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From the basic test kit to the smart test set

Introduction

The first energy generation and transmission systems came into existence at the start of the 20th century. Initial protective devices were also developed around the same time.

Responsible operators soon realized that thorough testing during commissioning and subsequent operation could help prevent damage and maintain a reliable supply. During the first tests, the behavior in the event of network faults was observed. The initial process of applying specified currents and voltages to the relays (made available via regulating transformers or resistors) was later replaced by measurement of the tripping time. The design and structure of the testing and measuring apparatus was complex and took a lot of time to set up.

The progression from a basic test kit, all the way up to intelligent testing equipment and new testing technologies has been documented in a range of protection relays and testing devices.

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The portable test kit

The first protection relays were constructed in the early 20th century. Development of the testing and measurement solutions required for this also began at around the same time. To be able to perform tests on relays, complex testing circuits with heavy auxiliary equipment had to be set up (voltage and current transformers, control chokes, measuring equipment), which took a great deal of time. To facilitate easier and faster testing, engineers quickly developed a portable test kit that was capable of performing the same tests as the large and heavy equipment used previously.

Manufacturer	Voigt und Haeffner, V&H (Germany)
Start of production	Around 1925
Specifications	
Voltage range	0 – 480 V
Current range	0.4 – 1200 A, short-term 2000 A
Power	1000 VA, 1 min; 3500 VA, around 5 s
Accessories	Leather transport case Testing cable for primary testing Test leads
Acquired from	EVI Energieversorgung, Reinhard Bretzke, Hildesheim (Germany)

Brief functional description

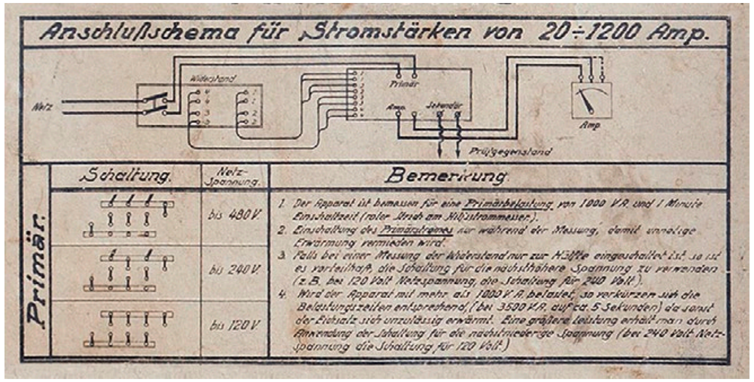
Thanks to the lightweight construction of the equipment and its portability in a case, it was also ideally suited for performing commissioning and regular on-site tests. Closing the blades allows the measuring range to be preselected, the mains switch allows the test variable to be activated, and the sliding resistor allows the level of the test variable to be adjusted. To prevent any unnecessary heat, the primary current may only be activated during the measurement.

Area of deployment

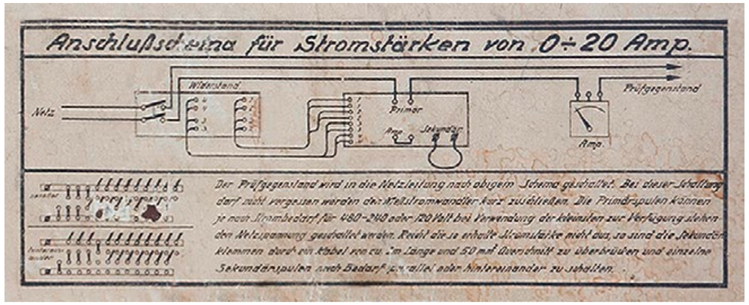
Single-pole primary and secondary testing of triggers and relays, particularly overcurrent, overvoltage and undervoltage relays, and later also for directional and distance relays.

This testing device was used into the 1970s and is still fully functional to this day.

Connection diagram

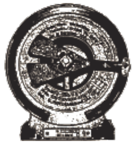


Wiring diagram for currents from 20 to 1200 A



Wiring diagram for currents from 0 to 20 A

Accessories



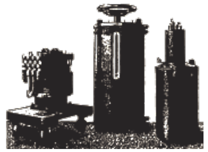
Regulating transformer

Ammeter

Dietze system

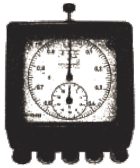
Sliding resistor

Voltmeter

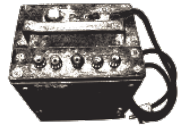


Auxiliary devices

Cycle counter



Time piece



Current transformer

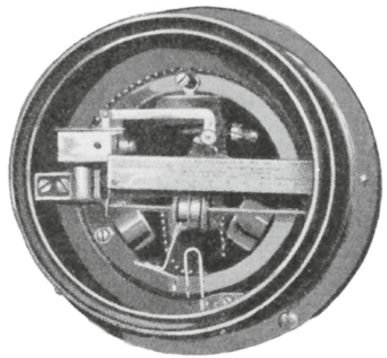
Sources and further literature:

- Sommer, E.M.K.: Die bestehenden Relaiskombinationen und ihre Anwendung, Prüfung und Wartung (Existing relay combinations and their application, testing, and maintenance). P. 114-157 in Rüdenberg, R. (publisher).: Relais und Schutzschaltungen in elektrischen Kraftwerken und Netzen (Relays and protection circuits in electrical power plants and grids). Julius Springer Verlag, Berlin 1929

Voltage reduction relay, PI number 69003

The first secondary protection devices used a mains voltage or operating current monitor to detect faults. The overvoltage/undervoltage or overcurrent specified was used as the reporting or tripping criterion.

Manufacturer	Allgemeine Elektrizitäts-Gesellschaft (AEG), Germany
Start of production	Around 1910
Specifications	
Voltage / frequency	100 V / 50 Hz
Setting values	$U_{out} = 67\,V$ $U_{in} = 72\,V$
Acquired from	Elektrothek Osterath, Germany
Construction	



Brief description of the function

In its de-energized state, the rotary anchor is held in a specific position by the mains voltage applied to the coil *S* relative to the counterweight *G*. As the voltage drops, the sliding weight moves in the longitudinal direction along the scale and eventually causes the tripping contact *D* to trip.

Area of deployment

Undervoltage protection for motors, generators, etc.

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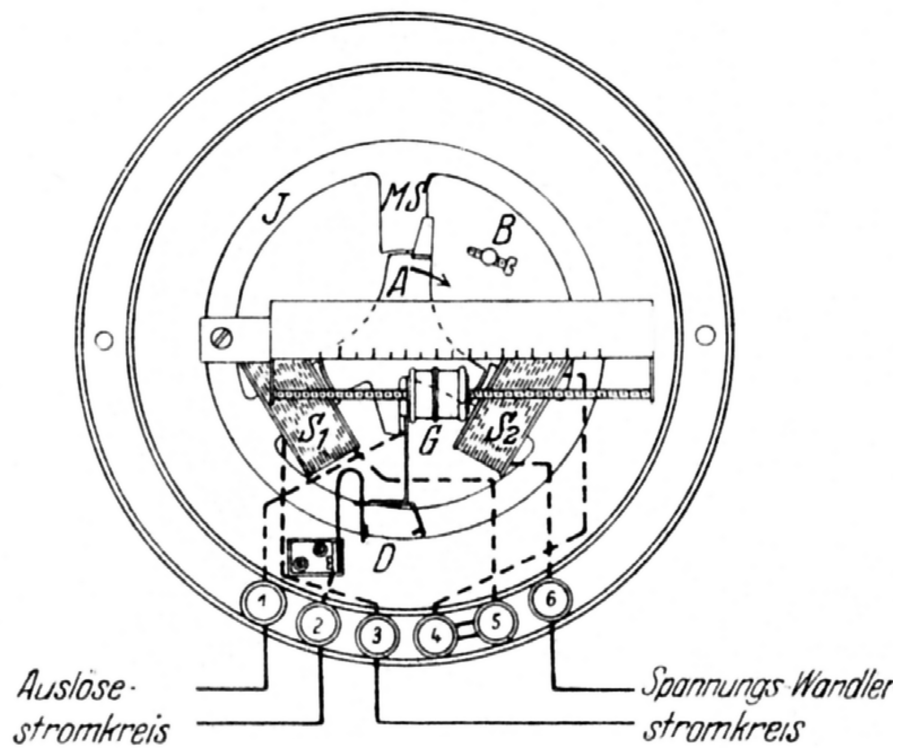
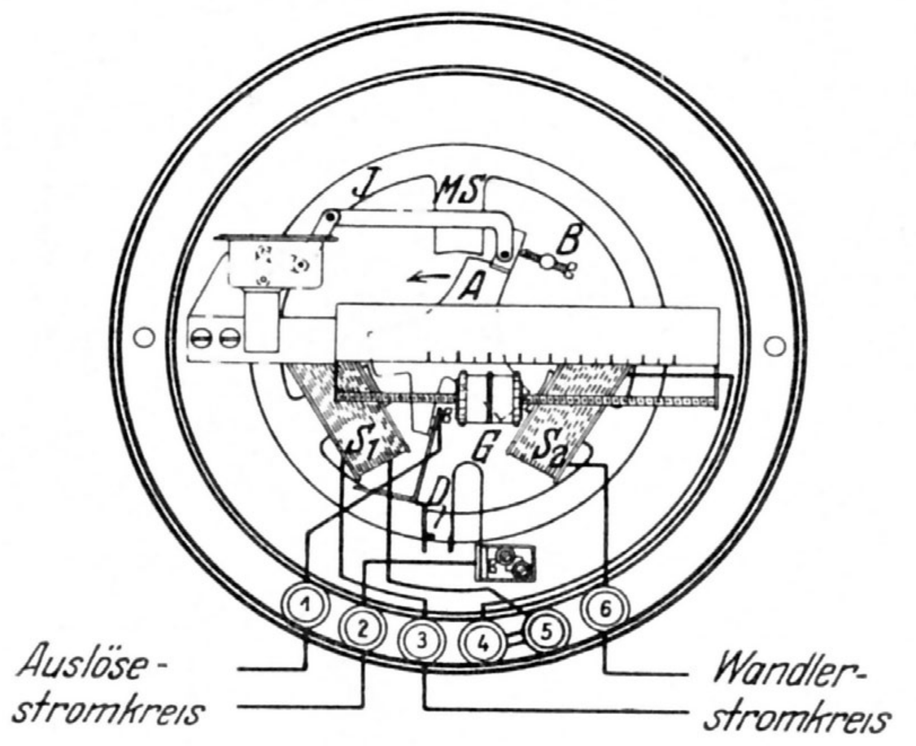
Circuit diagram of a voltage relay



Tripping circuit

Voltage transformer circuit

Circuit diagram of a current relay



Tripping circuit

Transformer circuit

Sources and further literature:

- Rüdenberg, R.: Relais und Schutzschaltungen in elektrischen Kraftwerken und Netzen (Relays and protection circuits in electrical power plants and grids). Julius Springer Verlag, Berlin 1929
- Schweden, B.: Forschen und Schaffen (Research and operations). Beiträge der AEG zur Entwicklung der Elektrotechnik bis zum Wiederaufbau nach dem zweiten Weltkrieg (Contributions made by AEG to the development of electrical engineering up to the reconstruction work following the Second World War), Volumes 1-3, Publisher AEG, Berlin 1965

PT-40/2 current relay

The PT-40 was used for many different applications. One such deployment was as an overvoltage excitement unit for overcurrent or zero-current time protection, although it was also used as a measuring element for cable and transformer differential protection. One special application worthy of note is its use for multi-stage overcurrent timing protection. No time selection is made here. Instead, the current setting is made based on the short-circuit current occurring in the object to be protected in such a way that only faults in a certain portion of the total path to be protected can be shut down. The tripping characteristic is then similar to that of distance protection.

Area of deployment

Overcurrent protection in medium-voltage networks

Manufacturer	Cheboksary Electric Apparatus Plant, Tscheboksary (RU)
Start of production	1965

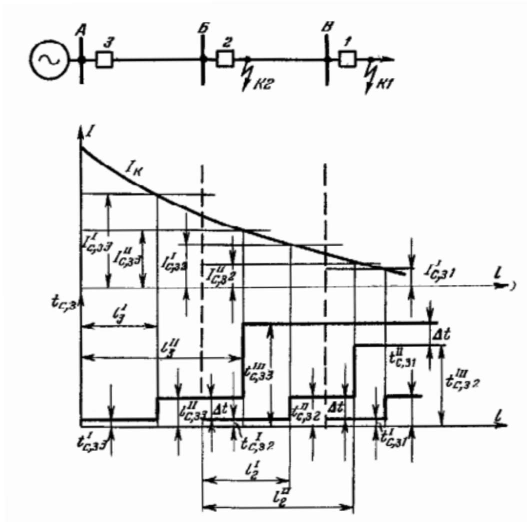
Specifications

I_n = 3.8 A or 7.6 A, f_n = 50…60 Hz

Adjustment range 0.5…1 I_n, single-pole, 1 N/C and 1 N/O contact

Acquired from	Evaldas Oleskevicius, OMICRON

Characteristic



Sources and further literature:

- Федосеев, А.М.: Релейная Защита Електрических Систем. Енергия. Москва 1976 (Relay protection in power systems. Energija, Moscow: 1976
- Fedossejew, A.M.: Relaisschutz von elektrischen Netzen und Anlagen (Relay protection in electrical grids and systems). Volumes 1 and 2, Verlag Technik Berlin, 1955
- Засыпкин, АС.: Релейная Защита Трансформаторов. Москва Енергомиздат 1989 (Relay protection of transformers. Energomizdat, Moscow: 1989)

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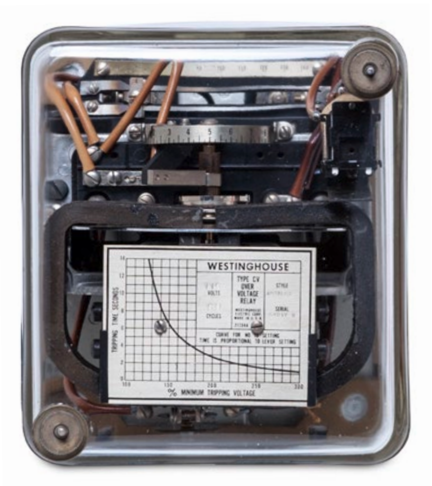
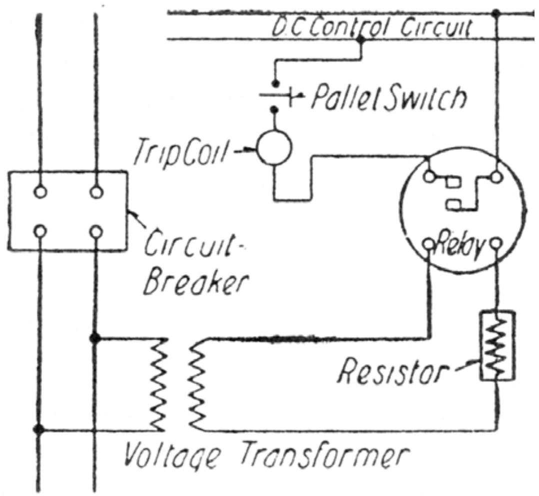
CV overvoltage/undervoltage relay

One application of this relay is for overvoltage/undervoltage protection in generators, motors, and electrical systems. When a measured value falls below or exceeds the specified threshold, an OFF command is issued to the power switch either directly or via an external, downstream time relay. There are also further potential applications in the field of network automation, such as in automatic switching systems.



Manufacturer	Westinghouse Electric & Manufacturing Co., East Pittsburgh (USA)
Start of production	Around 1920
Specifications	
$U_n = 110\,V$, $f_n = 50 \ldots 60\,Hz$	
Operating range 125 to 300 % of U_n and $t = f(U_>)$ 1 to 14 s	
Acquired from	Will Knapek, OMICRON
Circuit diagram	



Area of deployment

Independent overvoltage protection for motors, generators, and transformers

Sources and further literature:
- Sanderson, C.H.; Crichton, L.N.; Traver,O.C.; Allen, A.J.; Taylor, D.W.; Hester, A.E.; Harvey, H.G.; Brown, H.W.; Cook, J.A.; Hamdi, A.F.; Braley, H.D.: Relay Handbook. National Electric Light Association. First Edition, February 1926, N.E.L.A. Publication no. 25-3, Charles Francis Press, New York

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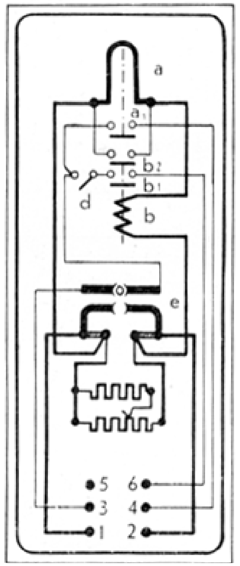
ST thermal overcurrent time relay

BBC BROWN BOVERI

Thanks to its thermal time constant, which can be set in stages of between 20 and 110 minutes, the thermal overload relay allows complete overload protection for electrical equipment. It allows users to specify the same temperature for this equipment as the object being protected at any time, meaning that said equipment is only shut down once the final overtemperature threshold has been exceeded.

Manufacturer	Brown, Boveri & Cie. AG, Mannheim (Germany)
Start of production	1943
Specifications	
$I_n = 5$ A, $f_n = 50/60$ *Hz*, $I_{60°}$ for 60 °C	
Short-circuit resistance 1s	200 A
Values that can be adjusted/set	
Thermal time constant T	20, 30, 40, 60, 80, 110 min
Overtemperature display	Adjustable from 4 to 5 A
Overtemperature tripping	20 °C to 120 °C (68°F to 248 °C)
Limit current tripping	3 to 10 $I_{60°}$ and ∞
Acquired from	Walter Schossig, VDE Thüringen
Circuit diagram	



Area of deployment

Thermally-dependent overload protection for motors, generators, transformers, and cables, as well as short-circuit protection thanks to limit current tripping.

Sources and further literature:
- Wiring diagram for currents from 40 to 60 Hz AN6c2 List, February 1950. Brown, Boveri, Cie, Mannheim
- Happoldt, H., Meinhardt, H.: Generatorschutz-Einrichtungen (Generator protection devices), BBC publication C 1009a/p (460.3R)

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R3Z24a distance relay

SIEMENS

The introduction of distance protection reduced tripping times. Additional casings were required for the relay's extended functionalities, such as shunts for measurement, underimpedance detection, direction detection, and automatic reactivation.

Brief description of the function

The current-proportional voltages provided via the current shunt resistance, as well as the transformer voltage are applied to the activation and measurement units of the electromechanical distance relay. In parallel to the start of overcurrent, underimpedance also occurs during low-load periods. A measuring circuit shift towards *R* provides arc compensation, while a pendulum lock prevents any incorrect behavior in the event of network oscillations. The tripping impulse is issued based on impedance, with a time delay.

Area of deployment

Line protection for high voltage, very high voltage networks, independent of the neutral-point handling of transformers.

Manufacturer	Siemens & Halske (S & H) (Germany)
Start of production	Around 1950
Specifications	
$I_n = 5$ A or 1 A, $f_n = 50$ Hz	
Overcurrent starting function	1 – 2 I_n, switchable to 2 – 4 I_n
Measured variable switchover	0.4 – 0.8 I_n
Pickup/dropout ratio	Around 0.85
Nominal voltage	$U_n = 100$ V / 110 V
Power consumption in the current path	including shunt: At $I_n = 1$ A around 2 VA, at 5 A around 6 VA
Power consumption in the voltage path	during standard operation 0; following start-up 10 VA – 42 VA
Resistance measurement	Lowest adjustment range: $Z = 0.05\,\Omega$ / core at 5 A I_n $Z = 0.25\,\Omega$ / core at 1 A I_n
Shortest tripping time	35 ms for all fault types Adjustment: in five stages; continuous up to 7.4 s or ∞
Accuracy	Max. deviation: 0.1 s
Directional sensitivity	< 1‰ of nominal voltage at nominal current
Maximum load	1 s at 100 I_n; 10 s at 30 I_n; continuous 4 I_n
Acquired from	Elektrothek Osterath, Germany

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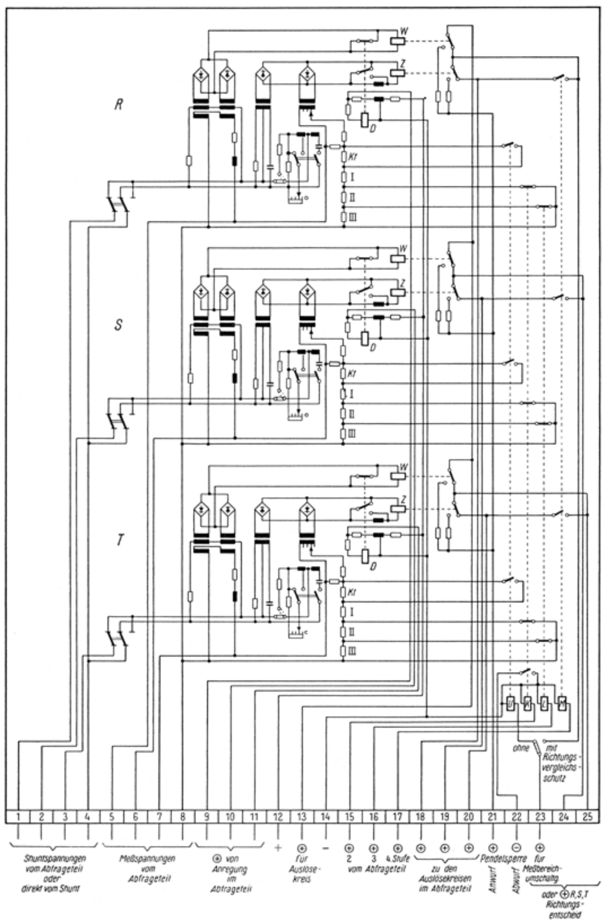
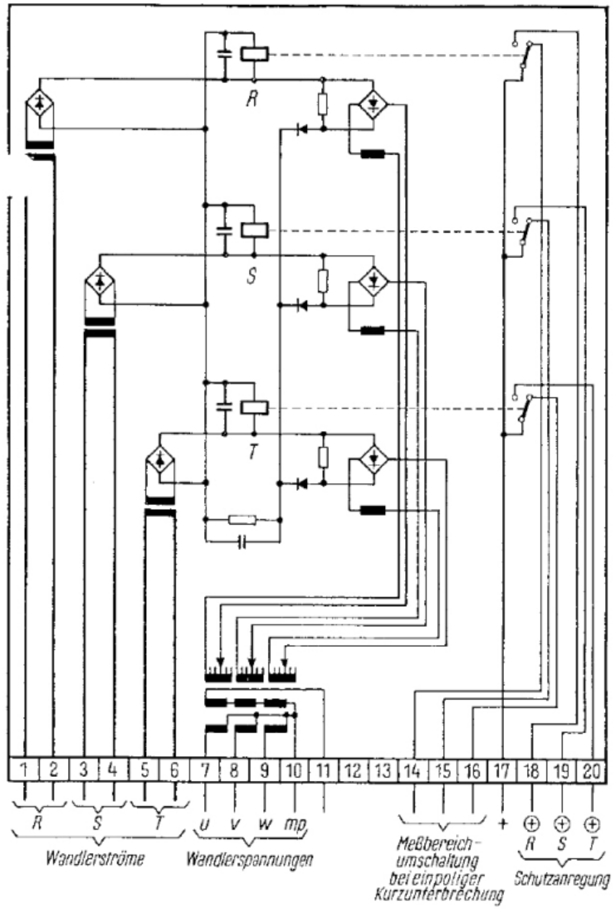
Circuit diagrams



Measurement part



Start of underimpedance

Sources and further literature:

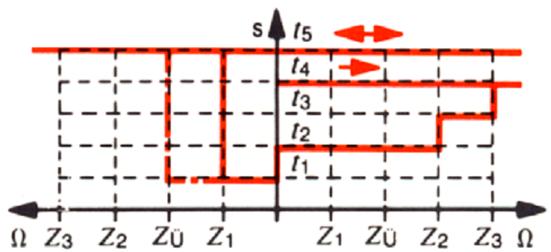
- R3Z24 Distanzschutz (distance protection). Specifications. 21 S., Siemens-Schuckert Aktiengesellschaft, Berlin – Erlagen, TS 12 R/512.324/Ga. Erlangen, July 1960, 4 TS R B2 4445, TS Rel. 4177 Bl. 1-21
- R3Z24 Distanzschutz (distance protection). Specifications. 40 S., Siemens-Schuckert Aktiengesellschaft

SD36 distance relay

AEG

The newly developed static distance protection relays were capable of measuring the distance from faults and then determining the precise location of the fault. In comparison with earlier models, mechanical components were replaced by the first microprocessors, which significantly reduced the time and costs associated with maintenance and also allowed communication with station controllers.

Manufacturer	AEG (Germany)
Start of production	1985
Specifications	
I_n = 1 A or 5 A (depending on order)	
U_n = 100 V; f_n = 50 Hz or 60 Hz	
Impedance adjustment range	0.1 – 99.99 Ω at 1 A 0.02 – 19.998 Ω at 5 A
Five time stages can be set from 0 to 9.95 s in steps of 0.05 s	
Nominal consumption in the current transformer circuit	with auxiliary power supply < 1 VA per core at I_n, with transformer supply < 1 VA per core at I_n, 57 VA in the L2 core with three-pole fault and U_{12}, U_{23}, $U_{31} \leq 50$ V
Acquired from	Manfred Dohmann, OMICRON



Tripping characteristic

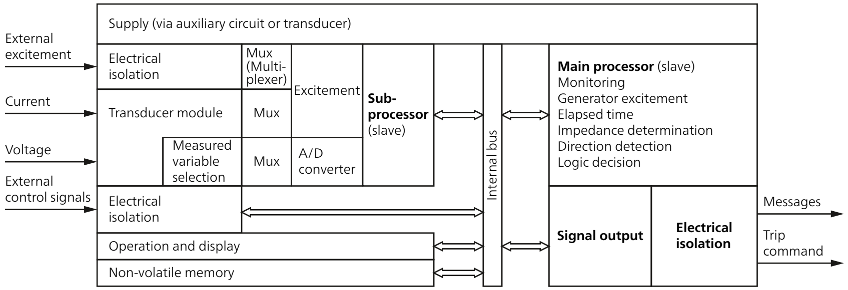
Brief description of the function

Single-system, static and partially digitalized distance relay based on the principle of distance-independent time intervals.

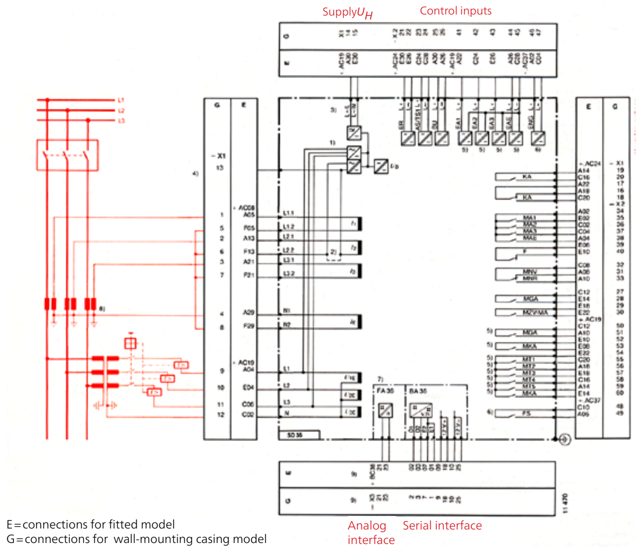
Area of deployment

Distance protection for medium voltage and high voltage lines, independent of the neutral-point handling of transformers.

Basic structure

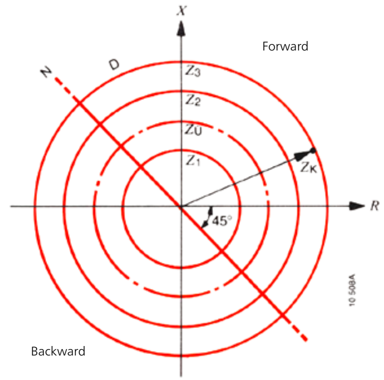


Circuit diagram

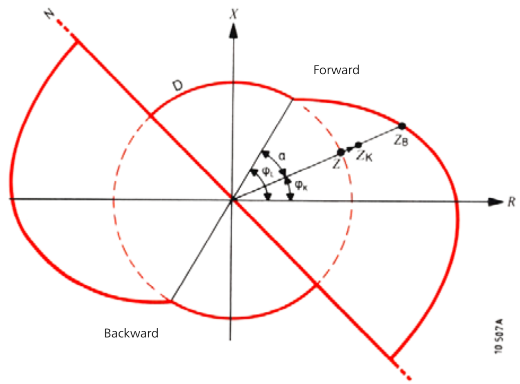


E = connections for fitted model
G = connections for wall-mounting casing model

Characteristics



Impedance and directional characteristics



Arc compensation

Sources and further literature:

- SD 36 distance protection relay. Operating manual. AEG, A232.12.1057/0390 DE
- Offhaus, W.; Schegner, P.: Entwicklungstendenzen beim digitalen Leitungsschutz (Development tendencies in the field of digital line protection). AEG special publication from etz (1992) 17, A232.14.424/11.92

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7VP4800-0 and 7VP4900-0 portable relay testing devices

SIEMENS

Thanks to the ongoing development of new relays, the providers of testing solutions were required to revise their testing systems and adapt them for use with the new generation of relays. The increased precision and accuracy of the relays also placed completely new demands on the testing equipment.

Brief description of the function

The variables to be tested, i.e. current, voltage, impedance, and angle, are set up manually using the operator controls. The activation and deactivation values, as well as the tripping time is recorded and then documented in a test report.

Area of deployment

Three-pole testing of electromechanical and static overcurrent time, directional and distance protection relays.

Manufacturer	Siemens Nuremberg (Germany)
Start of production	1984
Specifications	
Current unit	
Testing power	3 x 300 VA 20 A or 4 A continuous load 50 A or 10 A for 20 s
Power supply	3 x 380 V AC, max. 3 A; 50 – 60 Hz
Weight	43 kg (95 lbs)
Voltage unit	
Voltage range	0.03 – 70 V
Accuracy	3 %
Testing power	3 x 90 VA
Angular adjustment	0° – 360°
Weight	35 kg (77 lbs)
Transport case	
Weight	6.5 kg (14 lbs)
Accessories	Connection and testing cables, Aluminum box
Acquired from	Siemens

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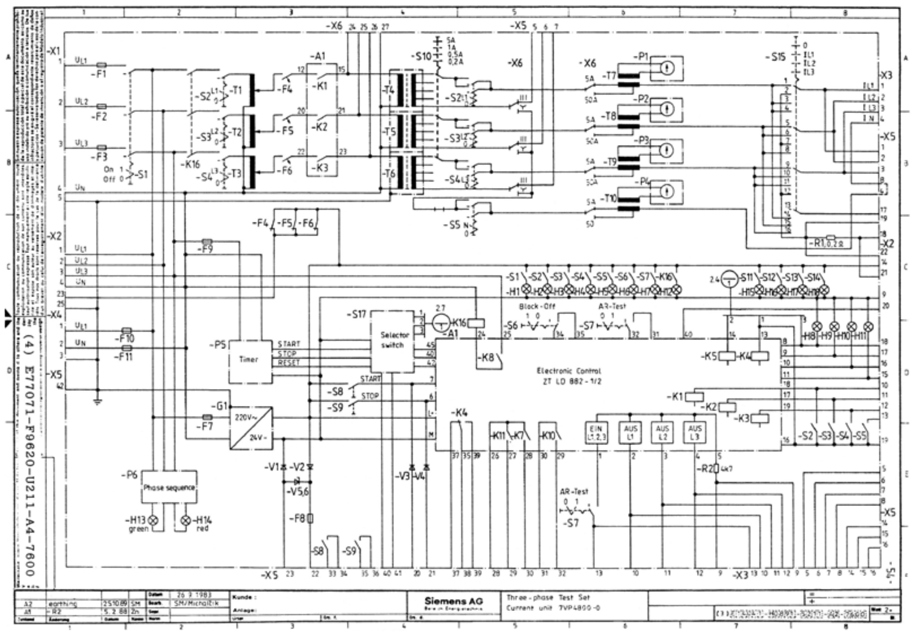
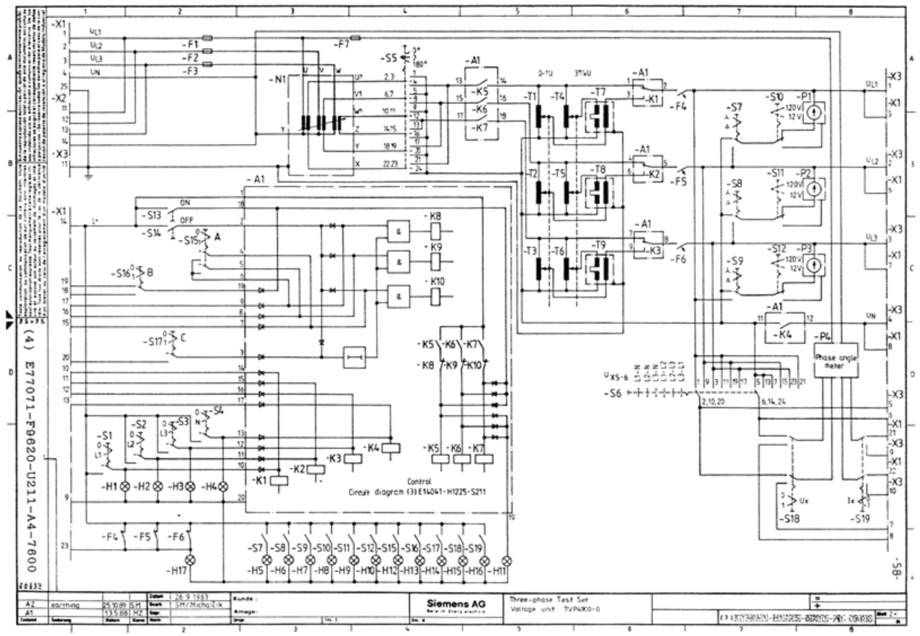
Circuit diagrams



7VP48 current unit



7VP49 voltage unit

Sources and further literature:

- Protective Relaying. Three-Phase Portable Test SET for Protection. 7VP48 Current Unit, 7VP49 Voltage Unit. Siemens, Order No. E771/319-101, (4) E77071-F9620-U211-A4-7600

CMC 56 portable relay testing device

OMICRON electronic

The introduction of digital protection relays and high-precision measuring transducers also required new approaches to testing. OMICRON's innovative hardware and software solution was originally only designed for testing measuring transducers. However, further development steps soon made it possible to test the most diverse of protection relays (distance relays, overcurrent relays, frequency relays), which set a new standard in the field of measurement and testing technology. With this new development, OMICRON achieved the role of a market leader within a very short space of time.

Brief description of the function

Single-pole and multi-pole testing of measuring transducers and protection relays. The system came with software solutions for distance relays, *I*, *U*, and *f* relays, as well as measuring transducers.

Area of deployment

Single-pole primary and secondary testing of triggers and protection relays, particularly overcurrent, overvoltage and undervoltage relays, but later also directional, distance and differential relays.

Manufacturer	OMICRON electronics
Start of production	1991
Specifications	
3 current generators	
Adjustment range	0 – 10 A
Power	3 x 15 VA
Resolution	< 500 µA
3 voltage generators	
Adjustment range	0 – 250 V
Power	1 x 100 VA; 2 x 10 VA
Resolution	< 12 mV
General information on generators	
Accuracy	< 0.1 % error
Phase errors	< 0.1 %
Frequency resolution	< 5 µHz
Frequency accuracy	< 100 ppm
Angular error	< 0.1°
Angular resolution	< 0.001°
Miscellaneous information	
DC inputs	1 x 0 – 20 mA; 1 x 0 – 10 V
Weight	15 kg (33 lbs)
First CMC 56 (1990/91)	
Binary inputs	4 (< 100 µs)
Dimensions	460 x 160 x 370 mm (18 x 6 x 15 in)
First series production CMC 56 device (1991)	
Binary inputs	10 (< 100 µs)
Binary outputs	2

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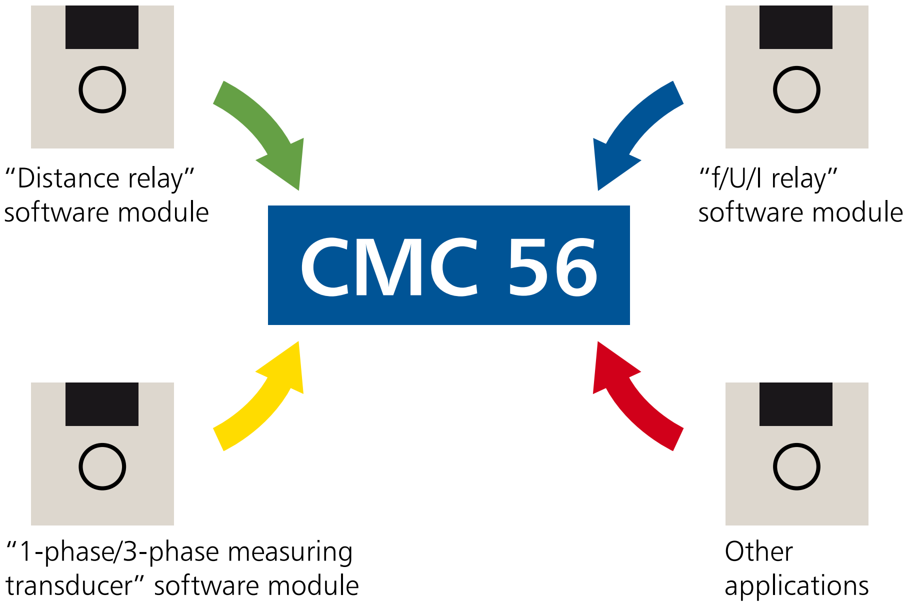
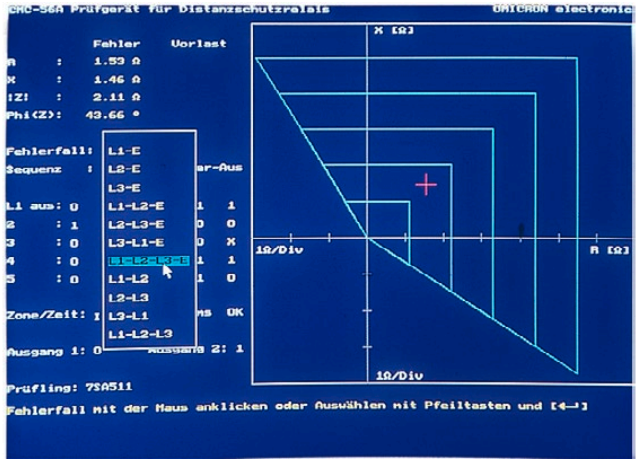
Software modules





Software screenshot (1992)

Sources and further literature:

- CMC-56. 3-phase AC power calibrator. Application booklet 1. Example: Effective power transducer test. OMICRON electronic, 1991
- Aberer, R.; Ferstl, H.: Selektivschutz in EVU – schnelles, einfaches und zuverlässiges Vor-Ort-Prüfen von Distanzrelais mit dem Prüfsystem CMC-56 (Selective protection in EVU – fast, simple, and reliable on-site testing of distance relays using the CMC-56) OMICRON electronic event, Energy Technology in Sigmarszell, 1992
- Software module: Distance relay test. CMC 56 datasheet. 1992, OMICRON electronic

OMICRON is an international company serving the electrical power industry with innovative testing and diagnostic solutions. The application of OMICRON products allows users to assess the condition of the primary and secondary equipment on their systems with complete confidence. Services offered in the area of consulting, commissioning, testing, diagnosis and training make the product range complete.

Customers in more than 150 countries rely on the company's ability to supply leading-edge technology of excellent quality. Service centers on all continents provide a broad base of knowledge and extraordinary customer support. All of this together with our strong network of sales partners is what has made our company a market leader in the electrical power industry.

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