7UM511 Generator protection relay (version V3)

Scope of functions

27 51
32F 51N
32R 59
40 64
46 64R
49S 81

Fig. 1
7UM511 generator protection relay (version V3)

Application

The 7UM511 is a numerical generator protection relay offering a practical combination of protection functions for generators. The device provides all the necessary protection functions for small generators of the type used in emergency diesel generating sets or private power plants. The unit also serves as a basic module for more comprehensive protection systems based on the 7UM51 series for large generators. The 7UM51 protection system is supplemented by the 7UT51 differential protection units.

The protective functions integrated in the device allow use of the 7UM511 as system disconnector.

Design

The compact device contains all components required for:

- Measured-value acquisition and evaluation
- Operation and display
- Indication and command output
- Acquisition of binary signals
- Serial data transfer
- Auxiliary power supply.

The device can be supplied with housings for flush or surface mounting. The version for control panel mounting or cubicle mounting is supplied with connection terminals at the rear of the device and is available with or without a glass cover. The version for control panel mounting is equipped with 100 screw terminals accessible from the front.

Functions

The following protection functions are implemented:

- Overcurrent-time protection (with undervoltage seal-in)
- Single-phase overcurrent protection (can be implemented as rotor earth-fault protection)
- Stator overload protection
- Underexcitation protection
- Overvoltage protection
- Undervoltage protection
- Overfrequency protection
- Underfrequency protection
- Reverse power protection
- Forward power monitoring
- Unbalanced–load protection
- Stator earth-fault protection V_0>
- Direct injection (for separate protection equipment)
- Trip circuit monitoring.

Measurement method

The influence of harmonics, high-frequency transients, transient direct current components and differing CT saturation levels are suppressed to a large degree by the use of powerful microprocessors and complete digital signal processing (measured-value acquisition, measured-value conditioning and measured-value processing).

Availability and precise measurement even with varying frequencies are assured by automatic follow-up of the sampling frequency for the range 10 to 68 Hz.

Several of the integrated protection functions make use of variables that are available in the form of symmetrical components. A change in the phase sequence, as is used in reversal in pumped-storage power plants, must be communicated to the 7UM511 protection device to ensure that the symmetrical components are correctly formed. A binary signal input can be assigned this switchover function.

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Serial interfaces

The relay is equipped with two serial interfaces. The interface at the front is suitable for connection of an AT-compatible PC. The program DIGSI is available as a convenient way of making settings, evaluating fault recordings and faults, and commissioning. The interface located at the rear of the device is available either as an isolated RS 232 interface or as a fibre-optic interface. It is intended for use either as a system interface for connection to the SINAUT LSA substation control and protection system to a central protection data unit (protocol according to VDEW/ZVEI recommended), or as an operator interface for connecting a PC.

Settings

All setting parameters are entered with menu guidance via the integrated operator and display panel or a PC. They are written to a non-volatile memory so that they are not lost even if the supply voltage is interrupted.

Self-monitoring

All important components such as the hardware and software are continuously monitored and any irregularities in the hardware or in the program sequence are detected and signalled. This significantly improves the reliability and availability of the protection system.

Overcurrent-time protection (ANSI 51)

This protection function comprises two stages. The first stage generally serves as short-circuit and back-up protection for upstream relays such as differential protection and distance protection.

An undervoltage stage maintains the excitation when the current falls below the starting threshold and at the same time the voltage drops because the excitation system can no longer be sufficiently supplied.

The second stage can be implemented, for example, as a high-speed stage for low-voltage generators or for constant voltage generators.

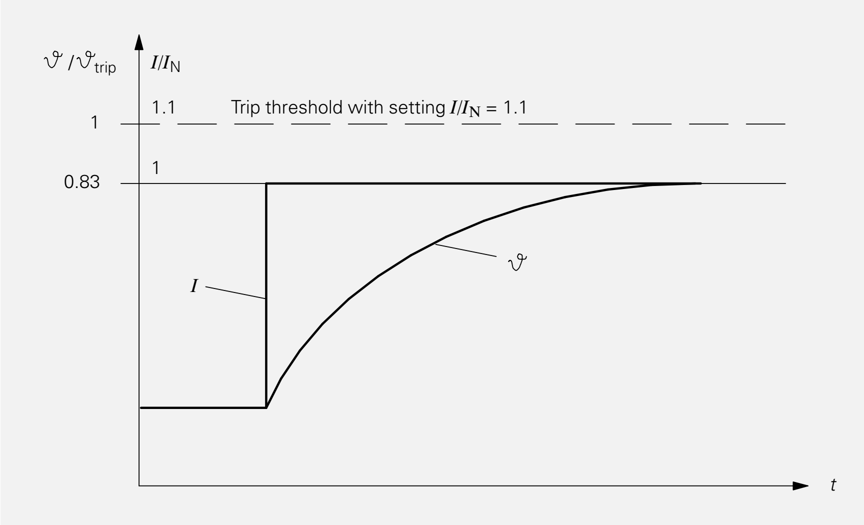

Fig. 2
Calculation of temperature from the phase currents according to the mathematical model

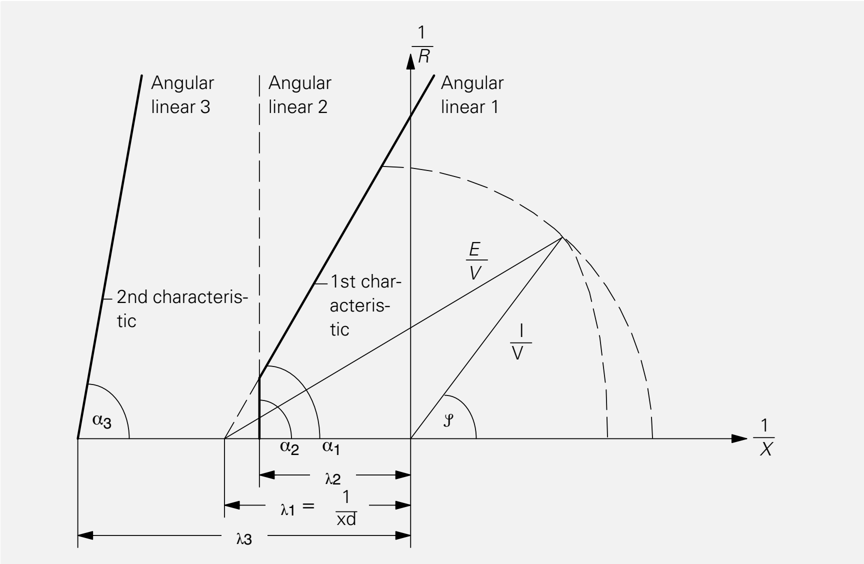

Fig. 3
Admittance diagram with the response characteristics for the static and dynamic stability limit

Single-phase overcurrent-time protection (ANSI 51N or ANSI 64R)

This single-phase overcurrent protection can be implemented as a stator earth-fault protection. This function detects the earth-fault current limited by an impedance.

This protection system is so sensitive that it can also be used as a rotor earth-fault protection with the relevant accessories. A measuring-circuit monitoring function is available for this application.

Stator overload protection (ANSI 49)

The task of the overload protection is to protect the stator windings from high, continuous overload currents. All load cycles are evaluated by the mathematical model used. The thermal effect of the effective current value forms the basis of the calculation. The ambient temperature or the temperature of the coolant can be injected as a proportional voltage to achieve adaptation to the prevailing conditions; otherwise a constant ambient temperature is assumed. By monitoring the minimum voltage, a wire break at the input for the temperature injection is detected. If this input is suitably connected, 4 mA to 20 mA transducers can also be used for temperature acquisition.

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Underexcitation protection (ANSI 40)

The load angle is calculated as the complex admittance derived from the generator terminal voltage and current. This protection prevents damage due to loss of synchronism resulting from underexcitation. The protection function provides two characteristics for monitoring static and dynamic stability. Monitoring of the exciter voltage ensures fast response of the protection on exciter failure.

The positive sequence systems of current and voltage are used to calculate the variables. This ensures that the protection always operates correctly even with asymmetrical network conditions.

Overvoltage protection (ANSI 59)

This protection prevents insulation faults that result when the voltage is too high. The protection function uses the positive-sequence components of the voltages and is therefore independent of the neutral point displacement caused by earth faults. This protection function is implemented in two stages.

Undervoltage protection (ANSI 27)

Undervoltage protection compares the positive-sequence components of the voltages with a lower limit value. This function is used for asynchronous machines and pumped-storage sets and prevents the voltage-related instability of such machines.

Frequency protection (ANSI 81)

The 7UM511 protection relay includes a four-stage frequency protection. Each stage can be implemented either as an overfrequency or underfrequency protection. The complicated algorithm successfully filters out the fundamental waves and determines the frequency extremely precisely even if the voltage is distorted.

Reverse power protection (ANSI 32)

The reverse power protection monitors the direction of power flow and responds when the mechanical energy fails because then the drive energy is taken from the network. This function provided by the 7UM511 can be used for operational shutdown of the generator but also prevents damage to the steam turbines. The reverse power is calculated from the positive-sequence systems of current and voltage. Asymmetrical network faults do not therefore cause reduced measuring accuracy. The position of the emergency trip valve is injected as binary information and is used to switch between two switch-off command delays.

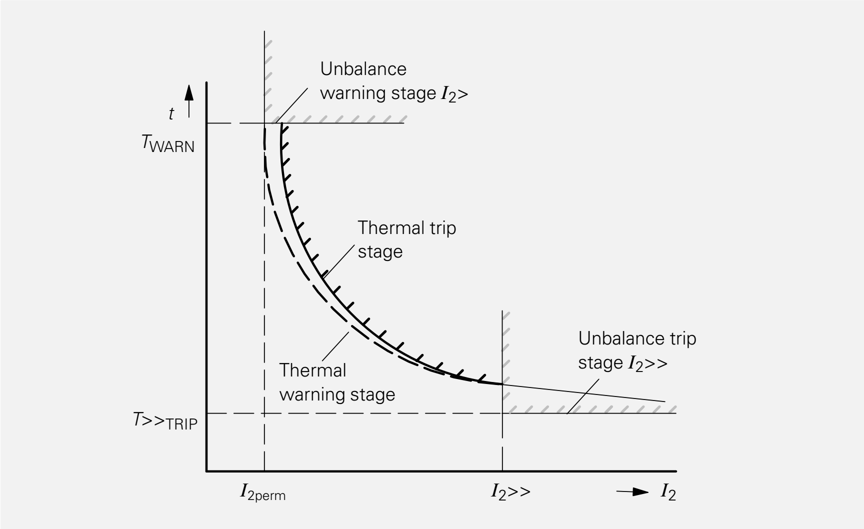

Fig. 4
Trip range of the load unbalance protection

Forward power monitoring (ANSI 32)

Monitoring of the power produced by a generator can be useful for starting up and shutting down generators. One stage monitors violation beyond one limit value while another stage monitors violation below another limit value. The power is calculated using the positive-sequence component of current and voltage.

Unbalanced–load protection (ANSI 46)

Asymmetrical current loads in the three phases of a generator cause a temperature rise in the rotor because of the reverse field produced.

This protection detects an asymmetrical load in three-phase machines. It functions on the basis of symmetrical components and evaluates the negative phase-sequence system of the phase currents. The thermal processes are represented in a mathematical model. Warning and triggering stages that can be set separately compare the calculated overtemperature against relevant threshold values. In addition, the load unbalance is evaluated by an independent stage which is supplemented by a time-delay element.

Stator earth-fault protection (ANSI 64)

Earth faults manifest themselves in generators that are operated in isolation by the occurrence of a displacement voltage in the generator neutral point which is equivalent to a zero-phase sequence system in the phase-to-earth voltage.

The 7UM511 protection relay calculates the zero-phase system of the phase-to-earth voltage and compares the resulting displacement voltage with a settable limiting value. This provides earth-fault protection for up to 95% of the stator winding.

Direct injection

Direct injection of the 7UM511 protection relay is a function used for the acquisition of digital information. This digital information is entered in the fault indication memory. They can influence the LEDs "alarm relay" and "command relay". Each "direct injection" can delay the effect of the digital information with an individual timer. The function "direct injection" is used to process information from the Buchholz protection or machine commands.

Trip circuit monitoring

The 7UM511 protection relay can monitor two trip circuits (circuit-breaker coils including supply conductor) for correct functioning. If a fault is detected in the monitored circuits the protection relay outputs an indication.

Status measurements

The values acquired and calculated by the device such as primary and secondary conductor current and voltage, earth current, neutral voltage, positive-sequence components of active and reactive power, frequency, active power, reactive power, power factor, current-voltage angle, rotor displacement angle, exciter voltage, calculated conductor-related overtemperature, coolant temperature, negative phase-sequence components of the phase currents, overtemperature resulting from load unbalance and the direction of rotating field can be displayed on the LC display or on a PC.

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Fault recording

Depending on the parameters set, either recording of current (display of input variables) or rms values (one value for each period) is implemented in the protection relay. The maximum duration of time during which faults are recorded depends on the recording frequency. Several faults can be recorded (max. 8) in a memory one after the other. This number which can be set also depends on the number of faults. The lead time and overtravel time and triggering event (start of fault recording with activation and triggering) can be set to meet different demands. The recorded fault data can be transferred either to the SINAUT LSA substation control and protection or to a PC where they are then analysed.

Trip matrix/trip circuits

The device is equipped with five trip relays. These can be arbitrarily assigned to the protection functions described above by parameterization (software matrix). Furthermore, each protection function can be switched “ON” or “OFF” via the operator panel. A third “blocked” position permits commissioning of the unit with the local indications and the alarm relay circuits operative, but without tripping the circuit-breakers. With the many parameterized possibilities provided, testing of and alterations to the circuit-breaker operation can be performed during commissioning, as well as during normal operation without the need for rewiring.

Indication memory

The device provides detailed data for analysing faults and checking operating states. All the indication memories listed below are protected against power supply loss.

- Time
  A battery-backed clock is provided as standard and synchronized via a binary input or system interface. All indications are assigned a time and date.
- Fault indications
  The indications of the last three faults are can be accessed at any time.
- Operational indications
  All indications that are not directly connected to a fault are stored in the operational indication memory.

Assignable alarm relays, LEDs and binary inputs

Alarm relays and LEDs can be freely assigned by the user to provide user-specific output and display of indications. The LED displays are protected against loss of power.

All binary inputs are also freely assignable and each input can be assigned to several logical inputs.

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Technical data

Input circuits	Rated current	1 or 5 A
	Rated voltage, can be parameterized	100 to 125 V AC
	Rated frequency, can be parameterized	50/60 Hz
	Thermal overload capability	
	in voltage path, continuous	140 V AC
	in current path, continuous	4 x I_N
	≤ 1 s	100 x I_N
	≤ 10 s	20 x I_N
	in earth-fault path, continuous	15 A
	≤ 1 s	300 A
	≤ 10 s	100 A
	DC inputs	60 V DC
	Power consumption	
	in voltage path at V_N = 100 V	<0.3 VA
	in current path at I_N = 1 A	<0.1 VA
	at I_N = 5 A	<0.5 VA
Voltage supply with integrated converter	Rated auxiliary voltage V_{aux}	24, 48 V DC or 60, 110, 125 V DC or 220, 250 V DC
	Permissible tolerance of rated auxiliary voltage	–20 to +15 %
	Power consumption	max. 20 W
Setting ranges		
Overcurrent-time protection (ANSI 51)	Current I>, I>>	0.1 to 8 x I_N
	Trip delay, reset delay	0 to 32 s
	Resetting ratio	0.95
	Response time	approx. 50 ms
	Undervoltage seal-in V<	20 to 100 V
	Starting hold time on undervoltage	0 to 32 s
	Resetting ratio	1.05
Single-phase overcurrent protection (ANSI 51N)	Current I_E>	10 to 1000 mA
	Trip delay, reset delay	0 to 32 s
	Reset ratio	0.9
	Response time	approx. 50 ms
	Measuring circuit monitoring current I_E<	2 to 50 mA, (setting 0 mA prevents indication output)
	Delay (not settable)	2 s
	Reset ratio	1.1
Stator overload protection (ANSI 49)	k factor (acc. to IEC 255–8–2)	0.5 to 2.5
	Thermal time constant τ	30 to 32000 s
	Warning temperature (referred to release overtemperature)	70 to 100 % $\vartheta/\vartheta_{off}$
	Overtemperature at rated current	40 to 100 °C
	Coolant temperature (not settable)	40 °C
	Voltage proportional to temperature	0 to 10 V DC
Underexcitation protection (ANSI 40)	Distance of the trip characteristic from the coordinate origin in the admittance plane: λ_1, λ_2, λ_3	0.25 to 3
	Slope angle: α_1, α_2, α_3	50 to 120°
	Trip delay (with/without excitation voltage), reset delay	0 to 32 s
	Reset ratio	0.95
	Response time	≤ 100 ms
	Exciter voltage scan	0.5 to 8 V DC
Overvoltage protection (ANSI 59)	Voltage V>, V>>	30 to 180 V
	Trip delay, reset delay	0 to 32 s
	Reset ratio	0.95
	Response time	approx. 50 ms
Undervoltage protection (ANSI 27)	Voltage V<	20 to 100 V
	Trip delay, reset delay	0 to 32 s
	Reset ratio	1.05
	Response time	approx. 50 ms

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Technical data (cont.)

Setting ranges (cont.) **Frequency protection (ANSI 81)**	Number of stages Frequency f_1, f_2, f_3, f_4 Number of repeat measurements (one repeat measurement 3/f) Response time Undervoltage blocking V< Reset ratio of blocking	4 40 to 65 Hz 2 to 10000 approx. 60 ms + time for measurement 40 to 100 V 1.05
Reverse power protection (ANSI 32)	Reverse power –P> (referred to SN) Trip delay (with/without emerg. trip), reset delay Reset ratio Response time	–30 to –0.5 % 0 to 32 s 0.6 approx. 350 ms
Forward power monitor (ANSI 32)	Upper power limit violation +P> (referred to SN) Reset ratio Lower power limit violation +P< (referred to SN) Reset ratio Trip delay, reset delay Response time at 50 Hz Setting: precise Setting: fast	1 to 120 % 0.9 0.5 to 120 % 1.1 0 to 32 s approx. 350 ms approx. 60 ms
Unbalanced–load protection (ANSI 46)	Warning level I_2> (referred to I_N) Warning delay Thermal time constant Thermal warning level (referred to triggering overtemperature) Trip stage I_2>> (referred to I_N) Reset ratio Trip delay, reset delay Response time of the independent characteristic	3 to 30 % 0 to 32 s 100 to 2500 s 70 to 99 % 10 to 80 % 0.95 0 to 32 s approx. 50 ms
Stator earth-fault protection (ANSI 59N)	Displacement voltage Reset ratio Trip delay, reset delay Response time	5 to 100 V 0.7 0 to 32 s approx. 50 ms
Direct injection	Number Trigger delay t_1, t_2, t_3, t_4 Reset delay t_1, t_2, t_3, t_4 Response time	4 0 to 32 s 0 to 32 s <15 ms
Phase-sequence reversal	Response time	200 ms (on condition that $I < 0.1 \times I_N$ and $V < 0.1 \times V_N$)
Response tolerances under rated conditions	Current Voltage Active power Reverse power Forward power (Setting: Precise) Forward power (Setting: Fast) Times	≤3 % of setting value ≤3 % of setting value ≤0.25 % of SN or 3 % of setting value ≤0.25 % of SN or 3 % of setting value ≤0.50 % of SN or 3 % of setting value ≤10 ms
Status measured values	Display of values Voltage Input circuits Power Power factor Phase angle, rotor displacement angle Out-of-balance load Reverse current Overcurrent temperature Exciter voltage Frequency Overtemperature, coolant temperature	 V_{PH1}–E, $V_{PH2–E}$, $V_{PH3–E}$, $V_{PS/PH–PH}$, V_0 I_{PH1}, I_{PH2}, I_{PH3}, I_{PS}, I_0 P/SN, Q/SN cos φ ϕ, THETA I_2 I_{2TH} $V_{EXCIT.}$ f Θ/Θ_{trip}, $\Theta_{COOLANT}$
Fault data acquisition	Either instantaneous values (12 values per period) or calculated values (1 value per period)	v_{PH1}, v_{PH2}, v_{PH3}, $V_{EXCIT,}$ i_{PH1}, i_{PH2}, i_{PH3}, i_E $V_{PH1–E}$, $V_{PH2–E}$, $V_{PH3–E}$, V_{PS}, V_0 V_{PS}, I_{PS}, I_{PH1}, I_{PH2}, I_{PH3}, I_E , cos ϕ, f–f_N

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Technical data(cont.)

Contacts	Potential-free trip contacts		3 x 2 S, 2 x 1 S (total of 5 trip relays)
	Switching capacity	Make Break	1000 W or VA 30 W or VA
	Permissible current	Continuous 0.5 s	5 A 30 A
	Switching voltage		250 A DC
	Alarm contacts		13
	Switching capacity	Make/break	20 W or VA
	Permissible current		1 A
	Switching voltage		250 V DC
Displays, signal inputs	LED displays at the front of the device		16
	Optocoupler 24 to 250 V DC		8
	Current consumption independent of voltage range		approx. 2.5 mA
Design of device	For panel surface mounting Weight		In housing 7XP2040–1 approx. 12 kg
	For panel flush mounting/cubicle mounting Weight		In housing 7XP2040–2 approx. 10.5 kg
	Degree of protection to EN 60 529		IP 51
CE conformity, regulations	This product is in conformity with the directive of the Council of the European Communities on the approximation of the laws of the Member States relating to the electromagnetic compatibility (EMC Council Directive 89/336/EEC). The product conforms with the international standard IEC 255 and the national standard DIN VDE 57 435/part 303. The relay is designed for use in an industrial environment, for installation in standard relay rooms and compartments so that with proper installation electro–magnetic compatibility (EMC) is ensured.		Conformity is proved by tests performed by Siemens AG in line with article 10 of the Council Directive in accordance with the generic standards EN 50081–2 and EN 50082–2.
Insulation tests IEC 255–5, DIN VDE 0435 Part 303	Voltage test (routine test), all circuits excluding auxiliary voltage		2 kV (rms value), 50 Hz
	Voltage test (routine test), auxiliary voltage only		2.8 kV DC
	Impulse voltage test (type test), all circuits, class III		5 kV (peak value), 1.2/50 µs, 0.5 J, 3 positive and 3 negative impulses in intervals of 5 s
EMC tests for noise immunity (Type tests) Standards: IEC 255–22 (product standard) EN 50082–2 (basic specification) DIN VDE 0435 Part 303	High frequency test IEC 255–22–1, Class III and DIN VDE 0435 Part 303, Class III		2.5 kV (peak value), 1 MHz, τ = 15 µs, 400 impulses per s, length of test 2 s
	Electrostatic discharge test IEC 255–22–2, Class III and EN 61000–4–2, Class III		4 kV/6 kV contact discharge, 8 kV air discharge, both polarities, 150 pF, R_l = 330 Ω
	Radiation with high frequency field, unmodulated IEC 255–22–3 (Report), Class III		10 V/m, 27 to 500 MHz
	Radiation with high frequency field, amplitude modulated EN 61000–4–3		10 V/m, 80 to 1000 MHz, AM 80 %, 1 kHz
	Radiation with high frequency field, pulse modulated ENV 50204 / EN 61000–4–3		10 V/m, 900 MHz, repetition frequency 200 Hz, duty cycle 50 %
	Fast transient interference/burst IEC 255–22–4 and EN 61000–4–4, Class III		2 kV, 5/50 ns, 5 kHz, burst length = 15 ms, Repetition rate 300 ms, both polarities, R_l = 50 Ω, duration of test 1 min
	Conducted HF, amplitude modulated EN 61000–4–6		10 V, 150 kHz to 80 MHz, AM 80 %, 1 kHz
	Magnetic field with high-voltage equipment frequency EN 61000–4–8, Class IV		30 A/m continuous, 300 A/m für 3 s, 50 Hz
EMC tests for emitted interference (Type tests) Standards: EN 50081–2 (basic specification)	Radio interference voltage on lines, auxiliary voltage only CISPR 11, EN 55011, limit value class A and DIN VDE 0875 Part 11, limit value class A		150 kHz to 30 MHz
	Interference field strength CISPR II, EN 55011, limit value class A and DIN VDE 0875 Part 11, limit value class A		30 to 1000 MHz
Climatic conditions	Permissible ambient temperature	during operation during storage during transport	–5 to +55 °C –25 to +55 °C –25 to +70 °C
	Humidity class		Annual average ≤75 % relative humidity, on 30 days per year up to 95 % relative humidity, condensation not permissible
Mechanical stress tests IEC 255–21–1, IEC 68–2	Permissible mechanical stress	during operation	10 to 60 Hz, 0.035 mm amplitude 60 to 500 Hz, 0.5 *g* acceleration
		during transport	5 to 8 Hz, 7.5 mm amplitude 8 to 500 Hz, 2 *g* acceleration

7UM511 Generator protection relay (version V3)

Selection and ordering data

7UM511 generator protection relay (V3)	Order No. **7UM511 □ – □ □ B 0 1 – 0 □ B 0**
Rated current at 50 to 60 Hz, 100 to 125 V AC	
1 A	**1**
5 A	**5**
Rated auxiliary voltage	
24, 48 V DC	**2**
60, 110, 125 V DC	**4**
220, 250 V DC	**5**
Construction	
For panel flush mounting/cabinet mounting	**C**
For panel surface mounting	**D**
For panel flush mounting or cabinet mounting, without glass cover	**E**
Rear, serial interface (suitable for substation control and protection and DIGSI operating program)	
Electrical	**B**
Fibre-optic	**C**

Accessories

Rotor earth-fault protection			
Ballast 100/45 V AC	(W x H x D in mm)	135 x 170 x 85	**7XR8500–0**
Coupling device 2 x 4 µF		196 x 300 x 110	**7XR6000**
Series resistor		196 x 300 x 146	**3PP1336–0DZ013002**
Operation			
DIGSI program (suitable for all 7UM..., 7UT..., 7SJ..., 7SA..., ... protection relays)		German	**7XS5020–0AA00**
		English	**7XS5020–1AA00**
	Test version:	German	**7XS5021–0AA00**
		English	**7XS5021–1AA00**
Connecting cable protection relay (25-pin) – PC (9-pin); (other versions available on request)			**7XV5100–2**

Documentation

German		
Katalogblatt LSA 2.5.2:	Maschinenschutz 7UM511 (Version V3)	**E50001–K5752–A121–A2**
Handbuch:	Maschinenschutz 7UM511 (Version V3)	**C53000–G1100–C109–1**
English		
Catalog LSA 2.5.2:	7UM511 Generator protection relay (Version V3)	**E50001–K5752–A121–A2–7600**
Manual:	7UM511 Generator protection relay (Version V3)	**C53000–G1176–C109–1**

7UM511 Generator protection relay (version V3)

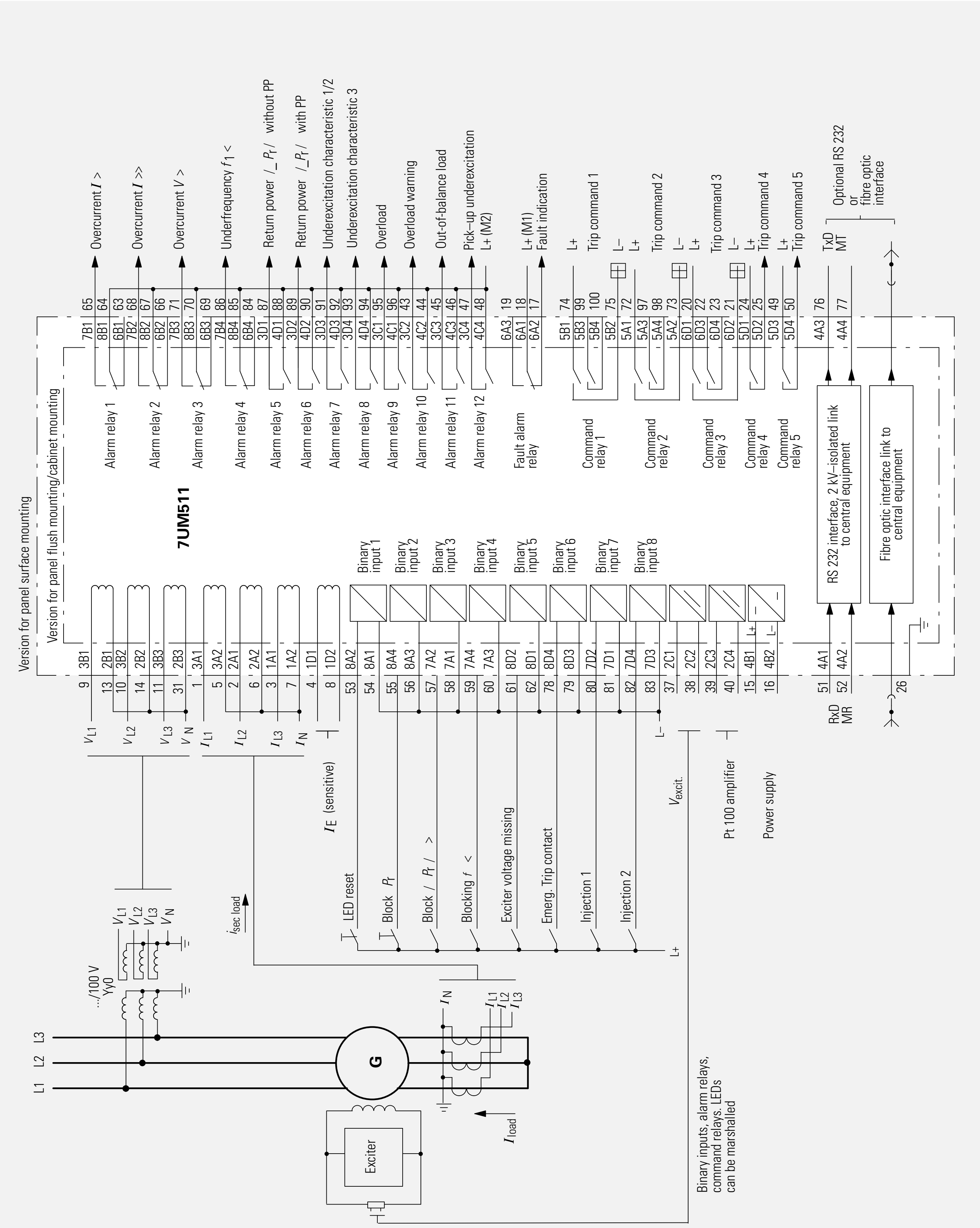

Fig. 5
Connection diagram of the 7UM511 generator protection relay (version V3)

Dimension drawings in mm

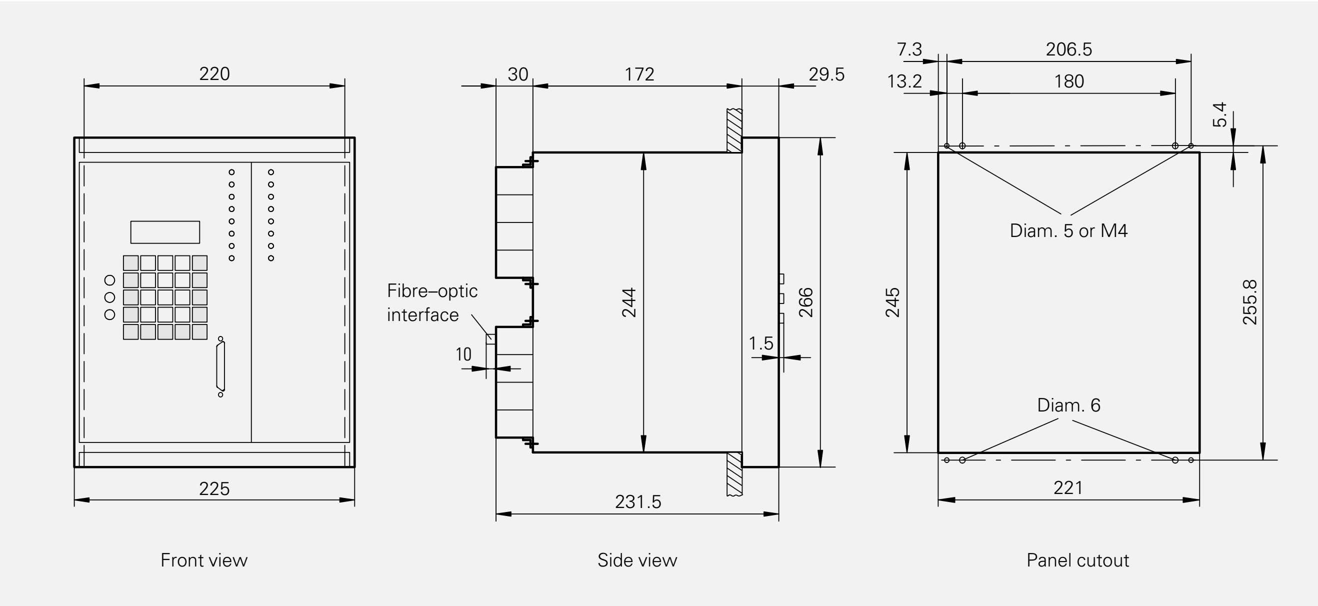

Fig. 6
7UM511 with housing 7XP2040–2 (for panel flush mounting or cubicle mounting)

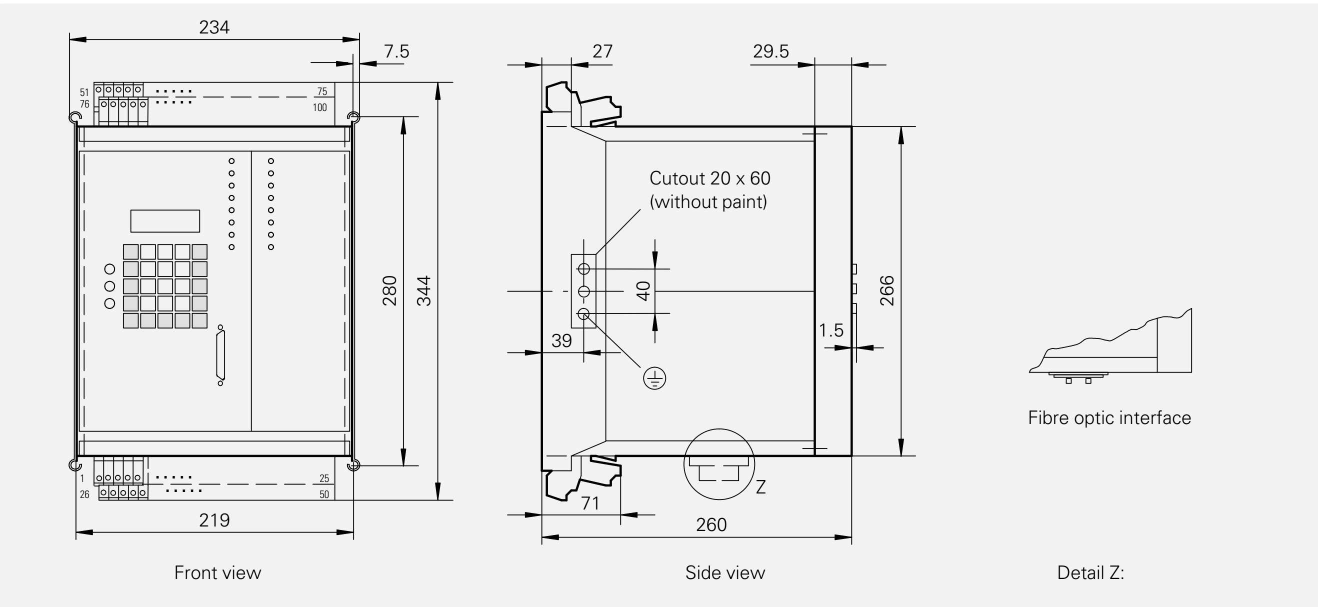

Fig. 7
7UM511 with housing 7XP2040–1 (for panel surface mounting)

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All dimensions in this catalog are given in mm.

Responsible for

Technical contents: Carsten Laves,
Siemens AG, EV S V 13, Nürnberg

General editing: Roland Reichel/Claudia Kühn–Sutiono,
Siemens AG, EV S SUP22, Nürnberg/EV MK2, Erlangen

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