Under voltage relay, AEG, appr. 1910 100 V, 50 Hz
Settings: $U_{ab} = 67$ V
$U_{an} = 72$ V

Connections for watt relays as recommended by Westinghouse Co. um 1920

Reverse power relay RR2, AEG, appr. 1930

Induction type overload relay, GE, appr. 1920

Voltage relay CW, Westinghouse, appr. 1920

History is the tutor of life

B4 Reyrolle, appr. 1960
The Beginning of electromechanical Overcurrent Protection

Generations of Protection

The development of protection took place according to the development of the energy systems and the devices used. The progress in development as well as the new requirements of the customers have been the base for several activities.

In the last issues we covered history of line protection as well as for transformers and generators. The new series shall cover the different generations in general. In this article we talk about three main generations as shown in Figure 3.

Direct Overcurrent Release

Substituting high voltage fuses releases have been precursors of our protection devices. In the beginning of the last century such devices were used in main circuit. Circuit breakers have been mainly oil circuit breakers at this time. The main disadvantage of such devices was the explosion risk. Figure 5 shows an example. The device for 10 kV, 300 A was produced in German Sachsenwerk Dresden in 1910. The maximum current was 15 kA. The release device (mounted on the right hand side) operates in case of a short circuit the linking mechanism.

Without auxiliary power and measurement transformers releases could be simple. The characteristic could be compared with a fuse. Testing was not that easy because this could not be done during operation, and false trips occurred often.

Oerlikon started producing the release HZM in 1912. It consisted of a magnet, built on bushing of oil circuit breaker with the escapement mechanism. When improving circuit breakers for higher short circuit currents it was also necessary to increase the fault withstand capability of releases. According to thermal and mechanical requirements, HJZ was developed in 1946 (Figure 9). The strength was up to 500 In (nominal currents between 6 and 1250 A) with a reset ratio of 0.85. Further technical data: setting 1...2 In; accuracy ± 2 % operating time between 0.2...6 s (frequency 50 Hz) or 5 s (60 Hz).

Overcurrent Releases

The most important project for an electrical engineer in the US in the years 1894 – 1900 was the construction of the first huge hydro power station using the power of Niagara Falls. Niagara-Falls Power Co. constructed the first 5000 HP machines in 1895 – 1897- one machine per year. In the next years the construction was faster and thus, 8 machines have been in operation in 1900. Every machine generated two AC voltages (25 Hz, shifted by 90°). The voltage was 2.25 kV, current 775 A. The distribution of power was arranged in groups of 2 or 3 machines. The groups had to stay unconnected to minimize the risks in case of a short circuit. The machine switch (page 71 - above) have been operated with compressed air. The apparatus consists of 2-poles with 4 interruptions in
groups connected to a resistance of 1.2 Ω. So, each current was interrupted 16 times. The distance of a single contact was 25 mm. Purported that’s every single switch should be capable for the power of the entire machine. But in any way there was in case of emergencies an additional pneumatic protection device, switching off the excitation in the entire machine within a short time. Additional contactors switched off the connection to the line. The main switch stayed connected. It was reported that the system, also in combination with commands from the control room worked properly. The power from the Niagara plants was mainly used locally - for carbide production and 2.2 kV transformers. A transmission line was connected in 1899 – 11 kV and prospectively 22 kV (Figure 6).

To avoid loss of power supply two lines in parallel have been built. This main requirement (redundancy) was the base for several future definitions regarding protection.

So also relays have been combined - maximum time relays and reverse current relays as shown in the figure. The relays in the plant have been set to a longer time than the other relays - another protection principle. Definite time delay overcurrent tripping device was invented by L.B.Stillwell, electrical director of Niagara-Falls Power Co. (1899, patent 633920).

As visualized in the patent, the device consists of a definite time relay with current transformer release and a time control. Current transformer excites supervising magnet, tripping block in case of over current. Tripping magnet is short circuited with contact disc. The tripping magnet trips in case of certain level after a certain time. Devices in Niagara Fall’s plant worked as described in this patent, but with DC. devices produced by GEC (Figures 2 and 4) worked with 2-phase-tripping. The reverse current protection was also produced by GEC.

The relay worked with a small fan motor. The approach was, that in case of connecting AC, the direction of a DC motor would change. The anchor moved between the two blocks. In case of a reverse power, the auxiliary circuit was connected and tripped the automat. See the figure with panel in Figure 12.

First dead-tank oil circuit breakers with direct release (Figure 1) have been produced by A. Aichele, BBC in 1900 already. When switching on, the heavy device was lifted, turned at 180° and latched. The release happened with 3 Ferraris-discs. They were on a single axle and connected to an arm with a weight. Since this has to be lifted at first, a dependent time delay was built in already. An example for a reverse current release is shown in Figure 7a and 7b. In DC stations polarized relays could be used to increase sensibility (Figure 8).

**High-Voltage Overcurrent Relay**

A special solution was the high voltage overcurrent relay. The startup element was mounted on high voltage potential. With a cord it operates the time element (ground potential) which closes the contact to the circuit breaker. Figure 11a / 11b shows the General Electric plunger overcurrent relay type PM-33 (22–110 kV).

**Secondary Relays**

When G. Benischke invented the current transformer in 1898 it took two years to supply protection devices with current transformers. In the early 20th century all vendors of switchgears produced protection relays as well. Just to mention some of them:

- **In Europe**: AEG, BBC, Reyrolle, Siemens & Halske, Vogt & Haeflner A.G., Maschinenfabrik Oerlikon
The redundancy requirement was the base for several future definitions regarding protection.

- **In the USA:** General Electric Company, Westinghouse Electric & Manufacturing Co., Schweitzer and Conrad, Inc.

  First generations of protection relays have been moving coil and other devices as described in the PAC World Autumn 2007 issue. Another possibility has been Ferraris relays (induction relays, Figure 13). Current direction relay of V & H (1920) shows Figure 14. The Ferraris drum was moved by 4 mechanisms with 2 voltage and 2 current coils. An arm connected to them was moving according to the direction of power. At the end of the arm there was a mica plate that moved between two contacts. Due to that, only the circuit according to direction of power was closed.

  Building an overcurrent relay with delay was already proposed by Charles Brown in 1902. His patent DP 143 556 utilized a Ferraris disc which lifts a heft (see Figure 22 in the PAC World Autumn 2007 issue). The time could be set up with heft. TOSHIBA has been producing Plunger-core overcurrent relays since 1907.

  Release devices have been called “automatic switch off devices for AC systems.” Even the term selectivity was known already, but was used for telephone circuits only (to distinguish between intermittent and permanent currents).

  Kuhlmann published in the magazine ETZ (Germany) a paper in 1908 using the terms “definite” and “inverse time” (dependent) for the first time as well for relays as release.

  Just to remember, a solution for time delays when switching off batteries in case of line faults we mention a solution proposed by G. Dedreux (Munich) in his patent DRP 59192 (1891) - Figure 18. An inclined channel (d) with spring (f) was the base. When the anchor moves, a bullet moves, presses spring (k), and thus interrupts the circuit. Later mechanical...
The huge braking magnets. S & H produced in 1925 single pole overcurrent relays RA1 (figure 21 in the PAC World Autumn 2007 issue) and the RS1 (in the spread).

**Overcurrent Protection**

The Swedish Vattenfall operates a widespread grid with two-phase relays with current dependent characteristic (Figure 19). The relays were produced by the Swedish vendor Allmänna Svenska. A time relay Rs2 (S & H, 1931, 220 VDC, 0.25...2.5 s, contact power max. 1000VA) is shown in Figure 20, ASEA’s RK3 in Figure 21. The relay Rs107 (Figure 22, 1955) by S & H shows the changeover contact (quicksilver compensator). Westinghouse’s 3-phase-device COA shows Figure 28. To use distention by heat was already proposed by Laurence and Scott 1889 (DRP 53876).

A bimetal with a heating coil was used as a thermal relay (Figure 27) and thermal replica of the asset to be protected (e.g. motor). AEG’s RSZ2t (1937) solved the main problem of bimetals - slow contact making. Figure 29 shows a device of East German AEG-Berlin-successor EAW RSZ3t (1970).

A solution for time delays for switching off batteries in case of line faults, was proposed by G. Dedreux - (DRP 59192).

Westinghouse’s CO overcurrent relay with inverse definite minimum time characteristics is shown in Figure 16. The choice of startup current (4, 6, 8, 10 or 12 A) was made with a contact bar. A device with direction detection made also by Westinghouse in 1920 is shown in Figure 17. Typical for American relays (up to today in electromechanical relays) are escapements (as balance springs in clocks, Figure 10) have been used. Another possibility was a synchronized induction motor (Figure 24). The required torque for escapement a was produced with spring d, stretched by solenoid c. A completely different proposal was made by GEC (Figures 15, 26). An immerse anchor a worked with a bellows b, delaying the trip. The time could be set up by changing air’s stream (c/d).

For pull-out, AEG used the force of a weight hanging on a cord. To setup current a - defined tap of winding was used, to setup time - the way of contact was changed. Siemens preferred to use the power of springs. The increasing torque can be compensated with a cord on a cone-shaped screw (Figure 23). GEC solved the torque issue with a disc with trenches (Figure 25).

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An interesting example for a mechanically coupled current-
23 **Inverse time overcurrent relay, Siemens**

Figure 23:  
To setup current:  
- A defined tap of winding was used  
To setup time:  
- The way of contact was changed

and time-element is the “clock release” produced by V&H in the 1920s (Figures 31, 33). The overcurrent magnet A moves an arm a, and the clockwork, winded by a key. After the time (1 ... 6 s or 2 ... 12 s) the arm b is moved, releasing the switch. If the overload was for a short time only, the arm would have moved back. If the overcurrent was a short circuit current, the arm would have moved immediately, and would have tripped the device. A single winding was sufficient for 25 overload releases. If the device was not winded early enough, the device would finally trip without a delay and could not be switched on before winding again. The round housing of the first relays was similar to the already established measurement devices at this time. This was also due to the same measurement elements that have been used. A definite time limit overload relay by Westinghouse (1910) is shown in Figures 34, and an inverse power relay is shown in Figure 36.

AEG improved his overcurrent relay PLNr. 69036G in 1914 (Figure 30). The setting range was between 5 A and 15 A, 0.5 s up to 5 s or 1 s up to 10 s. The time variation was ± 0.1 s. The relay was not equipped with a scale for settings in Amps or seconds. It was equipped with small disks with numbers to regulate the settings. To translate between these numbers and the values, a table was necessary. Also the inverse time overcurrent characteristic relay was improved. It operated according to the induction principle. A driving magnet works on an aluminum disk (Figure 32). The improvement was the startup system, guaranteeing a stable behavior.

At the end of the 1920s, in addition to the relays mentioned, devices of "Dr. Paul Mayer AG" were delivered after the takeover by AEG. These devices were delivered in rectangle housings, which allowed an easy combination of different devices on a panel or even a common housing. IDMT RSZ3 (Figure 35) combines the protection for a transmission line in one housing. Later, the improved RSZ3f was produced (1935). In 1960 Cheboksary Electric Apparatus Plant (USSR) started producing the very popular overcurrent relay PT-40 (0.2...8 A, Figure 37).

In the next issues we will write more on electromechanical protection, and electronics moving into relays.

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21 **RK3, ASEA** 22 **Rs107, S & H, 1955** 23 **Inverse time overcurrent relay, Siemens** 24 **Definite time relay with induction motor** 25 **Overcurrent relay, GEC** 26 **Elektromagnetic relay, GEC, appr. 1920**
27 Bimetal relay

28 COA, Westinghouse, appr. 1920

29 RSZ3t, EAW, appr. 1970

30 Relays PLNr 69036G, AEG, 1914

31 Primary release, V & H, appr. 1910

32 ITOC relay, Pl.-Nr. 69007, AEG, 1916

33 Clockwork relay, V & H, appr. 1910

34 Overload relay, Westinghouse, 1910

35 RSZ3, AEG, appr. 1930

36 Inverse power relay

37 PT-40, CheAZ, 1960