SIEMENS

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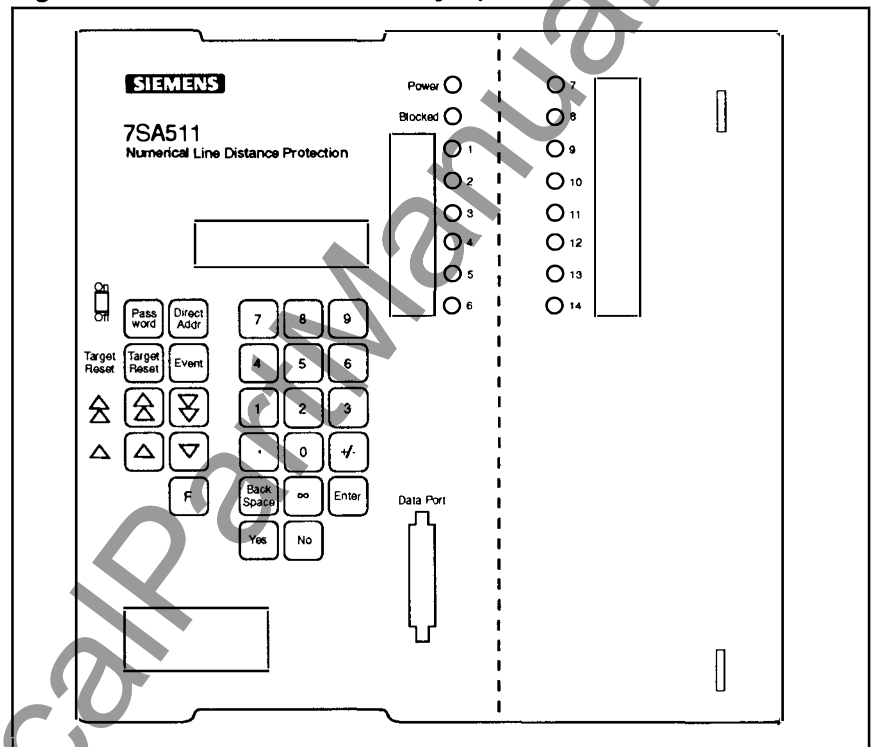
7SA511 Numerical Line Distance Protection

IEEE Device Numbers

21 · 21N · 85 · 21P · 21NP · 78 · 50 · 50N · 67N · 51 · 51N · 79M

Figure 1. 7SA511 Protection Relay Operator Panel



Features

- Microprocessor-based Technology
- Fully Numerical Design
- Five Zones Phase & Ground Distance
- Polygonal Characteristics
- Selectable Forward, Reverse or NonDirectional
- Separate R-Setting for Phase & Ground
- Seven Independent Time Delays
- Fault Detector Options
  - Overcurrent
  - Voltage-Controlled Overcurrent
  - Impedance
- Pilot Logic Schemes
  - Permissive Overreach Transfer Trip (POTT)
  - Permissive Underreach Transfer Trip (PUTT)
  - Blocking
  - Unblocking
  - Directional Comparison
  - Directional Pilot Wire (requires 7PA5210)
- Weak Feed Echo Keying Logic
- Transient Blocking
- Zone Extension Scheme
- Reverse Interlock Function (Bus Protection)
- Single/Three Pole Trip
- Single/Three Pole Multi-Shot Reclosing
- Loss of Potential (LOP) Block
- Overcurrent Protection on LOP
- Power Swing Block/Trip
- Close-Into-Fault Protection
- High Impedance Fault Detection
- Directional Ground Overcurrent
- Programmable Binary Inputs, LEDs, Signal and Trip Relays
- Four Independent Setting Groups
- Fault Locating (Parallel Line Compensation Option)
- Fault Target Data
- Fault Waveform Capture (0.83 ms resolution)
- Operations Event Log
- Circuit Breaker Operations Counter
- Accumulated Circuit Breaker Interrupting Current
- Real-time Clock
- Circuit Breaker Trip Test Function
- Circuit Breaker Reclose Test
- Metering Functions (online)
  - Voltage
  - Current
  - Real Power (watts)
  - Reactive Power (vars)
  - Frequency
  - Impedances
  - Phase Sequence
- Two (2) Serial Ports
- IEC 870-5 Communication Standard
- Self-Monitoring
- Draw Out Construction

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Description

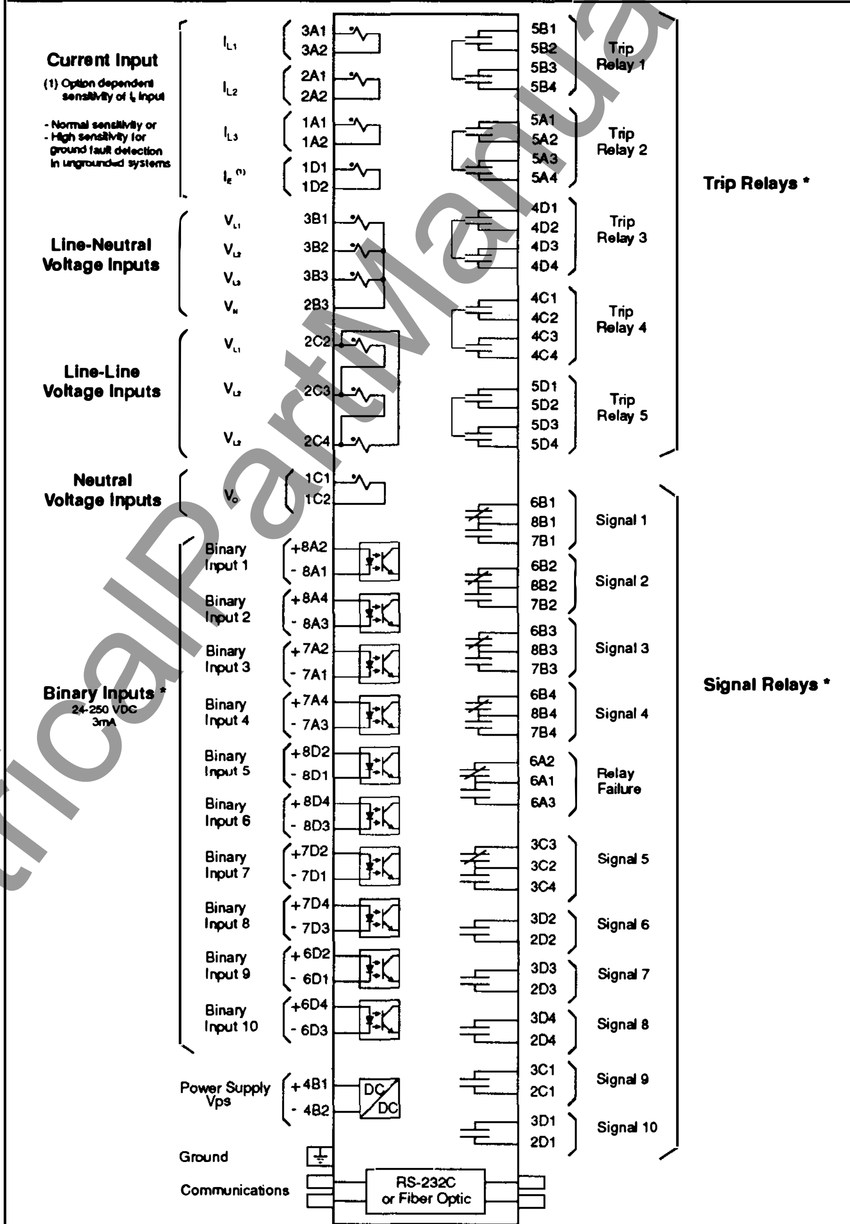
The 7SA511 is a microprocessor-based distance relay used to protect overhead lines and cables. Basic functions include 5 zones of phase and ground distance measurements, over-current backup function, multi-shot reclosing, fault locating, pilot logic, loss of potential block, power swing block/ trip logic, reverse interlocking and waveform capture.

The analog inputs of voltage and current are isolated in the relay through transformers. Anti-aliasing filters remove high frequency components from the analog signals, which are sampled 20 times per cycle (0.83 milliseconds). The microprocessor performs all impedance and overcurrent calculations and makes all protection logic decisions. A separate algorithm is used for fault location.

As shown in Figure 1, the relay has a built-in numeric key pad and a 32-character liquid crystal display for setting the relay, monitoring measured and calculated values, and reading target data. LEDs are provided on the front for quick display of relay status and target indication. Two serial communication ports are provided: one on the front for direct connection to an operator PC, and one on the back for interface to a substation control system.

The 7SA511 has 7 analog voltage inputs and 4 current inputs. Three voltage inputs are for line-to-ground voltages, 3 are for line-to-line voltages and 1 input is for ($3V_o$). The relay also provides 10 optically isolated binary inputs, 16 LEDs, 5 trip relays and 10 signal relays (see Figure 2). The ability to program the inputs, outputs and LEDs provides the user flexibility to configure the relay to his specific requirements.

Figure 2. 7SA511 Relay Connection Diagram



***Factory Presettings**

Binary Input 1 - LED reset	Binary Input 10 - Switch AR off	Signal 4 - Measured value supervision
Binary Input 2 - VT MCB operator	Trip Relay 1 - Reclose command	Signal 5 - General trip
Binary Input 3 - CB Aux contact	Trip Relay 2 - General fault detection	Signal 6 - Fault detection L1
Binary Input 4 - Manual close	Trip Relay 3 - Trip command L1	Signal 7 - Fault detection L2
Binary Input 5 - Carrier receive	Trip Relay 4 - Trip command L2	Signal 8 - Fault detection L3
Binary Input 6 - Carrier receive fault	Trip Relay 5 - Trip command L3	Signal 9 - Fault detection (E)
Binary Input 7 - CB ready	Signal 1 - Carrier send	Signal 10 - Reverse direction
Binary Input 8 - AR block	Signal 2 - AR block	
Binary Input 9 - Switch AR on	Signal 3 - CB alarm suppressed	

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The relay is suitable for either panel or rack mounting and comes in either a flush or surface mounting case. External connections are made on the rear for flush mounting or on the front for surface mounting.

Draw out construction provides easy removal and replacement of the relay. All CT inputs are automatically shorted and all other circuits are disconnected.

Application

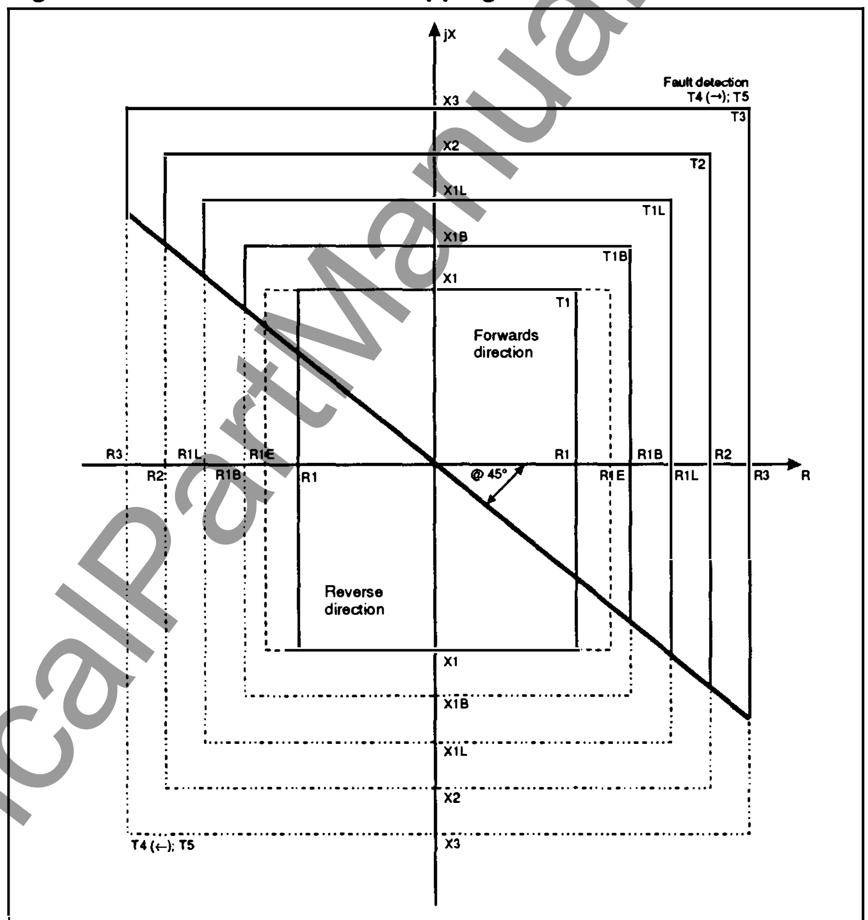
The 7SA511 is a complete transmission line protection package providing distance protection, fault locating, reclosing, waveform capture, metering and event recording. It is recommended for the protection of overhead lines and cables and can be installed on grounded or ungrounded systems. It can also be used as local backup and/or bus protection through reverse interlocking or to provide backup protection for generators.

The broad range of settings, protection logic, user-defined configuration, and polygonal characteristics permits application to short or long lines of all voltage levels. The polygonal characteristics provide additional arc fault coverage especially for ground faults on short lines.

Five distance zones (Figure 3) are used in pilot and nonpilot schemes. Each zone can be set to look forward or reverse or to be nondirectional. The basic pilot schemes include: blocking, unblocking, POTT, PUTT, and directional comparison. Both weak feed echo keying and transient blocking logic are included.

A special application over short lines uses the 7SA511 as a directional pilot wire scheme (Figure 4). This requires the 7PA5210 pilot wire interface. For lines shorter than minimum reach, Zone 1 must be set out of service or timer T1 set equal to Zone 2 timer.

Figure 3. Distance Protection Tripping Characteristics



The 7SA511 can be used for 3-pole or single-pole tripping applications. It can be fitted with a multi-shot reclosing function for 3/1 pole operations. The automatic reclosing function can be initiated from an external source (i.e., backup protection), and/or internal protection functions.

The 7SA511 has a built-in fault detector and fault locator. The fault detector can be either a nondirectional overcurrent unit, a voltage-controlled overcurrent unit or an impedance unit. The impedance fault detector uses a special "dog-bone" characteristic (Figure 5) to provide secure pickup for faults without pickup on load.

A separate fault locating algorithm is included to provide the distance to fault. The fault locating function can include parallel line $3I_0$ compensation to improve accuracy.

Waveform capture can be initiated for storage by pickup, trip or binary input.

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Figure 4. Overreaching Zone Comparison via Pilot Wires - Schematic Diagram

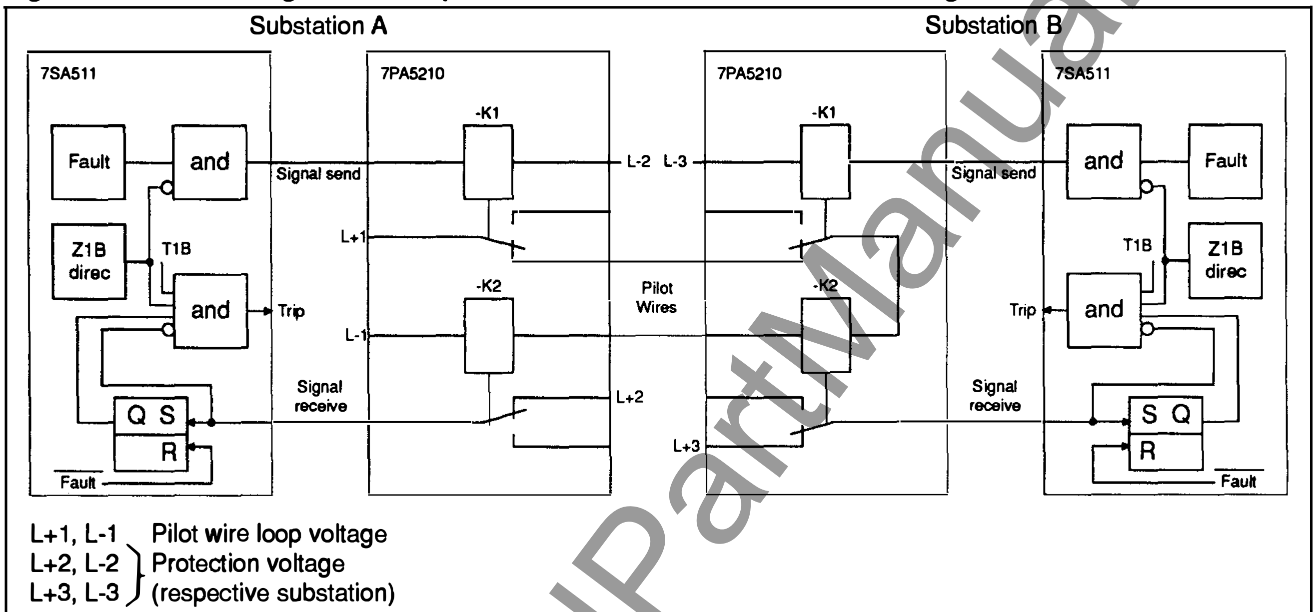
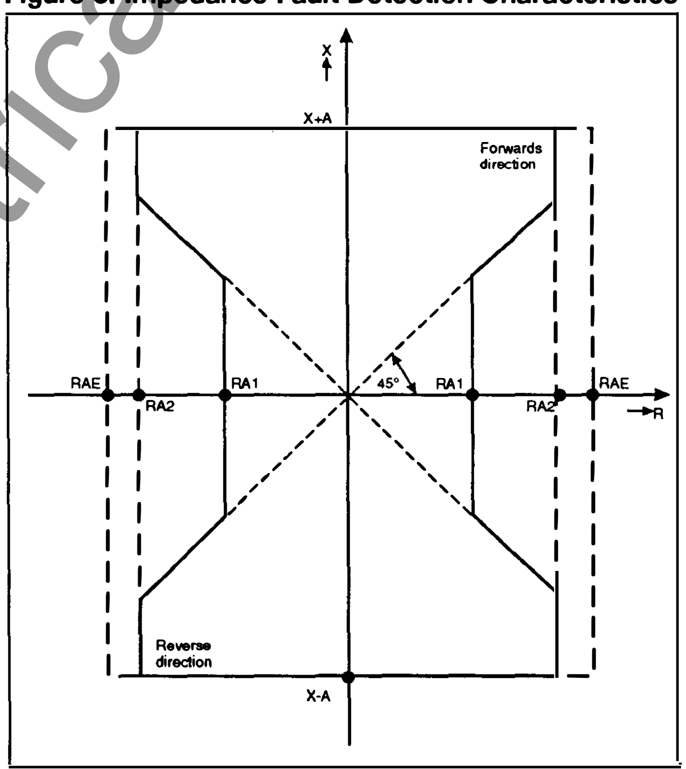


Figure 5. Impedance Fault Detection Characteristics



The waveform record contains 5 cycles of prefault and up to 145 cycles post fault data with 0.83 milliseconds resolution.

Bus and local backup protection can be accomplished using reverse interlocking. If the protection system is installed as backup on a single end feed bus, then it can be used to provide high speed protection and remain selective with the outgoing lines.

Additional functions include loss of potential block, power swing block/ trip, close-into-fault, overcurrent emergency backup, metering, targets, event log and accumulated circuit breaker interrupting duty/counter.

The 7SA511 relay stores 4 separate groups of programmable settings. With the *parameter changeover* function, you can instantaneously change operating settings to another predefined and pretested group to

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accommodate new or changing system conditions. The parameter changeover function can be actuated by a binary input or through serial communications.

Operating Principles

The 7SA511 relay's primary protection is the polygonal distance unit (Figure 3). The characteristic is defined by a separate reactive and resistive setting value and a directional element.

The polygonal characteristic provides improved fault coverage particularly on short lines. The reach is set according to the line reactance. Independent phase and ground resistance settings provide greater coverage for arcing faults or highly resistive ground faults.

Using the instantaneous values, the relay calculates the resistance R and reactance X based on the line differential relationship:

$$L\left(\frac{di}{dt}\right) + Ri = V$$

For phase-to-phase faults this becomes:

$$L\left(\frac{di_{L1}}{dt} - \frac{di_{L2}}{dt}\right) + R\left(i_{L1} - i_{L2}\right) = V_{L1} - V_{L2}$$

and for phase-to-ground faults:

$$L\left(\frac{di_L}{dt} - \frac{X_g}{X_1}\frac{di_g}{dt}\right) + R\left(i_L - \frac{R_g}{R_1} i_g\right) = V_{1g}$$

Where $\frac{R_g}{R_1} = \frac{1}{3}\left(\frac{R_0}{R_1} - 1\right)$

and $\frac{X_g}{X_1} = \frac{1}{3}\left(\frac{X_0}{X_1} - 1\right)$

Separate ground reactance and resistance factors allow for greater flexibility. This is advantageous for applications such as cables, where there is a difference between conductor impedance (Z) and resistance (R).

Directional determination is made using sound phase and stored reference voltages. Two cycles of voltage are stored and used only if the measured voltage is insufficient for directional determination.

Figure 6 shows the theoretical directional characteristic. In practice, the directional characteristic is dependent on the source impedance and load current. Figure 7 shows the directional characteristic taking source impedance into consideration without load current. Since the unfaulted voltage equals the generator voltage and does

Figure 6. 7SA511 Directional Characteristic

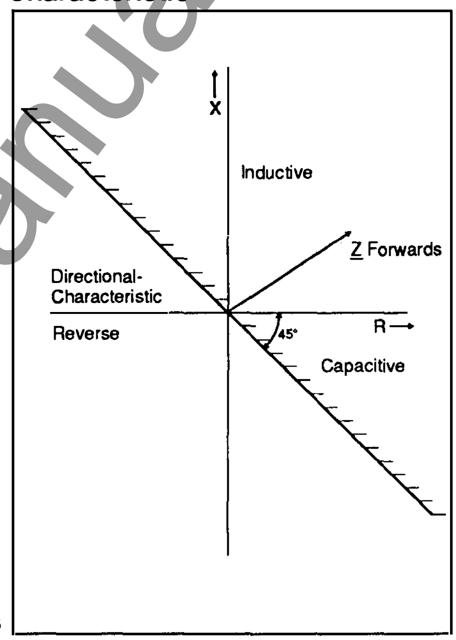
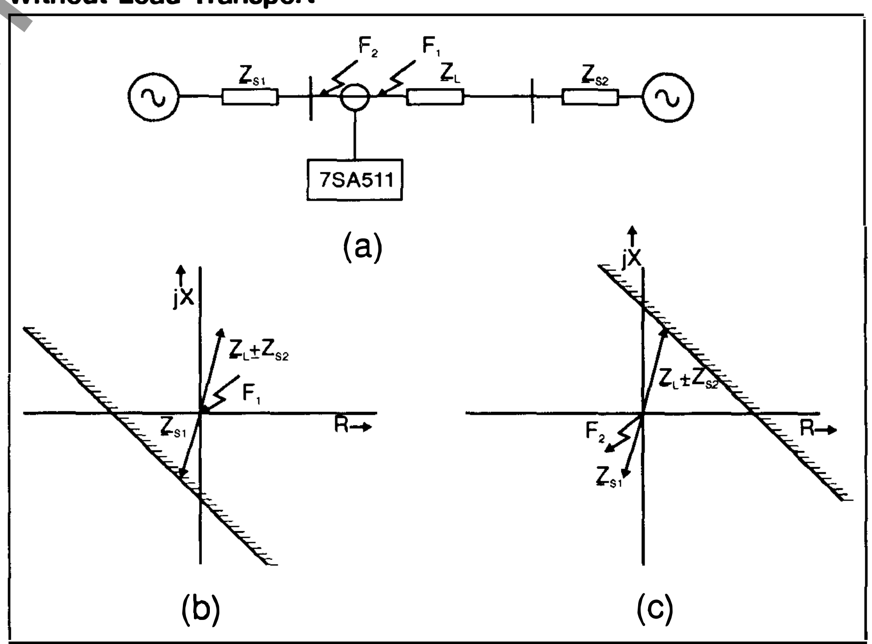


Figure 7. Directional Characteristic with Source Impedance, Without Load Transport



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not change after fault inception, the directional characteristic in the impedance diagram appears to be displaced by the source impedance (Figure 7b). All forward fault locations right up to the relay CTs are clearly recognized as "forwards". When the current flows in the opposite direction, the directional characteristic changes immediately as in Figure 7c. For this case, the directional characteristic appears to be displaced in the opposite direction. All reverse fault locations right up to the relay CTs are clearly recognized as "reverse".

If load is carried by the line, then a voltage drop at the source impedance will occur. Since, at the measuring point, the voltage V is not the generator voltage E, the directional characteristic will suffer a rotation by the load angle "delta". Therefore, the directional characteristic has a safety distance from the limits of the first quadrant in the R-X diagram.

Fault Locating

The 7SA511 calculates fault location independently from the distance protection. It has separate memory space to store samples of a favorable time interval and uses its own digital filter.

Normally, the fault locating function is initiated by the relay trip command, but it can also be initiated by an external input. Paired values of fault current and voltage (at 1/20th cycle intervals) are stored in a circulating buffer and frozen 15 milliseconds later.

Resultant pairs of R and X are calculated from the samples, and the average value and standard deviation are determined. After the elimination of the "exceptions" (values outside standard deviation), another average value is calculated for X. This value is taken as the fault location.

The relay provides the fault location in terms of X, R, distance in kilometers or miles, and in percent of line length. For parallel lines terminated in the same substations, the 7SA511 relay can be fitted with an input for the parallel line ground current to improve fault locating accuracy. The differential equation becomes:

$$L\left(\frac{di_L}{dt} - \frac{X_g}{X_L} \times \frac{di_g}{dt} - \frac{X_m}{X_L} \times \frac{di_{gm}}{dt}\right) +$$

$$R\left(i_L - \frac{R_g}{R_L} \times i_g - \frac{R_m}{R_L} \times i_{gm}\right) = V_{Lg}$$

Where:

i_{gm} is parallel line ground current

i_g is faulted line ground current

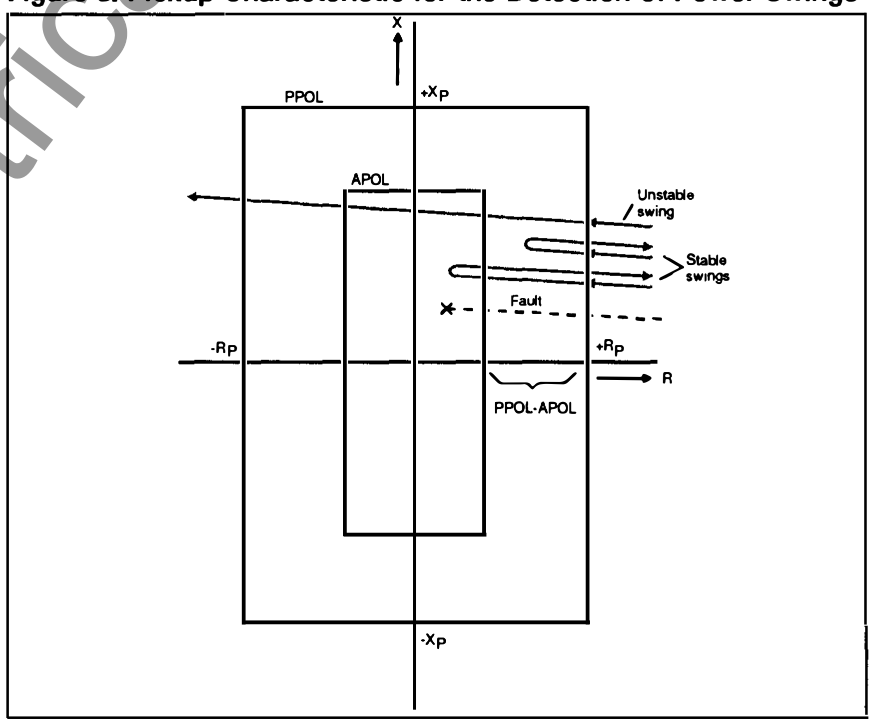
$\frac{R_g}{R_L}$ and $\frac{X_g}{X_L}$ are ground compensation factors

$\frac{R_m}{R_L}$ and $\frac{X_m}{X_L}$ are mutual coupling compensation factors

LOP & Emergency Overcurrent

Upon detection of a loss of potential (LOP) condition, the relay can be programmed to block the distance elements and activate a 2-stage, definite-time, overcurrent protection. When the measured voltages reappear, the distance protection is put back in service. An alarm contact will change states during loss of potential conditions.

Figure 8. Pickup Characteristic for the Detection of Power Swings



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Power Swing Block/Trip

An optional power swing block/trip function can be added to the 7SA511 relay. This requires the impedance fault detector option. The scheme uses two concentric polygonal impedance characteristics (Figure 8) and measures the rate of change of the impedance vector. If a power swing is detected, then the relay can be programmed to either block tripping or to initiate tripping.

In the blocking mode, the relay can be programmed to block all distance zones, Zone 1 & 1B only, or Zone 2 and 3 only.

In the tripping mode, the relay will block all distance zones in order to prevent tripping by them. When the impedance vector leaves the power swing polygon, the *R* component's sign is checked with that at the point of entry. If the sign is the same, then the swing is stabilizing and no trip is issued. If the sign is opposite, then an unstable swing has occurred and the relay trips with power swing trip indication.

High-Resistance Ground Fault Protection

High-resistance ground fault protection is another optional feature of the 7SA511 relay. In grounded networks where the ground path can be extremely high (e.g., overhead lines without lightning protection conductors, or ground paths in sandy soils), overcurrent and under-impedance elements do not always pick up. Even when using impedance fault detection, ground fault impedance can occur which appear to lie outside the pickup characteristic of the relay. The high-resistance ground fault protection is provided by a sensitive overcurrent function which can be selected to be directional or nondirectional.

The directional ground fault protection provides definite-time, overcurrent protection with nondirectional backup and standby protection. This function can be extended by an integrated directional comparison logic scheme so a carrier channel can be used for fast, selective tripping for high-resistance ground faults.

A nondirectional, inverse time overcurrent protection function for ground faults, with adjustable characteristics, can also be selected.

Automatic Reclosing

The 7SA511 can include an optional automatic reclosing function. It can be chosen for 3-pole and single-pole tripping schemes. One high speed reclose and up to nine time-delayed reclose attempts can be programmed. If a successful reclose has not occurred by the last permissible attempt, the function will lock out. If a reclose is successful, the relay will reset all of its functions after the expiration of the reset timer.

A separate distance zone, Z1L with timer T1L, becomes operational during the delayed automatic reclose cycles. It will remain in service until the reset timer expires.

For single-pole trip operations, the reclose function can be set for a single shot single-pole reclose only, or single-pole reclose for single-phase faults and 3-pole reclose for multi-phase faults.

The automatic reclose function of the 7SA511 can be initiated by an external source such as another protective relay or from an internal function. In addition, a scheme can be implemented with 2 protective relays and 2 automatic reclose devices.

Open Delta PTs

The 7SA511 distance relay can be connected to 3 phase-to-ground PTs or to 2 PTs in open delta. Both phase-to-ground and phase-to-phase voltage inputs are provided.

For the open delta connection, the relay will correctly measure phase-to-phase faults. For single phase-to-ground faults, a measuring error will occur due to the absence of zero sequence voltage. The error depends on the zero sequence source impedance. The measured impedance will always be greater than the actual impedance. A separate ground relay should be used in this application.

Programmable Inputs/Outputs

The 7SA511 numerical distance relay includes an integrated trip matrix. The trip and signaling relays can be programmed by the user to operate for any internal protection or alarm function, or they can be linked to an external function (e.g., external reclose initiated via the user-programmable binary inputs). In addition, the LEDs can be programmed to provide quick indication of trip and alarm functions. These features allow the user to configure the relay to best suit his protection system.

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Self-Checking

The 7SA511 numerical distance relay incorporates comprehensive monitoring functions which cover both hardware and software. Detection of a failure will block the relay and provide an alarm contact output. In some cases, an LED indication is available.

The relay monitors the auxiliary and reference voltages, A/D converter, trip circuits and memory modules.

Hardware

The DC voltages are monitored for correct operation of the internal equipment. If the voltages deviate outside the permissible limits, then the protection functions are blocked, and an alarm occurs via a fail-safe contact. The relay can withstand transient dips in the supply voltage up to 50 milliseconds for power supplies above 60 volts.

The trip relays are controlled by two command channels and one release channel. Open and short circuits in the coil are monitored and alarmed.

Software

The memory modules are checked through a cyclic checksum, which is compared to the stored checksum.

A watchdog timer is provided for continuous monitoring of the program sequence. It will reset the processor in the event of a processor failure or if the program falls out of step. Additional plausibility checks are performed to detect faults in the program processing caused by interference and will reset the processor. If these faults are not eliminated after three reset attempts, the relay will take itself out of service and provide an alarm and blocked LED indication.

Operational Values

The rms values of all phase currents and voltages are available continuously from the relay front display or via the serial interfaces. In addition, the relay provides real and reactive power flow measurements.

Fault Data

The relay stores fault target information for the last three faults. When the fault occurred, the function that initiated trip, and the value of the voltages and current are provided for each record.

Waveform Capture

The relay will record the fault waveforms for the last fault. The length of the record is 145 cycles with 0.83 milliseconds resolution.

Remote Communications

An RS-232 serial interface on the relay's operator panel (see Figure 1) allows you to connect the relay to any PC, such as a laptop. There also is an RS-232 serial or fiber optic interface on the back of the unit, which can be used for online communications with a substation control system.

Technical Data - Relay Specifications

Measuring circuits	Rated current I_N	1 A or 5 A
	Rated voltage V_N	100 V to 125 V
	Rated frequency f_N	50 or 60 Hz (programmable)
	Burden: CT circuits per phase & residual path	
	- at I_N = 1 A	approx. 0.1 VA
	- at I_N = 5 A	approx. 0.2 VA
	- highly-sensitive ground fault detection at 1 A	approx. 0.3 VA
	Burden: VT circuits	
	- at 120 V	approx. 0.6 VA
	- for ground fault detection at 120 V	approx. 0.6 VA
	Overload capability: CT circuits, phases and ground	
	- thermal (rms)	100 x I_N for 1 second
		20 x I_N for 10 seconds
		4 x I_N continuous
	- dynamic (impulse)	250 x I_N one half cycle (peak value)

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Technical Data - Relay Specifications

Measuring circuits (cont.)	Overload capability: VT circuits - thermal (rms) Overload capability: CT circuits for highly-sensitive ground fault detection - thermal (rms)	 140 V continuous 300 A for 1 second 100 A for 10 seconds 15 A continuous
Power system DC power supply via integrated DC/DC converter	**Rated voltage (VDC)** 24/48 V 60/110/125 V 220/250 V Ripple, peak-to-peak Power consumption - Quiescent - Energized Loss of DC supply ride through	**Operating range (VDC)** 19 to 56 V 48 to 144 V 176 to 288 V ≤ 12% at rated voltage ≤ 6% at the limits of the voltage ranges approx. 16 W approx. 26 W ≥ 50 ms at V_{rated} ≥ 110 VDC
Trip relays	Number of relays Contacts per relay Switching capacity MAKE BREAK Switching voltage Permissible current	5 1 form A 1000 W/VA 30 W/VA 250 V 5 A continuous, 30 A for 0.5 seconds
Signal/failure relays	Number of signal relays Number of failure relays Contacts per relay Switching capacity MAKE/BREAK Switching voltage Permissible current	10 1 6 with 1 form C, 5 with 1 form A 20 W/VA 250 V 1 A
Binary inputs	Number of inputs Operating voltage range Current consumption	10 24 to 250 VDC approx. 2.5 mA, independent of operating voltage
Serial interfaces	**Operator interface (front port)** - Connection **Rear port interface - Wire** - Standards	non-isolated at the front, 25-pole subminiature connector according to ISO 2110 for connection of a personal computer isolated similar to CCITT V.24/V.28; EIA RS-232C; according to IEC 870-5 protocol

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Technical Data - Relay Specifications

Serial Interfaces (cont.)	**Rear port interface - Wire** (cont.)	
	- Transmission speed	as delivered 9600 bps max. 19200 bps min. 4800 bps
	- Hamming distance	d = 4
	- Connection directly	at the housing terminals; 2 core pairs, with individual and common screening
	- Transmission distance	max. approx. 0.6 miles (3280 ft.)
	- Test voltage	2 kV at rated frequency for 1 minute
	Rear port interface - Fiber Optic	integrated F-SMA connector for direct fiber optic connection, e.g. glass fiber; 62.5/125µm
	- Optical wave length	820 nm
	- Permissible line attenuation	max. 8 dB
	- Transmission distance	max. approx. 1.25 miles (6560 ft.)
	- Normal signal position	reconnectable; factory setting: "light off"
Weight	- in housing for flush mounting - in housing for surface mounting	approx. 22.0 lbs. approx. 25.4 lbs.

Technical Data - System Specifications (Standards: ANSI C37.90.0, C37.90.1, C37.90.2; or IEC 255-5 and IEC 255-6)

Insulation tests	- High voltage test (routine test) ANSI C37.90.0; IEC 255-5	2 kV (rms), 50/60 Hz, 1 minute; alt. 2.8 kVDC, 1 minute
	- Impulse voltage test (type test) IEC 255-5	5 kV (peak); 1.2/50 µs; 0.5 J; 3 positive and 3 negative shots at intervals of 5 seconds
Disturbance tests	- High frequency test (type test) ANSI C37.90.1; IEC 255-22-1 class III	2.5 kV (peak); 1 MHz; τ=15 µs; 400 shots per second for 2 second duration
	- Electrostatic discharge test (type test) IEC 255-22-2 class III	8 kV (peak); 5/30 ns; 10 positive shots
	- Radiated electromagnetic fields (type test) IEC 255-22-3 class III ANSI C37.90.2	test with walkie-talkie; 68 MHz; 151 MHz; 450 MHz 25 MHz thru 1 GHz; 10 V/M
	- Fast transients (type test) IEC 41B (CO) class III ANSI C37.90.1	2 kV (peak); 5/50 ns; 5 kHz; 4 mJ per shot 5 kV; 10/150 ns

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Technical Data - System Specifications (Standards: ANSI C37.90.0, C37.90.1, C37.90.2; or IEC 255-5 and IEC 255-6)		
Mechanical stress tests	- during service - during transport	10 Hz to 60 Hz: 0.035 mm amplitude; 60 Hz to 500 Hz: 0.5 g acceleration 5 Hz to 8 Hz: 7.5 mm amplitude; 8 Hz to 500 Hz: 2 g acceleration
Climatic tests	- Permissible ambient temperature during service during storage during transport - Humidity class	 -20° C to +55° C (-4° F to +131° F) -25° C to +55° C (-13° F to +131° F) -25° C to +70° C (-13° F to +158° F) The relative humidity must be within limits such that neither condensation nor ice forms.
Technical Data - Specifications for Distance Protection		
Ground impedance matching	R_E/R_L X_E/X_L	-7.00 to +7.00 (steps 0.01) -7.00 to +7.00 (steps 0.01)
Mutual impedance match for fault location with parallel line compensation	R_M/R_L X_M/X_L	-7.00 to +7.00 (steps 0.01) -7.00 to +7.00 (steps 0.01)
Phase preferences	For double ground faults in grounded systems For double ground faults in ungrounded or compensated systems	phase-to-phase OR leading phase-to-ground OR lagging phase-to-ground L3 (L1) or L1 (L3) acyclic OR L2 (L1) or L1 (L2) acyclic OR L3 (L2) or L2 (L3) acyclic OR L3 (L1) or L1 (L3) cyclic
Fault detection	**Overcurrent fault detection**, general fault detection parameters Phase currents $I_{ph}>>/I_N$ Ground current $I_E>/I_N$ Displacement voltage pickup $V_E>$ (= $\sqrt{3} \times V_0$) Drop-out ratios Measuring tolerances **Voltage-controlled, overcurrent fault detection,** (optional) Characteristic Voltage control	 0.25 to 4.00 (steps 0.01) 0.10 to 1.00 (steps 0.01) 10 V to 100 V (steps 1 V) approx. 0.95 ± 5% 2-stage with settable inclination by V_{ph-e} or V_{ph-ph}

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Technical Data - Distance Protection Specifications

Fault detection (cont.)	**Voltage-controlled, overcurrent, fault detection** (optional)	
	Setting ranges:	
	- minimum current pickup $I_{ph}>$	0.10 to 1.00 x I_N (steps 0.01 x I_N)
	- undervoltage pickup $V_{ph-e}<$	20 V to 70 V (steps 1 V)
	$V_{ph-ph}<$	40 V to 130 V (steps 1 V)
	Drop-out ratios:	
	- $I_{ph}>$	approx. 0.95
	- $V_{ph-e}<$, $V_{ph-ph}<$	approx. 1.05
	Measuring tolerances	± 5%
	Voltage-controlled, overcurrent, polygonal impedance fault detection (optional)	
	Characteristic	polygonal, phase angle dependent R-section
	Setting values (based on I_N = 1 A*):	
	- X+A = forward reach (for all faults)	0.10 Ω to 200.00 Ω (steps 0.01 Ω)
	- X-A = reverse reach (for all faults)	0.10 Ω to 200.00 Ω (steps 0.01 Ω)
	- RA_2 = resistance tolerance (phase-phase, $\phi_{sc} > 45°$)	0.10 Ω to 200.00 Ω (steps 0.01 Ω)
	- RA_1 = resistance tolerance (phase-phase, $\phi sc < 45°$)	0.10 Ω to 100.00 Ω (steps 0.01 Ω)
	- RA_G = resistance tolerance (phase-ground)	0.10 Ω to 200.00 Ω (steps 0.01 Ω)
	- $I_{ph}>$ = minimum operating phase current	0.10 to 4.00 x I_N (steps 0.01 x I_N)
	Drop-out ratios:	
	- for R, X	approx. 1.06
	- for $I_{ph}>$	approx. 0.95 (for $I > I_N$)
	Measuring tolerances with sinusoidal quantities	$\left\|\frac{\Delta X}{X}\right\| \leq 5\%$ for $30° \leq \phi_{sc} \leq 90°$
		$\left\|\frac{\Delta R}{X}\right\| \leq 10\%$ for $0° \leq \phi_{sc} \leq 60°$
Distance measurement	Characteristic	polygonal, 3 independent + 2 controlled elements
	Setting values (based on IN = 1 A*)	
	- X = forward reach (for all faults)	0.05 Ω to 130.00 Ω (steps 0.01 Ω)
	- R = resistance tolerance (phase-phase)	0.05 Ω to 65.00 Ω (steps 0.01 Ω)
	- R_G = resistance tolerance (phase-ground)	0.05 Ω to 130.00 Ω (steps 0.01 Ω)
	Measuring tolerances with sinusoidal quantities	$\left\|\frac{\Delta X}{X}\right\| \leq 5\%$ for $30° \leq \phi_{sc} \leq 90°$
		$\left\|\frac{\Delta R}{X}\right\| \leq 5\%$ for $0° \leq \phi_{sc} \leq 60°$
Directional determination	For all types of faults	with quadrature voltages and voltage memory
	Sensitivity	dynamically unlimited

** Secondary values are related on I_N = 1 A; for I_N = 5 A, the values are to be divided by 5.*

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Technical Data - Specifications for Distance Protection		
Times All elements can be set to operate in forward or reverse direction or to be nondirectional. The set times are pure delay times.	Shortest tripping time Resetting time Time elements: - Setting ranges for all elements Timeout tolerances	approx. 25 milliseconds approx. 40 milliseconds 0.00 s to 32.00 s (steps 0.01 s) OR ∞ (i.e., element ineffective) ≤ 1% of set value or 10 milliseconds
Overcurrent emergency protection With measured voltage failure, e.g., VT secondary mcb trip or detected fuse failure	Phase overcurrent $I_{ph}>/I_N$ Definite-time delay $T_{Iph}>$ Ground overcurrent $I_E>/I_N$ Definite-time delay $T_{IE}>$ High-set phase overcurrent $I>>/I_N$ Definite-time delay $T_{I>>}$ Drop-out ratios - for $I \geq I_N$ - for $I \geq 0.25 \times I_N$ Measuring tolerances	0.10 to 4.00 (steps 0.01) 0.00 s to 32.00 s (steps 0.01 s) OR ∞ (i.e., element ineffective) 0.10 to 4.00 (steps 0.01) 0.00 s to 32.00 s (steps 0.01 s) OR ∞ (i.e., element ineffective) 0.50 to 9.99 (steps 0.01) 0.00 s to 32.00 s (steps 0.01 s) OR ∞ (i.e., element ineffective) approx. 0.95 approx. 0.90 ± 5%

Technical Data - Specifications for Power Swing Detection (optional)		
Power swing detection	Detection Setting the difference ΔR between the polygons (secondary based on I_N = 1 A*) Setting rate of change dR/dT Programs Action time	rate of change of the impedance vector between "power swing polygon" and "fault detection polygon" 0.10 Ω to 50.00 Ω (steps 0.01 Ω) 0 Ω/s to 200 Ω/s (steps 1 Ω/s) block first distance zone only, block all zones but first zone, block all distance zones, out-of-step tripping 0.01 s to 32.00 s (steps 0.01 s) OR ∞ (i.e., until drop-out of the power swing polygon)

** Secondary values are related on I_N = 1 A; for I_N = 5 A, the values are to be divided by 5.*

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Technical Data - Specifications for Pilot Protection

Pilot Protection modes (user-programmable)	**Permissive underreach transfer trip**	- zone acceleration (special zone Z1B) - fault detection acceleration
	- Transmit signal prolongation	0.01 s to 32.00 s (steps 0.01 s)
	- Transmit signal delay	0.00 s to 32.00 s (steps 0.01 s)
	- Received signal prolongation	0.00 s to 32.00 s (steps 0.01 s)
	Permissive overreach transfer trip	- release overreaching zone Z1B - release fault detection zone directional unblocking zone Z1B - unblocking fault detection zone directional blocking zone Z1B
	- Transmit signal prolongation	0.01 s to 32.00 s (steps 0.01 s)
	- Transmit signal delay	0.00 s to 32.00 s (steps 0.01 s)
	- Echo delay time	0.01 s to 32.00 s (steps 0.01 s); ∞
	- Echo pulse duration	0.02 s to 32.00 s (steps 0.01 s)
	- Echo block duration	0.01 s to 32.00 s (steps 0.01 s)
	- Transient blocking time	0.01 s to 32.00 s (steps 0.01 s)
	- Waiting time for transient blocking	0.01 s to 32.00 s (steps 0.01 s); ∞
	Overreaching transfer via pilot wires	NC link with DC control cable
	Reverse interlocking	with NO or NC interlock loop

Technical Data - Specifications for Ground Fault Detection in Ungrounded Systems

Detection	Displacement voltage V_E>	10 V to 100 V (steps 1 V)
	Delay	approx. 1 second (settable up to 320 sec.)
	Measuring tolerance	≤ 5% of set value
Faulted phase determination	Measuring principle	voltage measurement phase-to-ground
	V< (faulted phase)	10 V to 100 V (steps 1 V)
	V> (unfaulted phases)	10 V to 100 V (steps 1 V)
	Measuring tolerance	≤ 5% of set value
Directional determination	Measuring principle	measurement of active and reactive power
	Pickup value I_E> (active or reactive component) CT angle error correction	3 mA to 1000 mA (steps 1 mA) 0.0° to 5.0° (steps 0.1°) for 2 operating points of the CT characteristic
	Measuring tolerance	≤ 10% of set value for tan ϕ ≤ 20 (with active component)

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Technical Data - Specifications for High-Resistance Ground Fault Protection in Grounded Systems		
Fault detection	Ground current pickup $I_E>/I_N$ (for trip) Lower pickup value (for measurement release) Displacement voltage $V_E>$ Drop-out ratio Measuring tolerance	0.10 to 4.00 (steps 0.01) $0.75 \times I_E>/I_N$ 1.0 V to 10.0 V (steps 0.1 V) approx. 0.95 ≤ 5% of set value
Directional determination	Measuring principle Forwards angle Measuring tolerances at V_N and I_N with sinusoidal quantities Directional comparison	with I_E (= $3 \times I_0$) and V_E (= $\sqrt{3} \times V_0$) -14° to +166° ≤ 5° release mode
Times	Shortest tripping time Reorientation time after change of direction Trip delay time Backup time T directional Backup time T nondirectional Echo delay time Echo pulse duration Echo block duration Transient blocking time Waiting time for transient blocking Timeout tolerances	approx. 30 milliseconds approx. 30 milliseconds 0.00 s to 32.00 s (steps 0.01 s); ∞ 0.00 s to 32.00 s (steps 0.01 s); ∞ 0.00 s to 32.00 s (steps 0.01 s); ∞ 0.01 s to 32.00 s (steps 0.01 s); ∞ 0.02 s to 32.00 s (steps 0.01 s) 0.01 s to 32.00 s (steps 0.01 s) 0.01 s to 32.00 s (steps 0.01 s) 0.01 s to 32.00 s (steps 0.01 s); ∞ ≤ 1% or 10 milliseconds
Inverse time ground fault backup protection (Can be used instead of the ground fault protection described above.)	Characteristics Pickup value $I_E>/I_N$ Time setting $T_{IE}>$ corresponds to TM factor Measuring tolerances - ground current pickup value - timeout	normal inverse OR very inverse OR extremely inverse, acc. to IEC 255-4, 3.5.2; or BS142 0.10 to 4.00 (steps 0.01) 0.00 s to 32.00 s (steps 0.01 s); ∞ 0.000 to 3.200 (steps 0.001); ∞ +5% to +15% ≤ 5% ± 15 ms for $2 \leq I/I_E \leq 20$ and $1 \leq T_{IE}/s \leq 20$

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Technical Data - Specifications for Automatic Reclose (optional)

Automatic Reclose	Max. number of possible shots	1 RAR (first shot) up to 9 DAR (further shots)
	Automatic reclose modes	single-pole or three-pole OR single/three-pole (1st shot RAR); further shots three-pole (DAR)
	Action time	0.01 s to 320.00 s (steps 0.01 s)
	1st dead time single-pole	0.01 s to 320.00 s (steps 0.01 s)
	1st dead time three-pole	0.01 s to 320.00 s (steps 0.01 s)
	Further dead times	0.01 s to 320.00 s (steps 0.01 s)
	Discrimination time for evolving faults	0.01 s to 320.00 s (steps 0.01 s)
	Reset time	0.50 s to 320.00 s (steps 0.01 s)
	Reset time after manual close	0.50 s to 320.00 s (steps 0.01 s)
	Duration of RECLOSE command	0.01 s to 320.00 s (steps 0.01 s)

Technical Data - Specifications for Fault Location

Fault location	Output of fault distance	in Ω primary in km line length ** in percent line length **
	Start-to-measure command	by trip signal or by drop-out of fault detection OR by external command via binary input
	Setting reactance per unit length (secondary *)	0.010 Ω/km to 5.000 Ω/km (steps 0.001 Ω/km)
	Parallel line mutual compensation	can be ordered as an option (see Ordering Data diagram)
	Measuring tolerances with sinusoidal quantities	≤ 2.5% of line length for 30° ≤ ϕ_{sc} ≤ 90° and V_{sc}/V_N ≤ 0.1

Technical Data - Specifications for Ancillary Functions

Output of measured values	Operational values of currents	I_{L1}, I_{L2}, I_{L3} in A primary and in percent I_N
	Operation values of voltages	V_{L1-L2}, V_{L2-L3}, V_{L3-L1} in kV primary and in percent I_N
	Operational values of powers	P_a, P_r (active and reactive power), in MW or MVAr and in percent P_N ($= \sqrt{3} \times V_N \times I_N$)
	Operational values of frequency	f in percent f_N
	Measuring tolerances	≤ 2% of respected rated value

* *Secondary values are related on I_N = 1 A; for I_N = 5 A, the values are to be divided by 5.*
***Output of fault distance in km or miles or percents only for homogeneous lines! When setting related reactance in Ω/mile, the output can be read in miles.*

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Technical Data - Specifications for Ancillary Functions		
Measured values plausibility checks	Sum of currents Sum of voltages	phases and ground phases and ground, phase-to-phase, phase-to-phase against phase-to-ground
Steady-state measured value supervision	Current unbalance	I_{max}/I_{min} > symmetry factor as long as $I > I_{limit}$
	Voltage unbalance (phase-to-phase and phase-to-ground)	V_{max}/V_{min} > symmetry factory as long as $V > V_{limit}$
	Voltage failure (3-phase)	$\lvert V \rvert < 0.6\ V_N$ as long as $\lvert I_{max} \rvert > 0.06\ I_N$
	Voltage failure (single-phase)	V_E> and I_E< (with impedance fault detection)
	Phase sequence	clockwise phase rotation
Waveform capture	Recording time - using operator interface (front port)	-100 ms to +2900 ms at 50 Hz -83 ms to +2416 ms at 60 Hz
	- using the rear port	-60 ms to +600 ms at 50 Hz -50 ms to +500 ms at 60 Hz
	Sampling rate	1 instantaneous value per ms at 50 Hz 1 instaneous value per 0.83 ms at 60 Hz
Fault annunciations	Fault event data storage	- Annunciations of the last three faults
Operational annunciations	Operational data storage	- Annunciations from 50 most recent events - 1 minute resolution
Real-time clock	Resolution for operational annunciations Resolution for fault event annunciations Maximum time deviation Buffer battery	1 minute 1 millisecond 0.01% Lithium battery 3 V/1 Ah, Type CR 1/2 AA self-discharge time > 5 years

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Ordering Information

Line Protection Relay 7SA511 □-□□ A5 □-□□□□

Rated current at 50/60 Hz AC	
1 A	1
5 A	5
Rated power supply voltage VDC	
24, 48 VDC	2
60, 110, 125 VDC	4
220, 250 VDC	5
Mounting construction	
Surface mounting	B
Flush mounting	C
Fault detection systems	
Overcurrent fault detectors	1
Overcurrent, voltage controlled overcurrent, polygonal impedance characteristic, fault detectors	2
Overcurrent, voltage controlled overcurrent, fault detectors	3
Ground fault detection input	
For grounded systems, input for I_E (protected line) only	0
For ungrounded systems, without parallel line compensation	1
For grounded systems, input for I_{EP} (parallel line compensation)	2
Serial system interface (rear port)	
None	A
Isolated, hard-wired	B
Integrated fiber optic interface	C

Automatic Reclose/Parameter Changeover (AR/PCO)		
without AR	without PCO	A
with AR 3-pole	without PCO	B
with AR 1/3-pole	without PCO	C
without AR	with PCO	E
with AR 3-pole	with PCO	F
with AR 1/3-pole	with PCO	G
Power Swing/High-Resistance Ground Fault Protection * (PS/GF)		
without PS	without GF	0
with PS	without GF	1
without PS	with GF	2
with PS	with GF	3

** The Power Swing (PS) option is only applicable when the Fault Detection System selected has the polygonal impedance characteristic (code = 2). The High-Resistance Ground Fault (GF) protection is only applicable for grounded systems, i.e., the Ground Fault Detection Input code must be 0 or 2.*

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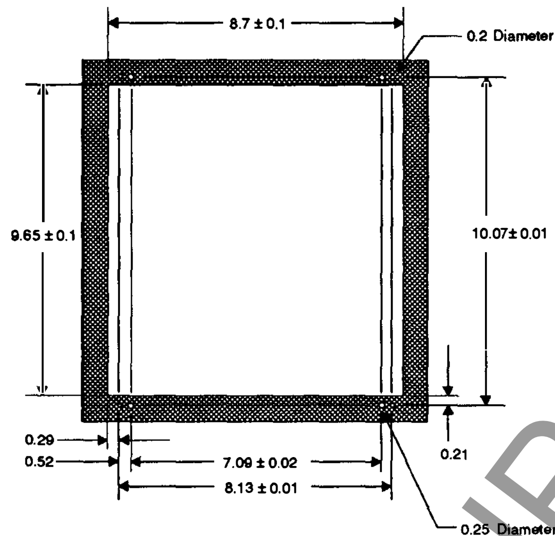
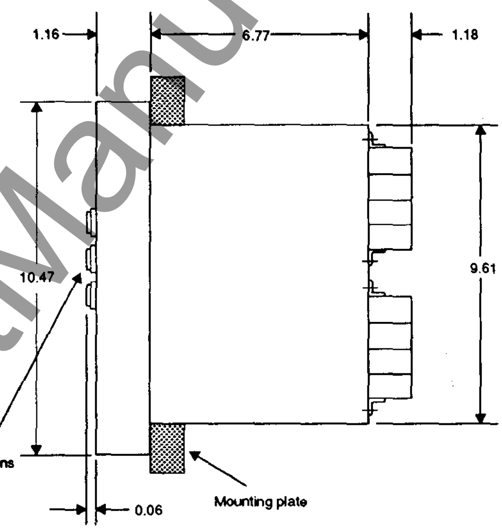
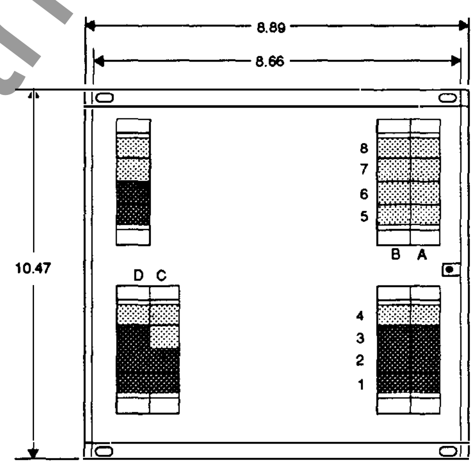
Dimensions of the 7SA511 Relay (Flush mounting case. Dimensions shown are in inches.)



Front View
(Switchboard cutout)



Side View



Rear View

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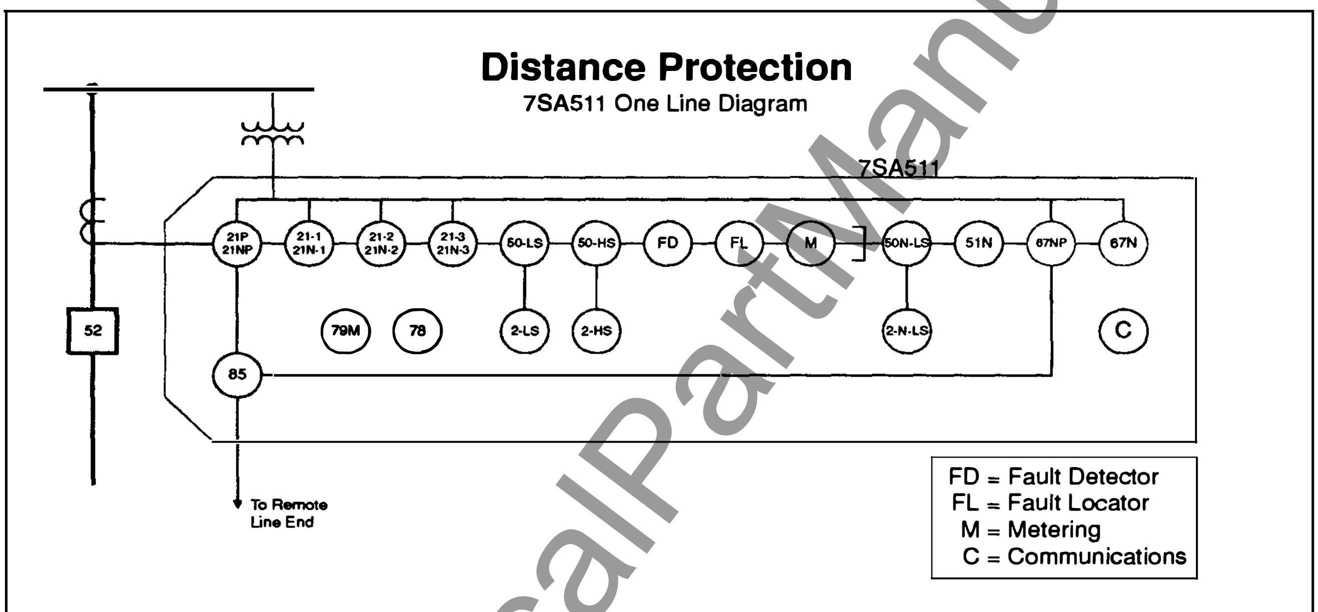

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