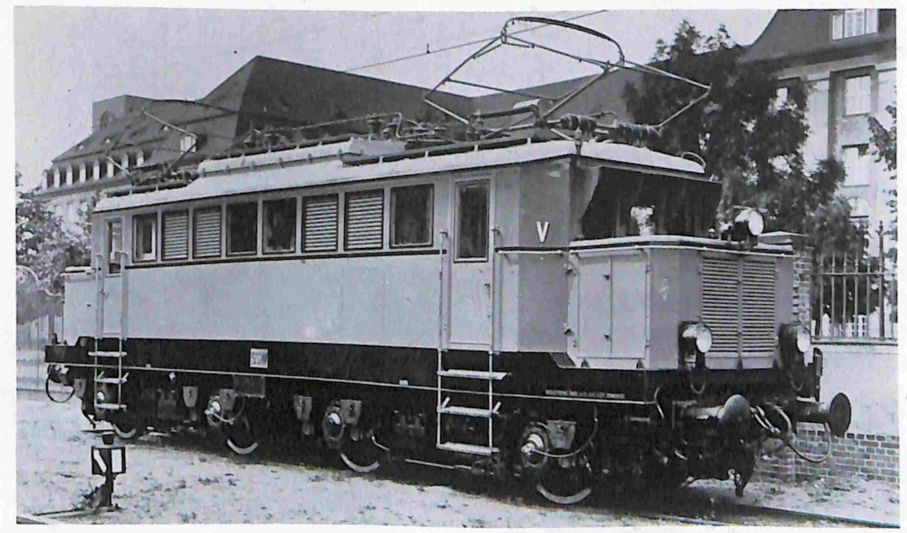
Experience had been obtained at the Siemens-Schuckertwerke in the welding of large housings and frames from sheet-metal for generators and machinery.

Thus, the E 44 001 locomotive can be built as the first with all-welded and therefore very light mechanical equipment. The drive is by means of simple nose-suspended traction motors on all wheels. Trailing axles can be dispensed with. The class E 44 is used as a standard locomotive for passenger and freight service and is considered one of the most successful locomotive designs.

The class E 80 is developed for shunting at the Munich main station. In this case, the direct-current traction motors receive their energy either from a catenary via a transformer and mercury-arc glass-bulb rectifiers or from built-in batteries. Thus, the class E 80 becomes the first German dual-system locomotive. Toward the end of the 1930s, one of these locomotives is equipped with selenium rectifiers and, in 1956, with silicon rectifiers.

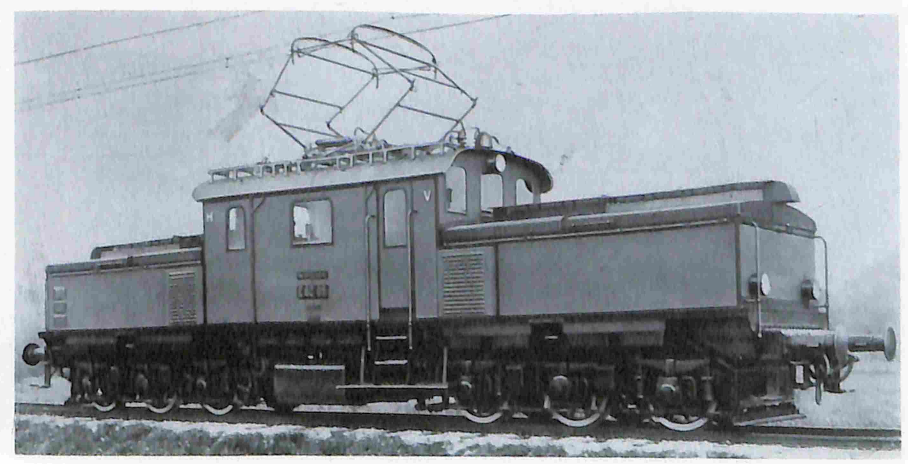


The first express locomotive with individually-driven axles in the form of nose-suspended drives 1925



The E 44 001 locomotive – the first with all-welded mechanical equipment 1930

One of the class E 80 locomotives, the first dual-system locomotive with silicon – rectifiers, both for overhead traction supply and for battery operation



1932
Automatic train control (INDUSI), using the three-frequency resonance system still reliably in use today, is introduced for the first time for high-speed railcar service on the Berlin-Hamburg line. Up to 1978, Siemens produces more than 7000 Indusi vehicle devices and 47,000 Indusi track devices.

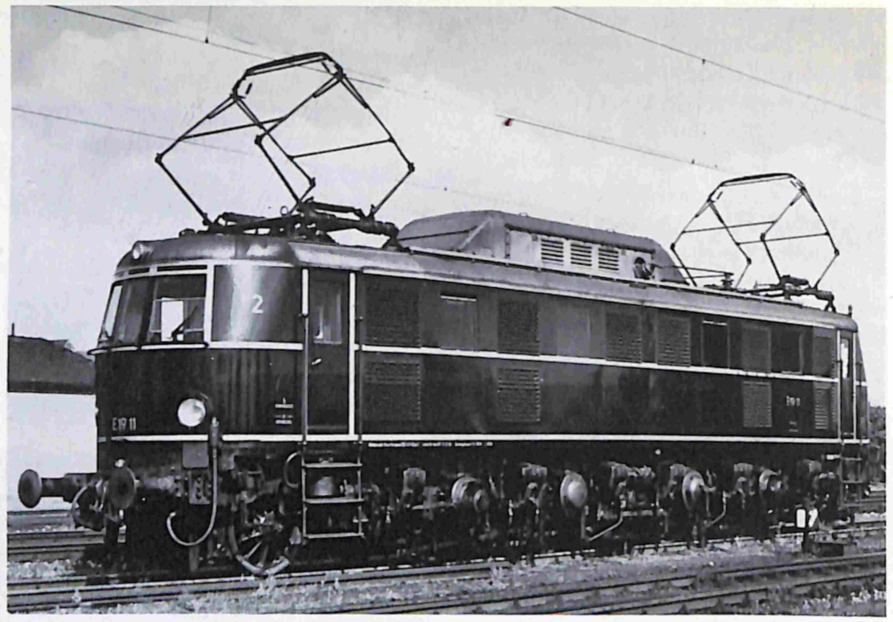
1936
In the railway automatic dialling system, all larger places in Germany are connected to one another by means of long-distance dialling, with about 200,000 telephone offices, 23 years earlier than in the public telephone system.

1940
Siemens and Henschel supply the particularly powerful class E 19 11 and E 19 12 express locomotives. Their top speed is 180 kilometres per hour. During trials they achieve 225 kilometres per hour.

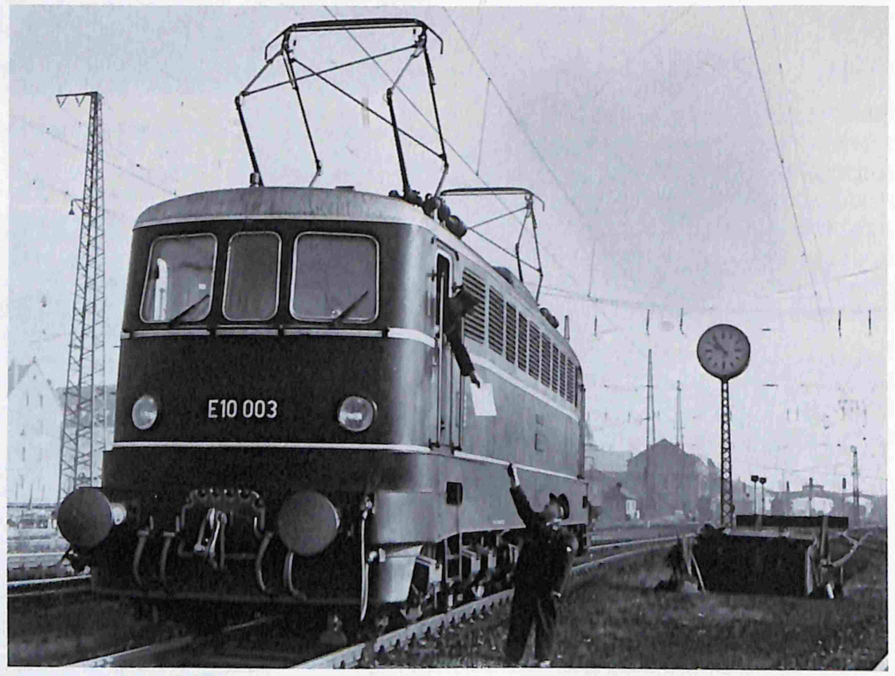
1948
The first track-diagram control desk entrance-exit tower (NX-TOWER) with push-button control, in which routing is controlled by simultaneously depressing start and destination buttons, goes into operation for the German Federal Railways in Düsseldorf-Derendorf. By 1970 there are already over 1000 track-diagram control desk entrance-exit towers installed for the German Federal Railways, and almost as many again for main-line and local railways nationally and internationally.

1951
Siemens & Halske install a centralized control box in Lourenço Marquez in Mozambique, from which all stations on the 88 kilometre line to Ressano Garcia can be centrally controlled.

1952
The increase of train speeds requires changes to the previously-used drives. The wear-resistant rubber-ring spring drive is created for the prototype of a new generation of locomotives – the class E 10 003 –, the first locomotive developed after the war. This drive, invented by Günther Kloss at Siemens, assures the desired elasticity between traction motor and axle. It is later installed as standard equipment on practically all new locomotives of the German Federal Railways. In 1979 there are about 10,000 rubber-ring spring drives in operation on the German Federal Railways, thus establishing a unique line of production.



Express locomotive for the Deutsche Reichsbahn with a top speed of 180 km/h 1940



Locomotive of class E 10 with new-style rubber-ring spring drive 1952

Class E 320 21 two-frequency locomotive (left) and the first class K locomotive, delivered to the USSR 1959

1956
Siemens resumes the export of locomotives and railcar equipment, e.g. to Brazil and Egypt.

1957
In Sweden, a centralized control box centrally operates 36 stations with signalling systems and also the disconnecting switches of the catenary system. The stations are part of the approximately 300 kilometre single-track, ore line Ludvika-Oxelösund. This system is a milestone in the automation of railway traffic in Europe.

1959
For international public transport, particularly to Northern France with its 50 hertz system, the class E 320 21 multiple-frequency locomotive is placed in service. Based on the favourable results of experiments of the Siemens-Schuckertwerke, silicon rectifier sets are used to convert the single-phase alternating current into pulsating direct current for the traction motors. The experience with this locomotive is also used for the construction of twenty locomotives ordered by the USSR.

1962
The German Federal Railways award a contract for four prototypes of the class E 03 high-speed locomotives (today 103) with approximately 6000 kilowatt continuous rating and a top speed of 200 kilometres per hour.

1963
The German Federal Railways make available a line section between Bamberg and Forchheim for high-speed trials. Automatic train operation devices show the engineer the theoretical speed and braking information. Operation is by means of "electric sight".

1964
The first major centralized signal box in track-diagram technology in the Federal Republic of Germany is placed in operation in Munich. It enables the close concentration of the operational control of 17 conventional signal boxes.

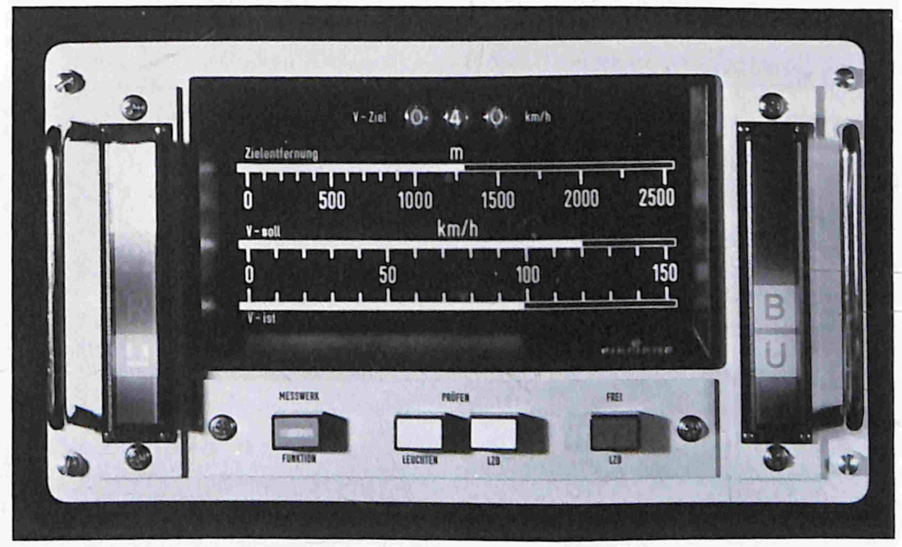
1965
During the transportation exhibition in Munich, a locomotive-drawn train travels at a top speed of 200 kilometres per hour in scheduled service, for the first time in the world, between the exhibition grounds and Augsburg. It is hauled by a locomotive of class E 03 (now 103). It also uses automatic train operation by "electric sight".

The world's first thyristor-chopper-controlled motive power unit is placed in operald's first thyristor-chopper-controlled motive power unit is placed in operation on the 600 volt direct-current electric works railway system within the Siemens plant in Berlin, a two-axle locomotive powered by two 144 kilowatt motors. The control system of this locomotive becomes the model for nearly 1000 chopper units that Siemens – often in cooperation with AEG – built for traction-motor control on direct-current motive power units of all types up to 1979.

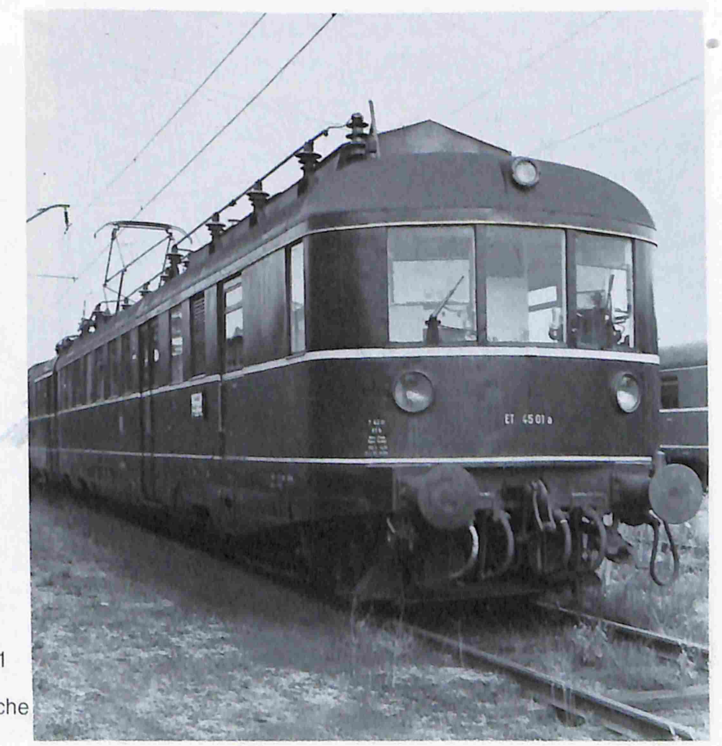
1967
The "Hanover cybernetic island", represents the beginning of a regionally-limited trial to automate control of the entire German Federal Railway transportation system, using data processing systems. The trial is part of the initial steps of the ITS project.

On June 15, for the first time, the regenerative brake of the ET 45 01 motive power unit, equipped with thyristor-control, returns energy to the 16 2/3 hertz system of the German Federal Railways upon braking.

A large number of test runs supply evidence that in rapid transit service, approximately 20 % of the energy can be recovered through regenerative braking.



Automatic train operation equipment to operate by "electric sight" 1964:
top: stopping distance
middle: speed limit
botton: actual speed



The first thyristor-controlled motive power unit ET 45 01 with regenerative brake of the Deutsche Bundesbahn 1967

1969

Series production of the class 103 electric locomotives is under way. In comparison with the prototype model, the rated power is increased to 7080 kilowatt. This class ultimately reaches a total of 149 locomotives. No. 103 118 is later used for the breakthrough into higher speed ranges. A speed of 252 kilometres per hour is attained on many occasions.

1970

For high-speed rail service in conurbations, the German Federal Railways develops the ET 420 train unit. The wide-ranging application of power electronics for control is used for the first time. The new trains prove themselves on the occasion of the 1972 Olympic Games in Munich, and round about 400 are built in the subsequent period for other rapid transit systems.

The Wuppertal suspension railway is the first European railway company to decide on the new, thyristor-chopper technology for equipping a new generation of 28 articulated railcars.

1971

A new, four-axle express locomotive is developed for the German Federal Railways, the class 111. The objective is to obtain particularly good riding qualities at high speeds and to further reduce operating costs. In addition, the driver is to be provided with a more favorable work environment.

High-speed express locomotive 103 118-6 of the Deutsche Bundesbahn for 250 km/h 1969

The new thyristor-controlled articulated heavy rail transit car unit class ET 420 of the Deutsche Bundesbahn 1972

Articulated motor car of the Wuppertal suspension railway with the new thyristor-chopper technology 1970

New four-axle locomotive class 111 of the Deutsche Bundesbahn 1971

1972

In Munich, together with the S-Bahn service, the first stage of a regional control centre is placed in operation. The second stage begins in 1979 with remote control operation on the Pasing-Tutzing line.

The first articulated tramcar motor unit in the world equipped with chopper control operates in Graz, Austria. The problem of obtaining very high deceleration with electric brakes is now also resolved for power electronics.

1973

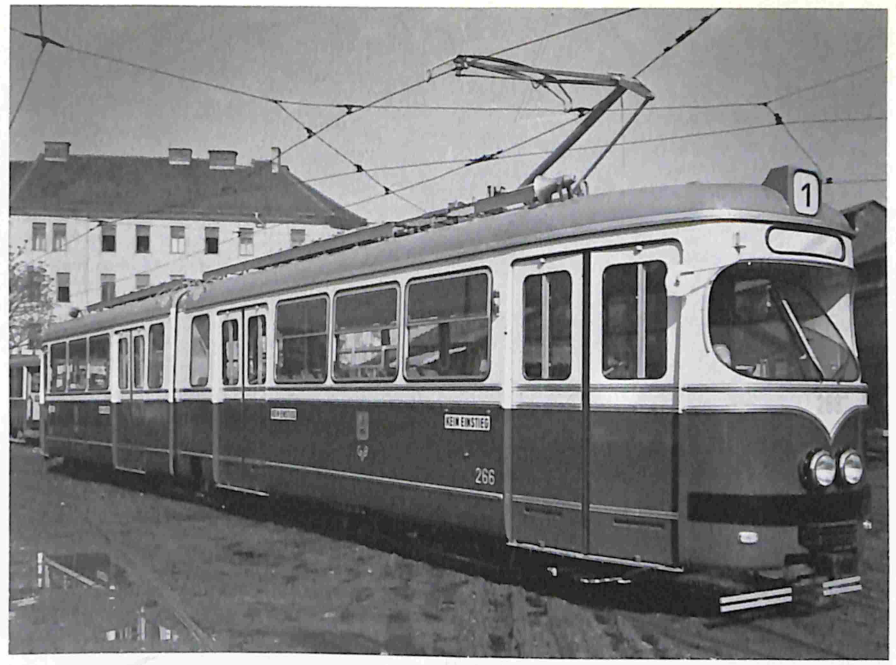
The city of Hanover transport undertaking (ÜSTRA) decides in favour of the new chopper technology with regenerative brake system in connection with the procurement of 100 light rail transit cars. Energy savings of approximately 25 % have proved possible with the new technology.

1974

A computer is installed at the Ebertplatz station of the Cologne underground that enables the dispatch of 120 trains per hour.

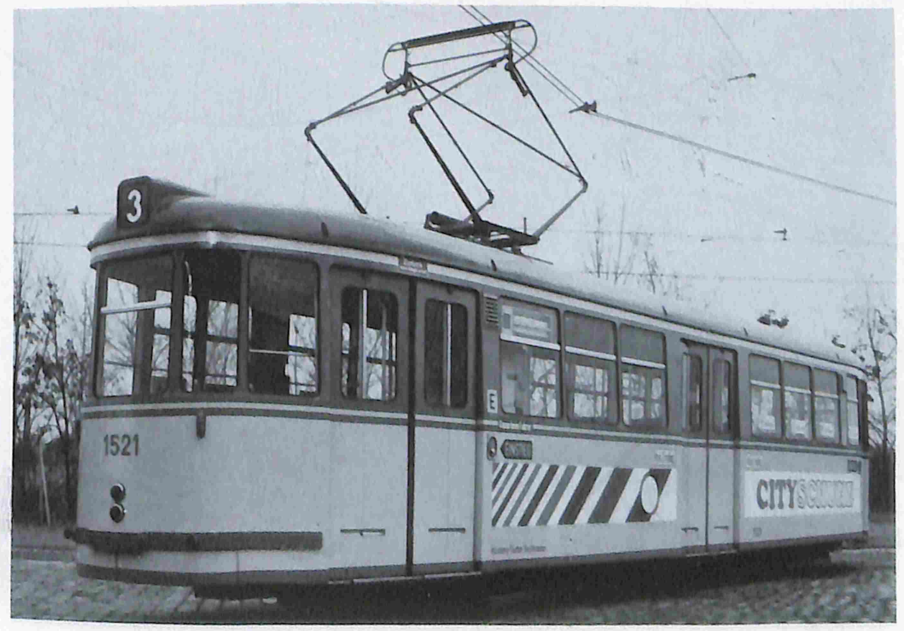
1975

Since the end of 1975, the first tramcar with thyristor-controlled alternating-current drive is operating in Nuremberg.



The first articulated tramcar equipped with chopper control for the Stadtwerke Graz (Austria) 1972

Light Rail Vehicle of the City of Hanover with thyristor-chopper technology and regenerative brake system 1973



The first tramcar with thyristor-controlled alternating current drive for the VAG in Nuremberg 1975

1977

The Vienna underground receives a double motor-car train with alternating-current drive. It becomes the model for new underground cars in Nuremberg, Berlin and Munich.

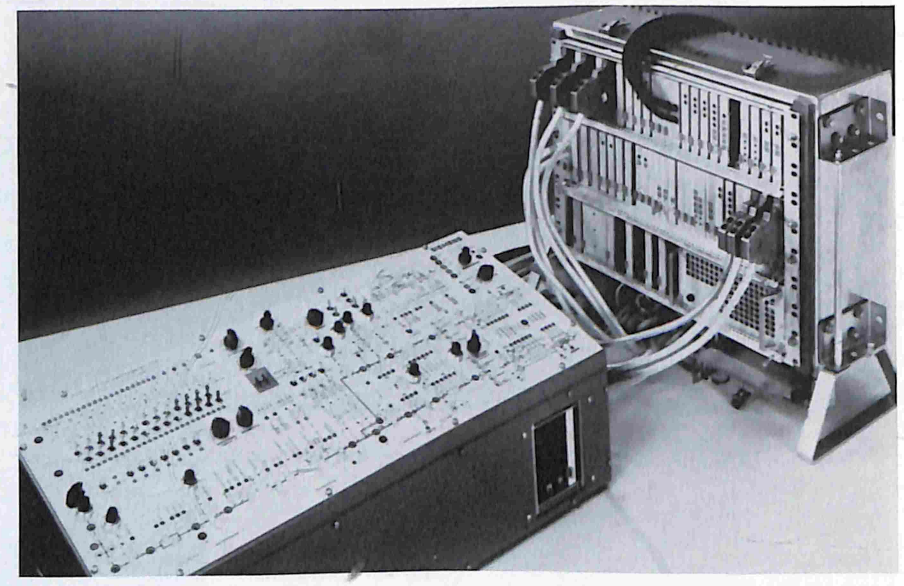
The SICARID® (Siemens car identification) microwave system identifies freight cars fully automatically.

The largest computer-controlled marshalling yard in Europe is opened in Maschen, near Hamburg. When completed, more than 10,000 cars daily will be shunted automatically by means of switches, car retarders and handling equipment onto the marshalling tracks and made up into new trains.

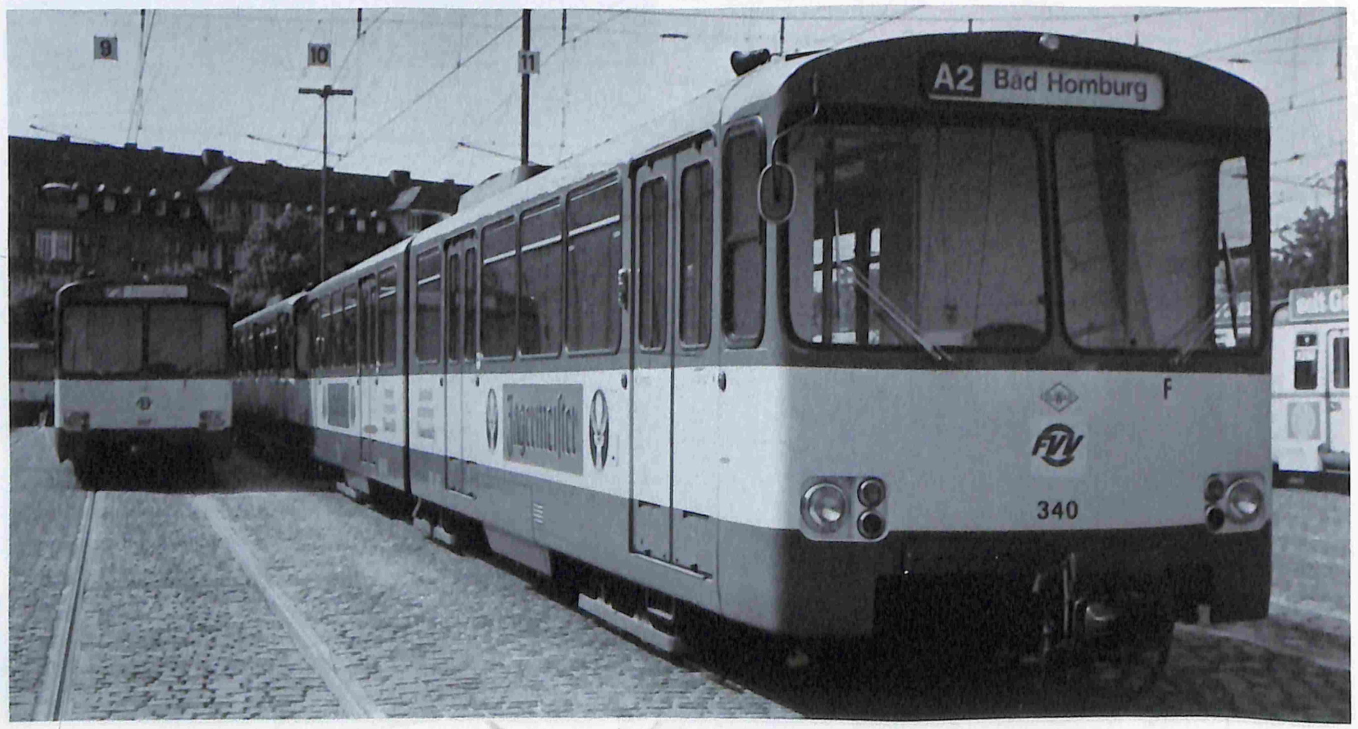
Double motor-car unit with alternating current drive for the City of Vienna 1977

1978

Large series of new electronic controls for light rapid transit cars are in use in many cities, e.g. one hundred each of Types P 8 and U 2 in Frankfurt, Type 6000 in Hanover and Type B in Cologne and Bonn. All types operate with the SIMATIC units developed by Siemens. The use of this technology is spreading in foreign countries and is being supplied, among others, also to Canada and Brazil. Up to the beginning of 1979, some 1700 SIMATIC controls have been delivered or are under construction.



SIMATIC®-car control unit for stepless acceleration and braking



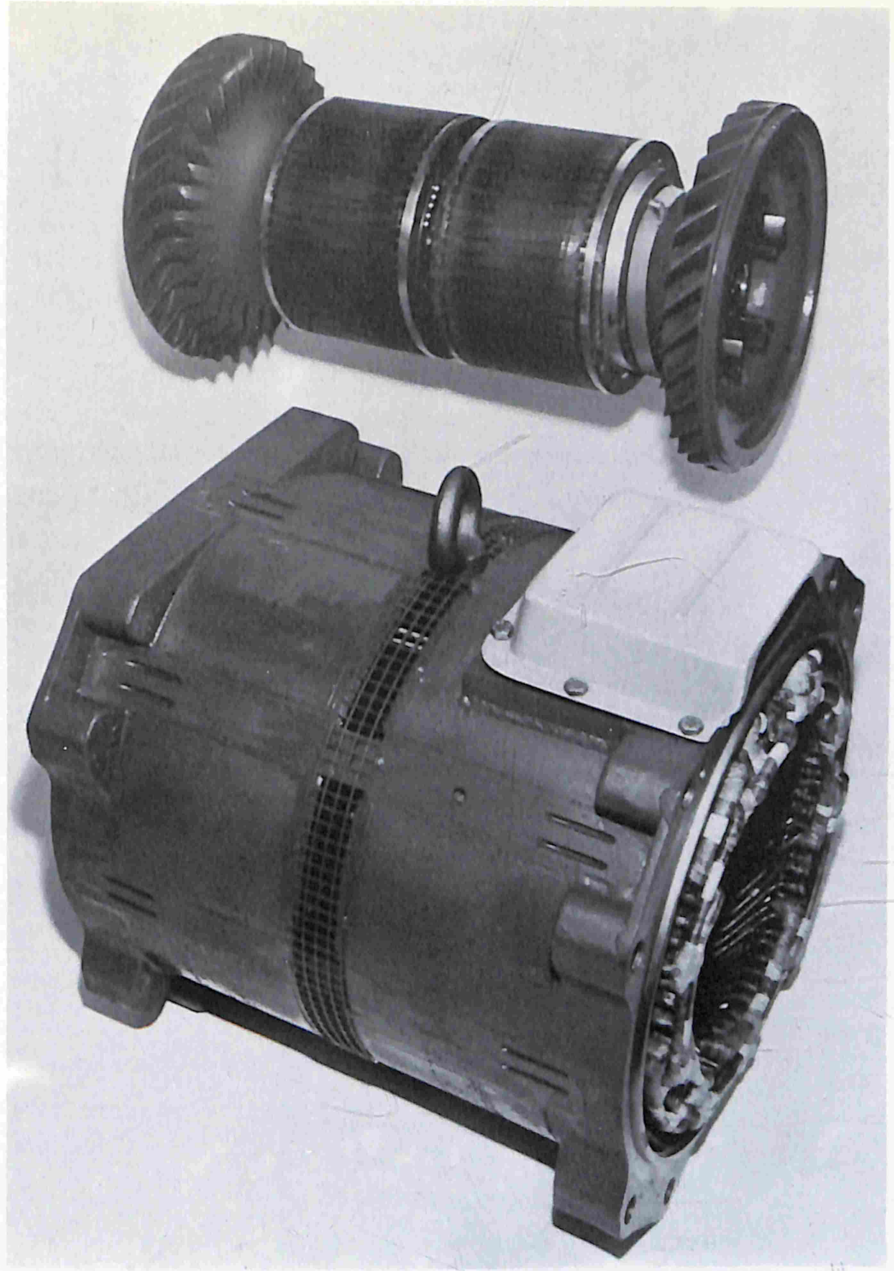
The most succesful Light Rail Vehicle of type U2 is seen here in Frankfort on Main 1968

1979

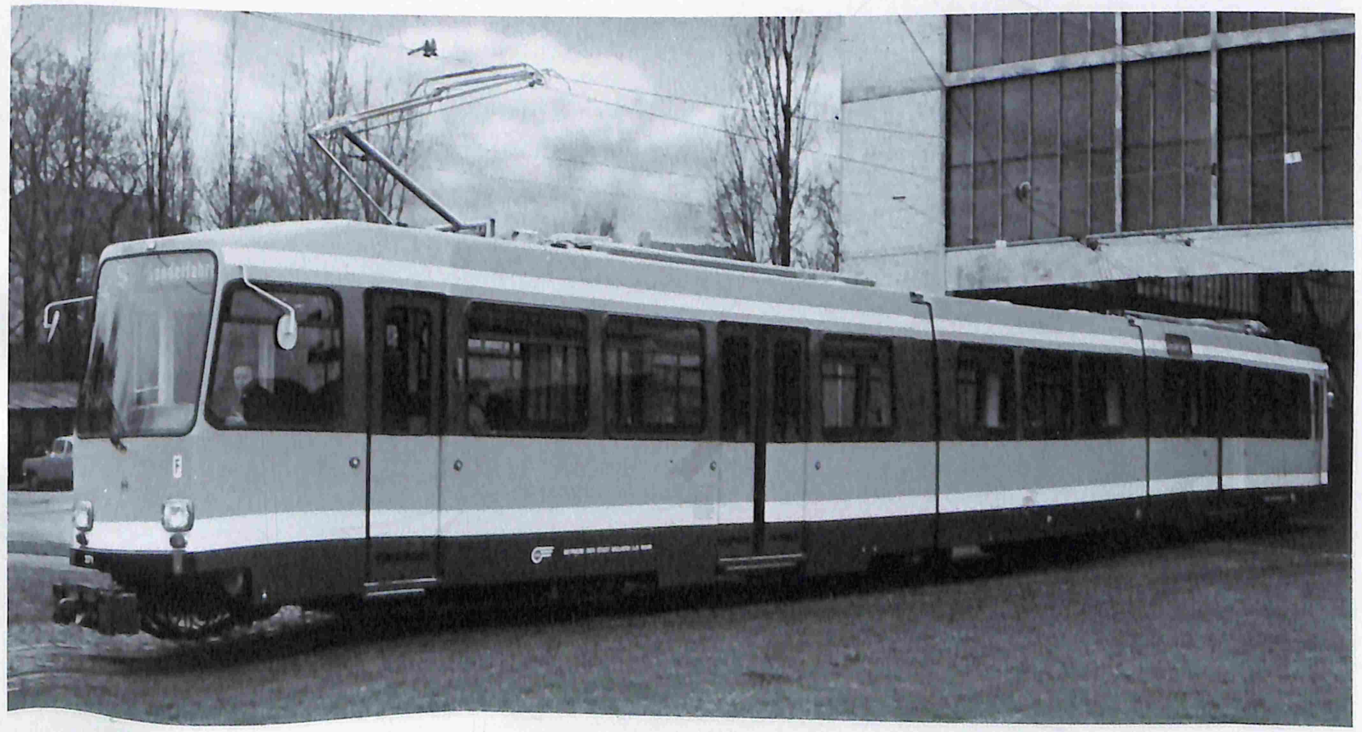
A signal box using a new type of track-diagram technology goes into operation at Helmstedt railway station. It is a further development of the existing pushbutton track-diagram signal boxes.

The new drive technology introduced for transit vehicles, initially in Nuremberg and Vienna, draws considerable interest. In the meantime, there are more than 100 transit vehicles with thyristor-controlled a.c. three-phase induction traction motors under construction, predominantly for underground railways. After commissioning of the first articulated motor unit with this technology for Light Rapid Transit in Mülheim (Ruhr), production is now under way for a series of twelve Type B high-speed light rail vehicles for the city of Düsseldorf.

Microprocessors begin to take over a portion of the control and monitoring tasks associated with railways. A light rail transit car in Hanover is the first system with this microcomputer technology. Because of it, a multiple of the previously possible automation tasks can be realized in the existing accommodation space.



A.C. induction traction motor and double rotor 1979



Mülheim 282, the world's first Light Rail Vehicle with inverter-controlled three-phase a.c. induction motors 1979