Generator Protection / 7UM62

SIPROTEC 7UM62 multifunction generator, motor and transformer protection relay

Fig. 11/1 SIPROTEC 7UM62 multifunction protection relay for generators, motors and transformers

Description

The SIPROTEC 7UM62 protection relays can do more than just protect. They also offer numerous additional functions. Be it ground faults, short-circuits, overloads, overvoltage, overfrequency or underfrequency asynchronous conditions, protection relays assure continued operation of power stations. The SIPROTEC 7UM62 protection relay is a compact unit which has been specially developed and designed for the protection of small, medium-sized and large generators. They integrate all the necessary protection functions and are particularly suited for the protection of:
- Hydro and pumped-storage generators
- Co-generation stations
- Private power stations using regenerative energy sources such as wind or biogases
- Diesel generator stations
- Gas-turbine power stations
- Industrial power stations
- Conventional steam power stations.

The SIPROTEC 7UM62 includes all necessary protection functions for large synchronous and asynchronous motors and for transformers.

The integrated programmable logic functions (continuous function chart CFC) offer the user high flexibility so that adjustments can easily be made to the varying power station requirements on the basis of special system conditions.
The flexible communication interfaces are open for modern communication architectures with the control system.

The following basic functions are available for all versions:

Current differential protection for generators, motors and transformers, stator ground-fault protection, sensitive ground-fault protection, stator overload protection, overcurrent-time protection (either definite time or inverse time), definite-time overcurrent protection with directionality, undervoltage and overvoltage protection, underfrequency and overfrequency protection, overexcitation and underexcitation protection, external trip coupling, forward-power and reverse-power protection, negative-sequence protection, breaker failure protection, rotor ground-faults protection (f_n, R-measuring), motor starting time supervision and restart inhibit for motors.

Function overview

Standard version

Scope of basic version plus:
- Inadvertent energization protection
- 100 %-stator ground-fault protection with 3rd harmonic
- Impedance protection

Full version

Scope of standard version plus:
- DC voltage protection
- Overcurrent protection during start-ups
- Ground-current differential protection
- Out-of-step protection

Additional version

Available for each version:
- Sensitive rotor ground-fault protection (1–3 Hz method)
- Stator ground-fault protection with 20 Hz voltage
- Rate-of-frequency-change protection
- Vector jump supervision

Monitoring function
- Trip circuit supervision
- Fuse failure monitor
- Operational measured values V, I, f, ...
- Energy metering values W_p, W_q
- Time metering of operating hours
- Self-supervision of relay
- 8 oscillographic fault records

Communication interfaces
- System interface
  - IEC 61850 protocol
  - IEC 60870-5-103 protocol
  - PROFIBUS DP
  - Modbus RTU
  - DNP 3
  - PROFINET

Hardware

- Analog inputs
- 8 current transformers
- 4 voltage transformers
- 7/15 binary inputs
- 12/20 output relays

Front design
- User-friendly local operation
- 7/14 LEDs for local alarm
- Function keys
- Graphic display with 7UM623

Application, construction

Application

The 7UM6 protection relays of the SIPROTEC 4 family are compact multifunction units which have been developed for small to medium-sized power generation plants. They incorporate all the necessary protective functions and are especially suitable for the protection of:

– Hydro and pumped-storage generators
– Co-generation stations
– Private power stations using regenerative energy sources such as wind or biogases
– Power generation with diesel generators
– Gas turbine power stations
– Industrial power stations
– Conventional steam power stations.

They can also be employed for protection of motors and transformers.

The numerous other additional functions assist the user in ensuring cost-effective system management and reliable power supply. Measured values display current operating conditions. Stored status indications and fault recording provide assistance in fault diagnosis not only in the event of a disturbance in generator operation.

Combination of the units makes it possible to implement effective redundancy concepts.

Protection functions

Numerous protection functions are necessary for reliable protection of electrical machines. Their extent and combination are determined by a variety of factors, such as machine size, mode of operation, plant configuration, availability requirements, experience and design philosophy.

This results in multifunctionality, which is implemented in outstanding fashion by numerical technology.

In order to satisfy differing requirements, the combination of functions is scalable (see Table 11/3). Selection is facilitated by division into five groups.

Generator Basic

One application concentrates on small and medium generators for which differential protection is required. The function mix is also suitable as backup protection. Protection of synchronous motors is a further application.

Generator Standard

In the case of medium-size generators (10 to 100 MVA) in a unit connection, this scope of functions offers all necessary protection functions. Besides inadvertent energization protection, it also includes powerful backup protection for the transformer or the power system. The scope of protection is also suitable for units in the second protection group.

Generator Full

Here, all protection functions are available and the main application focuses on large block units (more than 100 MVA). The function mix includes all necessary protection functions for the generator as well as backup protection for the block transformer including the power system. Additional functions such as protection during start-up for generators with starting converters are also included.The scope of functions can be used for the second protection group, and functions that are not used, can be masked out.

Asynchronous motor

Besides differential protection, this function package includes all protection functions needed to protect large asynchronous motors (more than 1 MVA). Stator and bearing temperatures are measured by a separate thermo-box and are transmitted serially to the protection unit for evaluation.

Transformer

This scope of functions not only includes differential and overcurrent protection, but also a number of protection functions that permit monitoring of voltage and frequency stress, for instance. The reverse-power protection can be used for energy recovery monitoring of parallel-connected transformers.

Construction

The SIPROTEC 4 units have a uniform design and a degree of functionality which represents a whole new quality in protection and control.

Local operation has been designed according to ergonomic criteria. Large, easy-to-read displays were a major design aim. The 7UM623 is equipped with a graphic display thus providing and depicting more information especially in industrial applications. The DIGSI 4 operating program considerably simplifies planning and engineering and reduces commissioning times.

The 7UM621 and 7UM623 are configured in 1/2 19 inches width. This means that the units of previous models can be replaced. The height throughout all housing width increments is 243 mm.

All wires are connected directly or by means of ring-type cable lugs. Alternatively, versions with plug-in terminals are also available. These permit the use of prefabricated cable harnesses.

In the case of panel surface mounting, the connecting terminals are in the form of screw-type terminals at top and bottom. The communication interfaces are also arranged on the same sides.

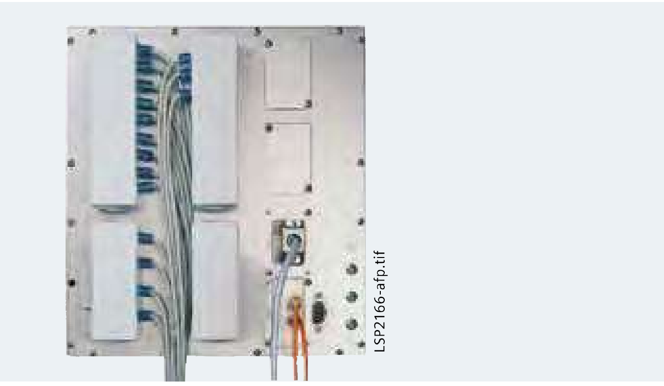

Fig. 11/2 Rear view with wiring terminal safety cover and serial interface

Protection functions

Protection functions	Abbreviation	ANSI No.	Generator Basic	Generator Standard	Generator Full	Motor Asynchronous	Transformer
Current differential protection	ΔI	87G/87T/87M	■	■	■	■	■
Stator ground-fault protection non-directional, directional	$V_0>$, $3I_0>$ $\backslash(V_0, 3I_0)$	59N, 64G 67G	■	■	■	■	■
Sensitive ground-fault protection (also rotor ground-fault protection)	$I_{EE}>$	50/51GN (64R)	■	■	■	■	■
Sensitive ground-fault prot. B (e.g. shaft current prot.)	$I_{EE\text{-}B}>$ $I_{EE\text{-}B}<$	51GN	■	■	■	■	■
Stator overload protection	I^2t	49	■	■	■	■	■
Definite-time overcurrent prot. with undervolt. seal-in	$I> +V<$	51	■	■	■	■	■
Definite-time overcurrent protection, directional	$I>>$, Direc.	50/51/67	■	■	■	■	■
Inverse-time overcurrent protection	$t = f(I)+V<$	51V	■	■	■	■	■
Overvoltage protection	$V>$	59	■	■	■	■	■
Undervoltage protection	$V<$, $t = f(V)$	27	■	■	■	■	■
Frequency protection	$f<$, $f>$	81	■	■	■	■	■
Reverse-power protection	$-P$	32R	■	■	■	■	■
Overexcitation protection (Volt/Hertz)	V/f	24	■	■	■	■	■
Fuse failure monitor	V_2/V_1, I_2/I_1	60FL	■	■	■	■	■
External trip coupling	Incoup.		4	4	4	4	4
Trip circuit supervision	T.C.S.	74TC	■	■	■	■	■
Forward-power protection	$P>$, $P<$	32F	■	■	■	■	■
Underexcitation protection (loss-of-field protection)	1/xd	40	■	■	■		
Negative-sequence protection	$I_2>$, $t = f(I_2)$	46	■	■	■	■	
Breaker failure protection	$I_{min}>$	50BF	■	■	■	■	■
Motor starting time supervision	$I_{start}{}^2t$	48	■	■	■	■	
Restart inhibit for motors	I^2t	66, 49 Rotor	■	■	■	■	
Rotor ground-fault protection (f_n, R-measuring)	$R<$	64R (f_n)	■	■	■		
Inadvertent energization protection	$I>$, $V<$	50/27		■	■		
100 % stator ground-fault protection with 3rd harmonics	V_0 (3rd harm.)	59TN, 27TN 3rd h		■	■		
Impedance protection with ($I>+V<$) pickup	$Z<$	21		■	■		
Interturn protection	$U_{Interturn}>$	59N(IT)		■	■		
DC voltage / DC current time protection	$V_{dc}>$ $I_{dc}>$	59N (DC) 51N (DC)			■		
Overcurrent protection during startup (for gas turbines)	$I>$	51			■		
Ground-current differential protection	ΔI_e	87GN/TN	■ 1)	■ 1)	■	■ 1)	■ 1)
Out-of-step protection	$\Delta Z/\Delta t$	78			■		
Rotor ground-fault protection (1 – 3 Hz square wave voltage)	$R_{REF}<$	64R (1 – 3 Hz)	■ 1)	■ 1)	■ 1)		
100 % stator ground-fault protection with 20 Hz voltage	$R_{SEF}<$	64G (100 %)	■ 1)	■ 1)	■ 1)		
Rate-of-frequency-change protection	$df/dt>$	81R	■ 1)	■ 1)	■ 1)	■ 1)	■ 1)
Vector jump supervision (voltage)	$\Delta\varphi>$		■ 1)	■ 1)	■ 1)	■ 1)	■ 1)
Threshold supervision			■	■	■	■	■
Supervision of phase rotation	A, B, C	47	■	■	■	■	■
Undercurrent via CFC	$I<$	37	■	■	■	■	■
External temperature monitoring via serial interface	ϑ (Thermo-box)	38	■	■	■	■	■

1) Optional for all function groups.

Table 11/3 Scope of functions of the 7UM62

Current differential protection (ANSI 87G, 87M, 87T)

This function provides undelayed short-circuit protection for generators, motors and transformers, and is based on the current differential protection principle (Kirchhoff's current law).

The differential and restraint (stabilization) current are calculated on the basis of the phase currents. Optimized digital filters reliably attenuate disturbances such as aperiodic component and harmonics. The high resolution of measured quantities permits recording of low differential currents (10 % of I_N) and thus a very high sensitivity.

An adjustable restraint characteristic permits optimum adaptation to the conditions of the protected object. Software is used to correct the possible mismatch of the current transformers and the phase angle rotation through the transformer (vector group). Thanks to harmonic analysis of the differential current, inrush (second harmonic) and overexcitation (fifth harmonic) are reliably detected, and unwanted operation of the differential protection is prevented. The current of internal short-circuits is reliably measured by a fast measuring stage (I_{Diff}>>), which operates with two mutually complementary measuring processes. An external short-circuit with transformer saturation is picked up by a saturation detector with time and status monitoring. It becomes active when the differential current (I_{Diff}) moves out of the add-on restraint area.

If a motor is connected, this is detected by monitoring the restraint current and the restraint characteristic is briefly raised. This prevents false tripping in the event of unequal current transmission by the current transformers.

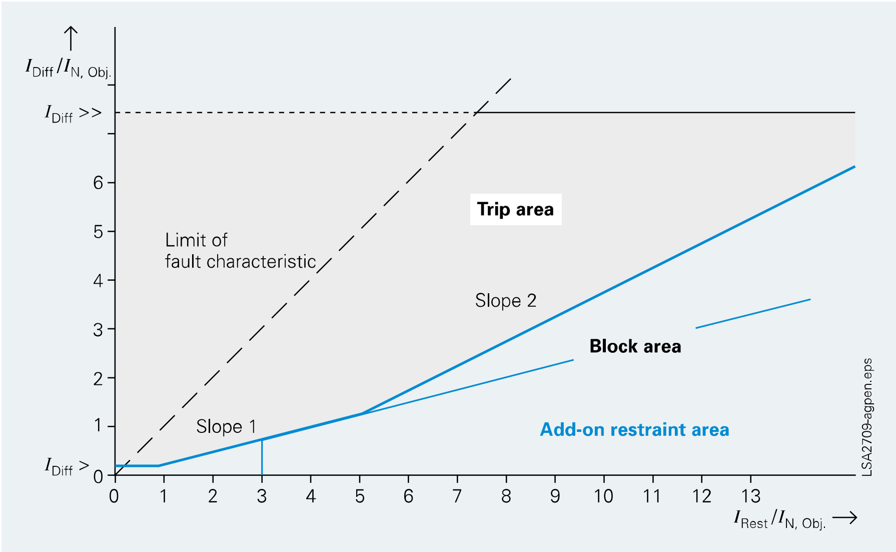

Fig. 11/3 Restraint characteristic of current differential protection

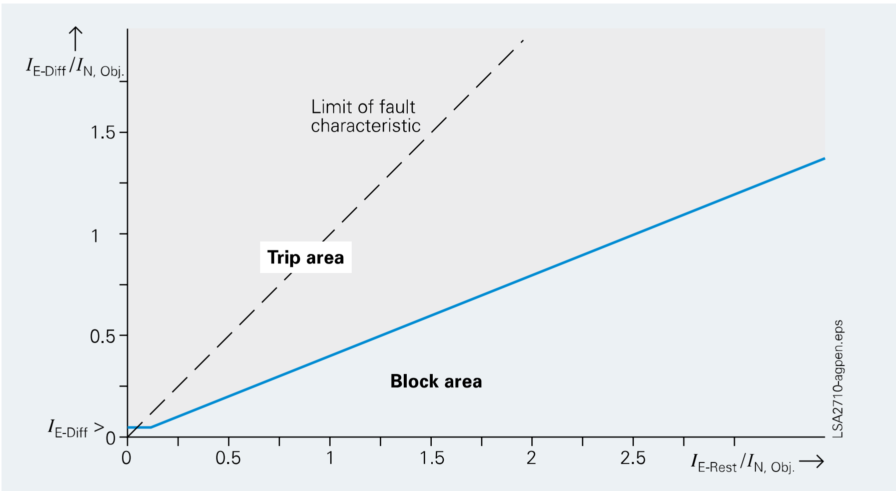

Fig. 11/4 Restraint characteristic of ground-current differential protection

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Figure 11/36 shows the restraint characteristic and various areas.

Ground-current differential protection (ANSI 87GN, 87TN)

The ground-current differential protection permits high sensitivity to single-pole faults. The zero currents are compared. On the one hand, the zero-sequence current is calculated on the basis of the phase currents and on the other hand, the ground current is measured directly at the star-point current transformer.

The differential and restraint quantity is generated and fitted into the restraint characteristic (see Fig. 11/37).

DC components in particular are suppressed by means of specially dimensioned filters. A number of monitoring processes avoid unwanted operation in the event of external short-circuits. In the case of a sensitive setting, multiple measurement ensures the necessary reliability.

However, attention must be drawn to the fact that the sensitivity limits are determined by the current transformers.

The protection function is only used on generators when the neutral point is grounded with a low impedance. In the case of transformers, it is connected on the neutral side. Low impedance or solid grounding is also required.

Definite-time overcurrent protection I>, I>> (ANSI 50, 51, 67)

This protection function comprises the short-circuit protection for the generator and also the backup protection for upstream devices such as transformers or power system protection.

An undervoltage stage at I> maintains the pickup when, during the fault, the current drops below the threshold. In the event of a voltage drop on the generator terminals, the static excitation system can no longer be sufficiently supplied. This is one reason for the decrease of the short-circuit current.

The I>> stage can be implemented as high-set instantaneous trip stage. With the integrated directional function it can be used as backup protection on the transformer high-voltage side. With the information of the directional element, impedance protection can be controlled via the CFC.

Inverse-time overcurrent protection (ANSI 51V)

This function also comprises short-circuit and backup protection and is used for power system protection with current-dependent protection devices.

IEC and ANSI characteristics can be selected (Table 11/4).

The current function can be controlled by evaluating the generator terminal voltage.

The "controlled" version releases the sensitive set current stage.

With the "restraint" version, the pickup value of the current is lowered linearly with decreasing voltage.

The fuse failure monitor prevents unwanted operation.

Stator overload protection (ANSI 49)

The task of the overload protection is to protect the stator windings of generators and motors from high, continuous overload currents. All load variations are evaluated by a mathematical model. The thermal effect of the r.m.s. current value forms the basis of the calculation. This conforms to IEC 60255-8.
In dependency of the current, the cooling time constant is automatically extended. If the ambient temperature or the temperature of the coolant are injected via a transducer (TD2) or PROFIBUS DP, the model automatically adapts to the ambient conditions; otherwise a constant ambient temperature is assumed.

Negative-sequence protection (ANSI 46)

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

This protection detects an asymmetrical load in three-phase generators. It functions on the basis of symmetrical components and evaluates the negative sequence of the phase currents. The thermal processes are taken into account in the algorithm and form the inverse characteristic. In addition, the negative sequence is evaluated by an independent stage (alarm and trip) which is supplemented by a time-delay element (see Fig. 11/38). In the case of motors, the protection function is also used to monitor a phase failure.

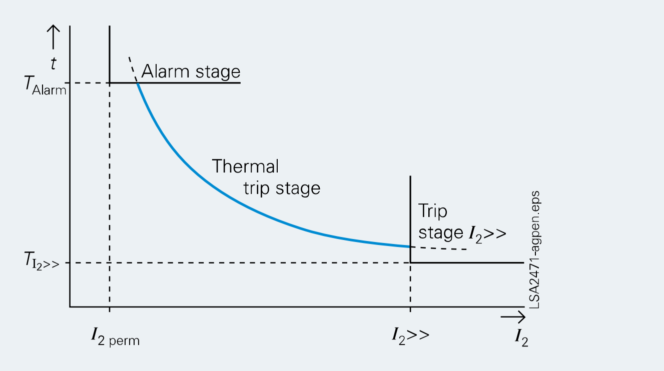

Fig. 11/5 Characteristic of negative-sequence protection

Available inverse-time characteristics		
Characteristics	*ANSI*	*IEC 60255-3*
Inverse	•	•
Moderately inverse	•	
Very inverse	•	•
Extremely inverse	•	•
Definite inverse	•	

Table 11/4

Underexcitation protection (Loss-of-field protection) (ANSI 40)

Derived from the generator terminal voltage and current, the complex admittance is calculated and corresponds to the generator diagram scaled in per unit. This protection prevents damage due to loss of synchronism resulting from underexcitation. The protection function provides three characteristics for monitoring static and dynamic stability. Via a transducer, the excitation voltage (see Figure 11/52) can be injected and, in the event of failure, a swift reaction of the protection function can be achieved by timer changeover.

The straight-line characteristics allow the protection to be optimally adapted to the generator diagram (see Figure 11/39). The per-unit-presentation of the diagram allows the setting values to be directly read out.

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

If the voltage deviates from the rated voltage, the admittance calculation has the advantage that the characteristics move in the same direction as the generator diagram.

Reverse-power protection (ANSI 32R)

The reverse-power protection monitors the direction of active power flow and picks up when the mechanical energy fails. This function can be used for operational shut-down (sequential tripping) 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 power system faults therefore do not cause reduced measuring accuracy. The position of the emergency trip valve is injected as binary information and is used to switch between two trip command delays. When applied for motor protection, the sign (±) of the active power can be reversed via parameters.

Forward-power protection (ANSI 32F)

Monitoring of the active power produced by a generator can be useful for starting up and shutting down generators. One stage monitors exceeding of a limit value, while another stage monitors falling below another limit value. The power is calculated using the positive-sequence component of current and voltage. The function can be used to shut down idling motors.

Impedance protection (ANSI 21)

This fast short-circuit protection protects the generator and the unit transformer and is a backup protection for the power system. This protection has two settable impedance stages; in addition, the first stage can be switched over via binary input. With the circuit-breaker in the “open” position the impedance measuring range can be extended (see Figure 11/40).

The overcurrent pickup element with undervoltage seal-in ensures a reliable pickup and the loop selection logic ensures a reliable detection of the faulty loop. With this logic it is possible to perform correct measurement via the unit transformer.

Undervoltage protection (ANSI 27)

The undervoltage protection evaluates the positive-sequence components of the voltages and compares them with the threshold values. There are two stages available.

The undervoltage function is used for asynchronous motors and pumped-storage stations and prevents the voltage-related instability of such machines.

The function can also be used for monitoring purposes.

Overvoltage protection (ANSI 59)

This protection prevents insulation faults that result when the voltage is too high.

Either the maximum line-to-line voltages or the phase-to-ground voltages (for low-voltage generators) can be evaluated. The measuring results of the line-to-line voltages are independent of the neutral point displacement caused by ground faults. This function is implemented in two stages.

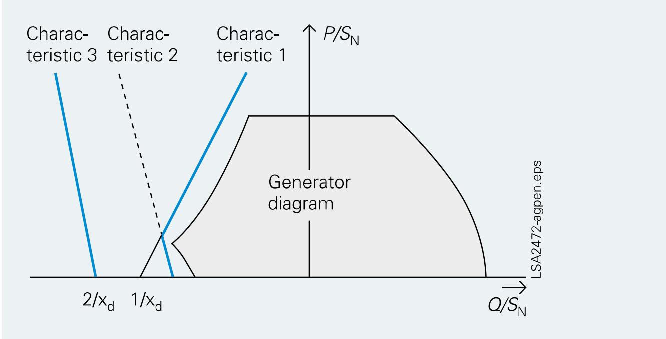

Fig. 11/6 Characteristic of underexcitation protection

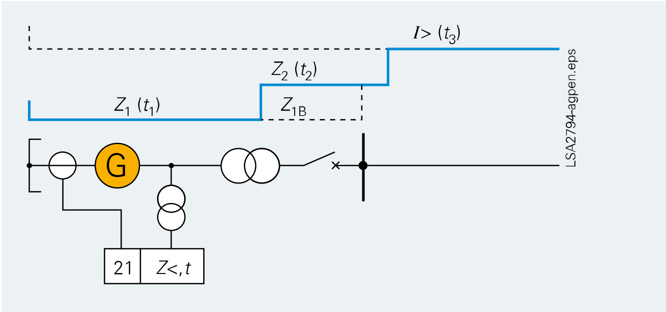

Fig. 11/7 Grading of impedance protection

Frequency protection (ANSI 81)

The frequency protection prevents impermissible stress of the equipment (e.g. turbine) in case of under or overfrequency. It also serves as a monitoring and control element.

The function has four stages; the stages can be implemented either as underfrequency or overfrequency protection. Each stage can be delayed separately.

Even in the event of voltage distortion, the frequency measuring algorithm reliably identifies the fundamental waves and determines the frequency extremely precisely. Frequency measurement can be blocked by using an undervoltage stage.

Overexcitation protection Volt/Hertz (ANSI 24)

The overexcitation protection serves for detection of an unpermissible high induction (proportional to *V*/*f*) in generators or transformers, which leads to thermal overloading. This may occur when starting up, shutting down under full load, with weak systems or under isolated operation. The inverse characteristic can be set via eight points derived from the manufacturer data.

In addition, a definite-time alarm stage and an instantaneous stage can be used. For calculation of the *V*/*f* ratio, frequency and also the highest of the three line-to-line voltages are used. The frequency range that can be monitored comprises 11 to 69 Hz.

90 % stator ground-fault protection, non-directional, directional (ANSI 59N, 64G, 67G)

Ground faults manifest themselves in generators that are operated in isolation by the occurence of a displacement voltage. In case of unit connections, the displacement voltage is an adequate, selective criterion for protection.

For the selective ground-fault detection, the direction of the flowing ground current has to be evaluated too, if there is a direct connection between generator and busbar.

The protection relay measures the displacement voltage at a VT located at the transformer star point or at the broken delta winding of a VT. As an option, it is also possible to calculate the zero-sequence voltage from the phase-to-ground voltages.

Depending on the load resistor selection, 90 to 95 % of the stator winding of a generator can be protected.

A sensitive current input is available for ground-current measurement. This input should be connected to a core-balance current transformer. The fault direction is deduced from the displacement voltage and ground current. The directional characteristic (straight line) can be easily adapted to the system conditions. Effective protection for direct connection of a generator to a busbar can therefore be established. During startup, it is possible to switch over from the directional to the displacement voltage measurement via an externally injected signal.

Depending on the protection setting, various ground-fault protection concepts can be implemented with this function (see Figures 11/51 to 11/54).

Sensitive ground-fault protection (ANSI 50/51GN, 64R)

The sensitive ground-current input can also be used as separate ground-fault protection. It is of two-stage form. Secondary ground currents of 2 mA or higher can be reliably handled.

Alternatively, this input is also suitable as rotor ground-fault protection. A voltage with rated frequency (50 or 60 Hz) is connected in the rotor circuit via the interface unit 7XR61. If a higher ground current is flowing, a rotor ground fault has occurred. Measuring circuit monitoring is provided for this application (see Figure 11/56).

100 % stator ground-fault protection with 3rd harmonic (ANSI 59TN, 27TN (3rd H.))

Owing to the creative design, the generator produces a 3rd harmonic that forms a zero phase-sequence system. It is verifiable by the protection on a broken delta winding or on the neutral transformer. The magnitude of the voltage amplitude depends on the generator and its operation.

In the event of an ground fault in the vicinity of the neutral point, there is a change in the amplitude of the 3rd harmonic voltage (dropping in the neutral point and rising at the terminals).

Depending on the connection the protection must be set either as undervoltage or overvoltage protection. It can also be delayed. So as to avoid overfunction, the active power and the positive-sequence voltage act as enabling criteria.

The picked-up threshold of the voltage stage is restrained by the active power. This increases sensitivity at low load.

The final protection setting can be made only by way of a primary test with the generator.

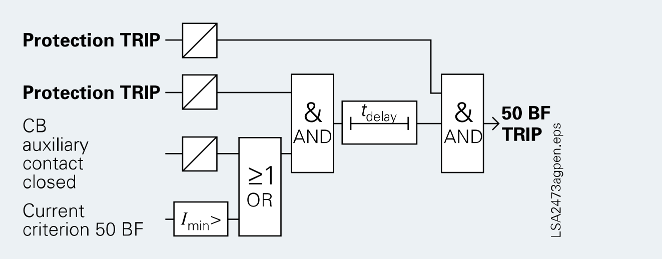

Fig. 11/8 Logic diagram of breaker failure protection

Breaker failure protection (ANSI 50BF)

In the event of scheduled downtimes or a fault in the generator, the generator can remain on line if the circuit-breaker is defective and could suffer substantial damage.

Breaker failure protection evaluates a minimum current and the circuit-breaker auxiliary contact. It can be started by internal protective tripping or externally via binary input. Two-channel activation avoids overfunction (see Figure 11/41).

Inadvertent energization protection (ANSI 50, 27)

This protection has the function of limiting the damage of the generator in the event of an unintentional switch-on of the circuit-breaker, whether the generator is standing still or rotating without being excited or synchronized. If the power system voltage is connected, the generator starts as an asynchronous machine with a large slip and this leads to excessively high currents in the rotor.

A logic circuit consisting of sensitive current measurement for each phase, measured value detector, time control and blocking as of a minimum voltage, leads to an instantaneous trip command. If the fuse failure monitor responds, this function is ineffective.

Rotor ground-fault protection (ANSI 64R)

This protection function can be realized in three ways with the 7UM62. The simplest form is the method of rotor-current measurement (see sensitive ground-current measurement).

Resistance measurement at system-frequency voltage

The second form is rotor ground resistance measurement with voltage at system frequency (see Fig. 11/56). This protection measures the voltage injected and the flowing rotor ground current. Taking into account the complex impedance from the coupling device (7XR61), the rotor ground resistance is calculated by way of a mathematical model. By means of this method, the disturbing influence of the rotor ground capacitance is eliminated, and sensitivity is increased. Fault resistance values up to 30 kΩ can be measured if the excitation voltage is without disturbances. Thus, a two-stage protection function, which features a warning and a tripping stage, can be realized. An additionally implemented undercurrent stage monitors the rotor circuit for open circuit and issues an alarm.

Resistance measurement with a square wave voltage of 1 to 3 Hz

A higher sensitivity is required for larger generators. On the one hand, the disturbing influence of the rotor ground capacitance must be eliminated more effectively and, on the other hand, the noise ratio with respect to the harmonics (e.g. sixth harmonic) of the excitation equipment must be increased. Injecting a low-frequency square wave voltage into the rotor circuit has proven itself excellently here (see Figure 11/57).

The square wave voltage injected through the controlling unit 7XT71 leads to permanent recharging of the rotor ground capacitance. By way of a shunt in the controlling unit, the flowing ground current is measured and is injected into the protection unit (measurement input). In the absence of a fault ($R_E \approx \infty$), the rotor ground current after charging of the ground capacitance is close to zero. In the event of an ground fault, the fault resistance including the coupling resistance (7XR6004), and also the injecting voltage, defines the stationary current. The current square wave voltage and the frequency are measured via the second input (control input). Fault resistance values up to 80 kΩ can be measured by this measurement principle. The rotor ground circuit is monitored for discontinuities by evaluation of the current during the polarity reversals.

100% stator ground-fault protection with 20 Hz injection (ANSI 64 G (100%))

Injecting a 20 Hz voltage to detect ground faults even at the neutral point of generators has proven to be a safe and reliable method. Contrary to the third harmonic criterion (see page 11/8), it is independent of the generator's characteristics and the mode of operation. Measurement is also possible during system standstill (Fig. 11/56).

This protection function is designed so as to detect both ground faults in the entire generator (genuine 100 %) and all electrically connected system components.

The protection unit measures the injected 20 Hz voltage and the flowing 20 Hz current. The disturbing variables, for example stator ground capacitance, are eliminated by way of a mathematical model, and the ohmic fault resistance is determined.

On the one hand, this ensures high sensitivity and, on the other hand, it permits use of generators with large ground capacitance values, e.g. large hydroelectric generators. Phase-angle errors through the grounding or neutral transformer are measured during commissioning and are corrected in the algorithm.

The protection function has a warning and tripping stage. The measurement circuit is also monitored and failure of the 20 Hz generator is measured.

Independent of ground resistance calculation, the protection function additionally evaluates the amount of the r.m.s. current value.

Starting time supervision (motor protection only) (ANSI 48)

Starting time supervision protects the motor against long unwanted start-ups, which might occur as a result of excessive load torque or excessive voltage drops within the motor, or if the rotor is locked.

The tripping time is dependent on the square of the start-up current and the set start-up time (Inverse Characteristic). It adapts itself to the start-up with reduced voltage. The tripping time is determined in accordance with the following formula:

$$t_{Trip} = \left(\frac{I_{start}}{I_{rms}}\right)^2 \cdot t_{start\ max}$$

t_{Trip}	Tripping time
I_{start}	Permissible start-up current
$t_{start\ max}$	Permissible start-up time
I_{rms}	Measured r.m.s. current value

Calculation is not started until the current I_{rms} is higher than an adjustable response value (e.g. 2 $I_{N,\ MOTOR}$).

If the permissible locked-rotor time is less than the permissible start-up time (motors with a thermally critical rotor), a binary signal is set to detect a locked rotor by means of a tachometer generator. This binary signal releases the set locked-rotor time, and tripping occurs after it has elapsed.

DC voltage time protection/DC current time protection (ANSI 59N (DC) 51N (DC))

Hydroelectric generators or gas turbines are started by way of frequency starting converters. An ground fault in the intermediate circuit of the frequency starting converter causes DC voltage displacement and thus a direct current. As the neutral or grounding transformers have a lower ohmic resistance than the voltage transformers, the largest part of the direct current flows through them, thus posing a risk of destruction from thermal overloading.

As shown in Fig. 11/55, the direct current is measured by means of a shunt transformer (measuring transducer) connected directly to the shunt. Voltages or currents are fed to the 7UM62 depending on the version of the measuring transducer. The measurement algorithm filters out the DC component and takes the threshold value decision. The protection function is active as from 0 Hz.

If the measuring transducer transmits a voltage for protection, the connection must be interference-free and must be kept short.

The implemented function can also be used for special applications. Thus, the r.m.s. value can be evaluated for the quantity applied at the input over a wide frequency range.

Overcurrent protection during start-up (ANSI 51)

Gas turbines are started by means of frequency starting converters. Overcurrent protection during start-up measures short-circuits in the lower frequency level (as from about 5 Hz) and is designed as independent overcurrent-time protection. The pickup value is set below the rated current. The function is only active during start-up. If frequencies are higher than 10 Hz, sampling frequency correction takes effect and the further short-circuit protection functions are active.

Out-of-step protection (ANSI 78)

This protection function serves to measure power swings in the system. If generators feed to a system short-circuit for too long, low frequency transient phenomena (active power swings) between the system and the generator may occur after fault clearing. If the center of power swing is in the area of the block unit, the "active power surges" lead to unpermissible mechanical stressing of the generator and the turbine.

As the currents and voltages are symmetrical, the positive-sequence impedance is calculated on the basis of their positive-sequence components and the impedance trajectory is evaluated. Symmetry is also monitored by evaluation of the

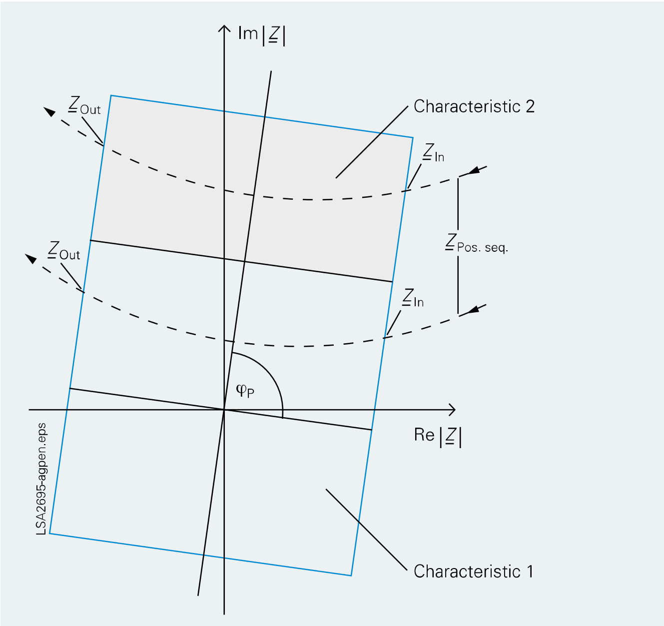

Fig. 11/9 Ranges of the characteristic and possible oscillation profiles

negative-phase-sequence current. Two characteristics in the R/X diagram describe the active range (generator, unit transformer or power system) of the out-of-step protection. The associated counters are incremented depending on the range of the characteristic in which the impedance vector enters or departs. Tripping occurs when the set counter value is reached.

The counters are automatically reset if power swing no longer occurs after a set time. By means of an adjustable pulse, every power swing can be signaled. Expansion of the characteristic in the R direction defines the power swing angle that can be measured. An angle of 120 ° is practicable. The characteristic can be tilted over an adjustable angle to adapt to the conditions prevailing when several parallel generators feed into the system.

Inverse undervoltage protection (ANSI 27)

Motors tend to fall out of step when their torque is less than the breakdown torque. This, in turn, depends on the voltage. On the one hand, it is desirable to keep the motors connected to the system for as long as possible while, on the other hand, the torque should not fall below the breakdown level. This protection task is realized by inverse undervoltage protection. The inverse characteristic is started if the voltage is less than the pickup threshold V_p<. The tripping time is inversely proportional to the voltage dip (see equation). The protection function uses the positive-sequence voltage, for the protection decision.

$$t_{TRIP} = \frac{I}{I - \frac{V}{V_P}} \cdot T_M$$

t_{TRIP}	Tripping time
V	Voltage
V_p	Pickup value
T_M	Time multiplier

System disconnection

Take the case of in-plant generators feeding directly into a system. The incoming line is generally the legal entity boundary between the system owner and the in-plant generator. If the incoming line fails as the result of auto-reclosure, for instance, a voltage or frequency deviation may occur depending on the power balance at the feeding generator. Asynchronous conditions may arise in the event of connection, which may lead to damage on the generator or the gearing between the generator and the turbine. Besides the classic criteria such as voltage and frequency, the following two criteria are also applied: vector jump, rate-of-frequency-change protection.

Rate-of-frequency-change protection (ANSI 81)

The frequency difference is determined on the basis of the calculated frequency over a time interval. It corresponds to the momentary rate-of-frequency change. The function is designed so that it reacts to both positive and negative rate-of-frequency changes. Exceeding of the permissible rate-of-frequency change is monitored constantly. Release of the relevant direction depends on whether the actual frequency is above or below the rated frequency. In total, four stages are available, and can be used optionally.

Vector jump

Monitoring the phase angle in the voltage is a criterion for identifying an interrupted infeed. If the incoming line should fail, the abrupt current discontinuity leads to a phase angle jump in the voltage. This is measured by means of a delta process. The command for opening the generator or coupler circuit-breaker is issued if the set threshold is exceeded.

Restart inhibit for motors (ANSI 66, 49Rotor)

When cold or at operating temperature, motors may only be connected a certain number of times in succession. The start-up current causes heat development in the rotor which is monitored by the restart inhibit function.

Contrary to classical counting methods, in the restart inhibit function the heat and cooling phenomena in the rotor are simulated by a thermal replica. The rotor temperature is determined on the basis of the stator currents. Restart inhibit permits restart of the motor only if the rotor has enough thermal reserve for a completely new start. Fig. 11/43 illustrates the thermal profile for a permissible triple start out of the cold state. If the thermal reserve is too low, the restart inhibit function issues a blocking signal with which the motor starting circuit can be blocked. The blockage is canceled again after cooling down and the thermal value has dropped below the pickup threshold.

As the fan provides no forced cooling when the motor is off, it cools down more slowly. Depending on the operating state, the protection function controls the cooling time constant. A value below a minimum current is an effective changeover criterion.

Sensitive ground-fault protection B (ANSI 51 GN)

The I_{EE-B} sensitive ground-fault protection feature of 7UM62 provides greater flexibility and can be used for the following applications:

- Any kind of ground-fault current supervision to detect ground faults (fundamental and 3rd harmonics)
- Protection against load resistances
- Shaft current protection in order to detect shaft currents of the generator shaft and prevent that bearings take damage.

The sensitive ground-current protection I_{EE-B} uses either the hardware input I_{EE1} or I_{EE2}. These inputs are designed in a way that allows them to cut off currents greater than 1.6 A (thermal limit, see technical data). This has to be considered for the applications or for the selection of the current transformers.

The shaft current protection function is of particular interest in conjunction with hydro-electric generators. Due to their construction, the hydroelectric generators have relatively long shafts. A number of factors such as friction, magnetic fields of the generators and others can build up a voltage across the shaft which then acts as voltage source (electro-motive force-emf). This inducted voltage of approx. 10 to 30 V is dependent on the load, the system and the machine.

If the oil film covering a bearing is too thin, breakdown can occur. Due to the low resistance (shaft, bearing and grounding), high currents may flow that destroy the bearing. Past experience has shown that currents greater than 1 A are critical for the bearings. As different bearings can be affected, the current entering the shaft is detected by means of a special transformer (folding transformer).

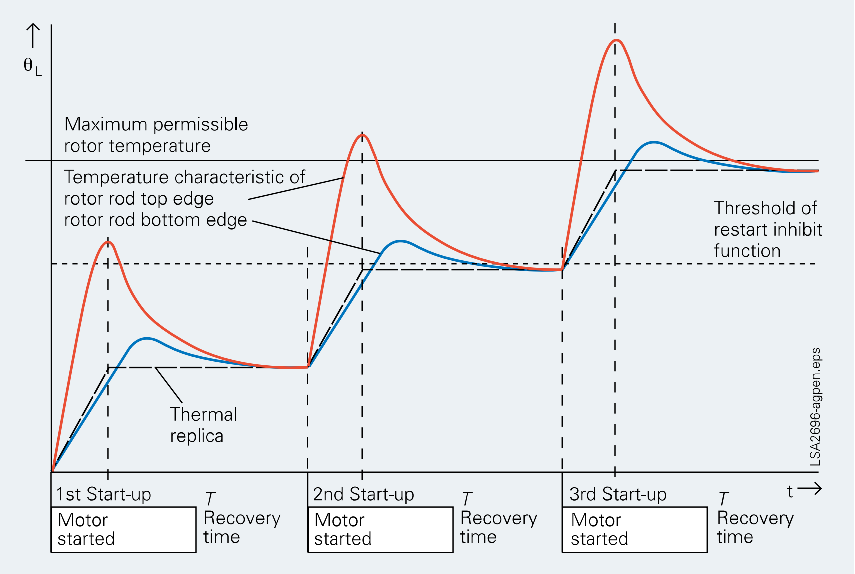

Fig. 11/10 Temperature characteristic at rotor and thermal replica of the rotor (multiple start-ups)

Interturn protection (ANSI 59N (IT))

The interturn fault protection detects faults between turns within a generator winding (phase). This situation may involve relatively high circulating currents that flow in the short-circuited turns and damage the winding and the stator. The protection function is characterized by a high sensitivity.

The displacement voltage is measured at the open delta winding by means of 3 two-phase isolated voltage transformers. So as to be insensitive towards ground faults, the isolated voltage transformer star point has to be connected to the generator star point by means of a high-voltage cable. The voltage transformer star point must not be grounded since this implies that the generator star point, too, would be grounded with the consequence that each fault would lead to a single-pole ground fault.

In the event of an interturn fault, the voltage in the affected phase will be reduced causing a displacement voltage that is detected at the broken delta winding. The sensitivity is limited rather by the winding asymmetries than by the protection unit.

An FIR filter determines the fundamental component of the voltage based an the scanned displacement voltage. Selecting an appropriate window function has the effect that the sensitivity towards higher-frequency oscillations is improved and the disturbing influence of the third harmonic is eliminated while achieving the required measurement sensitivity.

External trip coupling

For recording and processing of external trip information, there are 4 binary inputs. They are provided for information from the Buchholz relay or generator-specific commands and act like a protection function. Each input initiates a fault event and can be individually delayed by a timer.

Trip circuit supervision (ANSI 74TC)

One or two binary inputs can be used for monitoring the circuit-breaker trip coil including its incoming cables. An alarm signal occurs whenever the circuit is interrupted.

Phase rotation reversal

If the relay is used in a pumped-storage power plant, matching to the prevailing rotary field is possible via a binary input (generator/motor operation via phase rotation reversal).

2 pre-definable parameter groups

In the protection, the setting values can be stored in two data sets. In addition to the standard parameter group, the second group is provided for certain operating conditions (pumped-storage power stations). It can be activated via binary input, local control or DIGSI 4.

Lockout (ANSI 86)

All binary outputs (alarm or trip relays) can be stored like LEDs and reset using the LED reset key. The lockout state is also stored in the event of supply voltage failure. Reclosure can only occur after the lockout state is reset.

Fuse failure and other monitoring

The relay comprises high-performance monitoring for the hardware and software.

The measuring circuits, analog-digital conversion, power supply voltages, memories and software sequence (watch-dog) are all monitored.

The fuse failure function detects failure of the measuring voltage due to short-circuit or open circuit of the wiring or VT and avoids overfunction of the undervoltage elements in the protection functions.

The positive and negative-sequence system (voltage and current) are evaluated.

Filter time

All binary inputs can be subjected to a filter time (indication suppression).

Communication

With respect to communication, particular emphasis has been placed on high levels of flexibility, data integrity and utilization of standards common in energy automation. The design of the communication modules permits interchangeability on the one hand, and on the other hand provides openness for future standards (for example, Industrial Ethernet).

Local PC interface

The PC interface accessible from the front of the unit permits quick access to all parameters and fault event data. The use of the DIGSI 4 operating program during commissioning is particularly advantageous.

Rear-mounted interfaces

Two communication modules on the rear of the unit incorporate optional equipment complements and permit retrofitting. They assure the ability to comply with the requirements of different communication interfaces (electrical or optical) and protocols (IEC 60870, PROFIBUS, DIGSI).

The interfaces make provision for the following applications:

Service interface (fixed)

In the RS485 version, several protection units can be centrally operated with DIGSI 4. By using a modem, remote control is possible. This provides advantages in fault clearance, in particular in unmanned substations.

System interface

This is used to communicate with a control or protection and control system and supports, depending on the module connected, a variety of communication protocols and interface designs. Furthermore, the units can exchange data through this interface via Ethernet and IEC 61850 protocol and can also be operated by DIGSI.

IEC 61850 protocol

The Ethernet-based IEC 61850 protocol is the worldwide standard for protection and control systems used by power supply corporations. Siemens is of the first manufacturer to support this standard. By means of this protocol, information can also be exchanged directly between bay units so as to set up simple masterless systems for bay and system interlocking. Access to the units via the Ethernet bus will also be possible with DIGSI.

IEC 60870-5-103

IEC 60870-5-103 is an internationally standardized protocol for communication in the protected area.

IEC 60870-5-103 is supported by a number of protection unit manufacturers and is used worldwide.

The generator protection functions are stored in the manufacturer-specific, published part of the protocol.

PROFINET

PROFINET is the ethernet-based successor of Profi bus DP and is supported in the variant PROFINET IO. The protocol which is used in industry together with the SIMATIC systems control is realized on the optical and electrical Plus ethernet modules which are delivered since November 2012. All network redundancy procedures which are available for the ethernet modules, such as RSTP, PRP or HSR, are also available for PROFINET.

The time synchronization is made via SNTP. The network monitoring is possible via SNMP V2 where special MIB files exist for PROFINET. The LLDP protocol of the device also supports the monitoring of the network topology. Single-point indications, double-point indications, measured and metered values can be transmitted cyclically in the monitoring direction via the protocol and can be selected by the user with DIGSI 4. Important events are also transmitted spontaneously via confi gurable process alarms. Switching commands can be executed by the system control via the device in the controlling direction.

The PROFINET implementation is certified. The device also supports the IEC 61850 protocol as a server on the same ethernet module in addition to the PROFINET protocol. Client server connections are possible for the intercommunication between devices, e.g. for transmitting fault records and GOOSE messages.

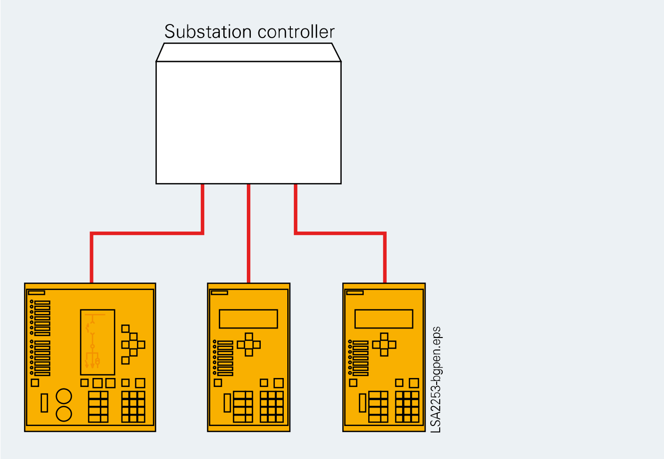

Fig. 11/11 IEC 60870-5-103 star-type RS232 copper conductor connection or fiber-optic connection

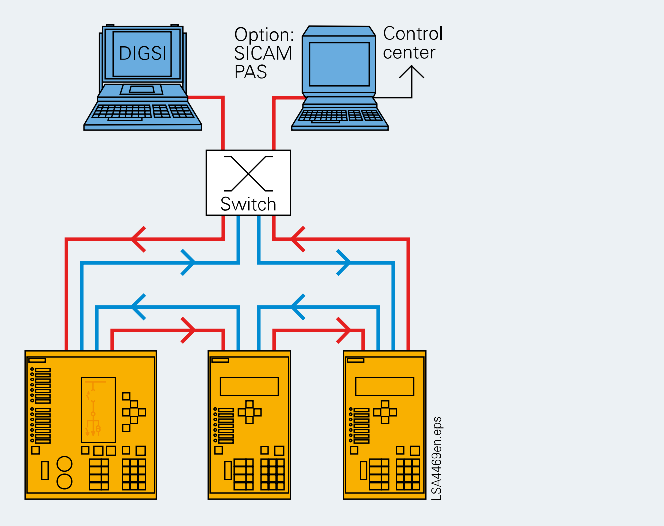

Fig. 11/12 Bus structure for station bus with Ethernet and IEC 61850, fiber-optic ring

Communication

PROFIBUS DP

PROFIBUS is an internationally standardized communication protocol (EN 50170). PROFIBUS is supported internationally by several hundred manufacturers and has to date been used in more than 1,000,000 applications all over the world.

With the PROFIBUS DP, the protection can be directly connected to a SIMATIC S5/S7. The transferred data are fault data, measured values and information from or to the logic (CFC).

MODBUS RTU

MODBUS is also a widely utilized communication standard and is used in numerous automation solutions.

DNP 3.0

DNP 3.0 (Distributed Network Protocol version 3) is a messaging-based communication protocol. The SIPROTEC 4 units are fully Level 1 and Level 2 compliant with DNP 3.0. DNP 3.0 is supported by a number of protection device manufacturers.

Safe bus architecture

- RS485 bus
  With this data transmission via copper conductors, electromagnetic interference influences are largely eliminated by the use of twisted-pair conductor. Upon failure of a unit, the remaining system continues to operate without any faults.
- Fiber-optic double ring circuit
  The fiber-optic double ring circuit is immune to electromagnetic interference. Upon failure of a section between two units, the communication system continues to operate without disturbance.

System solution

SIPROTEC 4 is tailor-made for use in SIMATIC-based automation systems.

Via the PROFIBUS DP, indications (pickup and tripping) and all relevant operational measured values are transmitted from the protection unit.

Via modem and service interface, the protection engineer has access to the protection devices at all times. This permits remote maintenance and diagnosis (cyclic testing).

Parallel to this, local communication is possible, for example, during a major inspection.

For IEC 61850, an interoperable system solution is offered with SICAM PAS. Via the 100 Mbit/s Ethernet bus, the unit are linked with PAS electrically or optically to the station PC. The interface is standardized, thus also enabling direct connection of units of other manufacturers to the Ethernet bus. With IEC 61850, however, the units can also be used in other manufacturers' systems (see Fig. 11/45).

Fig. 11/13 RS232/RS485 Electrical communication module

Fig. 11/14 820 nm fiber-optic communication module

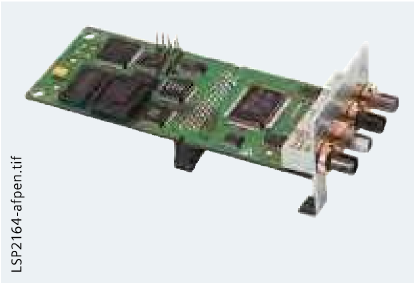

Fig. 11/15 PROFIBUS communication module optical, double-ring

Fig. 11/16 Optical Ethernet communication module for IEC 61850 with integrated Ethernet switch

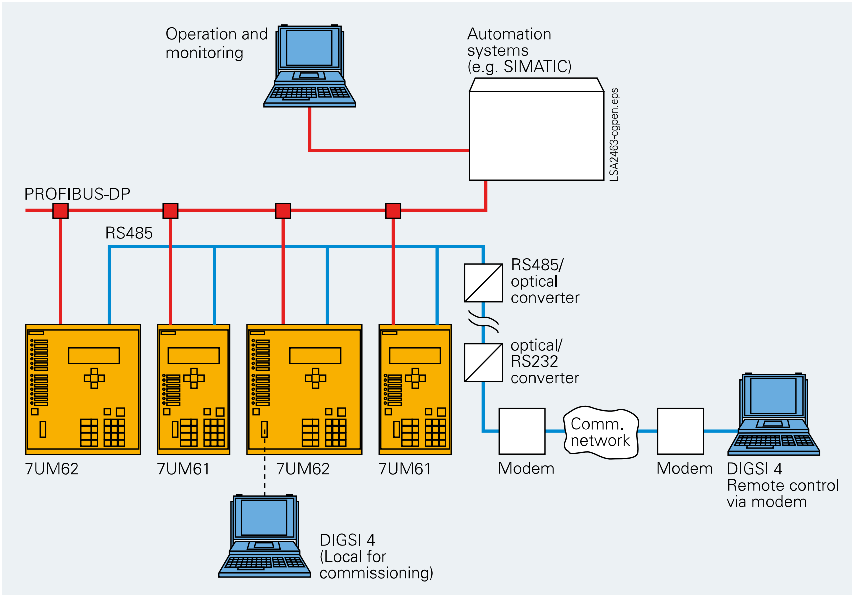

Fig. 11/17 System solution: Communications

Analog output 0 to 20 mA

Alternatively to the serial interfaces up to two analog output modules (4 channels) can be installed in the 7UM62.

Several operational measured values (I_1, I_2, V, P, Q, f, PF (cos φ), $\square_{\text{stator}}$, $\square_{\text{rotor}}$) can be selected and transmitted via the 0 to 20 mA interfaces.

Typical connections

Direct generator – busbar connection

Figure 11/51 illustrates the recommended standard connection when several generators supply one busbar. Phase-to-ground faults are disconnected by employing the directional ground-fault criterion. The ground-fault current is driven through the cables of the system.
If this is not sufficient, an grounding transformer connected to the busbar supplies the necessary current (maximum approximately 10 A) and permits a protection range of up to 90 %. The ground-fault current should be detected by means of core-balance current transformers in order to achieve the necessary sensitivity. The displacement voltage can be used as ground-fault criterion during starting operations until synchronization is achieved.

Differential protection embraces protection of the generator and of the outgoing cable. The permissible cable length and the current transformer design (permissible load) are mutually dependent. Recalculation is advisable for lengths of more than 100 m.

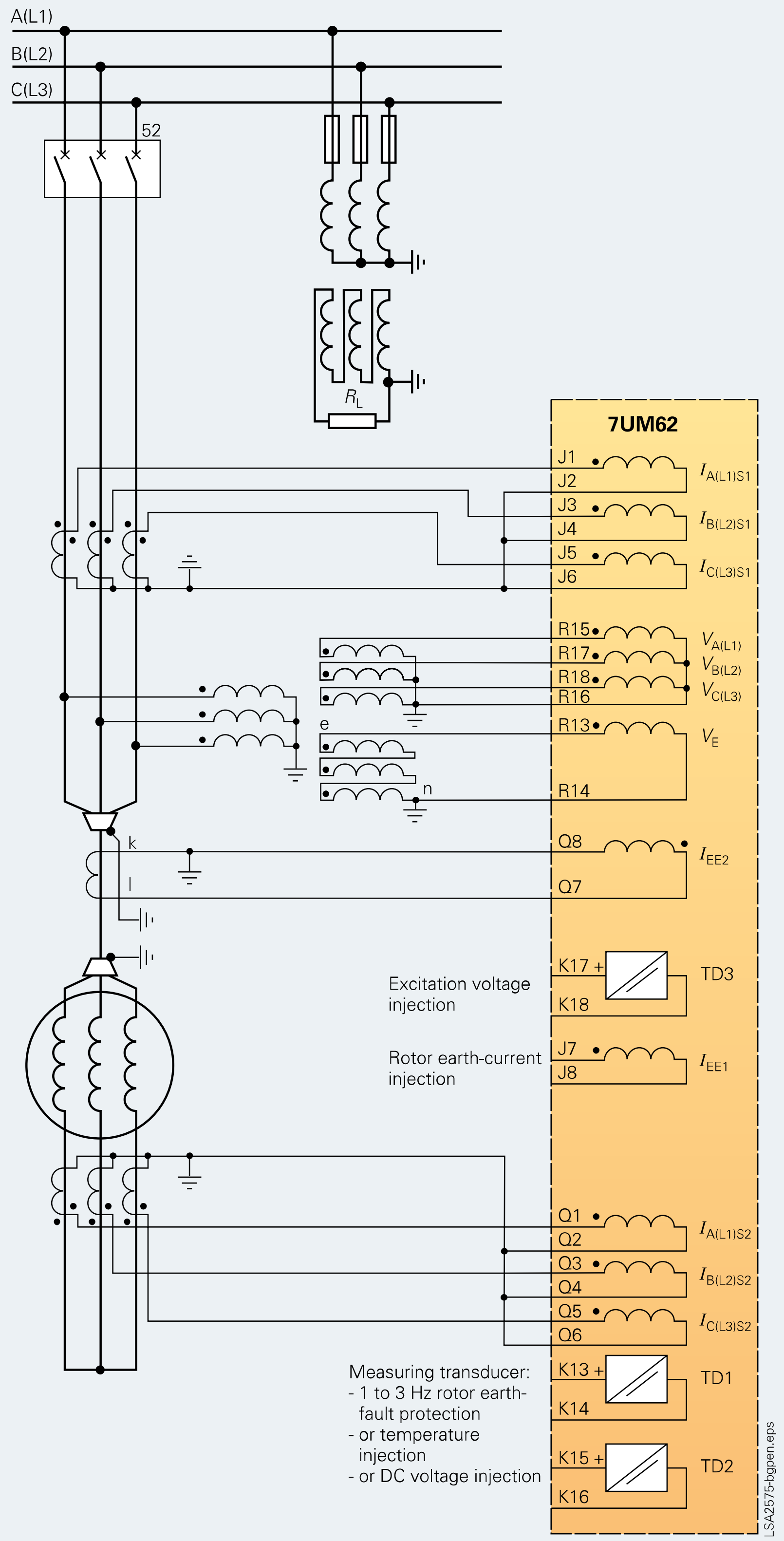

Fig. 11/18

Typical connections

Direct generator – busbar connection with low-resistance grounding

If the generator neutral point has low-resistance grounding, the connection illustrated in Fig. 11/52 is recommended. In the case of several generators, the resistance must be connected to only one generator, in order to prevent circulating currents (3rd harmonic).

For selective ground-fault detection, the ground-current input should be looped into the common return conductor of the two current transformer sets (differential connection). The current transformers must be grounded at only one point. The displacement voltage V_E is utilized as an additional enabling criterion.

Balanced current transformers (calibration of windings) are desirable with this form of connection. In the case of higher generator power (for example, I_N approximately 2000 A), current transformers with a secondary rated current of 5 A are recommended.

Ground-current differential protection can be used as an alternative (not illustrated).

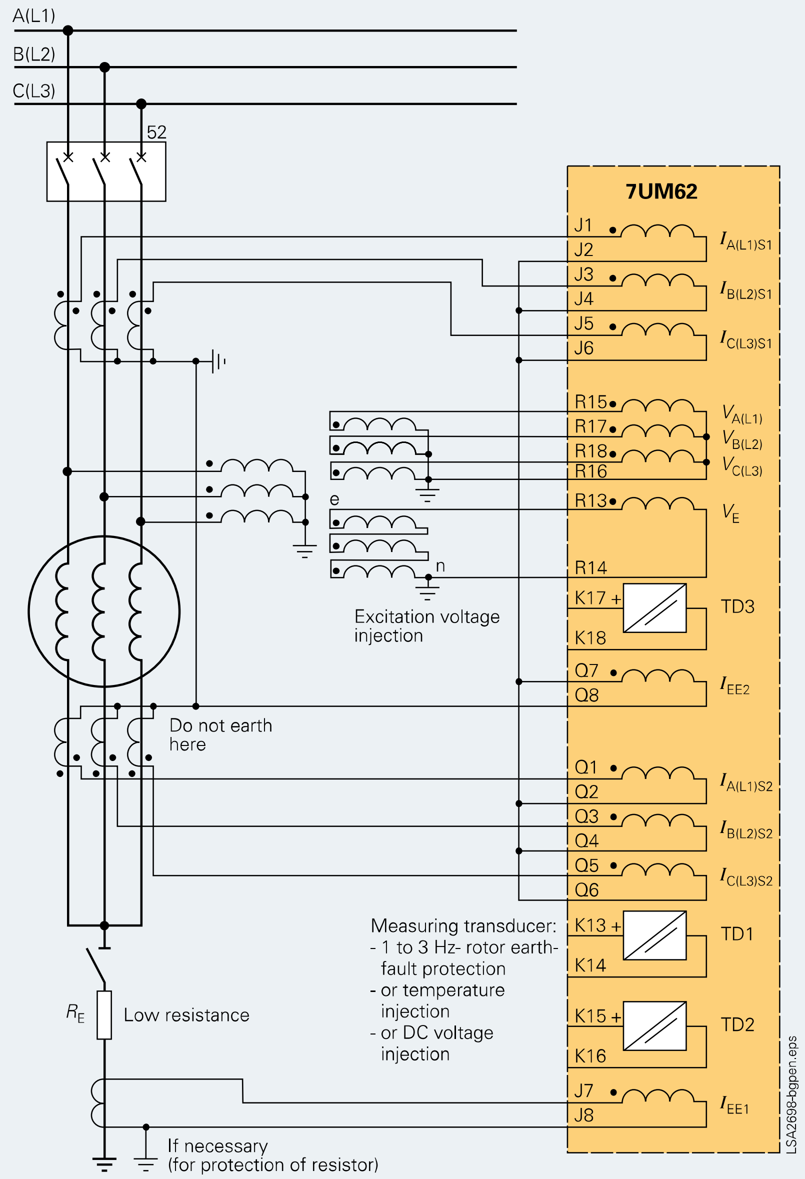

Fig. 11/19

Unit connection with isolated star point

This configuration of unit connection is a variant to be recommended (see Fig. 11/53). Ground-fault detection is effected by means of the displacement voltage. In order to prevent unwanted operation in the event of ground faults in the system, a load resistor must be provided at the broken delta winding. Depending on the plant (or substation), a voltage transformer with a high power (VA) may in fact be sufficient. If not, an grounding transformer should be employed. The available measuring winding can be used for the purpose of voltage measurement.

In the application example, differential protection is intended for the generator. The unit transformer is protected by its own differential relay (e.g. 7UT612).

As indicated in the figure, additional protection functions are available for the other inputs. They are used on larger generator/transformer units (see also Figures 11/56 and 11/58).

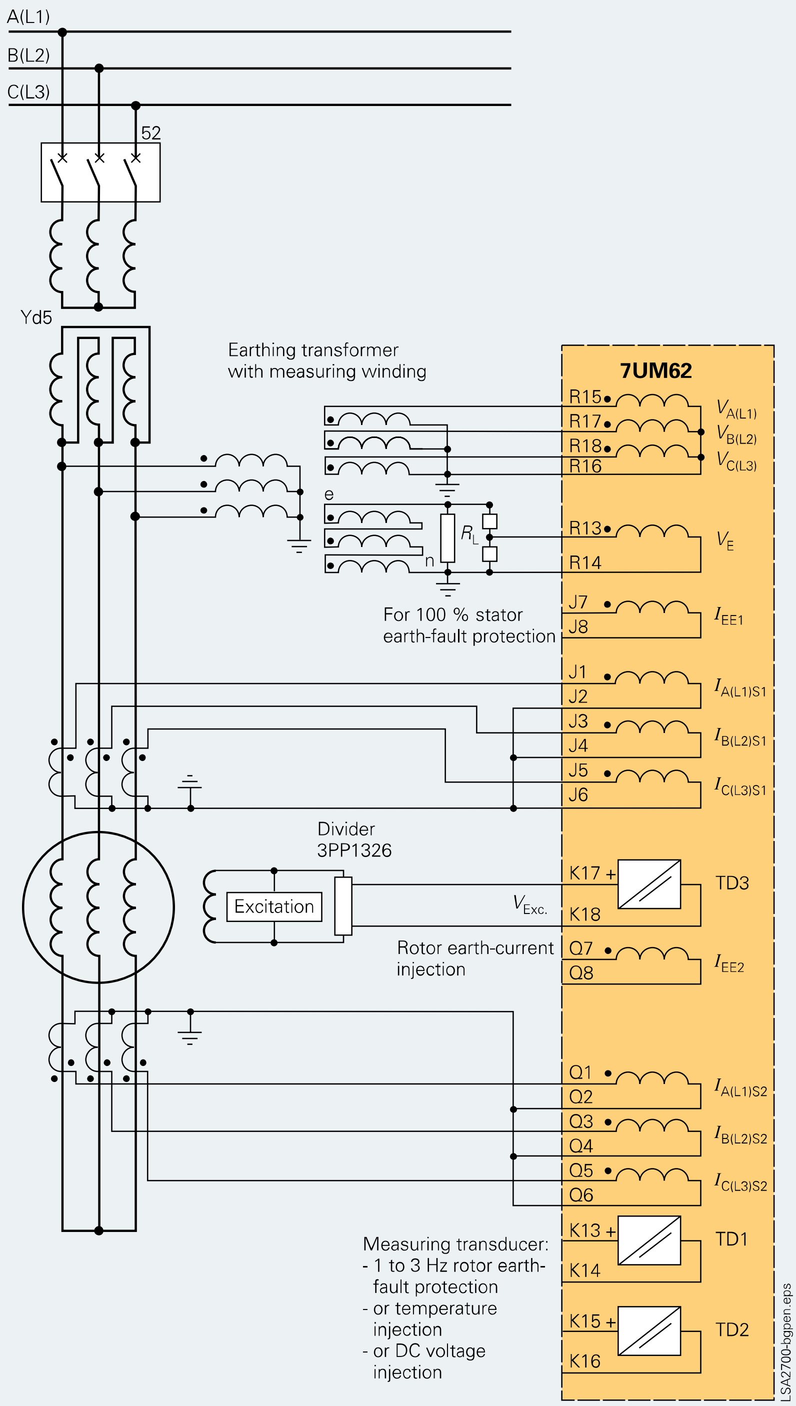

Fig. 11/20

Typical connections

Unit connection with neutral transformer

With this system configuration, disturbance voltage reduction and damping in the event of ground faults in the generator area are effected by a load resistor connected to the generator neutral point.

The maximum ground-fault current is limited to approximately 10 A. Configuration can take the form of a primary or secondary resistor with neutral transformer. In order to avoid low secondary resistance, the transformation ratio of the neutral transformer should be below

$$\left(\frac{V_{Gen}}{\sqrt{3}} \Big/ 500\ \text{V}\right)$$

The higher secondary voltage can be reduced by means of a voltage divider.

Electrically, the circuit is identical to the configuration in Fig. 11/53.

In the application opposite, the differential protection is designed as an overall function and embraces the generator and unit transformer. The protection function carries out vector group adaptation as well as other adaptations.

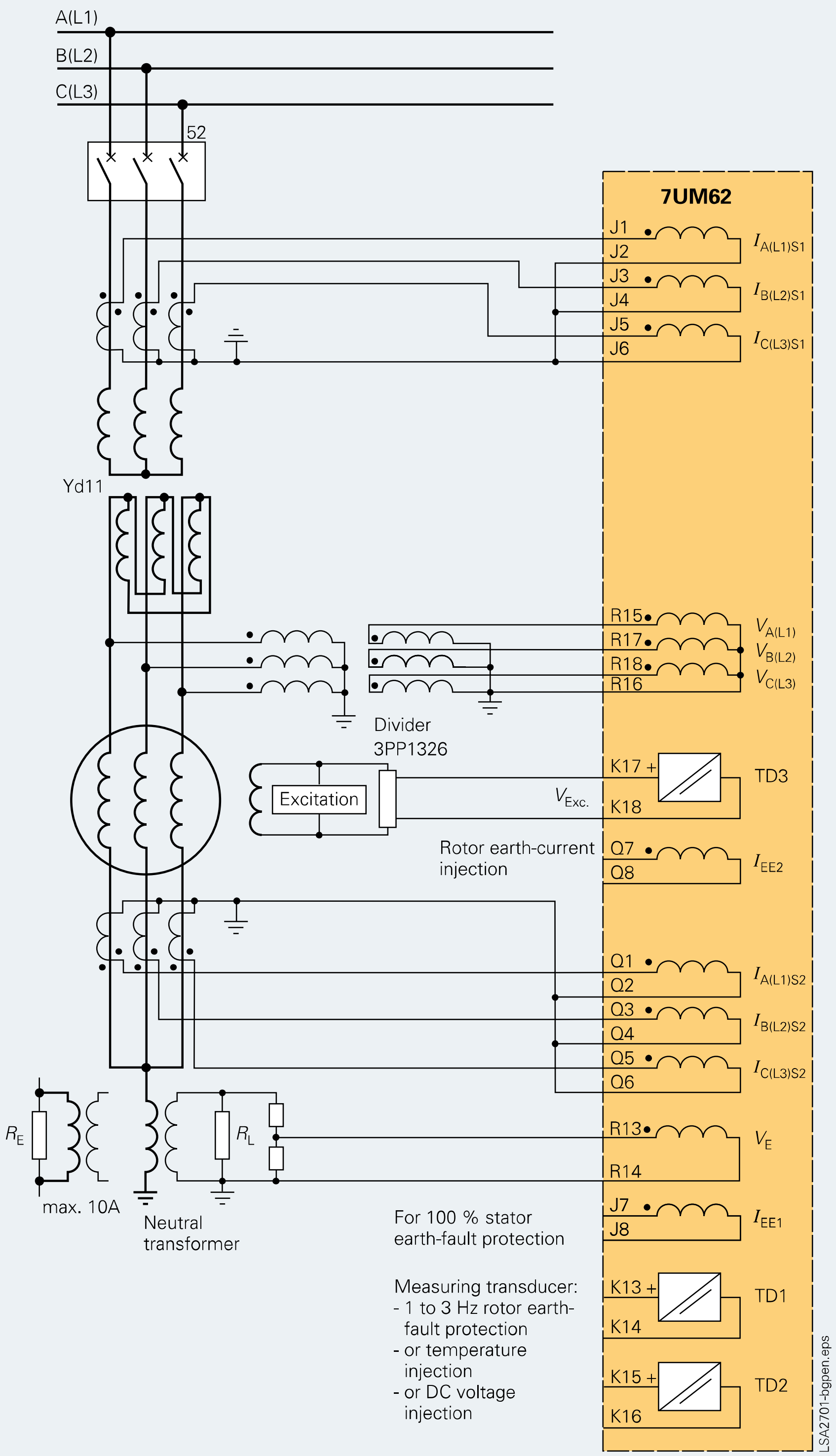

Fig. 11/21

Voltage transformer in open delta connection (V-connection)

Protection can also be implemented on voltage transformers in open delta connection (Fig. 11/55). If necessary, the operational measured values for the phase-to-ground voltages can be slightly asymmetrical. If this is disturbing, the neutral point (R16) can be connected to ground via a capacitor.

In the case of open delta connection, it is not possible to calculate the displacement voltage from the secondary voltages. It must be passed to the protection relay along a different path (for example, voltage transformer at the generator neutral point or from the grounding transformer).

100 % stator ground-fault protection, ground-fault protection during start-up

Fig. 11/56 illustrates the interfacing of 100 % stator ground-fault protection with voltage injection of 20 Hz, as meant for the example of the neutral transformer. The same interfacing connection also applies to the broken delta winding of the grounding transformer.

The 20 Hz generator can be connected both to the DC voltage and also to a powerful voltage transformer (>100 VA). The load of the current transformer 4NC1225 should not exceed 0.5 Ω.

The 7XT33, 7XT34 and load resistance connection must be established with a low resistance ($R_{Connection} < R_L$). If large distances are covered, the devices are accommodated in the grounding cubicle.

Connection of the DC voltage protection function (TD 1) is shown for systems with a starting converter. Depending on the device selection, the 7KG6 boosts the measured signal at the shunt to 10 V or 20 mA.

The TD 1 input can be jumpered to the relevant signal.

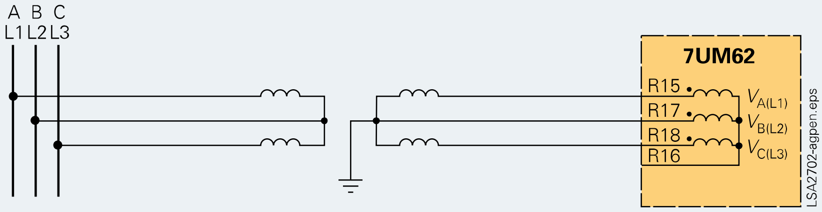

Fig. 11/22

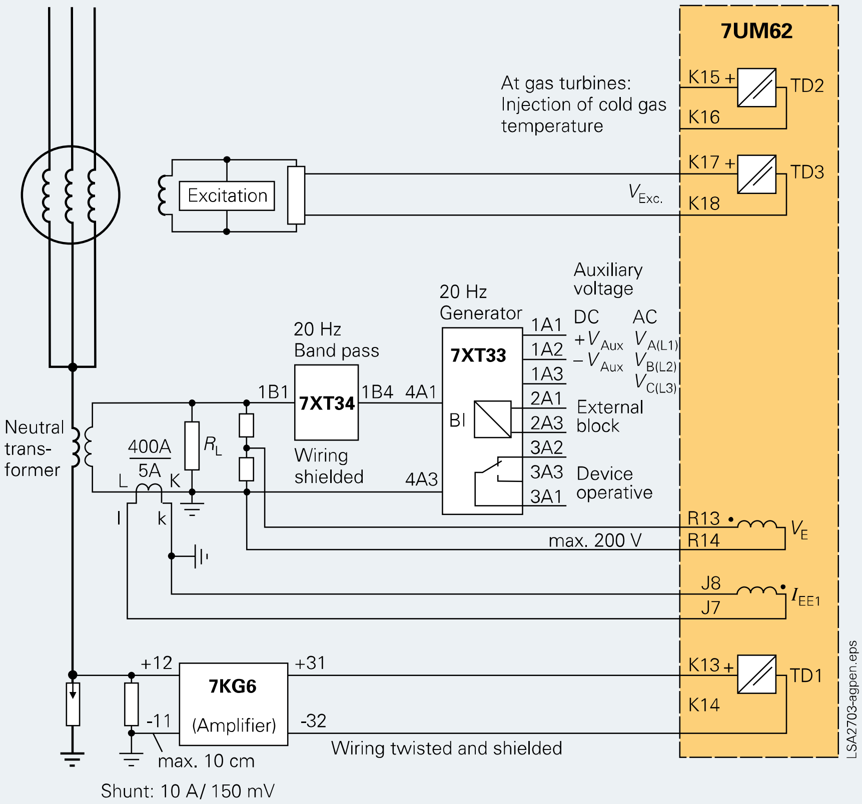

Fig. 11/23

Typical connections

Rotor ground-fault protection with voltage injection at rated frequency

Fig. 11/57 shows the connection of rotor ground-fault protection to a generator with static excitation. If only the rotor current is evaluated, there is no need for voltage connection to the relay.

Ground must be connected to the grounding brush. The external resistors 3PP1336 must be added to the coupling device 7XR61 if the circulating current can exceed 0.2 A as the result of excitation (sixth harmonic). This is the case as from a rated excitation voltage of >150 V, under worst-case conditions.

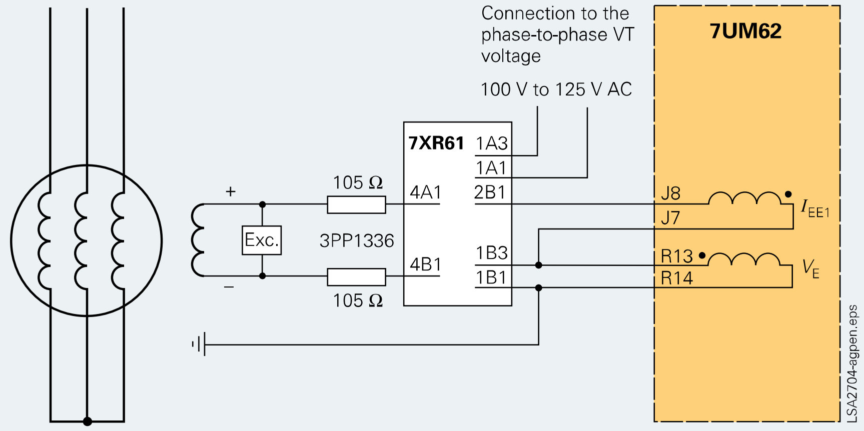

Fig. 11/24

Rotor ground-fault protection with a square wave voltage of 1 to 3 Hz

The measuring transducers TD1 and TD2 are used for this application. The controlling unit 7XT71 generates a square wave voltage of about ± 50 V at the output. The frequency can be jumpered and depends on the rotor ground capacitance. Voltage polarity reversal is measured via the control input and the flowing circular current is measured via the measurement input. Ground must be connected to the grounding brush.

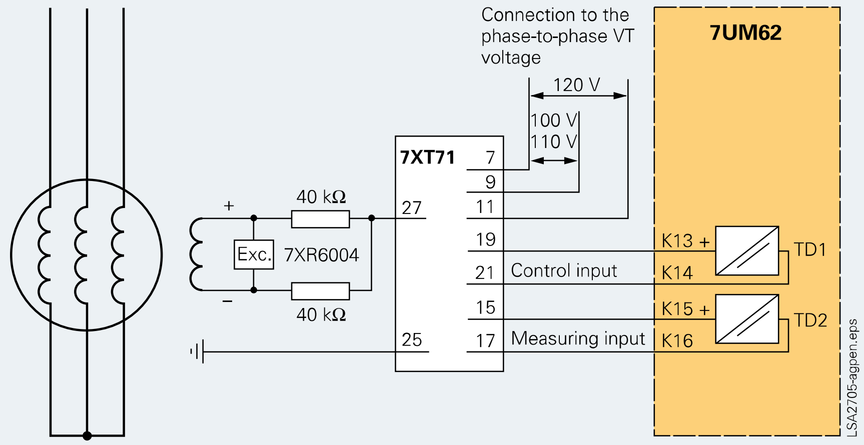

Fig. 11/25

11

Protection of an asynchronous motor

Fig. 11/59 shows a typical connection of the protection function to a large asynchronous motor. Differential protection embraces the motor including the cable. Recalculation of the permissible current transformer burden is advisable for lengths of more than 100 m.

The voltage for voltage and displacement voltage monitoring is generally tapped off the busbar. If several motors are connected to the busbar, ground faults can be detected with the directional ground-fault protection and selective tripping is possible. A core balance current transformer is used to detect the ground current. The chosen pickup value must be slightly higher if there are several cables in parallel.

The necessary shut-down of the motor in the event of idling can be realized with active power monitoring.

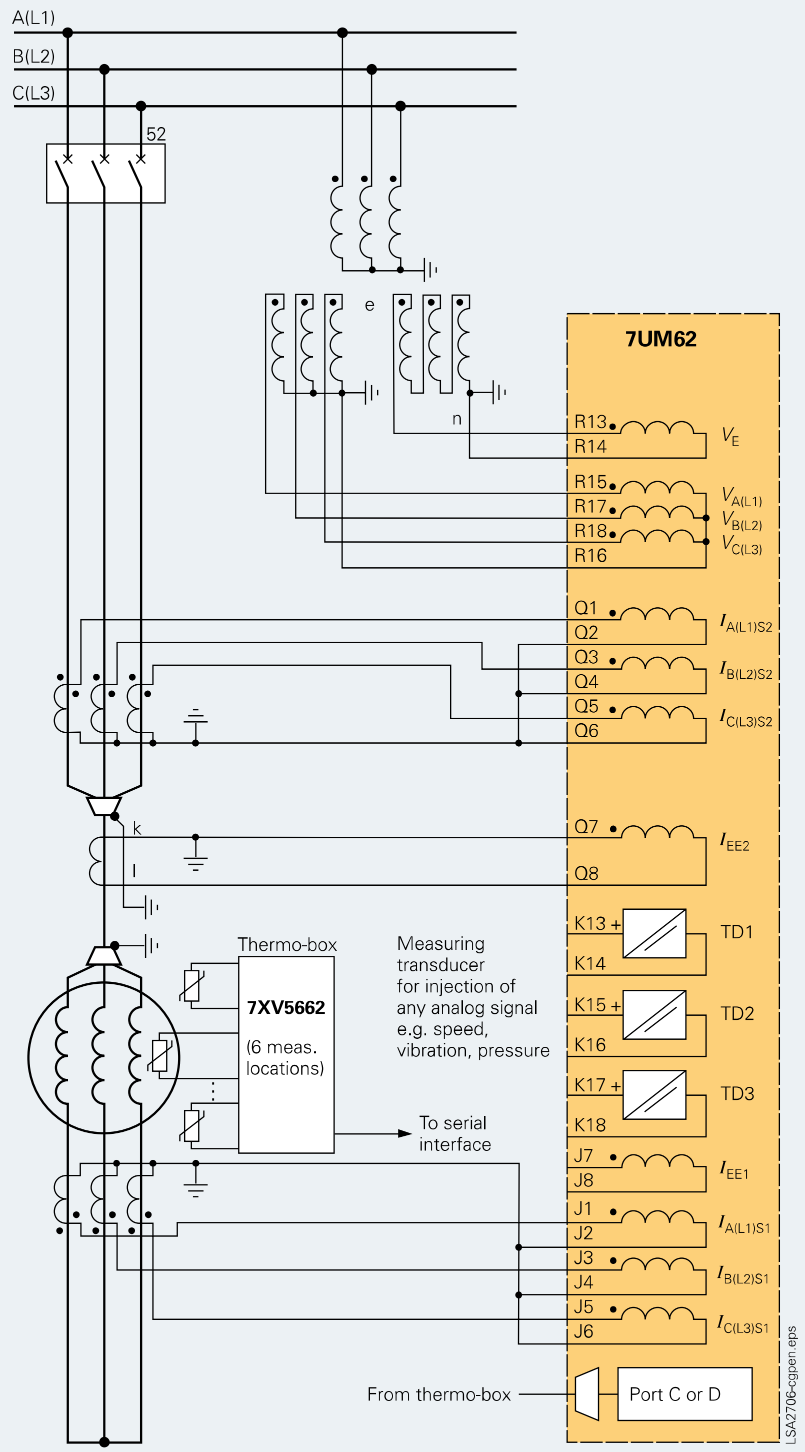

Fig. 11/26

Typical connections

Use of selected analog inputs

Several protection functions take recourse to the same analog inputs, thus ruling out certain functions depending on the application. One input may only be used by one protection function. A different combination can be used by the unit belonging to Protection Group 2, for example.

Multiple use refers to the sensitive ground-current inputs and the displacement voltage input (see Table 11/5).

The same applies to the measuring transducers (Table 11/6).

Current transformer requirements

The requirements imposed on the current transformer are determined by the differential protection function. The instantaneous trip stage (I_{Diff}>>) reliably masters (via the instantaneous algorithm) any high-current internal short-circuits.

The external short-circuit determines the requirements imposed on the current transformer as a result of the DC component. The non-saturated period of a flowing short-circuit current should be at least 5 ms. Table 11/7 shows the design recommendations.

IEC 60044-1 and 60044-6 were taken into account. The necessary equations are shown for converting the requirements into the knee- point voltages. The customary practice which presently applies should also be used to determine the rated primary current of the current transformer rated current. It should be greater than or equal to the rated current of the protected object.

	I_{EE1}	I_{EE2}	V_E
Sensitive ground-fault protection	■1)	■1)	
Directional stator ground-fault protection		■	■
Rotor ground-fault protection (f_n, R-measuring)	■		■
100 % stator ground-fault protection with 20 Hz voltage	■		■
Ground-current differential protection	■1)	■1)	

1) optional (either I_{EE1} or I_{EE2})

Table 11/5 Multiple use of analog inputs

	TD1	TD2	TD3
Injection of excitation voltage			■
DC voltage time/DC current time protection	■		
Injection of a temperature		■	
Rotor ground-fault protection (1 to 3 Hz)	■	■	
Processing of analog values via CFC	■	■	■

Table 11/6 Multiple use of measuring transducers

Symmetrical short-circuit limiting factor

Required actual accuracy limiting factor	Resulting rated accuracy limiting factor
$K'_{SSC} = K_{td} \cdot \frac{I_{pSC}}{I_{pn}}$	$K_{SSC} = \frac{R'_b + R_{CT}}{R_{BN} + R_{CT}} \cdot K'_{SSC}$

Current transformer requirements

	Transformer	*Generator*
Transient dimensioning factor K_{td}	≥ 4 $t_N \leq 100$ ms	> (4 to 5) $t_N > 100$ ms
Symmetrical short-circuit current I_{pssc}	$\approx \frac{1}{v_{sc}} \cdot I_{pn,\,Tr}$	$\approx \frac{1}{x''_d} \cdot I_{pn,\,G}$
Example	$v_{sc} = 0.1$ $K'_{ssc} > 40$	$x''_d = 0.12$ $K'_{ssc} >$ (34 to 42)
Note: Identical transformers have to be employed	Rated power ≥ 10 or 15 VA Example: Network transformer 10P10: (10 or 15) VA (I_{sn} = 1 or 5 A)	Note: Secondary winding resistance Example: $I_{N,\,G}$ approx. 1000 to 2000 A 5P15: 15 VA (I_{sn} = 1 or 5 A) $I_{N,\,G}$ > 5 000 A 5P20: 30 VA (I_{sn} = 1 or 5 A)

Knee-point voltage

IEC	*British Standard*	*ANSI*
$V = K_{SSC}(R_{ct} + R_b) I_{SN}$	$V = \frac{(R_{ct} + R_b) I_{SN}}{1.3} \cdot K_{SSC}$	$V = 20 \cdot I_{SN} \cdot (R_{ct} + R_b) \cdot \frac{K_{SSC}}{20}$ I_{sn} = 5A (typical value)

K_{td}	Rated transient dimensioning factor	R_{ct}	Secondary winding resistance
I_{pssc}	Primary symmetrical short-circuit current	v_{sc}	Short-circuit voltage (impedance voltage)
I_{pn}	Rated primary current (transformer)	x''_d	Subtransient reactance
R'_b	Connected burden	I_{sn}	Rated secondary current (transformer)
R_b	Rated resistive burden	t_N	Network time constant

Table 11/7 Multiple use of measuring transducers

11

General unit data	
Analog inputs	
Rated frequency	50 or 60 Hz
Rated current I_N	1 or 5 A
Ground current, sensitive I_{Emax}	1.6 A
Rated voltage V_N	100 to 125 V
Measuring transducer	- 10 to + 10 V (R_i=1 MΩ) or - 20 to + 20 mA (R_i = 10 Ω)
Power consumption With I_N = 1 A With I_N = 5 A For sensitive ground current Voltage inputs (with 100 V)	 Approx. 0.05 VA Approx. 0.3 VA Approx. 0.05 VA Approx. 0.3 VA
Capability in CT circuits Thermal (r.m.s. values)	 100 I_N for 1 s 30 I_N for 10 s 4 I_N continuous
Dynamic (peak)	250 I_N (one half cycle)
Ground current, sensitive	300 A for 1 s 100 A for 10 s 15 A continuous
Dynamic (peak)	750 A (one half cycle)
Capability in voltage paths	230 V continuous
Capability of measuring transducer As voltage input As current input	 60 V continuous 100 mA continuous
Auxiliary voltage	
Rated auxiliary voltage	DC 24 to 48 V DC 60 to 125 V DC 110 to 250 V and AC 115 V/230 V with 50/60 Hz
Permitted tolerance	–20 to +20 %
Superimposed (peak-to-peak)	≤ 15 %
Power consumption During normal operation 7UM621 7UM622 7UM623 During pickup with all inputs and outputs activated 7UM611 7UM612 7UM623	 Approx. 5.3 W Approx. 5.5 W Approx. 8.1 W Approx. 12 W Approx. 15 W Approx. 14.5 W
Bridging time during auxiliary voltage failure at V_{aux} = 48 V and V_{aux} ≥ 110 V at V_{aux} = 24 V and V_{aux} = 60 V	 ≥ 50 ms ≥ 20 ms
Binary inputs	
Number 7UM621, 7UM623 7UM622	 7 15
3 pickup thresholds Range is selectable with jumpers	DC 10 to 19 V or DC 44 to 88 V DC 88 to 176 V[1)]
Maximum permissible voltage	DC 300 V
Current consumption, energized	Approx. 1.8 mA

Output relays	
Number 7UM621 7UM622	 12 (1 NO, 4 optional as NC, via jumper) 21 (1 NO, 5 optional as NC, via jumper)
Switching capacity Make Break Break (for resistive load) Break (for L/R ≤ 50 ms)	 1000 W / VA 30 VA 40 W 25 VA
Switching voltage	250 V
Permissible current	5 A continuous 30 A for 0.5 seconds
LEDs	
Number RUN (green) ERROR (red)	 1 1
Assignable LED (red)	14
Unit design	
7XP20 housing	For dimensions see dimension drawings, part 14
Degree of protection acc. to EN 60529 For surface-mounting housing For flush-mounting housing Front Rear For the terminals	 IP 51 IP 51 IP 50 IP 2x with terminal cover put on
Weight Flush mounting housing 7UM621 (½ x 19") 7UM622 (1 x 19")	 Approx. 7 kg Approx. 9.5 kg
Surface mounting housing 7UM621 (½ x 19") 7UM622 (1 19")	 Approx. 12 kg Approx. 15 kg

Electrical tests	
Specifications	
Standards	IEC 60255 (product standards) ANSI/IEEE C37.90.0/.1/.2 UL 508 DIN 57435, part 303 For further standards see below
Insulation tests	
Standards	IEC 60255-5
Voltage test (routine test) All circuits except for auxiliary supply, binary inputs communication and time synchronization interfaces	2.5 kV (r.m.s.), 50 Hz
Voltage test (routine test) Auxiliary voltage and binary inputs	3.5 kV
Voltage test (routine test) only isolated communication interfaces and time synchronization interface	500 V (r.m.s. value), 50 Hz
Impulse voltage test (type test) All circuits except for communication interfaces and time synchronization interface, class III	5 kV (peak); 1.2/50 µs; 0.5 J; 3 positive and 3 negative impulses at intervals of 1 s

EMC tests for noise immunity; type test	
Standards	IEC 60255-6, IEC 60255-22 (product standards) EN 50082-2 (generic standard) DIN 57435 part 303
High frequency test IEC 60255-22-1, class III and DIN 57435 part 303, class III	2.5 kV (peak value), 1 MHz; ▯ = 15 ms 400 pulses per s; duration 2 s
Electrostatic discharge IEC 60255-22-2 class IV EN 61000-4-2, class IV	8 kV contact discharge; 15 kV air discharge; both polarities; 150 pF; R_i = 330 Ω
Irradiation with RF field, non-modulated IEC 60255-22-3 (report), class III	10 V/m; 27 to 500 MHz
Irradiation with RF field, amplitude-modulated, IEC 61000-4-3, class III	10 V/m; 80 to 1000 MHz; 80 % AM; 1 kHz
Irradiation with RF field, pulse-modulated IEC 61000-4-3/ ENV 50204, class III	10 V/m; 900 MHz; repetition frequency 200 Hz; duty cycle 50 %
Fast transient interference bursts IEC 60255-22-4, IEC 61000-4-4, class IV	4 kV; 5/50 ns; 5 kHz; burst length = 15 ms; repetition rate 300 ms; both polarities; R_i = 50 Ω; test duration 1 min
High-energy surge voltages (SURGE), IEC 61000-4-5 installation, class III	Impulse: 1.2/50 µs
Auxiliary supply	Common (longitudinal) mode: 2 kV; 12 Ω, 9 µF Differential (transversal) mode: 1 kV; 2 Ω, 18 µF
Measurement inputs, binary inputs and relay outputs	Common (longitudinal) mode: 2 kV; 42 Ω, 0.5 µF Differential (transversal) mode: 1 kV; 42 Ω, 0.5 µF
Line-conducted HF, amplitude-modulated IEC 61000-4-6, class III	10 V; 150 kHz to 80 MHz; 80 % AM; 1 kHz
Magnetic field with power frequency IEC 61000-4-8, class IV; IEC 60255-6	30 A/m continuous; 300 A/m for 3 s; 50 Hz 0.5 mT; 50 Hz
Oscillatory surge withstand capability ANSI/IEEE C37.90.1	2.5 to 3 kV (peak); 1 to 1.5 MHz damped wave; 50 surges per second; duration 2 s; R_i = 150 to 200 Ω
Fast transient surge withstand capability ANSI/IEEE C37.90.1	4 to 5 kV; 10/150 ns; 50 surges per second; both polarities; duration 2 s; R_i = 80 Ω
Radiated electromagnetic interference ANSI/IEEE C37.90.2	35 V/m; 25 to 1000 MHz
Damped oscillations IEC 60894, IEC 61000-4-12	2.5 kV (peak value), polarity alternating 100 kHz, 1 MHz, 10 and 50 MHz, R_i = 200 Ω
EMC tests for interference emission; type tests	
Standard	EN 50081-x (generic standard)
Conducted interference voltage on lines only auxiliary supply IEC-CISPR 22	150 kHz to 30 MHz Limit class B
Interference field strength IEC-CISPR 22	30 to 1000 MHz Limit class B

1) Conversion with external OLM
For fiber-optic interface please complete order number at 11th position with **4** (FMS RS485) or **9** and Order code **L0A** (DP RS485) and additionally order:
For single ring: SIEMENS OLM 6GK1502-3AB10
For double ring: SIEMENS OLM 6GK1502-4AB10

Mechanical stress tests	
Vibration, shock stress and seismic vibration	
During operation	
Standards	IEC 60255-21 and IEC 60068
Vibration IEC 60255-21-1, class 2 IEC 60068-2-6	Sinusoidal 10 to 60 Hz: ± 0.075 mm amplitude; 60 to 150 Hz: 1 *g* acceleration Frequency sweep 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, class 1 IEC 60068-2-27	Half-sinusoidal Acceleration 5 *g*, duration 11 ms, 3 shocks each in both directions of the 3 axes
Seismic vibration IEC 60255-21-2, class 1 IEC 60068-3-3	Sinusoidal 1 to 8 Hz: ± 3.5 mm amplitude (horizontal axis) 1 to 8 Hz: ± 1.5 mm amplitude (vertical axis) 8 to 35 Hz: 1 *g* acceleration (horizontal axis) 8 to 35 Hz: 0.5 *g* acceleration (vertical axis) Frequency sweep 1 octave/min 1 cycle in 3 orthogonal axes
During transport	
Standards	IEC 60255-21 and IEC 60068-2
Vibration IEC 60255-21-1, class 2 IEC 60068-2-6	Sinusoidal 5 to 8 Hz: ±7.5 mm amplitude; 8 to 150 Hz: 2 *g* acceleration Frequency sweep 1 octave/min 20 cycles in 3 orthogonal axes
Shock IEC 60255-21-2, class 1 IEC 60068-2-27	Half-sinusoidal Acceleration 15 *g*, duration 11 ms, 3 shocks each in both directions 3 axes
Continuous shock IEC 60255-21-2, class 1 IEC 60068-2-29	Half-sinusoidal Acceleration 10 *g*, duration 16 ms, 1000 shocks in both directions of the 3 axes

Climatic stress test	
Temperatures	
Type-tested acc. to IEC 60068-2-1 and -2, test Bd, for 16 h	–25 °C to +85 °C / –13 °F to +185 °F
Temporarily permissible operating temperature, tested for 96 h	–20 °C to +70 °C / –4 °F to +158 °F
Recommended permanent operating temperature acc. to IEC 60255-6 (Legibility of display may be impaired above +55 °C / +131 °F)	–5 °C to +55 °C / +25 °F to +131 °F
– Limiting temperature during permanent storage	–25 °C to +55 °C / –13 °F to +131 °F
– Limiting temperature during transport	–25 °C to +70 °C / –13 °F to +158 °F
Humidity	
Permissible humidity stress It is recommended to arrange the units in such a way that they are not exposed to direct sunlight or pronounced temperature changes that could cause condensation	Annual average ≤ 75 % relative humidity; on 56 days a year up to 93 % relative humidity; condensation is

Futher information can be found in the current manual at: www.siemens.com/siprotec

Description	Order No.	Order code
7UM62 multifunction generator, motor and transformer protection relay	7UM62□□-□□□□□-□□□0-□□□	
Housing, binary inputs and outputs		
Housing ½ 19", 7 BI, 12 BO, 1 live status contact	1	
Housing □ 19", 15 BI, 20 BO, 1 live status contact	2	
Graphic display, ½ 19", 7 BI, 12 BO, 1 live status contact	3	
Current transformer I_N		
1 A[1)], I_{EE} (sensitive)	1	
5 A[1)], I_{EE} (sensitive)	5	
Rated auxiliary voltage (power supply, indication voltage)		
DC 24 to 48 V, threshold binary input 19 V[3)]	2	
DC 60 to 125 V[2)], threshold binary input 19 V[3)]	4	
DC 110 to 220 V[2)], AC 115 V/230 V, threshold binary input 88 V[3)]	5	
DC 220 to 250 V, AC 115 V/230 V, threshold binary input 176 V	6	
Unit version		
For panel surface-mounting, 2 tier screw-type terminals top/bottom	B	
For panel flush-mounting, plug-in terminals (2-/3- pin connector)	D	
Flush-mounting housing, screw-type terminal (direct connection, ring-type cable lugs)	E	
Region-specific default setting / function and language settings		
Region DE, 50 Hz, IEC characteristics, language: German, (language can be selected)	A	
Region World, 50/60 Hz, IEC/ANSI characteristics, language: English (UK), (language can be selected)	B	
Region US, 60 Hz, ANSI characteristics, language: English (US), (language can be selected)	C	
Port B (System interface)		
No system interface	0	
IEC 60870-5-103 protocol, electrical RS232	1	
IEC 60870-5-103 protocol, electrical RS485	2	
IEC 60870-5-103 protocol, optical 820 nm, ST connector	3	
Analog output 2 x 0 to 20 mA	7	
PROFIBUS DP slave, electrical RS485	9	L 0 A
PROFIBUS DP slave, optical 820 nm, double ring, ST connector*	9	L 0 B
MODBUS, electrical RS485	9	L 0 D
MODBUS, optical 820 nm, ST connector*	9	L 0 E
DNP 3.0, electrical RS485	9	L 0 G
DNP 3.0, optical 820 nm, ST connector*	9	L 0 H
IEC 61850, 100 Mbit Ethernet, electrical, double, RJ45 connectors	9	L 0 R
IEC 61850, 100 Mbit Ethernet, optical, double, LC connector[4)]	9	L 0 S
PROFINET I/O, 100 Mbit Ethernet, electrical, double, RJ45-plug	9	L 3 R
PROFINET I/O, 100 Mbit Ethernet, with integrated switch, optical, double, LC connectors[3)]	9	L 3 S
Only Port C (Service interface)		
DIGSI 4 /modem, electrical RS232	1	
DIGSI 4 /modem, temperature monitoring box, electrical RS485	2	
Port C (Service interface) and Port D (Additional interface)	9	M□□
Port C (Service interface)		
DIGSI 4 /modem, electrical RS232		1
DIGSI 4 /modem, temperature monitoring box, electrical RS485		2
Port D (Additional interface)		
Temperature monitoring box, optical 820 nm, ST connector		A
Temperature monitoring box, electrical RS485		F
Analog outputs 2 x 0 to 20 mA		K

Continued on next page

1) Rated current can be selected by means of jumpers.

2) Transition between the two auxiliary voltage ranges can be selected by means of jumpers.

3) The binary input thresholds can be selected in stages by means of jumpers.

4) Not available with position 9 = "B"

* Not with position 9 = **B**; if 9 = "B", please order 7UM62 unit with RS485 port and separate fiber-optic converters.

Selection and ordering data

Description	Order No.
7UM62 multifunction generator, motor and transformer protection relay	**7UM62□□-□□□□□-□□□0**
Measuring functions	
Without extended measuring functions	0
Min./max. values, energy metering	3
Function	
Generator Basic	A
Generator Standard	B
Generator Full	C
Asynchronous Motor	F
Transformer	H
Functions (additional functions)	
Without	A
Sensitive rotor ground-fault protection and 100 % stator ground-fault protection	B
Restricted ground-fault protection	C
Network decoupling (d*f*/d*t* and vector jump)	E
All additional functions	G

1) For more detailed information on the functions see Table 11/3.

Accessories	Description	Order No.
	Connecting cable	
	Cable between PC/notebook (9-pin connector) and protection unit (9-pin connector) (contained in DIGSI 4, but can be ordered additionally)	7XV5100-4
	Cable between thermo-box and relay – length 5 m / 5.5 yd	7XV5103-7AA05
	– length 25 m / 27.3 yd	7XV5103-7AA25
	– length 50 m / 54.7 yd	7XV5103-7AA50
	Coupling device for rotor ground-fault protection	7XR6100-0CA00
		Short code
	Series resistor for rotor ground-fault protection (group: 013002)	3PP1336-0DZ K2Y
	Resistor for underexcitation protection (voltage divider, 20:1) (group: 012009)	3PP1326-0BZ K2Y
	Resistor for stator ground-fault protection (voltage divider, 5:1) (group 013001)	3PP1336-1CZ K2Y
	20 Hz generator	7XT3300-0CA00
	20 Hz band pass filter	7XT3400-0CA00
	Current transformer (400 A / 5 A, 5 VA)	4NC5225-2CE20
	Controlling unit f. rotor ground-fault protection (0.5 to 4Hz)	7XT7100-0EA00
	Resistor for 1 to 3 Hz rotor ground-fault protection	7XR6004-0CA00
	Temperature monitoring box (thermo-box)	
	AC/DC 24 to 60 V	7XV5662-2AD10
	AC/DC 90 to 240 V	7XV5662-5AD10

Accessories

Fig. 11/27 Mounting rail for 19" rack

Fig. 11/28
2-pin connector

Fig. 11/29
3-pin connector

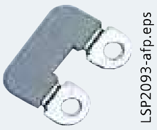

Fig. 11/30
Short-circuit link for current contacts

Fig. 11/31
Short-circuit link for voltage contacts/ indications contacts

Description		Order No.	Size of package	Supplier	Fig.
Connector	2-pin	**C73334-A1-C35-1**	1	Siemens	11/61
	3-pin	**C73334-A1-C36-1**	1	Siemens	11/62
Crimp connector	CI2 0.5 to 1 mm^2	**0-827039-1**	4000	1)	
		0-827396-1	1	1)	
	CI2 0.5 to 2.5 mm^2	**0-827040-1**	4000	1)	
		0-827397-1	1	1)	
	Type III+ 0.75 to 1.5 mm^2	**0-163083-7**	4000	1)	
		0-163084-2	1	1)	
Crimping tool	For type III+	**0-539635-1**	1	1)	
	and matching female	**0-539668-2**		1)	
	For CI2	**0-734372-1**	1	1)	
	and matching female	**1-734387-1**		1)	
19"-mounting rail		**C73165-A63-D200-1**	1	Siemens	11/60
Short-circuit links	For current terminals	**C73334-A1-C33-1**	1	Siemens	11/63
	For other terminals	**C73334-A1-C34-1**	1	Siemens	11/64
Safety cover for terminals	large	**C73334-A1-C31-1**	1	Siemens	11/35
	small	**C73334-A1-C32-1**	1	Siemens	11/35

1) Your local Siemens representative can inform you on local suppliers.

Connection diagram, IEC

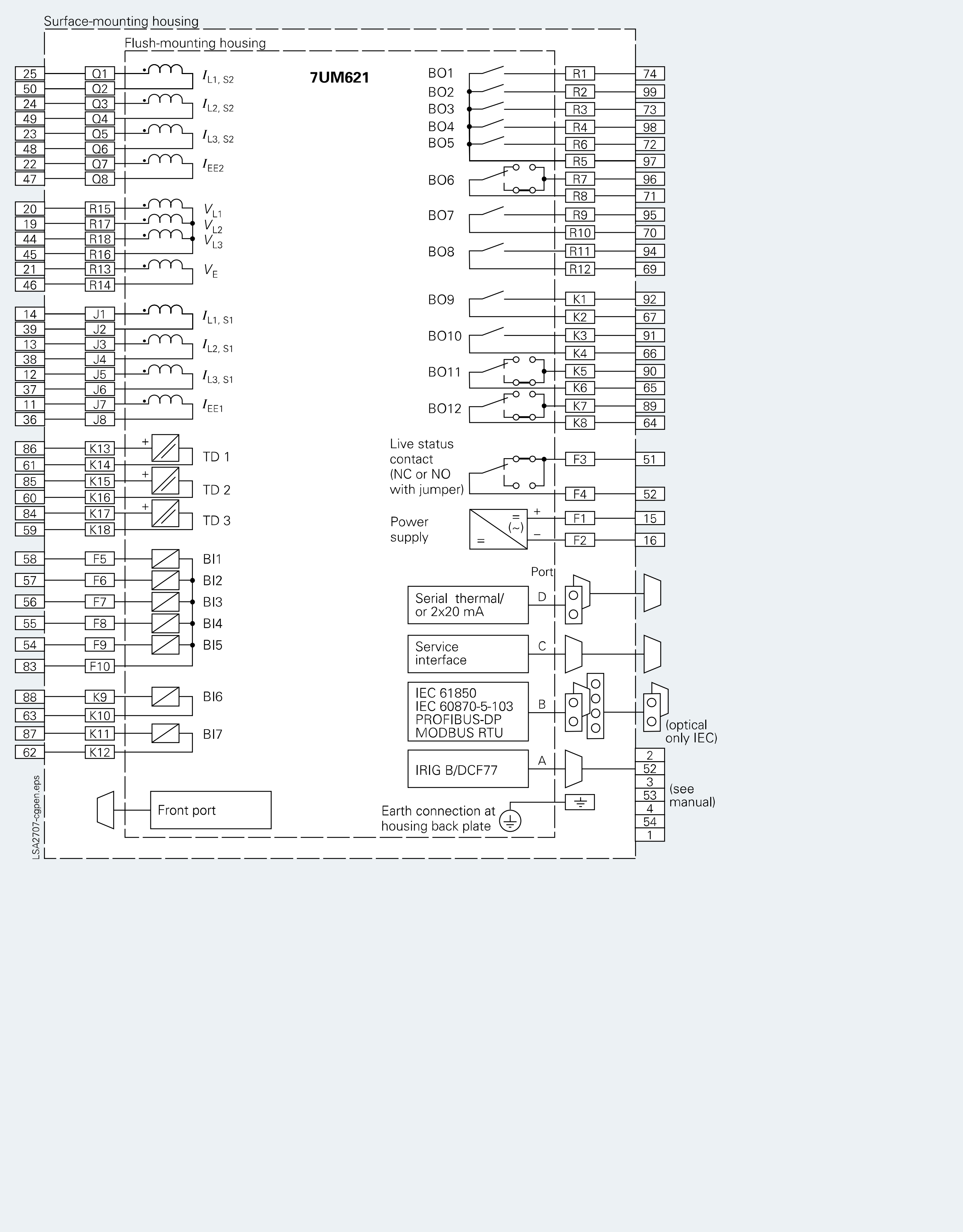

Fig. 11/32 7UM621 and 7UM623 connection diagram (IEC standard)

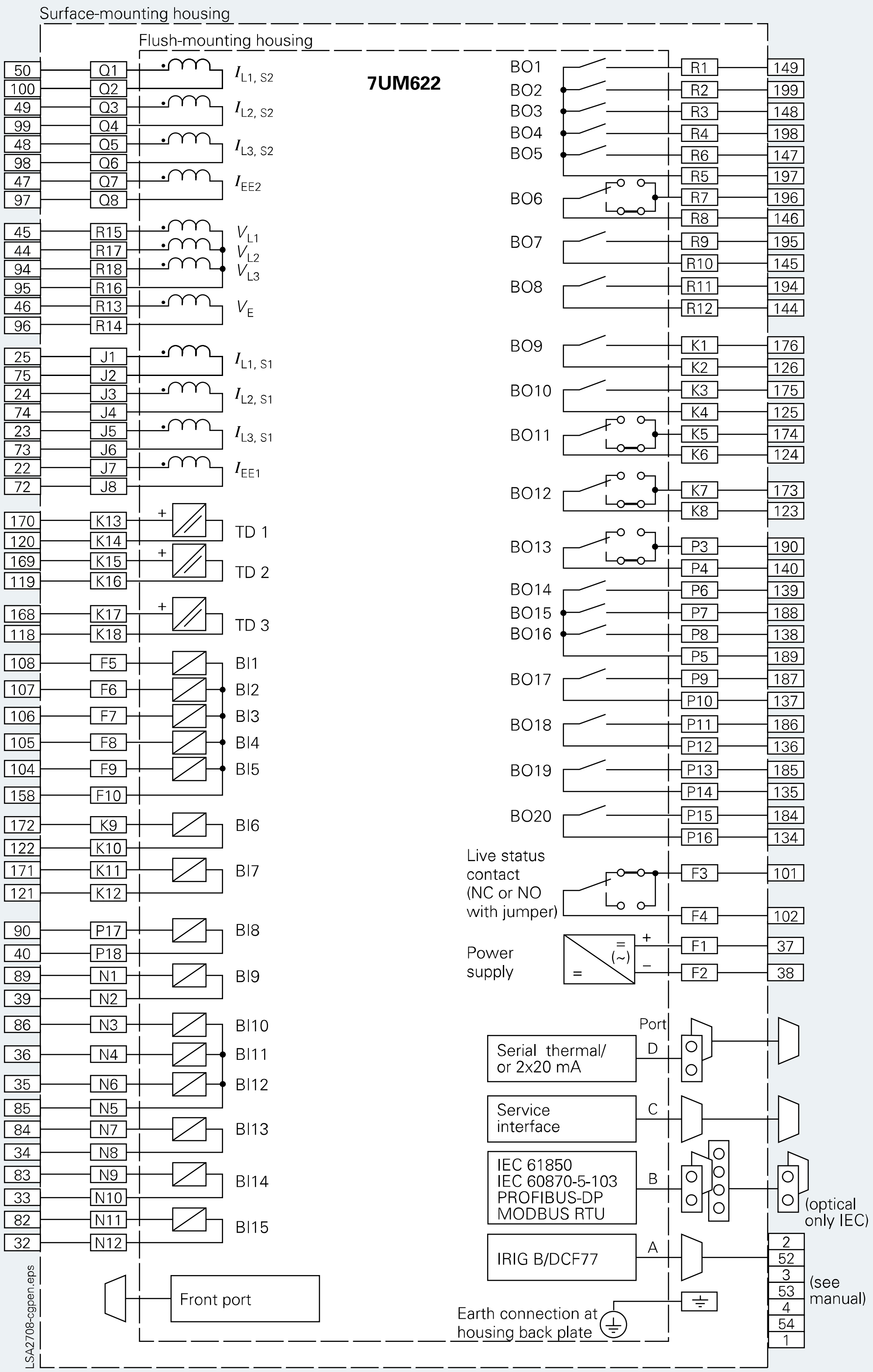

Fig. 11/33 7UM622 connection diagram (IEC standard)

Connection diagram, ANSI

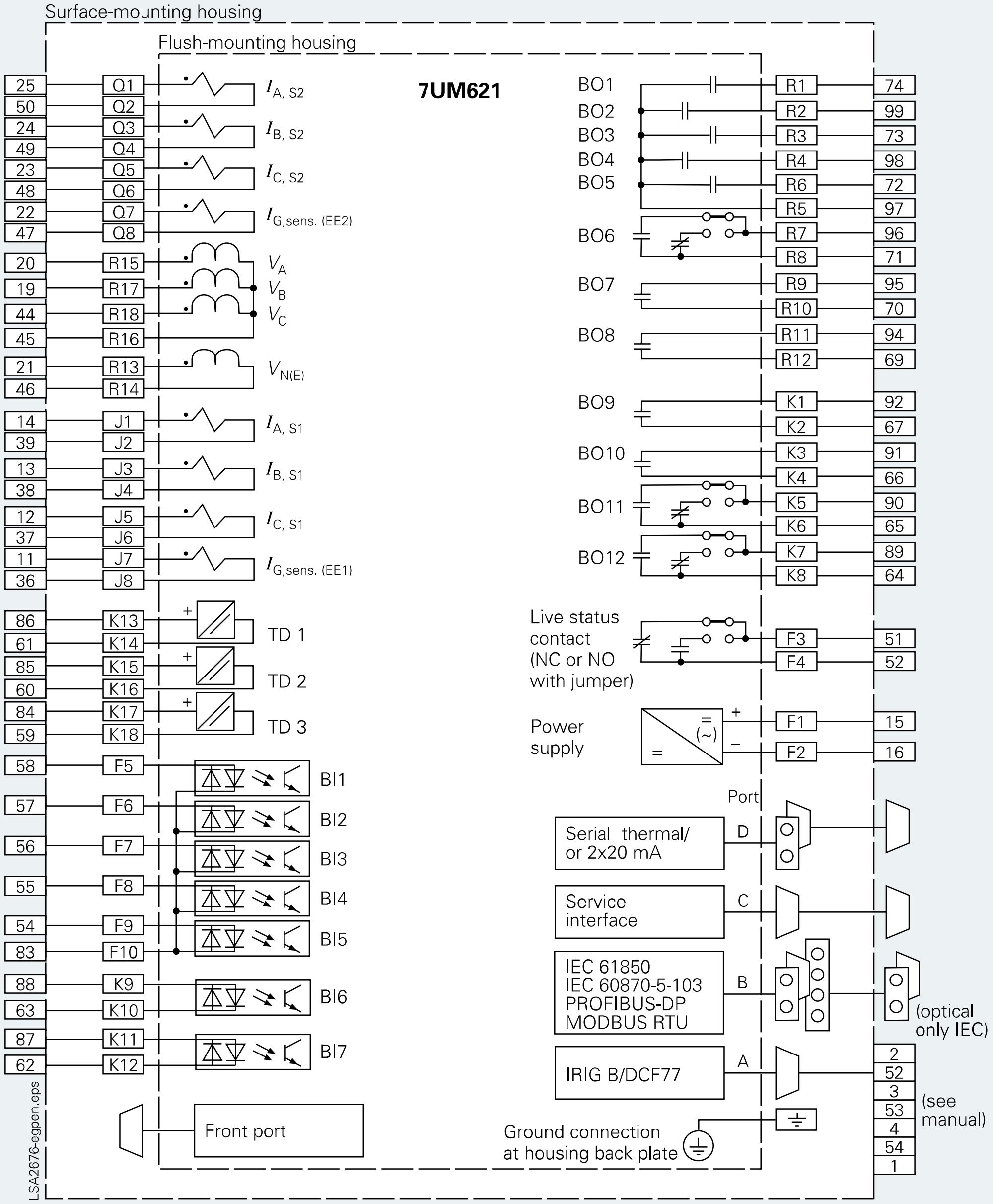

Fig. 11/34 7UM621 and 7UM623 connection diagram (ANSI standard)