ELECTRICAL-ENGINEERING.ACADEMY

History of protections engineering

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WELCOME dear friends of protection, control and electrical engineering.

He is one of the best-known experts in electrical protection and control engineering in German-speaking countries. In addition to his countless specialist lectures, Walter Schossig has always attached great importance to the processing and communication of the historical development of protection and control technology. We can learn a lot in his contribution "History of Protection Engineering", because only those who know history can understand the present.

Have fun reading, we hand over to Walter Schossig.

History of Protection Engineering

Primary Trigger a precursor to the relay

At the end of the 19th century, mainly fuses made of lead, silver, tin or similar were used in high-voltage systems - at that time mostly direct current systems - to protect generators, cables, motors and other consumers from the thermal effects of overload or short-circuit currents. With the development of the oil circuit breaker, a search was made for a possibility of triggering them when the current exceeded a certain value by means of current measuring devices, triggers or relays. When the term “relay” was used, however, one was more likely to think of the station in the stagecoach era, where the exhausted horses were replaced by fresh, more productive horses.

The development of the instantaneous and delayed acting overcurrent protection devices took place around 1900. With the primary release (Fig. 1) the primary current flows directly through the measuring winding and the release is transmitted to the circuit breaker via linkage [1].

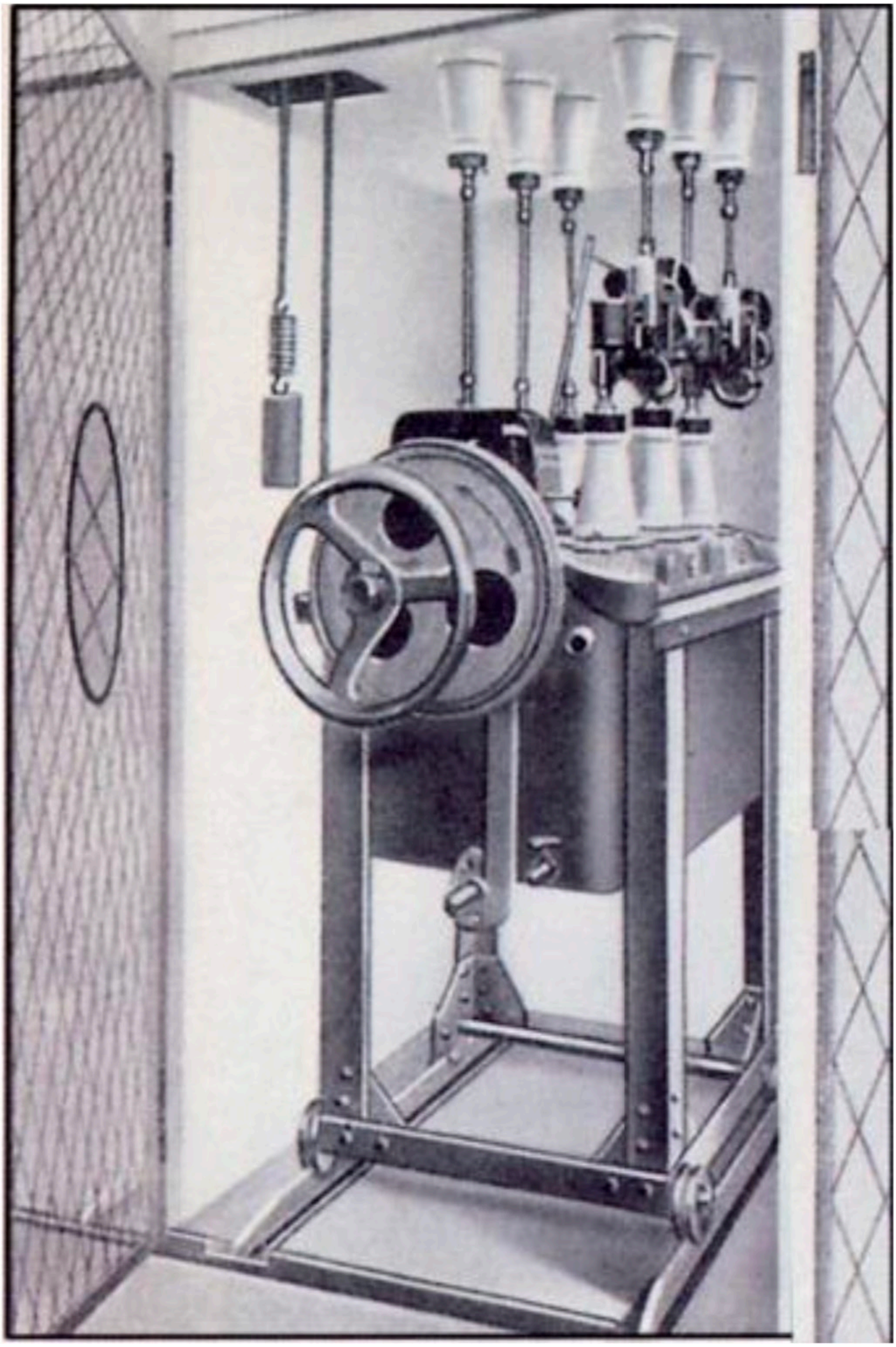


Fig. 1: Oil switch with primary trigger, BBC

The 1898 by Benischke, G. Invented current transformers made it possible to connect secondary relays, in which the short-circuit current from the secondary winding, which was then mostly designed for 5 A, was fed to the protective relay. In 1912, Rogowski and Steinhaus propose an ironless measurement conversion. This Rogowski coil was hardly used at the time, as the power was insufficient for the relays of the time. In 1903, Schuckert uses the voltage summation circuit for (unselective) earth fault detection. Nicholson made the first proposal for a summation current circuit for earth fault detection in 1908. This circuit was later - actually wrongly - used as the Holmgreen circuit and has established itself in linguistic usage.

Birth of the protective relay

Initially, they were interested in simulating the characteristic curve of fuses with the releases. However, it soon turned out that selectivity problems arose with protective devices in series. For line protection, the "Inverse Definite Minimum Time Protection" (IDMT), was left and the "Definite Time-Protection" (DEFT), was switched over.

Selective protection was born in the 19th century. Around 1899, the Niagara power plants required selective line protection for their 11 kV network. This was created in a truly ingenious way by the technical director at the time, Stillwell. He used the elements that were already in use, such as current and time relays and, as a directional element, a small fan motor from GE, whose field was traversed by the voltage and the armature by the current. He thus created reverse current protection for the double line. This is considered to be the birth of selective protection [2].

Around 1903 direction relays, so-called induction relays, were produced, which were mainly used to switch off generators that were operated in parallel by the criterion of reversing the energy direction.

The secondary relays required auxiliary energy for their own function and for actuating the auxiliary release (OFF coil) of the switch (at that time mostly oil tank).

Even then, this was already made available from an accumulator after a patent by Henri Owen Tudor (L) from 1886.

In insignificant systems, the transformer current release was used to operate the relay and the circuit breaker. It is interesting that in the first transformer current solutions, two full-fledged current transformers were used per phase, one of which fed the relay and the other the trigger.

In the so-called Cleveland protection from 1908, the transformer current was sent directly to the release of the switch lock and, in order to achieve a delayed release, a time fuse was switched in parallel to the release, which released the path through the release coil after the overcurrent had melted.

For reasons of selectivity, it became necessary to introduce a time delay.

The fixed time setting was achieved by a downstream, separate timing element in the form of a clock escapement or wind wing mechanism, oil piston, leather bellows or similar, which in the event of a malfunction was brought to run at constant speed by an electromagnet via a tensioned tension spring (Fig. 2).

As early as 1902, all major companies in Germany were building protective devices.

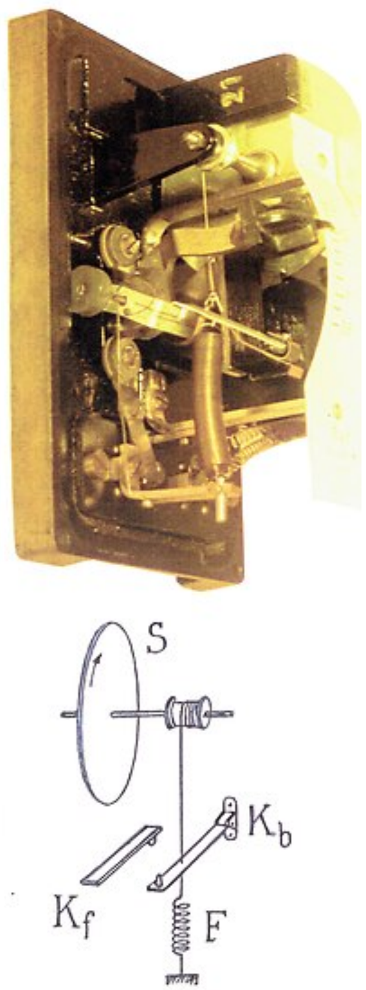


Fig. 2: Over current relais RA1, S&H, 1925

Differential protection

In 1903 the Englishmen Merz and Price suggested longitudinal current comparison protection (Fig. 3). They are considered the inventors of differential protection. A first major application took place in 1906 in the 20 kV cable network of the Country of Durham Electrical Power Distribution Co. in northern England [3]. In 1907, the Merz and Price patent became the property of AEG. Shortly thereafter, AEG introduced differential protection in Germany, at the Heinitz mine near Luisenthal (Saar) and at EW Westphalia. While differential protection is still used as standard line protection in the Anglo-Saxon region, it was mainly used in the German-speaking region for transformers and generators.

In 1920 W. Pfannkuch, AEG, developed a cable protection using pilot wires on the circumference of the main conductor and received his patent for "Pfannkuch" protection one year later [2]. In the same year, M. Höchstädter specifies the "Lypro cable protection" for the detection of two-pole short circuits and earth faults. These gap ladder systems initially caused a sensation, but after a few years had to give way to the more versatile distance relay.

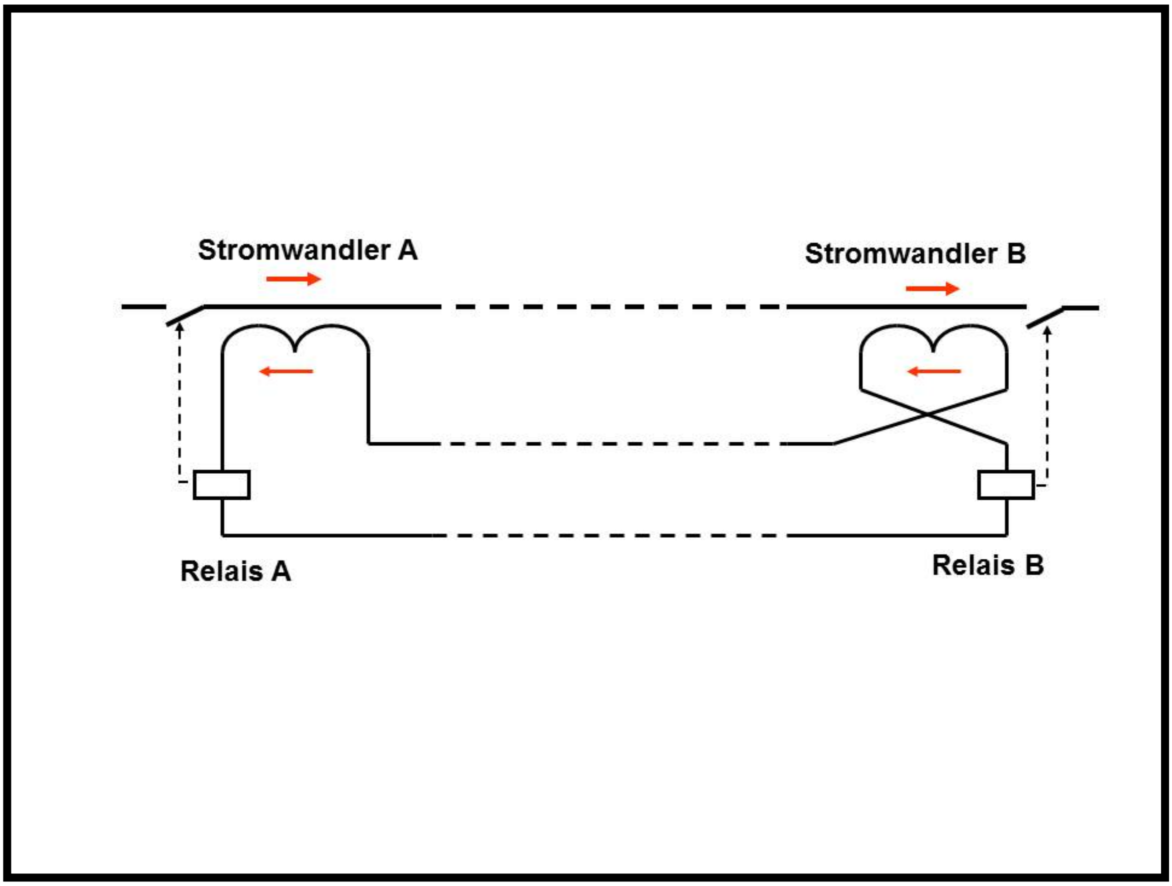


Fig. 3: Differential protection according to Merz und Price with mutually connected CT's

The distance-dependent voltage drop protection

In 1904 Chr. Krämer, F&G, received the patent “Relay for the automatic switching off of an alternating current”, in which the voltage drop relay is used as selective short-circuit protection with a Ferrari disk as a delay element. The principle of distance protection is given in broad outline and is considered the invention of distance protection.

In 1919 J. Biermanns, AEG, used AMZ protection as line relay protection. However, this had the disadvantage that the tripping times fluctuated greatly with the use of the generator. With higher currents, the tripping time decreased, which was desirable, but the relays of the time did not reduce the tripping time inversely proportional to the current, but rather faster. The time leaps between the individual stages became too small and led to a loss of selectivity. The switches and relays of that time required at least a graduation time of 0.5 to 1.5 s. At high currents, however, the relay times decreased to a time difference of 0.1 to 0.2 s, so that triggering of the upstream part of the system could not be prevented [2].

Scaled protection in the form of overcurrent time protection or overcurrent direction protection proved to be no longer sufficient at the beginning of the twentieth century due to the high fault shutdown times and the switching status, which is tailored to radial or ring operation. In order to freely design the networks, distance protection developed as the most important element of protection technology. As early as 1904, Krämer, Chr., F&G, proposed a protective relay that carried the basic features of the distance relay. The claim reads:

"Relay for the automatic switching off of an alternating current, which closes an auxiliary circuit when the normal current strength is exceeded, characterized in that a main and a shunt coil exert opposing torques on a rotatable metal disc, for the purpose of the extent to which the normal current strength is exceeded according to the to measure the point in time at which the auxiliary circuit closes based on the decrease in voltage. "(Fig. 4)

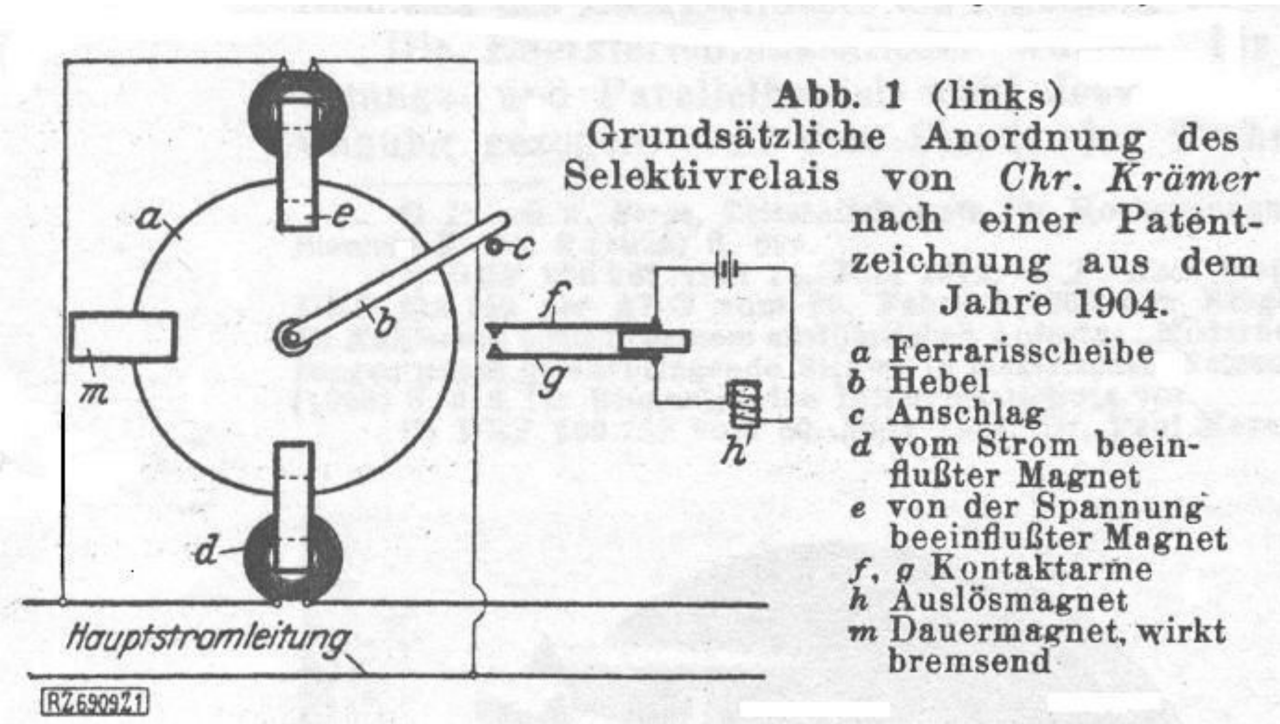


Fig. 4: Basic arrangement of the distance protection according to Chr. Krämer, F&G

AEG and Dr. Paul Meyer AG was acquired by being the first German company to successfully introduce the distance relay into practice almost simultaneously in 1923/24. Various patents preceded this. On April 23, 1908, a patent was granted to the AEG by the inventor Kuhlmann, K., After which a current-driven Ferraris disc was proposed for the first time, with a special voltage magnet acting in the braking sense, creating a distance-dependent command time results. Two months later, Kuhlmann, K. a fundamental patent for distance protection as a toggle relay (balance beam principle) depending on U <and I> with Ferraris disc and rotating armature. Since the balance arm relay is a mechanical device, the phase angle between current and voltage is insignificant, so that the impedance circuit typical of electromechanical relays is created.

An invention by Wecken, W followed in 1911. which forms the basis for selective voltage drop protection.

The impedance protection

In 1918 Meyer, G.J. the basis for the later N-relay, network protection relay. The city of Karlsruhe's 4 kV cable network received the first distance protection system in March / April 1923. The first Biermann relays named after the developer (Fig. 5) were installed in the 30 kV network of the Thuringian Electricity Delivery Company (ThELG) based in Gotha, put into operation.

The first years of the development of distance protection were accompanied by a flood of patents. From 1908 to the early twenties inventions followed by Kuhlmann, K .; Wecken, W .; Chrichton, L.N .; Meyer, G.J., Ackerman, P. and Biermanns, J. The expiry time changed in the ratio of voltage / current = impedance, which ultimately led to the designation "impedance protection" (or "resistance-dependent relay"). However, because of the distance-dependent tripping time, the term “distance protection” has become established.

Fig. 5: Biermanns relay, AEG

Entry of electrontics

The first electronic distance protection is used in 1959. EdF (F) reports on the commissioning of transistor distance protection in the 220 kV network, which in the first year worked perfectly with 40 single and multi-pole faults in 38 cases. According to the manufacturer, the relay only consumed 2 VA in the current and voltage path and the step characteristic should almost approach the ideal characteristic while being largely independent of the short-circuit current. An English manufacturer also reports on a transistorized distance relay with Mho characteristics, which was developed for the South African high-voltage network and has proven itself there in trial operation. It was noteworthy, however, that the English manufacturers of this relay had warned against excessive enthusiasm for transistor relays. They should only be used where they would actually be beneficial. The highly developed electromagnetic relays in rectifier bridge circuit, possibly in connection with transducers, would currently be even better and more economical.

The world's first distance relay with polygonal characteristics was the three-phase static relay ROZOG (Fig. 6) manufactured by ASEA in 1970 with an operating time of 21 ms.

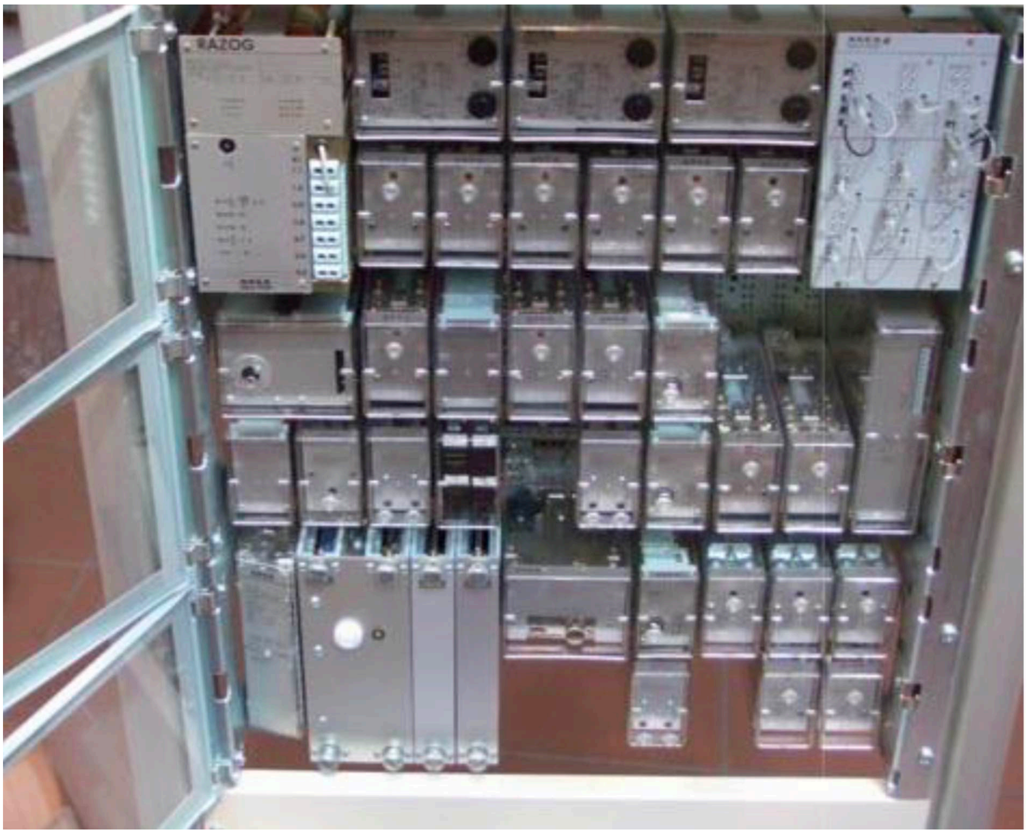


Fig. 6: First distance relay with polygonal characteristic, RAZOG, ASEA

Buchholz protection

In 1921 M. Buchholz received the first patent for the protective device that is named after him today. In contrast to the previous protection systems, the Buchholz relay (Fig. 7) was the first to use a device that did not activate the deviation of the current, voltage or power state from the setpoint, but rather through mechanical processes associated with malfunctions. Oil decomposition phenomena could already be determined in the initial stage [4].

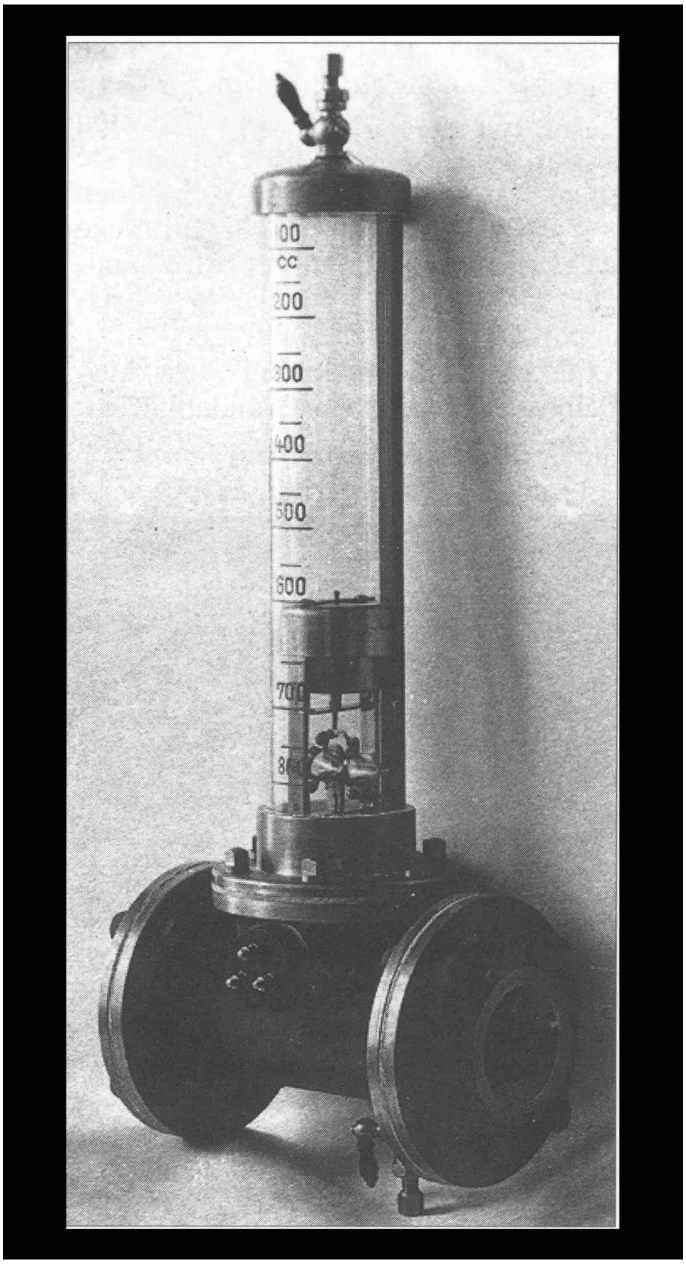


Fig. 7:Buchholz relay, 1925

Overload protection

The use of thermal relays to protect generators was introduced in Europe, especially by the BBC, and was very well received.

For generators over 5000 kVA, the VDE regulations stipulate the installation of six resistance thermometers or thermal elements in the stator to monitor the winding temperatures. After installation, they were difficult to access, which is why replacements were often dispensed with when they were defective. That is why it was decided to monitor the temperature of the generators using thermal relays. These devices included i.a. a thermal element, the heating of which by the relay current, which is proportional to the main current, is reflected in the heating of the main machine (Fig. 8).

Fig. 8: Thermal overcurrent relay ST, BBC

Stator ground fault protection

In 1924 W. Bütow, AEG, suggested the installation of current- and voltage-dependent resistors to increase the sensitivity of the earth fault protection in the event of a fault near the generator star point [2]. This went down in history as the "Bütow Protection". Figure 9 shows the iron-hydrogen resistors placed on the protective cabinet.

Fig. 9: Fe-H-Resistances, Bütow-Schutz

Frequency protection

Operation of the generators in the underfrequency range for a longer period of time has a particularly unfavorable effect on the service life of the turbo generators. On the other hand, generators have to stay connected to the grid for as long as possible in order to avoid grid breakdowns when the relationship between consumption and generation is out of balance.

The German-American electrical engineer Charles Proteus Steinmetz, later employed by GE and president of the professional association American Institute of Electrical Engineers (AIEE) in 1901/02, is considered to be the inventor of the frequency relay.

Arrival of semiconductor technology

It was a decisive step when the dry rectifier was used for the first time in selective protection technology in 1937, initially with the impedance measuring elements as the components of the distance relays that were in need of improvement. The most important difference was that the torque no longer increased quadratically but linearly with the short-circuit current and that saturation phenomena were avoided. It was no longer difficult to achieve an exact and electrically and mechanically perfect functioning even up to the highest current ranges. The command times were halved due to the smaller mass of the moving parts and later further reduced.

The extremely low power consumption of such rectifier circuits was also particularly advantageous; Consumption fell by more than an order of magnitude, although at the same time the shortest detectable cable routes were reduced to a fifth of what had been achieved up to that point. A major advantage of the rectifier operation was that the characteristic curves of the relays with simple ohmic resistances could be easily and precisely set according to the scale according to simple principles such as the measuring range extension of a voltmeter, which not least contributed to easier operation of the relays at the installation site to be able to.

A basic representation of the measuring arrangement in the first such rapid distance relay SD4 from AEG, which was used from 1937 until after the end of the war, is shown in Figure 10. The operating experience was so convincing that one finally turned to this construction principle in a general and on a broad basis [5]

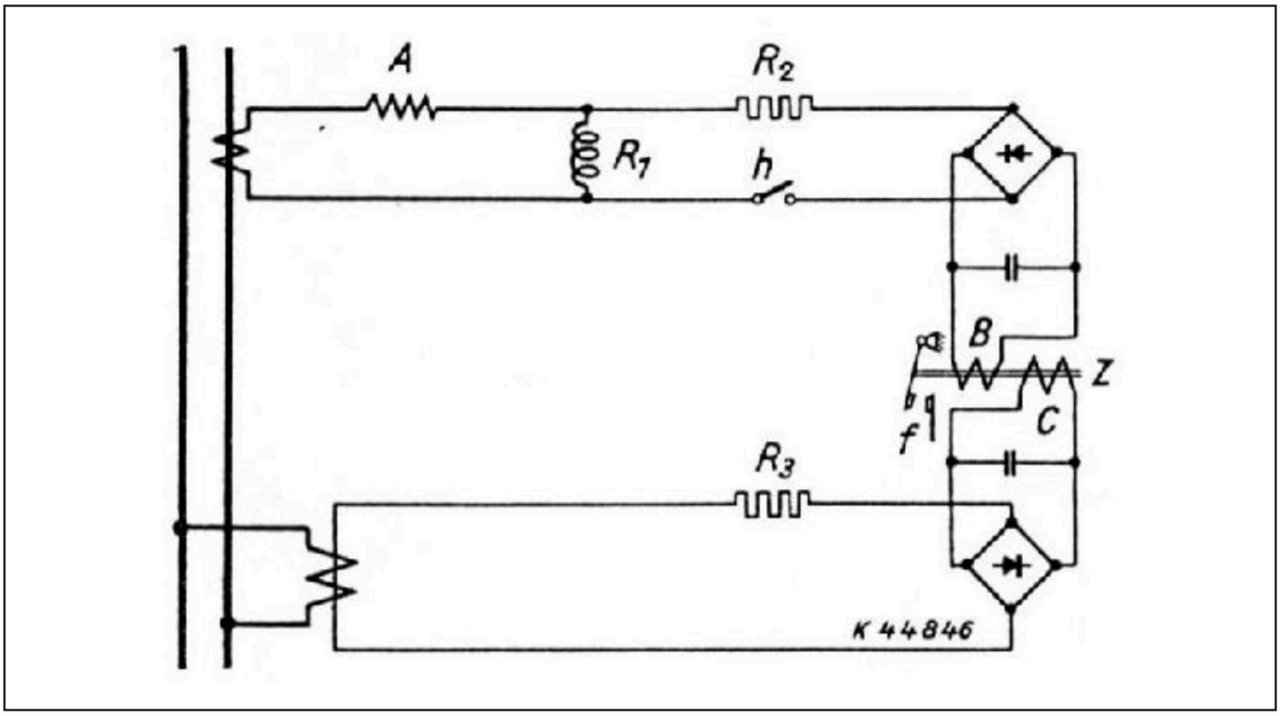


Fig. 10: Measuring arrangement of high-speed distance relay

The relay specialist Dr. Rolf Wideröe worked in Germany from 1928 to 1932 at Dr. Paul Meyer AG and later at AEG. After returning to his home country in 1933, he manufactured a distance relay using a neon tube at N. Jacobsen's Elektriske Verksted a / s, NJEV (N) (Fig. 11) [6].

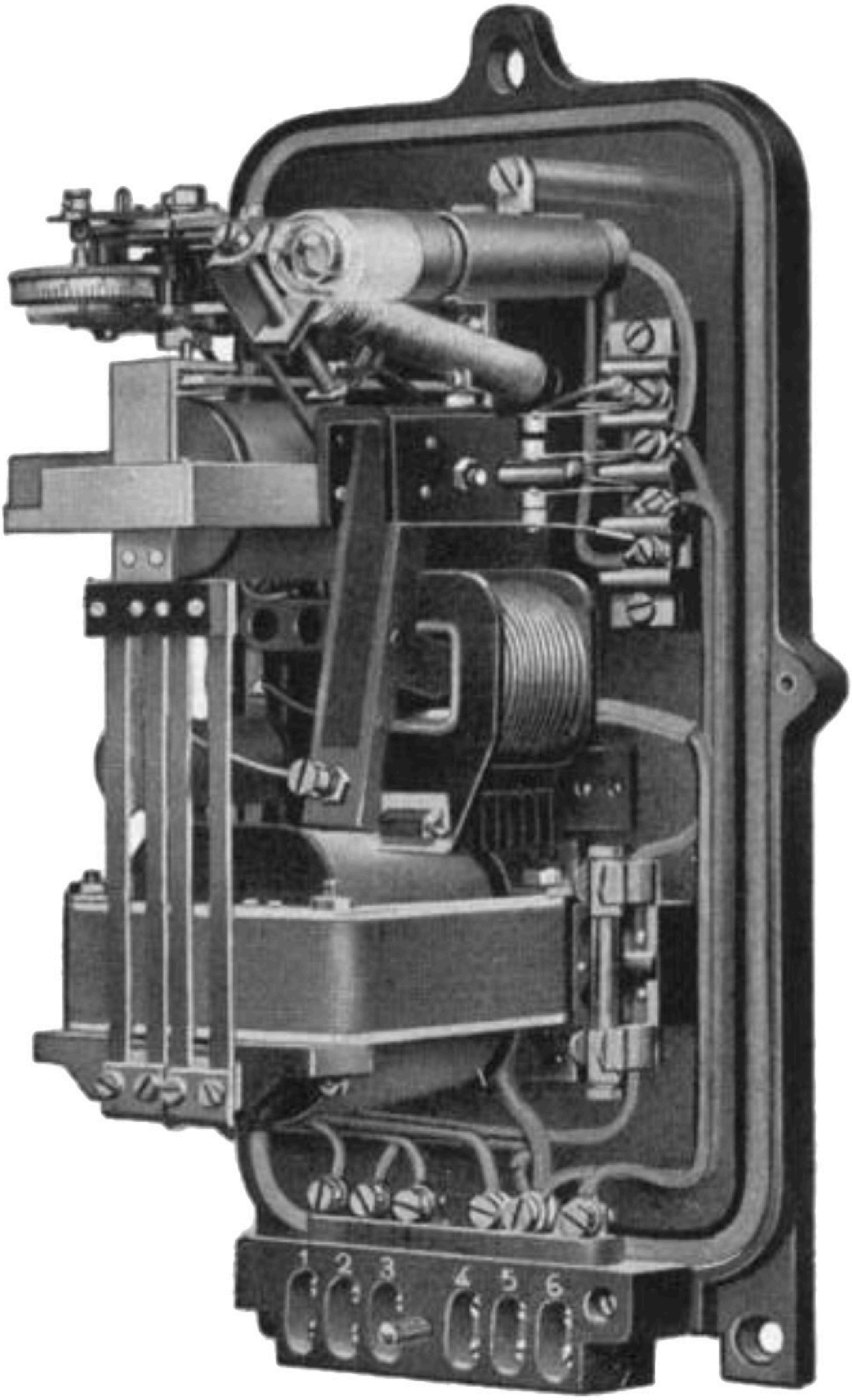


Fig. 11: Distance relay with neon tube

Since the moving contacts of the electromechanical relays represented a certain degree of uncertainty for the protective devices, attempts were initially made to use the electron tube as a contactless switching element. Because of the limited service life of the filament in tubes, solutions were sought using passive and active semiconductor components. With a few exceptions, the experiments with tubes were finally given up around 1955 because semiconductor technology promised to guarantee the highest level of operational reliability. The development towards static relays led to well-engineered constructions that were a valuable addition to the electromechanical relays. The discovery of the transistor in 1948 by the American physicist and later Nobel laureate William Bradford Shockley also revolutionized the protective relay sector].

Static protection relays

Solid-state relays appeared in the late 1950s. These relays were characterized by the use of electronic components such as diodes, transistors and operational amplifiers and offered greater flexibility than the electromechanical relays.

Based on the protection criteria and characteristics of electromechanical relays, components were initially partially replaced by analog-electronic (static) equivalents. At the same time, new measurement methods and characteristics were introduced. This eliminates many of the disadvantages of electromechanical relays, such as contact contamination and bearing damage. In the years around 1960, fully electronic protective relays came onto the market, which prevailed after overcoming the teething troubles (mainly due to the fact that influencing problems were not immediately mastered). Figure 12 shows the 7SL24 single-system static distance relay from Siemens from 1975.

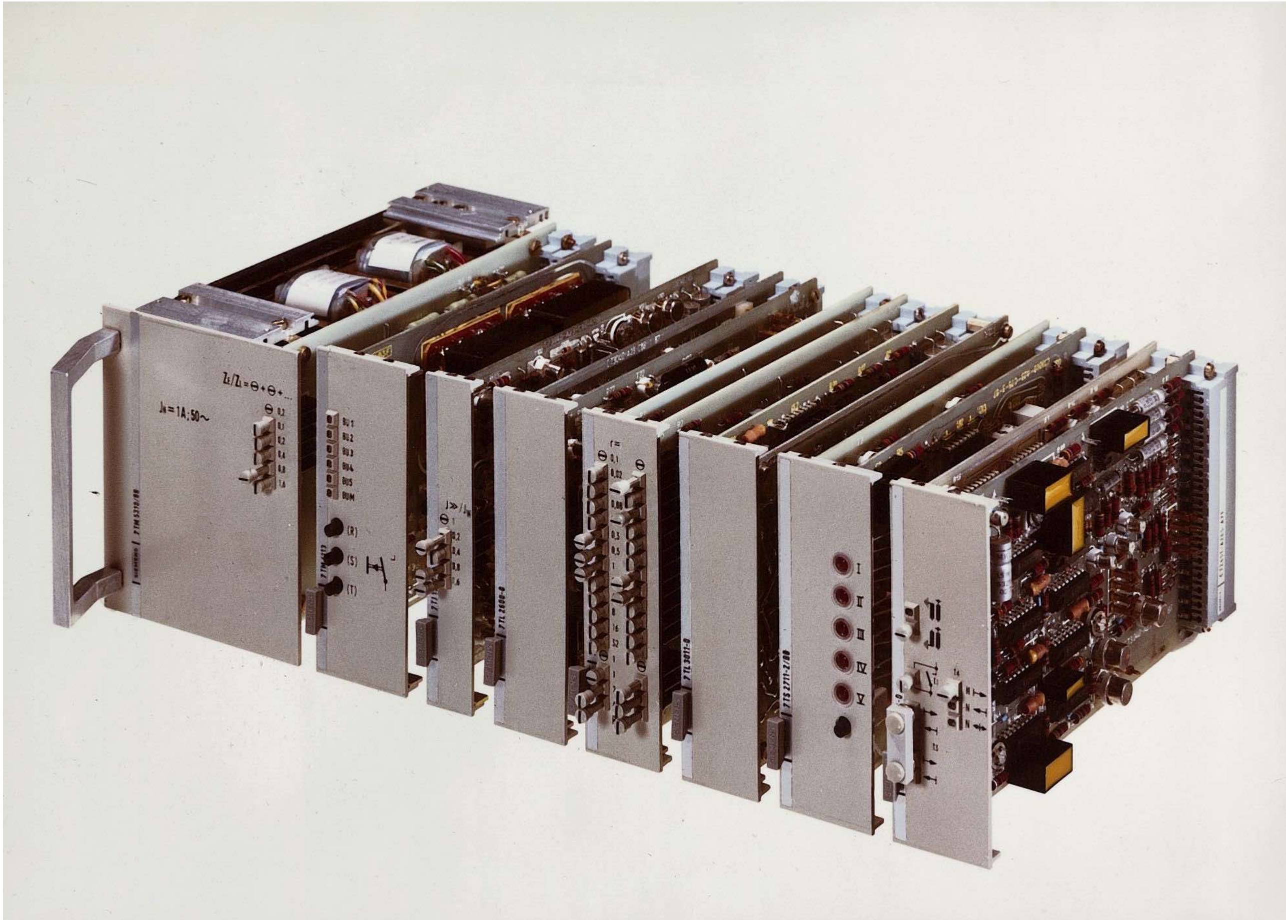
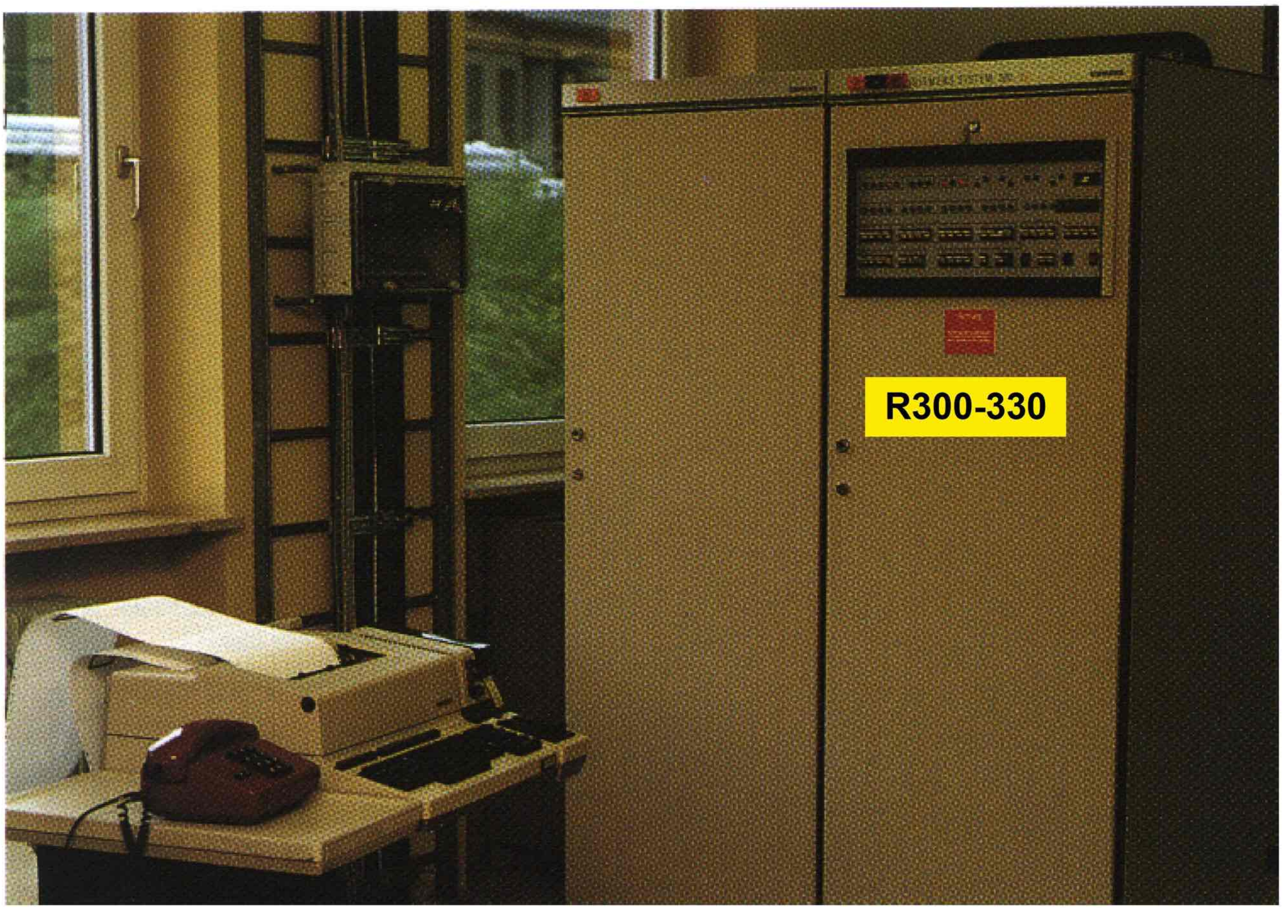


Fig. 12: Distance relay7SL24, Siemens

Digital protection relays

In particular, it was George, D. Rockefeller, Westinghouse, with his contribution written in 1968 and published in the IEEE in 1969 [8] who ushered in the new generation of protection. As early as 1971 Westinghouse tested the PRODAR line protection with a computer on the 220 kV Tesla-Bellota line, PG&E (US).

The first fully digitized protection system in Europe using a process computer for protection tasks and logging in real time (Fig. 13) goes into operation in 1977 in the 110/20 kV substation Bad Kissingen, ÜWU. [6]



Dig. 13: Central process computer use, Substation Bad Kissingen

Frequency and motor protection devices were the first protection relays with microprocessors. The frequency relay FC95 (Fig. 14) and the motor protection relay MC91, BBC [10] are typical examples.

Fig. 14: Frequency relay FC95, BBC, 1984

Multiprocessor arrangements with a common computer bus for the internal exchange of information with more complex protective devices have proven to be advantageous. With the partially digital distance protection device SD36, AEG (Fig. 15), which has been used in medium-voltage networks since 1985, data acquisition and operation were separated using 8-bit processors [11].

Fig. 15: Distance relay SDG36, AEG

The first digital distance relays include: RELZ100, ABB, 1986; PD551, AEG, 1995; DD1, EAW, 1992; SHNB, GEC, 1980; DTIVA2, Protecta, 1995; SEL-21, SEL, 1984 and 7SA502, Siemens, 1986. In addition to the distance protection function, automatic reclosing, underimpedance excitation, synchrocheck and fault locator are now combined in one device. Events, measured values and fault records can be transmitted to the control system via a serial interface and evaluated there in COMTRADE format. In addition, there is extensive self-monitoring.

From 1995 onwards, combined protection and control devices have been manufactured by all relay manufacturers, which are mainly used successfully in medium voltage. The DDE6-2 distance relay with a remote control panel from Sprecher Automation from 2008 serves as an example (Fig. 16).

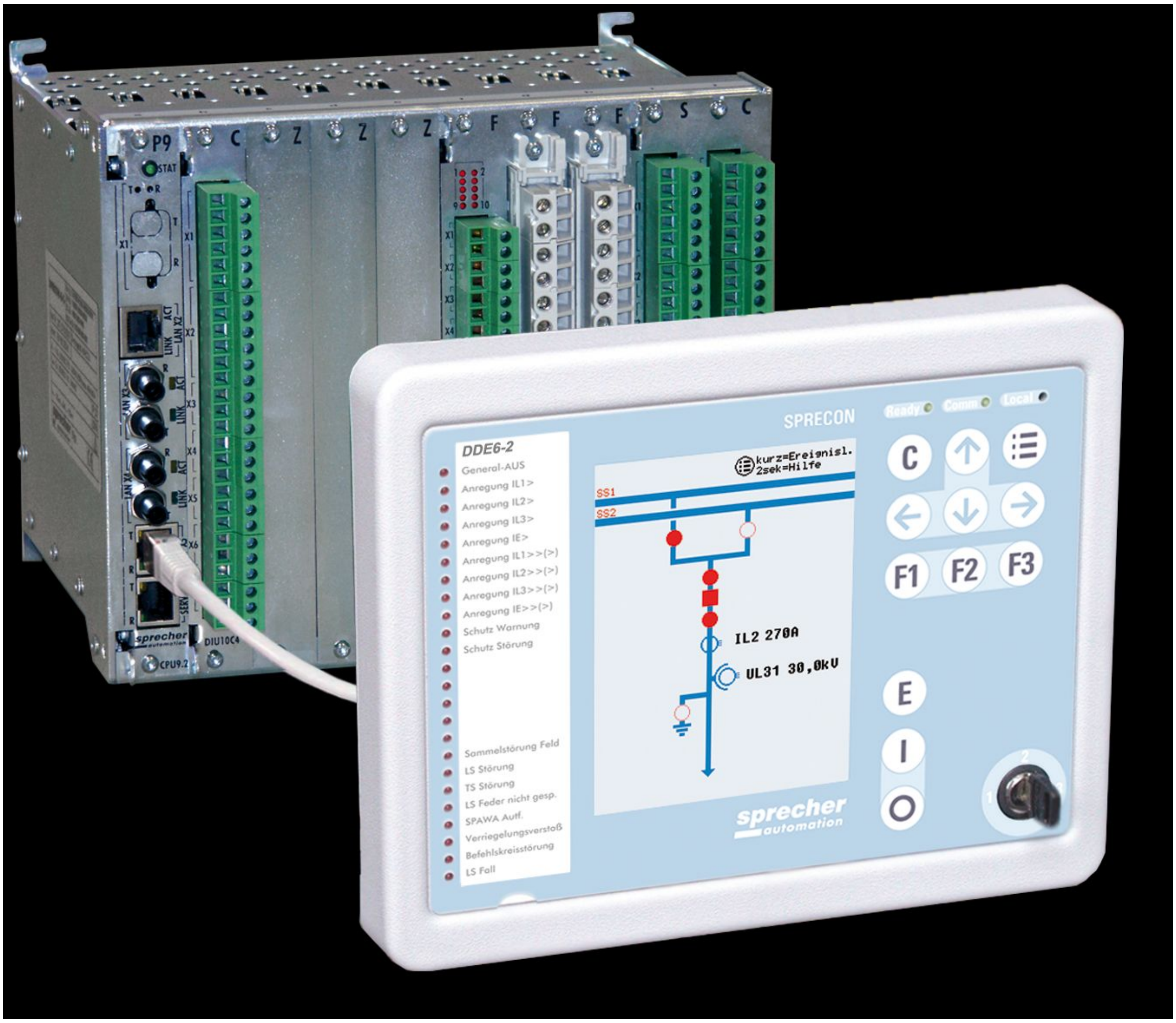


Fig. 16: Distance relyas DD6-2, Sprecher Automation

The protection and control technology is growing together and adaptive solutions allow the first steps in the automatic adjustment of the protection settings to the network topology or by means of fault evaluations.

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Warm wisches Your EEA-Team