	Operate time	5 ms
	Release time	5 ms
	Breakdown Voltage	1500 V_{ac} for one minute (coil to contact)
	Isolation between adjacent outputs	300 V_{dc} (with compression terminal block) 100 V_{dc} (with DB-25 connectors)
	Interposing Relay Option	Groups of 8 digital outputs can be directly interfaced to D20KI module
Digital Outputs (D25KE-4Z)	Standard Digital Outputs	8 or 16 relay output pairs switch both sides of the controlled load for additional control security; single component failure protection and detection preventing false control of any coil driver output; select-check-before execute security; master trip/master close bus scheme.
	Configurable Output Types	Latching (On/Off) Trip/Close Raise/Lower Programmable pulse duration from 5 to (2^{31}-1) ms in 1 ms intervals.
	Output Relay Contacts	1 Form A
	Maximum Switching Power	60 W or 125 VA (resistive)
	Maximum Switching Voltage	75 V_{dc} or 50 V_{ac} (DB-25) 120 V_{dc} (FACE-40)
	Maximum Switching Current	2 A
	Maximum Carrying Current	2 A
	Operate time	5 ms
	Release time	5 ms
	Breakdown Voltage	1500 V_{ac} for one minute (coil to contact)
	Isolation between adjacent outputs	300 V_{dc} (with compression terminal block) 100 V_{dc} (with DB-25 connectors)

	Interposing Relay Option	Groups of 8 digital outputs can be directly interfaced to D20KI module
Digital Outputs (D25K-4Z)	Standard Digital Outputs	8 relay outputs switch both sides of the controlled load for additional control security; single component failure protection and detection preventing false control of any coil driver output; select-check-before execute security; master trip/master close bus scheme.
	Configurable Output Types	Latching (On/Off) Trip/Close Raise/Lower Programmable pulse duration from 5 to (2^{31}-1) ms in 1 ms intervals.
	Output Relay Contacts	4 Form A
	Maximum Switching Power	60 W (resistive) or 125 VA
	Maximum Switching Voltage	75 V_{dc} or 50 V_{ac}
	Maximum Switching Current	1 A @ 50 Vac; 0.8 A @ 75 V_{dc}
	Maximum Carrying Current	3 A
	Operate time	5 ms
	Release time	5 ms
	Breakdown Voltage	1000 Vac for 1 minute (coil to contact)
	Isolation between adjacent outputs	250 V_{dc}
	T/C power supply fuse type	2 X MDQ3
	DO power supply fuse type	2 X MDA10
	Interposing Relay Option	Groups of 8 digital outputs can be directly interfaced to D20KI module

Auxiliary Digital Outputs	Auxiliary Digital Outputs	3 single digital outputs for System Fail indication, Radio Keying and General Purpose output
	Radio Keying and Auxiliary Control Output Relay Contacts	1 Form A
	System Fail Relay Contacts	1 Form B
	Maximum Switching Power	60 W (resistive), 125 VA
	Maximum Switching Voltage	75 V_{dc} or 50 V_{ac}
	Maximum Switching Current	2 A
	Maximum Carrying Current	2 A
	Breakdown Voltage	1500 V (coil to contact)
Available displays	Alphanumeric	Backlit LCD with keypad
	Graphical	Backlit LCD with touch screen 320 X 240 pixels 4.76" X 3.58"

4.2 Physical Specifications

Dimensions	Width	19" (48 cm)
	Height	8.75" (22 cm)
	Depth	9" (23 cm)
Weight	31 lbs. (14.1 kg) maximum	
Operational Temperature	-20°C to +70°C (without display) 0°C to +60°C (with alphanumeric display) 0°C to +50°C (with graphical display)	
Storage Temperature	-40°C to +90°C (without alphanumeric display) -20°C to +70°C (with alphanumeric display) 0°C to +70°C (with graphical display)	
Humidity Rating	0 to 95% relative humidity, non-condensing	
Environmental Rating	IP20	
Installation/Over-voltage Category	Class II	
Pollution Degree	2	

Field Terminations	Digital Outputs (D25KE)	Male DB-25 connectors for interconnect to an interposing relay panel or, 300 V_{dc} rated compression terminal blocks suitable for #14 AWG - #22 AWG
	Digital Outputs (D25K-4Z)	300 V_{dc} rated compression terminal blocks suitable for #14 AWG - #22 AWG
	Power Supply Inputs	#6-32 - 250 V_{ac} /250 V_{dc} rated barrier blocks suitable for #12 AWG - #22 AWG
	AC Analog Inputs	#6-32 - 600 V_{ac} rated barrier blocks suitable for #12 AWG - #22 AWG
	Digital Inputs, Auxiliary Digital Outputs and DC Analog Inputs	300 V_{dc} rated compression terminal blocks suitable for #14 AWG - #22 AWG

4.3 Compliance to Standards

Please consult the GE Energy Services' Product Compliance Table.

4.4 Reliability

Table 4 summarizes the D25 reliability with respect to the Bell and MIL-217 standards.

Reliability Standard	Minimally Populated			Fully Populated		
	MTBF (hours)	MTTR (hours)	Availability (%)	MTBF (hours)	MTTR (hours)	Availability (%)
Bell	43,600	0.35	99.9992	18,156	0.31	99.9983
MIL 217	24,775	0.35	99.9986	11,570	0.32	99.9972

Table 4 D25 Reliability Data

4.5 AC Data Availability

Availability of AC analog values depends on the meter type selected. *Table 5* shows the AC data available for each configured circuit. To determine if a particular data point is available, find the point of interest and look in the column corresponding to the meter type configured for the circuit. A "Y" in that cell indicates the data is available; an "N" indicates that it isn't. Note that the accuracy of values marked with an asterisk (*) are affected by circuit unbalance.

Table 5 AC Data Availability Matrix Based On Meter Type

Data Description	Meter Type				Comment
	1	2	2½	3	
RMS Magnitude - V_A/V_{AB} (Measured)	Y*	Y	Y	Y	Measured directly on PT
RMS Magnitude - V_B/V_{BC} (Measured)	Y*	Y	Y*	Y	Measured directly on PT
RMS Magnitude - V_C/V_{CA} (Measured)	Y*	Y	Y	Y	Measured directly on PT
RMS Magnitude - V_A/V_{AB} (Calculated)	Y*	N	Y*	Y*	Calculated from measured values
RMS Magnitude - V_B/V_{BC} (Calculated)	Y*	N	Y*	Y*	Calculated from measured values
RMS Magnitude - V_C/V_{CA} (Calculated)	Y*	N	Y*	Y*	Calculated from measured values
RMS Magnitude - I_A (Measured)	Y*	Y	Y	Y	Measured directly on CT
RMS Magnitude - I_B (Measured)	Y*	Y	Y	Y	
RMS Magnitude - I_C (Measured)	Y*	Y	Y	Y	
RMS Magnitude - I_N (Measured)	Y	N	Y	Y	Measured directly on CT
RMS Magnitude - I_N (Calculated)	Y	N	Y	Y	Calculated from measured values

Data Description	Meter Type				Comment
	1	2	2½	3	
Phase Angle - Φ V_A/V_{AB} (Measured)	Y*	Y	Y	Y	Measured directly on PT
Phase Angle - Φ V_B/V_{BC} (Measured)	Y*	Y	Y*	Y	Measured directly on PT
Phase Angle - Φ V_C/V_{CA} (Measured)	Y*	Y	Y	Y	Measured directly on PT
Phase Angle - Φ V_A/V_{AB} (Calculated)	Y*	Y	Y	Y	Calculated from measured values
Phase Angle - Φ V_B/V_{BC} (Calculated)	Y*	Y	Y*	Y	Calculated from measured values
Phase Angle - Φ V_C/V_{CA} (Calculated)	Y*	Y	Y	Y	Calculated from measured values
Phase Angle - Φ I_A (Measured)	Y*	Y	Y	Y	Measured directly on CT
Phase Angle - Φ I_B (Measured)	Y*	Y	Y	Y	
Phase Angle - Φ I_C (Measured)	Y*	Y	Y	Y	
Phase Angle - Φ I_N (Measured)	Y	N	Y	Y	Measured directly on CT
Phase Angle - Φ I_N (Calculated)	Y	N	Y	Y	Calculated from measured values
Frequency	Y	Y	Y	Y	Measured on AC input selected by Frequency Reference Hunting Algorithm
Total Harmonic Distortion - V_A/V_{AB}	Y	Y	Y	Y	Calculated from measured phase voltages
Total Harmonic Distortion - V_B/V_{BC}	Y	Y	N	Y	
Total Harmonic Distortion - V_C/V_{CA}	Y	N	Y	Y	
Total Harmonic Distortion - I_A	Y	Y	Y	Y	Calculated from measured phase currents
Total Harmonic Distortion - I_B	Y	N	Y	Y	
Total Harmonic Distortion - I_C	Y	Y	Y	Y	
Total Harmonic Distortion - I_N	Y	N	Y	Y	
Active Power - W_A	Y*	Y*	Y	Y	Calculated from measured values as required by the configured metering type
Active Power - W_B	Y*	Y*	Y*	Y	
Active Power - W_C	Y*	Y*	Y	Y	
Active Power – $W_{CIRCUIT\ TOTAL}$	Y*	Y	Y*	Y	
Reactive Power – VAr_A	Y*	Y*	Y	Y	Calculated from measured values as required by the configured metering type
Reactive Power – VAr_B	Y*	Y*	Y*	Y	
Reactive Power – VAr_C	Y*	Y*	Y	Y	
Reactive Power – $VAr_{CIRCUIT\ TOTAL}$	Y*	Y	Y*	Y	
Apparent Power – VA_A	Y*	Y*	Y	Y	Calculated from measured values as required by the configured metering type
Apparent Power – VA_B	Y*	Y*	Y*	Y	
Apparent Power – VA_C	Y*	Y*	Y	Y	
Apparent Power – $VA_{CIRCUIT\ TOTAL}$	Y*	Y	Y*	Y	
Power Factor - pf_A	Y*	Y*	Y	Y	Calculated from active and apparent power
Power Factor - pf_B	Y*	Y*	Y*	Y	
Power Factor - pf_C	Y*	Y*	Y	Y	
Power Factor – $pf_{CIRCUIT\ TOTAL}$	Y*	Y	Y*	Y	
Zero Sequence Voltage - V_0	N	Y	N	Y	Calculated from measured phase voltages
Positive Sequence Voltage - V_1	N	Y	N	Y	
Negative Sequence Voltage - V_2	N	Y	N	Y	
Zero Sequence Current - I_0	Y	Y	Y	Y	Calculated from measured phase currents

Data Description	Meter Type				Comment
	1	2	2½	3	
Positive Sequence Current - I_1	Y	Y	Y	Y	
Negative Sequence Current - I_2	Y	Y	Y	Y	
Voltage Unbalance - $\%V_{UNBALANCE}$	N	Y	N	Y	Calculated from measured phase voltages
Current Unbalance - $\%I_{UNBALANCE}$	Y	Y	Y	Y	Calculated from measured phase currents
Average Current - $I_{AVERAGE}$	Y	Y	Y	Y	Calculated from measured phase currents
Displacement Power Factor Angle - Φ pf_A	Y	N	Y	Y	Calculated from measured voltage and current phase angles
Displacement Power Factor Angle - Φ pf_B	Y	N	Y	Y	
Displacement Power Factor Angle - Φ pf_C	Y	N	Y	Y	
Harmonic Spectrum - DC - 21st Harmonic	Y	Y	Y	Y	Measured for each PT and CT input

4.6 AC Data Accuracy

Table 6 shows the default input conditions and signal levels for all AC accuracy measurements, unless otherwise specified. *Table 7* summarizes the accuracy of the AC values provided by the D25.

Table 6 Default Input Conditions For Accuracy Data In Table 7

Attribute	Required Condition
Voltage magnitude	5% of nominal ≤ V_{Input} ≤ 250% of nominal
Current magnitude	2% of nominal ≤ I_{Input} ≤ 195% of nominal
Ambient temperature	25° Celsius
Total Harmonic Distortion	0%
Voltage unbalance	0%
Current unbalance	0%
Frequency	Nominal system frequency ±0.5 Hz
Power Factor	Unity

Table 7 AC Analog Data Accuracy

Data Description	Measurement Range	Accuracy		Notes
		16x CTs with Calibration	42x CTs with Calibration	
RMS Magnitude – Voltage (Measured)	5% - 250% of nominal	±0.5% of nominal	±0.5% of nominal	2,4
RMS Magnitude – Voltage (Calculated)	5% - 250% of nominal	±0.5% of nominal	±0.5% of nominal	2,3,4,8,10
RMS Magnitude – Current (Measured)	2% - 195% of nominal	±0.5% of nominal	±0.3% of nominal	5,9,15
	195% - 500% of nominal	±3.0% of nominal	±1.0% of nominal	
	500% - 1000% of nominal	±1.0% of FS	±1.0% of nominal	

Data Description	Measurement Range	Accuracy		Notes
		16x CTs with Calibration	42x CTs with Calibration	
	1000% - 1600% of nominal	±1.0% of FS	±1.0% of nominal	
	1600% - 4200% of nominal	N/A	±1.0% of nominal	
RMS Magnitude - Neutral Current (Calculated)	2% - 195% of nominal	±1.0% of nominal	±1.0% of nominal	11
Phase Angle – Voltage (Measured)	0° - 360° or ±180°	±0.5°	±0.5°	-
Phase Angle – Voltage (Calculated)	0° - 360° or ±180°	±0.5°	±0.5°	3,8,10
Phase Angle – Current (Measured)	0° - 360° or ±180°	±0.5°	±0.5°	9
Phase Angle - Neutral Current (Calculated)	0° - 360° or ±180°	±2.0°	±2.0°	11
Frequency - Voltage	power system freq. ±5 Hz	±0.01 Hz	±0.01 Hz	16,17
Frequency - Current	power system freq. ±5 Hz	±0.03 Hz	±0.03 Hz	17
Total Harmonic Distortion - Voltage	1% - 30% of fundamental	±2.0%	±2.0%	12,13
Total Harmonic Distortion - Voltage	30% - 100% of fundamental	±5.0%	±5.0%	12,13
Total Harmonic Distortion - Current	2% - 30% of fundamental	±2.0%	±2.0%	12,13,18
Total Harmonic Distortion - Current	30% - 100% of fundamental	±5.0%	±5.0%	12,13,18
Active Power - Single Phase	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Active Power - Circuit Total	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Reactive Power - Single Phase	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Reactive Power - Circuit Total	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Apparent Power - Single Phase	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Apparent Power - Circuit Total	0% - 133% of nominal	±0.96% of nominal	±0.96% of nominal	6,7
Power Factor - Single Phase	0 - ±1.0	±2.85% of FS	±2.85% of FS	-
Power Factor - Circuit Total	0 - ±1.0	±2.85% of FS	±2.85% of FS	-
Symmetrical Components - Voltage	5% - 250% of nominal	±0.5% of nominal	±0.5% of nominal	-
Symmetrical Components - Current	2% - 195% of nominal	±0.5% of nominal	±0.5% of nominal	-
Unbalance - Voltage	0% - 100%	±0.2%	±0.2%	-
Unbalance - Current	0% - 100%	±0.2%	±0.2%	-
RMS Magnitude - Average Current	2% - 195% of nominal	±0.2% of nominal	±0.3% of nominal	-
Displacement Power Factor Angle	0° - 360° or ±180°	±2.0°	±2.0°	-
Harmonic Spectrum - DC-21*	1% - 30% of fundamental	±2.0%	±2.0%	1,14,19
Harmonic Spectrum - DC-21*	30% - 100% of fundamental	±5.0%	±5.0%	1,14,19
Active Energy - Single Phase	0% - 133% of nominal	±2.0% of reading	±2.0% of reading	6,7
Active Energy - Circuit Total	0% - 133% of nominal	±2.0% of reading	±2.0% of reading	6,7
Reactive Energy - Single Phase	0% - 133% of nominal	±2.0% of reading	±2.0% of reading	6,7
Reactive Energy - Circuit Total	0% - 133% of nominal	±2.0% of reading	±2.0% of reading	6,7
Apparent Energy - Single Phase	0% - 133% of nominal	±0.5% of reading	±0.5% of reading	6,7
Apparent Energy - Circuit Total	0% - 133% of nominal	±0.5% of reading	±0.5% of reading	6,7

Table 8 Notes On AC Data Accuracy

<table>
<tr><th colspan="2">Notes</th></tr>
<tr><td>1</td><td>Frequency response: 0 Hz to 1100 Hz for 50 Hz systems;
0 Hz to 1300 Hz for 60 Hz systems.</td></tr>
<tr><td>2</td><td>0% unbalance tolerated for 1-element metering.
0.2% unbalance tolerated for 2½-element metering.</td></tr>
<tr><td>3</td><td>For all meter types, if the PTs are connected line-to-line, the calculated line-to-neutral values assume balanced voltages.</td></tr>
<tr><td>4</td><td>For 1-element meters, any available voltage phase can be monitored. In this case, the accuracy of the values reported for the unmonitored voltages is affected by the voltage unbalance.</td></tr>
<tr><td>5</td><td>The 1-element meter can be configured to monitor a single voltage and a single current. In this case, the accuracy of the values reported for the unmonitored currents is affected by the current unbalance.</td></tr>
<tr><td>6</td><td>Nominal power is achieved at nominal current and voltage.</td></tr>
<tr><td>7</td><td>In 2 element metering, the total circuit power and energy are not affected by unbalance. In this case, phase power and energy are calculated by dividing the total circuit power and energy by three.</td></tr>
<tr><td>8</td><td>In 2-element metering, V_{CA} magnitude and phase angle are derived from the measured V_{AB} and V_{CB} voltages.</td></tr>
<tr><td>9</td><td>In 2-element metering, I_B magnitude and phase angle are derived from the measured I_A and I_C currents.</td></tr>
<tr><td>10</td><td>In 2½ element metering, V_B/V_{BC} magnitude and phase angle are derived from V_A/V_{AB}.</td></tr>
<tr><td>11</td><td>Neutral current magnitude must be ≥ 10% of nominal to achieve stated accuracy.</td></tr>
<tr><td>12</td><td>Magnitude of fundamental must be ≥ 5% of nominal to achieve stated accuracy.</td></tr>
<tr><td>13</td><td>Magnitude of individual harmonics must be ≥ 2.0% of the fundamental to achieve stated accuracy.</td></tr>
<tr><td>14</td><td>Harmonic spectrum data consists of the relative magnitude of the DC component and all integer harmonics up to and including the 21st, reported as a percentage of the fundamental.</td></tr>
<tr><td>15</td><td>Inputs greater than 400% of nominal must be applied for no more than 1 sec. with a duty cycle of 10 minutes. Database holds values up to 16x nominal. Data in the range of 16-42x nominal is available for DFR and protection only.</td></tr>
<tr><td>16</td><td>Accuracy of the reported frequency is 0.01 Hz for voltages that are at nominal input magnitude and within 1Hz of the nominal system frequency only. Accuracy for all other inputs is 0.03 Hz.</td></tr>
<tr><td>17</td><td>Accuracy of the reported frequency varies as the applied frequency differs from the frequency of the sampling reference as follows:
<table><tr><th>Frequency Difference</th><th>Accuracy</th></tr><tr><td>0.1 Hz - <1.0 Hz</td><td>±0.05 Hz</td></tr><tr><td>1.0 Hz - <2.0 Hz</td><td>±0.10 Hz</td></tr><tr><td>2.0 Hz - <5.0 Hz</td><td>±0.5 Hz</td></tr></table></td></tr>
<tr><td>18</td><td>The accuracy of the THD reported for current inputs is valid only when the current input magnitude is 5.0% - 195% of nominal.</td></tr>
<tr><td>19</td><td>The accuracy of individual harmonic components reported for current inputs is valid only when the current input magnitude is 5.0% - 195% of nominal.</td></tr>
</table>

REF542 (SCU)

Bay control and protection unit

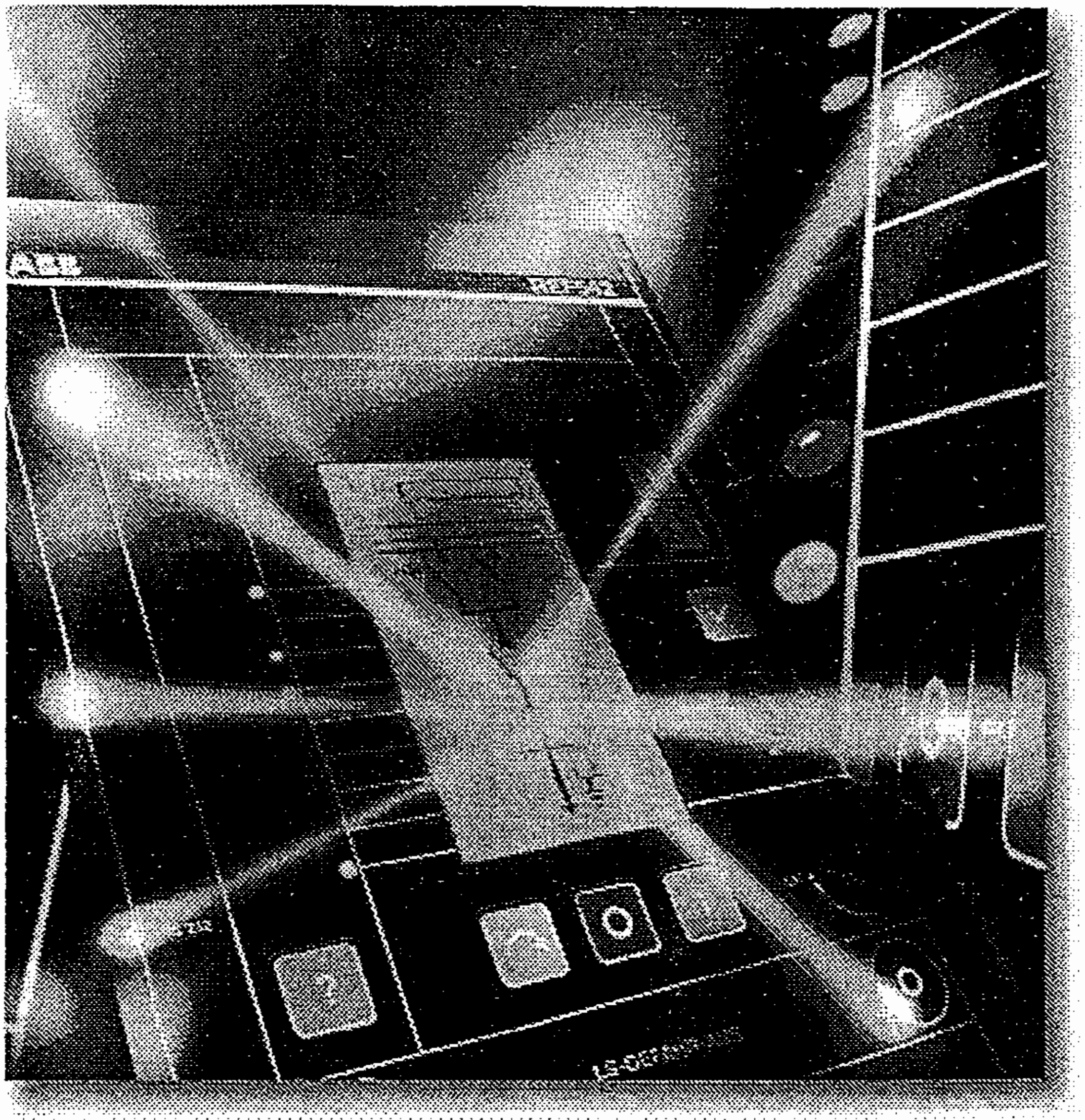


ABB Power Distribution

ABB

Contents:

1 General

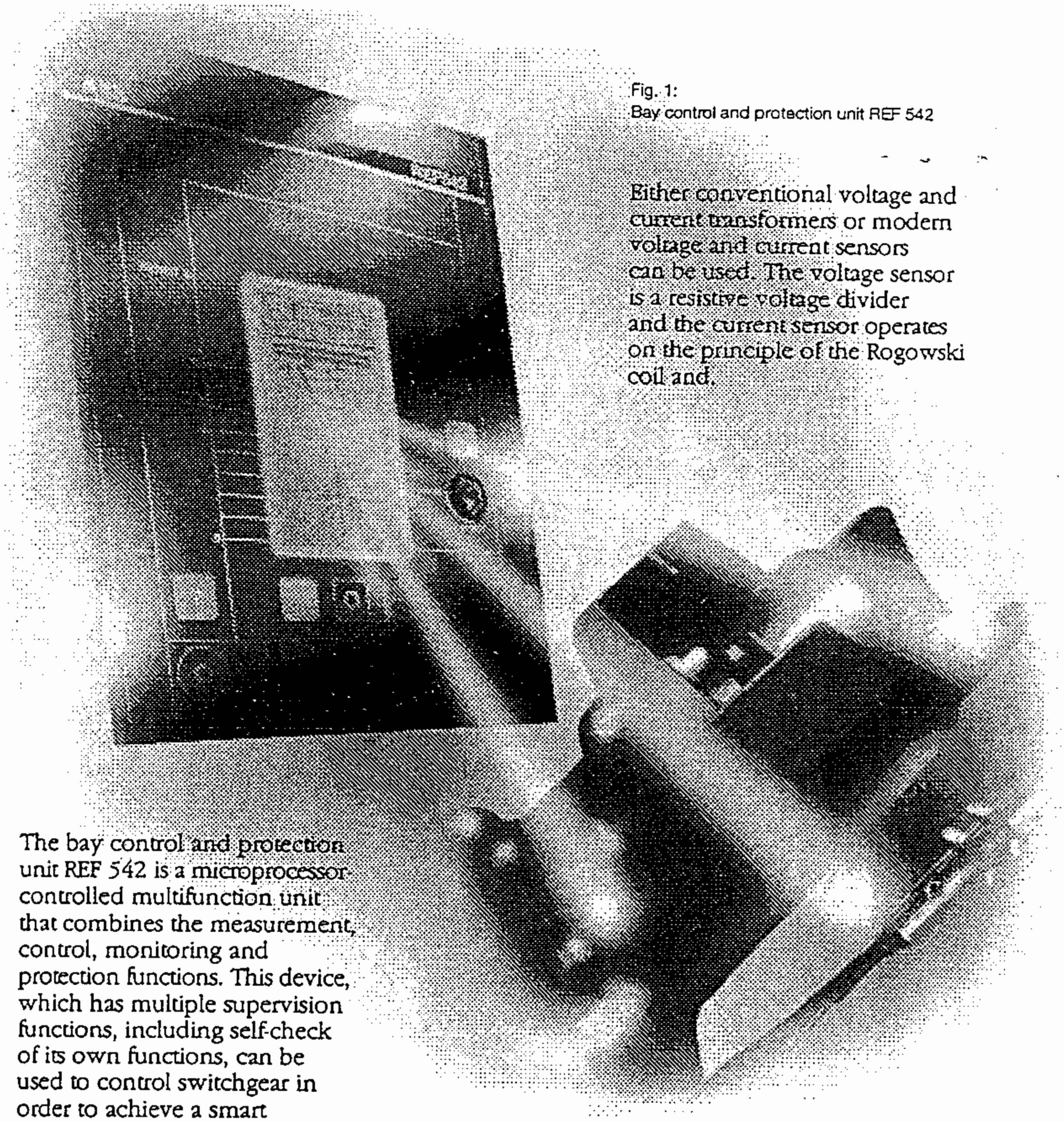


Fig. 1:
Bay control and protection unit REF 542

Either conventional voltage and current transformers or modern voltage and current sensors can be used. The voltage sensor is a resistive voltage divider and the current sensor operates on the principle of the Rogowski coil and.

The bay control and protection unit REF 542 is a microprocessor-controlled multifunction unit that combines the measurement, control, monitoring and protection functions. This device, which has multiple supervision functions, including self-check of its own functions, can be used to control switchgear in order to achieve a smart substation system. It can also be integrated into a substation automation system. The REF 542 is shown in Figure 1.

2 Operation

As shown in Figure 2, the REF 542 is based on a microprocessor system that can operate in real time. The main processor (MC), which runs the control and supervision functions, is supported by a digital signal processor (DSP). The protection and measurement functions are managed by the digital signal processor. If the unit is to be connected to a substation automation system, the extension by an optional communication processor (CP) is required.

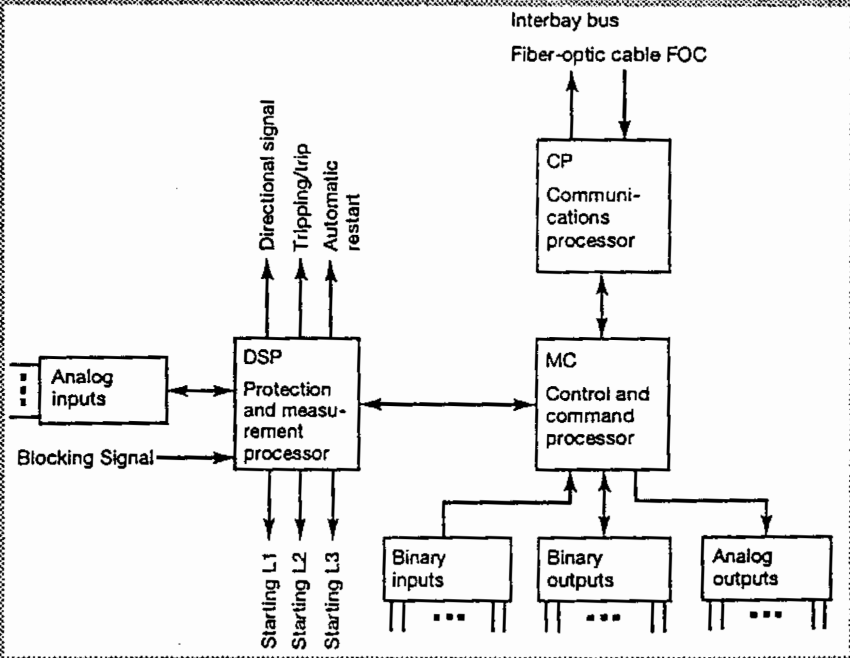


Fig. 2
Block diagram of the REF 542 multiprocessor system

The REF 542 has the following interfaces:

- Binary inputs with optocouplers for electrical decoupling of external signals
- Binary outputs with the option of conventional or static relays for actuating the switchgears
- Analog inputs for current and voltage measurement quantities
- Communication interface for connection to the substation automation system

The control panel has a backlit LC display and nine buttons for an user friendly interfaces.
The application and configuration tool enables the REF 542 functions to be set precisely for the requirements of the system. The user configuration is loaded during the commissioning. The computer required for this purpose (notebook) is connected to the REF 542 at the standard RS 232 port on the front control panel.

3 Sensors

A new generation of voltage and current sensors has been developed for the REF 542. Their special properties guarantee a high degree of precision and dependability in the acquisition of measured quantities. The sensors are installed in a unitary cast resin housing. If desired, conventional voltage and current transformer can be used instead of the sensors.

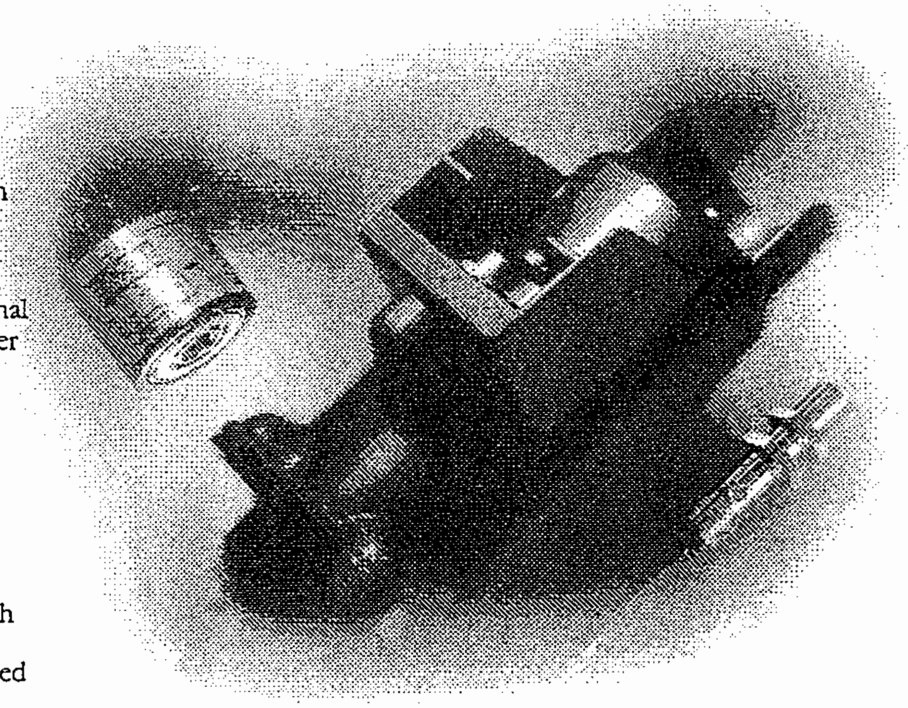


Fig. 3:
Combined sensor for
current and voltage recording

Note

The new sensor types are directly connected to the REF 542. They are linked to conventional transformers with supplementary matching transformers, which are installed on the back of the REF 542.

The REF 542 can meet the requirements of accuracy class 1 both with sensors and with transformers. This presumes that the current and the voltage quantities to be within the range of the rated value. In contrast to the conventional instrument transformer, the use of sensors can guarantee a linear response over a very wide range.
The current sensor - Rogowski coil - consists of an air-core coil, which cannot go into saturation. The current is measured by a voltage signal, which is proportional to the time derivation of the primary current. The actual momentary current value is calculated by numerical integration in the digital signal processor.

The voltage sensor evaluates the voltage quantities by a resistive voltage divider. The case is especially shaped to minimise influences from parasitic capacitance and inductance. Compared to conventional instrument transformers, the measuring sensors offer the following advantages:

- Linear systems behaviour
- High accuracy
- Extremely compact form

With the small dimensions, both measuring sensors can be integrated into a combination sensor as shown in Figure 3, enabling easy installation in the panels.

4 Functions

The REF 542 integrates all secondary functions in a single device. Self-checking function is also included. The functions are designed as freely programmable software modules. This allows the REF 542 to be easily adapted to the most varied requirements of medium voltage substations. Specialised programming knowledge is not required.

4.1 Human Machine Interface

The variety of functions offered by the REF 542 is controlled by a simple, user-friendly HMI (Human-Machine Interface). It includes the following components:

- 1 LC graphics display,
- 1 operation LED,
- 9 two-color LEDs,
- 1 red alarm LED,
- Control buttons and
- two keyswitches.

The display shows plain text messages (switchgear status, alarms, protection, self-checking) and also the mimic diagram of the switchgears controlled by the REF 542. The mimic diagram indicates the positions of the switchgears.
The operation LED shows the operational status of the REF 542. The alarm LED can be programmed as desired. One of the two-color LED's display the protection status and another violations of the interlock conditions. The remaining seven LEDs can have their assignments programmed as desired and user defined message texts can be added.

4.2 Measurement

REF 542 has seven analog inputs for measuring the current and voltage quantities. They are subdivided into three groups, two with three inputs and one with one input. Every group can measure the voltage or current quantities. For example, a six phase voltage measurement such as in a measuring field with double busbar is just as possible as a three phase current and a four phase voltage measurement, such as for a bus coupler equipped with overcurrent protection and synchro check function.
The most frequent combination is the group distribution with three current and three voltage measurements and one earth current measurement.

The following quantities are directly measured:

- Line current, three phase
- Earth current
- Phase voltage, three phase
- Frequency

The following quantities are calculated from above measured values:

- Line voltage, three phase
- Average value/maximum value current, three phase (determined over several minutes)
- Active and reactive power
- Power factor cos φ
- Active energy and reactive energy

The following quantities are recorded:

- Operating hours
- Switching cycles
- Total switched currents
- Metering pulses from external pulse transmitters (up to 10 transmitters)

All these values are shown in the upper section of the display after conversion to primary quantities. The display is selected by a ring menu. The current and voltage quantities are shown as numerical values and in the form of a bar graph relative to the rated value.
All measured values registered over an extended period (energy, numerical values, maximum values, circuit breaker data) are permanently saved. This ensures that they are still available even after a power failure. They can be reset to zero as required.

4.3 Control unit

The REF 542 offers convenient local control with complete switchgear interlocking. The operator view of the REF 542 provides the following functions :

- Position indication for the different switchgear in the LC display
- Switching commands using control buttons on the front panel

This enables all switching operations to be carried out.
In addition to local control, the switchgear can also be remotely controlled from a substation automation system without requiring any additional equipment. A keyswitch is used to switch between local control and remote control.
Programmable interlocking logic can be used to prevent operational error in the switchgear. Interlocking between the switchbays can also be taken into account. The position indications of the other bays can be implemented for this purpose with a conventional ring line and this makes it independent of central substation automation components.
Once an application has been created and loaded into the REF 542, the cycle time should be checked. The cycle time should be less than 30 ms to ensure proper functioning.

4.4 Protection

The REF 542 has a wide range of functions for protection of various system component. All of these functions can be used in any combination. The combination options are limited by the computing capacity of the signal processor. The maximum load is 100%. Every protection function can act as a tripping or simply as an indicating function.

4.5 Storing of events

The last 30 protection events can be observed on the REF 542. These event list contains the behaviour of the corresponding protective functions, the duration of the starting, the trip value, if available and also the attempted autoreclosures. In total, the last 50 events are stored in the REF 542, but they can only be read from a substation automation system.

4.6 Restrictions

Not all function blocks can be combined with one another to an unlimited extent. There are also additional restrictions for function blocks and connections as shown in the table below.

Funktion block	Restriction
Protective functions	• Max. 12 protective functions • Max. 120 protective parameters • 100% maximum DSP load
Fault recorder	• Max. 1 fault recorder • Min. 1 configured protective function
Cycle time of application	• Max. 30 ms
Memory object	• Max. 1
Power counter	• Max. 15
Switching object	• Max. 62
Threshold object	• Max. 10 per analog input
Direct write-read command	• Max. 100
Connections	• Max. 560, 502 numbers can be allocated
Indication LEDs	• Max. 7

5 Diagnosis and monitoring

The REF 542 makes it possible to adapt the service interval to the system condition in order to minimise the downtime. The table below shows the components that are supervised by the REF 542.

Software	REF 542 self-diagnosis
Electrical bay components	• Auxiliary voltage circuits • Power supply for switchgear motor drives • Trigger circuits
Mechanical bay components	• Status of the trip springs of the circuit-breaker • Switching cycle count • Gas pressure
Operating time	• Operating hours • Closing time (from closed to open state) from the event buffer

Programming the REF 542

The REF 542 is designed so that all of the functions are set up as simple program modules in any desired configuration. It is unnecessary to change hardware when changing functions. The program is saved in non-volatile memory in EEPROMs. The configuration software operates with the Windows 3.11 or Windows NT operating system. It operates with a FUnction PLAn program system, referred to below as FUPLA. Specialised programming knowledge is not required. The design of the display shows clearly the flexibility of the REF 542 software. The following elements can be used in any configuration.

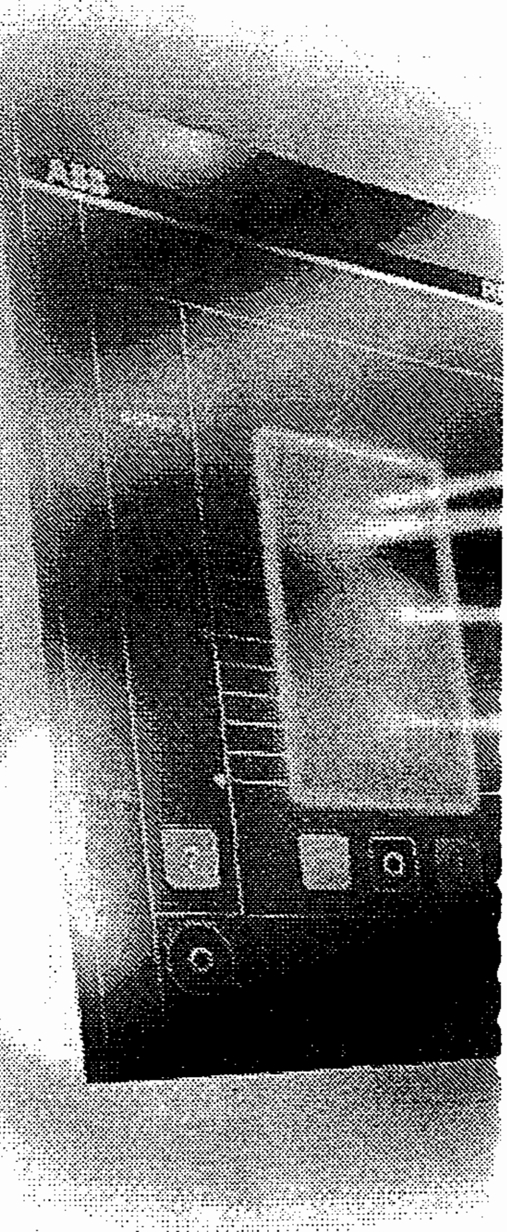
- Up to 8 switchgear icons (when input and output boards with mechanical relays are used a maximum of only 7 for control purposes)
- Icons for the various system component, motors, transformers, transducers, etc.
- Up to 40 individual lines

This flexibility is particularly advantageous for the automated sequences. These include interlocking, both device and protective interlocking, switching sequences and other automated functions. For the first time the option of using PLC functions as a component of the secondary technology is offered. This allows access to a number of logical functions as shown below:

- AND logic gate
- AND - NOT logic gate
- OR logic gate
- OR-NOT logic gate
- EXCLUSIVE OR logic gate
- Various FLIP-FLOP types
- Timer functions
- Pulse generators
- Counter

Like the logical functions, the protective functions and the binary interfaces can be combined in any way. The software enables the language of the REF 542 display to be selected. A standard Windows editor can be used to adapt the basic text modules to individual requirements. The REF 542 character sets also include adjustment options in different languages. Every REF 542 supplied by ABB comes with an initial user-specific configuration, which the user can change later with the accompanying configuration software.

However, this does not include the protective functions. Changes to the protective parameters, activation of functions or reset commands can be made independently from a computer directly at the device.



7 Communication

Communications with a control system is possible by an optional communications board. Simple binary commands can also be loaded via the binary inputs of the REF 542. The integrated object bus interface makes the REF 542 a component of the ABB control system. All data saved in the REF 542 can be transferred to the substation unit. Events are transferred with a timestamp. The timestamp is then completed in the substation unit. The substation unit can transfer all data simultaneously to the network control centre. The substation automation system can be an ABB system or an arbitrary system. The second option may require an adaptation to the system. When the complete ABB system is used the following functions can be accessed.

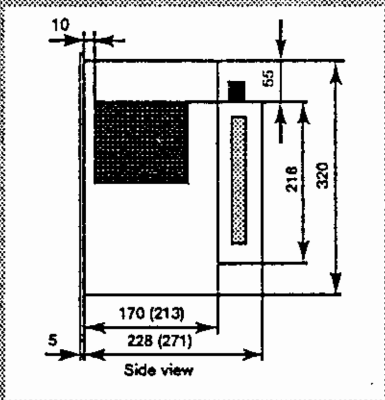
- Remote supersision
- Remote control
- Remote setup of protective parameters
- Central measuring
- Central event storing
- Switchgear management

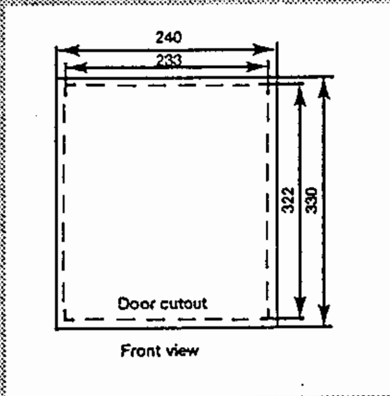
If a connection to another substation unit is required within the substation, an optional interface conforming to the IEC standard 60870-5-103 shall be used.

8 Housing

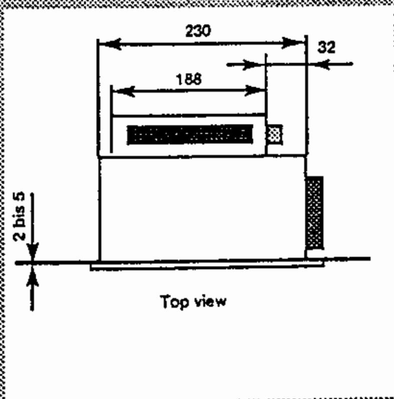
The REF 542 case is manufactured from aluminium and has a special black external coating. This coating protects the case against electromagnetic interference. There is a short and a deep case. The deep case can also accommodate a third binary input/output board and also the analogue output board. The front panel with its control elements are raised over the case to allow installation on a switch panel. The plugs for connecting the device to the switchgears are on the various boards that are installed in the case parallel to the front panel. They are accessible from above and are protected by a cover.
There is a signal converter screwed to the back or side of the case for use when current and voltage transformers are used for adapting the signal levels of the measurement quantities. This signal converter is not required when sensors are used. In this case the sensor terminal adapter with check tapping is attached to the side of the REF 542 case.

8Fig. 4: Dimensions of the REF 542 case





Weight	approx. 6 kg for short case or approx. 7 kg for deep case
Type of installation	Semiflush
Connections	DIN 41612
Dimensions	240x330x228 mm (W x H x D) short case
	240x330x271 mm (W x H x D) deep case
Panel cutout for installation	233x322 mm (W x H)
Protection class	Case IP30 standard design or IP54 on request
	Connections IP20 standard design or IP4x on request



9 Design

REF542 with short case:

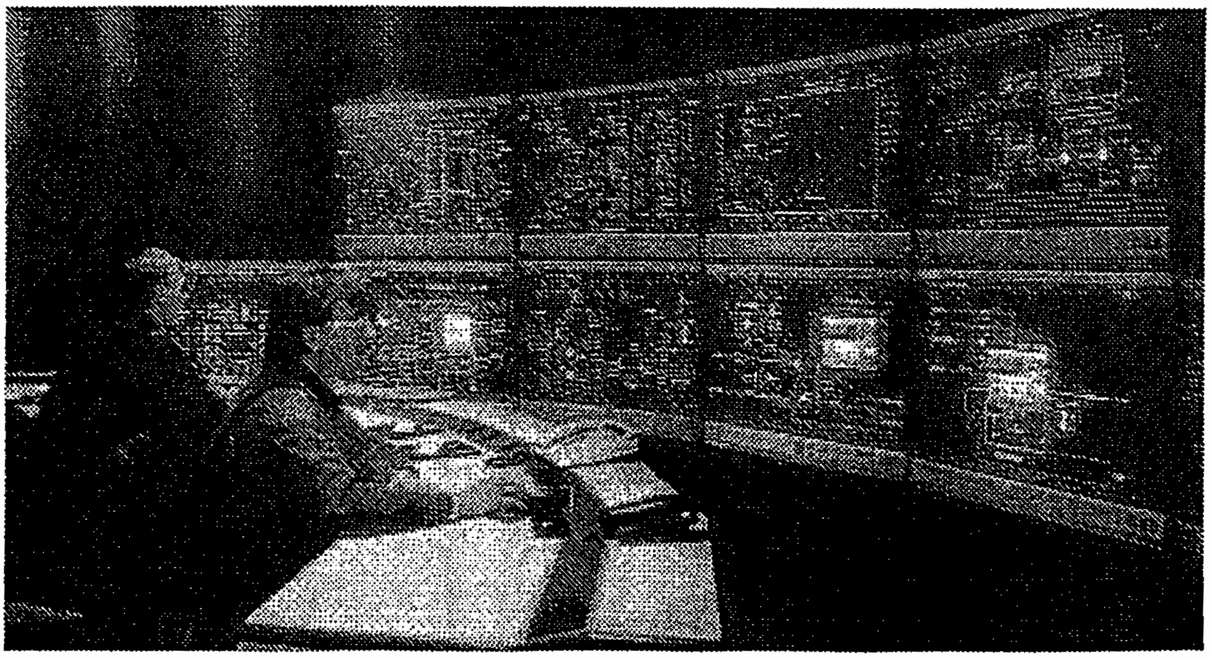
- 2 I/O plug-in boards for control of up to 5 switching devices
- 1 optional communications plug-in board as interface for ABB object bus (SPA Bus, LON as defined in LAG1.4) or in accordance to IEC 60870 - 5 -103.

REF542 with deep case:

- 3 I/O plug-in boards for control of up to 8 switching devices When used with I/O plug-in boards with mechanical relays only 7 switching devices can be controlled.
- 1 optional plug-in board for output of 4 programmable analog signals 0 (or 4) ... 20 mA
- 1 optional communications plug-in board as interface for ABB object bus (SPA Bus, LON as defined in LAG1.4) or in accordance to IEC 60870 - 5 -103.

Signal converter (rucksack) for adapting levels
Options:

- 6 current transformers for line currents
- 6 current transformers for line currents and 1 current transformer for earth current
- 3 current transformers for line currents
- 3 current transformers for line currents and 3 voltage transformers
- 3 current transformers for line currents, 3 voltage transformers for phase voltages and 1 current transformer for earth current 3 voltage transformers for phase voltages
- 3 voltage transformers for phase voltages and 1 for line voltage
- 6 voltage transformers for phase voltages



10 Protective functions with settings

ANSI Code	Protective function	Settings	DSP
68	Inrush stabilisation	Only in connection with I>> and I>	7 %
67	Overcurrent directional high	I>> = 0.05 ... 40 In t = 65 ... 300,000 ms	12 %
67	Overcurrent directional low	I> = 0.05 ... 40 In t = 65 ... 300,000 ms	12 %
50	Overcurrent instantaneous	I>>> = 0.1 ... 40 In t = 15 ... 300,000 ms	7 %
51	Overcurrent high	I>> = 0.05 ... 40 In t = 35 ... 300,000 ms	3 %
51	Overcurrent low	I> = 0.05 ... 40 In t = 35 ... 300,000 ms	3 %
51	IDMT Standard, very, extreme or long-term - inverse time characteristic	Ie = 0.05 ... 40 In K = 0.05 ... 1.0	6 %
51N	Earth fault high	IE>> = 0.05 ... 40 In t = 65 ... 100,000 ms	6 %
51N	Earth fault low	IE> = 0.05 ... 40 In t = 65 ... 100,000 ms	6 %
51N	Earth fault IDMT Standard, very, extreme or long-term - inverse time characteristic	Ie = 0.05 ... 40 In K = 0.05 ... 1.0	6 %
67N	Earth fault directional high	IE>> = 0.05 ... 40 In t = 35 ... 300,000 ms, forward/backward	6 %
67N	Earth fault directional low	IE> = 0.05 ... 40 In t = 35 ... 300,000 ms, forward/backward	6 %
67N	Earth fault directional sensitive	IE> = 0.05 ... 2 In t = 100 ... 100,000 ms, forward/backward UNE> = 0.05 ... 0.7 Un Slope angle α and δ	35 %
59	Overvoltage instantaneous	U>>> = 0.1 ... 3 Un t = 15 ... 300,000 ms	3 %
59	Overvoltage high	U>> = 0.1 ... 3 Un t = 15 ... 300,000 ms	3 %
59	Overvoltage low	U> = 0.1 ... 3 Un t = 15 ... 300,000 ms	3 %
27	Undervoltage instantaneous	U<<< = 0.1 ... 1.2 Un t = 45 ... 300,000 ms	4 %
27	Undervoltage high	U<< = 0.1 ... 1.2 Un t = 65 ... 300,000 ms	4 %
27	Undervoltage low	U< = 0.1 ... 1.2 Un t = 65 ... 300,000 ms	4 %
59N	Residual overvoltage high	UNE>> = 0.05 ... 3 Un t = 35 ... 300,000 ms	3 %
59N	Residual overvoltage low	UNE> = 0.05 ... 3 Un t = 35 ... 300,000 ms	3 %
49	Thermal overload protection With complete memory function	I(Mot) = 1 ... 10,000 A (primary) τAbb = 10 ... 20,000 s with I and n = 0 τExt = 10 ... 20,000 s with 0.1 ≤ I ≤ 2 In τExt = 10 ... 20,000 s I > 2 In	7 %
51	Motor start (adiabatic characteristic)	I(Mot) = 0.3 ... 1.2 In I(Start) = 0.1 ... 20 I(Mot) t = 65 ... 300,000 ms I> = 0.6 ... 0.8 I(Start)	3 %
51LR	Blocking rotor (definite time characteristic)	I(Mot) = 0.3 ... 1.2 In I> = 1 ... 19.99 In t = 65 ... 300,000	8 %

ANSI Code	Protective function	Settings	DSP
66	Number of starts	n(warm) = 1 ... 10 n(cold) = 1 ... 10 ϑ(warm) = 20 ... 200 °C	0 %
21+79	Distance protection	U / I starting: IE> or I> = 0.05 ... 4 In UF< = 0.05 ... 0.9 Un System ground = isolated/low-resistance Line priority = cyclic/acyclic Ground factor: K = 0.00 ... 10.00 φ (k) = -60 ... 60° 3 impedance stages and 1 overreach stage: R = 0.05 ... 120 Ω (secondary values) X = 0.05 ... 120 Ω (secondary values) t = 25 ... 10,000 ms 1 directional stage Direction 0 ... 90 or -45 ... 135° t = 25 ... 10,000 ms 1 non-directional stage t = 25 ... 10,000 ms Dependent maximum current time protection with KU/LU	53 %
87	Differential protection	Vector group = 0 ... 11 Transform ground = primary/secondary Rated current in primary and secondary = 0 ... 100,000 A Pick-up current (ID=0) = 0.10 ... 0.50 In ID1 = 0.2 ... 2 In ID2 = 0.5 ... 5 In ID3 = 0.2 ... 10.0 In Slope = 0.4 ... 1.0 Tripping current (Id) = 5 ... 40 In Current stabilization with 2nd and 5th harmonic = 0.10 ... 0.30	60 %
46	Unbalanced load (asymmetry)	Asymmetry = 5 ... 80% Imin = 5 ... 100 % In t = 1 ... 1000s	9 %
32	Directional Power	Pnom = 1 ... 1000.000 kW (primary) Pmax.rev = 1 ... 50 % Pn t = 1 ... 1000 s	2 %
37	Low load	Pnom = 50 ... 1000.000 kW (primary) Pmin = 5 ... 100% Pn Imin = 2 ... 20 % In t = 1 ... 1000 s	4 %
81	Frequency supervision	Start Δf = 0.04 ... 5 Hz Time = 1 ... 30 s	2 %
25	Synchrocheck	Δ U = 0.02 ... 0.4 Un Δ φ = 5 ... 50° t = 0.50 ... 1000.00 s	10 %
	Fault recorder	Record time = 1000 ... 5000 ms Time before the fault = 100 ... 2000 ms Time after the fault = 100 ... 4900 ms Max. 5 records	35 %
55	Power factor controller	Power factor cos φ = 0.70 ... 1.00 QC0 = 1.000 ... 20000.000 kVAr Series of banks = 1:1:1:1 ... 1:2:4:8 Number of banks: 1 ... 4 Insensitivity = 105 ... 200 % QC0 Response time = 0 ... 100 % QC0 Switching program = sequential/circuit switching	0 %

11 Technical data

With current and voltage transformer	
Rated current	1A / 5A
Rated voltage	100 V / 110 V
Thermal load capacity	4 . In continuous 100 . In for 1s 250 . In (peak value) dynamic
Consumption current path	0.1 VA with In = 1A or ≤ 0.3 VA with In = 5A
Consumption voltage path	0.25 VA with Un
With current and voltage sensor	
Rated current In	150 mV (corresponds to 1 A with current transformer)
Rated voltage Un	2V (corresponds to 100 V with voltage transformer)
Rated frequency	50 Hz / 60 Hz (distance protection only 50 Hz)
Inputs and outputs	with 2 (short case) or 3 (deep case) input or output boards
Number of inputs	14 per board for auxiliary voltage 48 to 220 VDC
Number of outputs	5 power and 2 signal outputs per board with conventional relays for auxiliary voltage 48 to 220 VDC 4 power and 2 signaling outputs per board with transistor relay for auxiliary voltage 48 to 220 VDC
Light-emitting diodes	3 with fixed configuration and 7 configurable in 3 colours red/green/orange 1 configurable alarm
Auxiliary direct voltage	48 to 220 VDC with 50 ms overbridging time
Input power	40 W with short case 50 W with deep case

Interface	
PC interface	RS 232, 9-pin, 9600 bit/s
Communications (optional)	SPA bus electrical/optical, LON optical (in accordance to LAG 1.4) or optical Bus system according to standard IEC 6870-5-103.
Analog output board (optional)	0 or 4 to 20 mA (max. 4)
Temperature Range	
For operation	-10 to 55°C
For transport and storage	-20 to 70°C
Type testing	
Earthquake safety	DIN IEC 60068-3-3 DIN IEC 60068-2-6 DIN IEC 60068-2-59 CEI IEC 61166 CEI IEC 60980
Insulation voltage	IEC 60255-5
Fast transient test	IEC 61000-4
Electrostatic discharge	IEC 61000-2
EMV	IEC 61000-3
Environmental conditions	IEC 60255-4

ABB Calor Emag Mittelspannung GmbH

Oberhausener Strasse 33
D-40472 Ratingen

Petzower Strasse 8
D-14542 Glindow

Phone: +49(0)21 02/12-12 30, Fax: +49(0)21 02/12-19 16
E-Mail: calor.info@de.abb.com
Internet: http://www.abb.de/calor

ABB Sace T.M.S. S.p.A

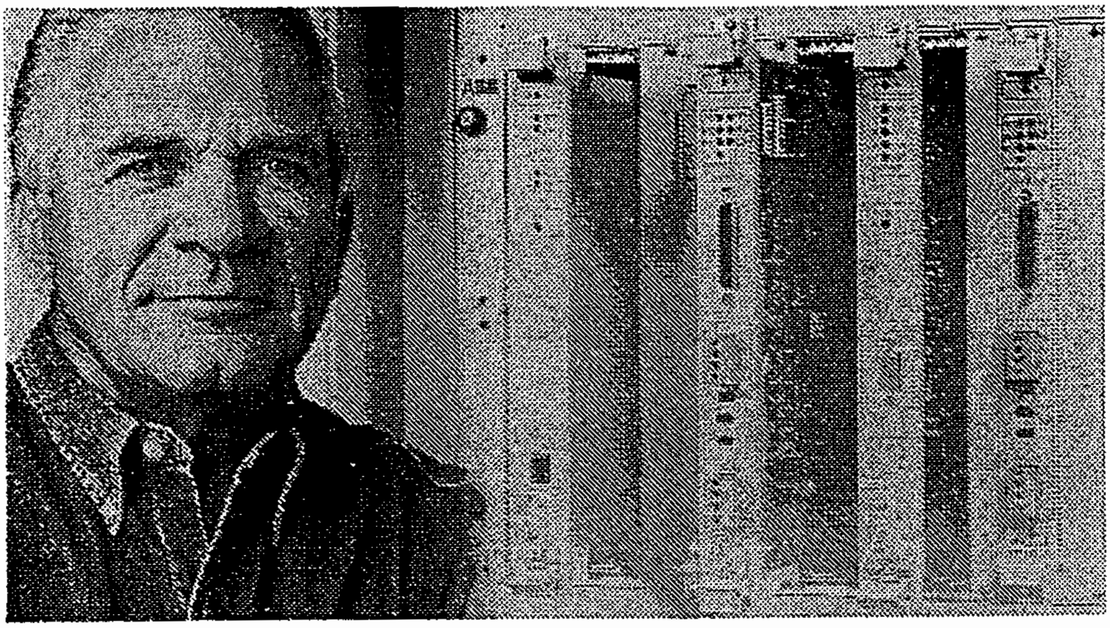
Via Friuli, 4
I-24044 Dalmine

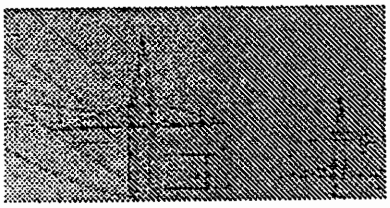
Phone: +39 035/395111, Fax: +39 035/395874
E-mail: sacetms.tipm@it.abb.com
Internet://www.abb.com

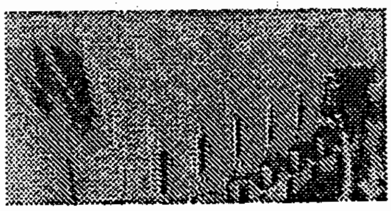
Leaflet no. **DECMS 2228 00 E** Printed in Germany (02.00-2000-PPI)

Industrial^{IT}
Power Line Carrier Communication

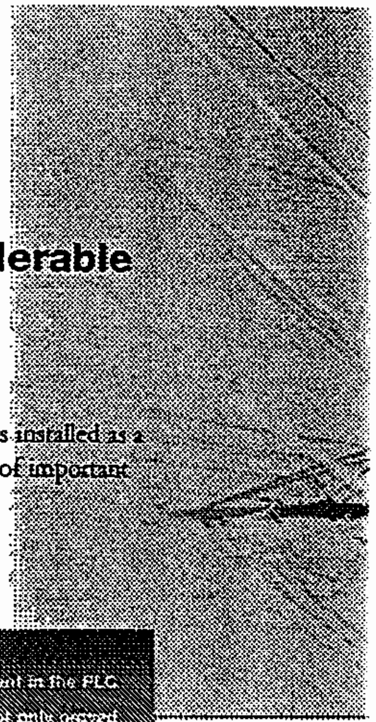
Design and Engineering







ABB



An existing PLC network represents a considerable investment made over many years.

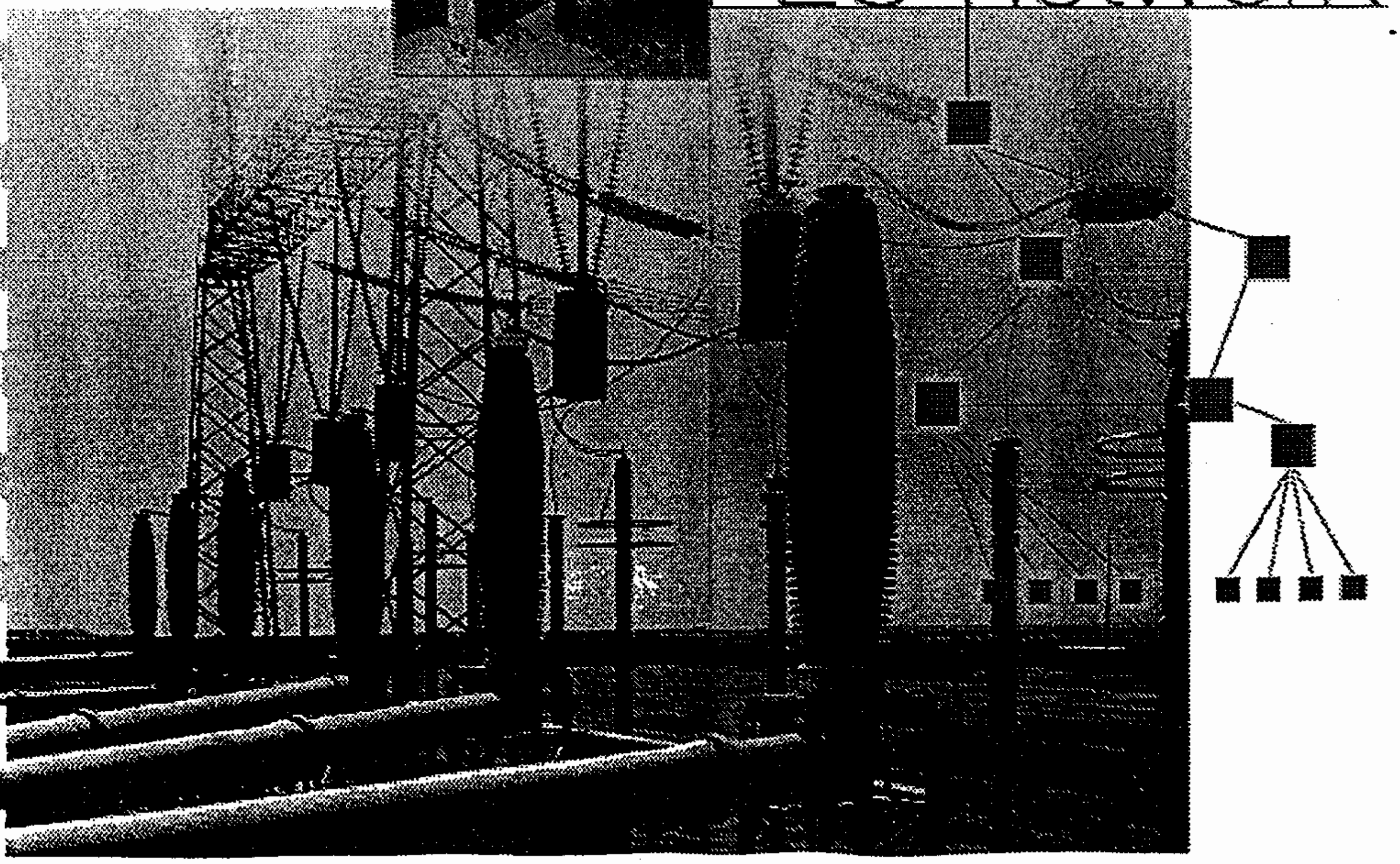
In spite of the growing significance of digital communication systems – especially those employing optical fibre links for which ABB produces a comprehensive line of equipment – PLC still remains in many cases the most cost-effective solution to cover the operational needs of a power system. This applies particularly when only low volumes of data have to be transmitted over long distances.

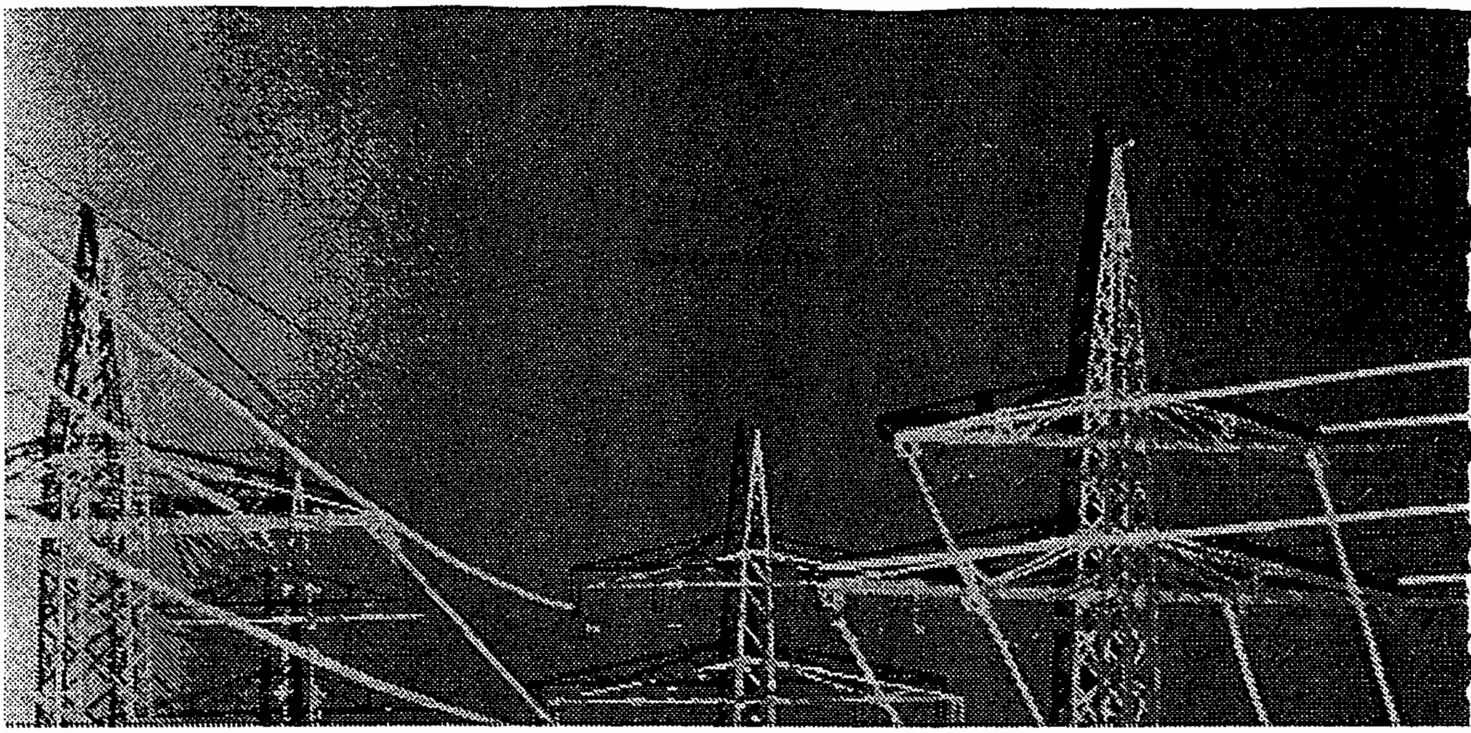
An existing PLC network represents a considerable investment made over many years, and for reasons of cost and system operation it is seldom possible to replace it by a digital system in a short space of time. More often than not, an existing PLC network is expanded rather than contracted and in such cases, frequency allocation has to be planned carefully because of the shortage of channels.

In other instances, a PLC channel is installed as a back-up to increase the availability of important new digital channels.

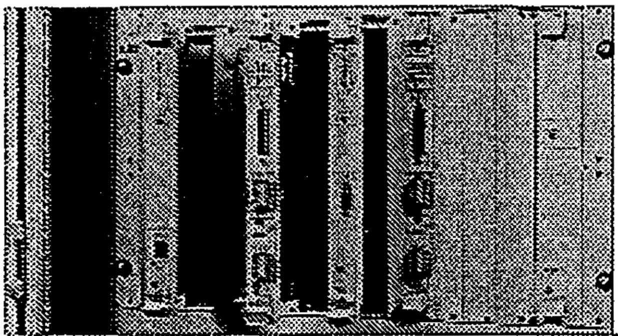
Over decades of successful involvement in the PLC and transfer tripping field, ABB has not only proved its high technical standard and competence by keeping at the forefront of the development and application of the latest technologies in communication and protection equipment, but has also built up a formidable capability in systems and applications engineering.

PLC network





Providing all-inclusive system solutions
ABB does not see itself just as a manufacturer of products used for transmitting information between the stations of an electrical power system, it is conscious of a responsibility to provide all-inclusive system solutions for its customers and in close cooperation with them. In the PLC and transfer tripping fields, ABB has the knowledge and the resources to give its customers every conceivable support in the search for the best possible solutions regardless of how complex their problems may appear.



Long years of experience in communications engineering and close links to the divisions responsible for power system protection and control have put ABB communications in the position of being able to propose an optimum total solution for the most diverse user problems.

ABB is one of the leading suppliers of PLC systems, because it fulfils the following essential requirements:

- **Understanding the customer's problem**
  Detailed knowledge of the processes which depend on a reliable means of communication, i.e. power system control, station control and protection.

- **A full range of products**
  PLC equipment, coupling devices, wave-traps, transfer tripping devices, data modems, and telephone exchange equipment.

- **Engineering know-how**
  ABB has acquired invaluable engineering expertise as a result of many years of experience in the field.

- **Computer-based project management**
  Application of computerized tools for project design, engineering, and processing.

The heart of the system is a data model of the user's specific problem and requirements.

Computer-based project management

An integrated data processing system supports our sales and systems engineers at every stage of processing a customer's order. This system comprises subroutines for preparing tenders, system design, system engineering, contract administration, production, assembly, testing, shipping, and accounting. The heart of the system is a data model of the user's specific problem and requirements.

The application of electronic data processing techniques enables the entire operation of processing a customer contract to be rationalized. The resulting benefits for the customer are:

- **Tender preparation**
  Efficient preparation of coherent, readily understandable specifications. This facilitates realistic planning of materials and resources and the shortest possible delivery in the event of an order.

- **Contract processing**
  Fast translation of the tender into a correctly tabulated order. System design and engineering takes place according to standard rules based on expert systems. The modular design of equipment and systems and the modular structure of software tools for CAD and data base management enable thema-nufacturing documents and the user's documentation to be produced automatically.

Design of PLC networks

For performing the diverse design and engineering tasks associated with the technical processing of a contract, the systems engineers have at their disposal a powerful expert system. One of the main parts of this system is a program for analysing the suitability of the HV lines for transmitting PLC signals. The program calculates the attenuation and performance of complex topologies and heterogeneous structures for different sets of boundary conditions. Another important function is that of the data base for systematically storing and maintaining the various PLC networks. These data form the basis for engineering additions to, and modifications of communication networks. In both cases, the data base is immediately updated so that consistent, currently valid information is always available for further modifications and system studies.

The following are some typical systems engineering problems which illustrate the advantages of computer-based engineering tools:

- Calculation of the attenuation of any network structure and topology while taking into account inhomogeneities such as transposition, radial lines, and mixed cable and overhead line power systems.
- Determination of the influence of HV line faults on signal attenuation which is one of the most important aspects influencing the propagation of protection signals.
- Determination of the optimum coupling to minimize signal attenuation in normal operation and the additional attenuation due to an HV fault.
- Resolution of matching problems
  Proposal of alternative solutions to overcome inhomogeneous transmission paths.
- Frequency planning
  Determination of alternatives to make the best use of the available frequency spectrum.
- Performance calculations
  Derivation of the signal-to-noise ratio from the calculated values for line noise and signal attenuation.
- Special applications
  For example, the design of PLC links on HVDC lines including the calculation of the additional filters needed to suppress the interference generated by the power semiconductors in the converters.
- Performance/cost optimization of communication networks.
- Recording, maintenance, and management of PLC network data.

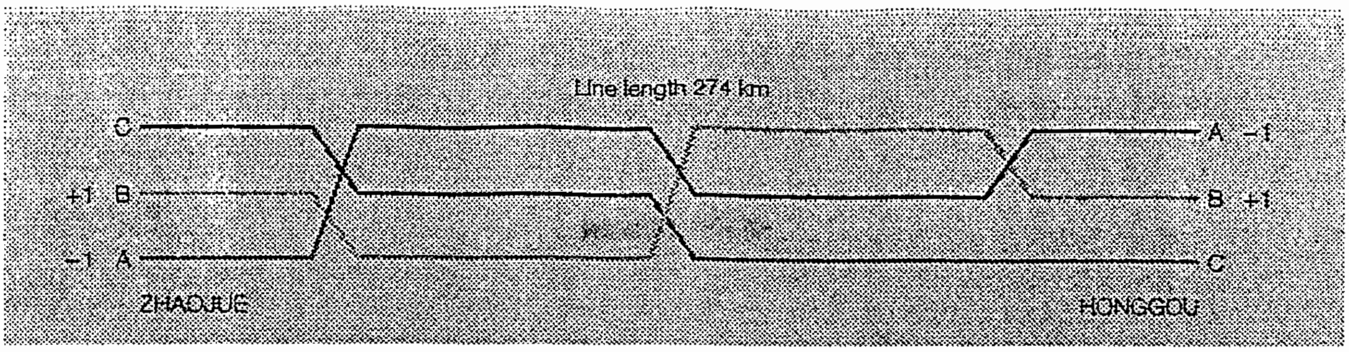


Fig. 1: 500 kV line transposed three times. PLC coupling: Phase-to-phase A-B / A-B.

Design example: The calculation of the parameters determining the performance of a PLC link is explained above for the example of a transposed 500 kV line in the People's Republic of China. (The line data must be complete and as accurate as possible in order to reliably calculate the transmission characteristics.)

View from station A towards station B

Name of station A : ZHAOJUE
Name of station B : HONGGOU
Nominal line voltage (KV) : Circuit 1: 500 2: ... 3: ... 4: ...

Section No.	1	2	3	4	5	6	7	8	9
Section length (km)	46.0	91.0	91.0	3.0	19.0	17.5	6.5		
Geometry No.	1	1	1	1	2	3	4		
Type of tower configuration	H11	H11	H11	H11	H11	H11	H11		
Kind of section termination	TR	TR	TR	NG	NG	NG	CE		
Average ground resistivity (Ωm)	100	100	100	100	100	100	100		
Average altitude above sea level (m)	2000	2000	2000	2000	2000	2000	2000		
Designation of phase conductor 1	C	A	B	A	A	A	A		
Designation of phase conductor 2	B	C	A	B	B	B	B		
Designation of phase conductor 3	A	B	C	C	C	C	C		
Designation of phase conductor 4									
Designation of phase conductor 5									
Designation of phase conductor 6									
Designation of phase conductor 7									
Designation of phase conductor 8									
Designation of phase conductor 9									
Designation of phase conductor 10									
Designation of phase conductor 11									
Designation of phase conductor 12									
Designation of groundwire 1									
Designation of groundwire 2									

Table 1: Basic data of High-Voltage line data

View from station A towards station B

Specification of groundwire conductors		Groundwire No. 1	Groundwire No. 2
Conductor designation		GJ-70A	GJ-70A
Conductor diameter D0	(mm)	11.0	11.0
Number of outer strands		12	12
Diameter of outer strands D1	(mm)	2.2	2.2
Material of conductors		ST	ST
Thickness of ice layer TI	(mm)	7.5	7.5
Horizontal displacement	(m)	-12.2	12.2
Suspension height	(m)	37.0	37.0
Maximum sag	(m)	14.0	14.0

Specification of phase conductors		Circuit 1	Circuit 2	Circuit 3	Circuit 4
Conductor designation		LGJ-400/50			
Number of conductors in the bundle				4	
Conductor distance within the bundle D	(cm)			45.0	
Conductor diameter D0	(mm)	27.6			
Number of outer strands		24			
Diameter of outer strands D1	(mm)			3.1	
Material of conductors		ACSR			
Thickness of ice layer TI	(mm)	7.5			
Horizontal displacement	(m) of conductor No.	1: -14.0	4:	7:	10:
Horizontal displacement	(m) of conductor No.	2: 0.0	5:	8:	11:
Horizontal displacement	(m) of conductor No.	3: 14.0	6:	9:	12:
Suspension height	(m) of conductor No.	1: 27.0	4:	7:	10:
Suspension height	(m) of conductor No.	2: 27.0	5:	8:	11:
Suspension height	(m) of conductor No.	3: 27.0	6:	9:	12:
Maximum sag	(m)	17.6			

Table 2: Geometry 1, Conductor specification and co-ordinates

The basic data of the HV line are given in Table 1 and include the number and length of the individual sections, the ID numbers for assigning the conductor pattern (geometry), type of mast, number and type of transposition, specific resistance of the ground path, etc.

Tables 1 and 2 are taken from a questionnaire which we prepared to help our partners collect the line data needed.

Table 2 gives the detailed specification for a particular conductor geometry. In the example of the above line, the data for 4 different line geometries would have to be specified. The data include the line dimensions and the precise specification of the phase conductors and the ground wires. The parameter "Thickness of ice layer" takes account of the attenuation of the signal caused by ice on the conductors.

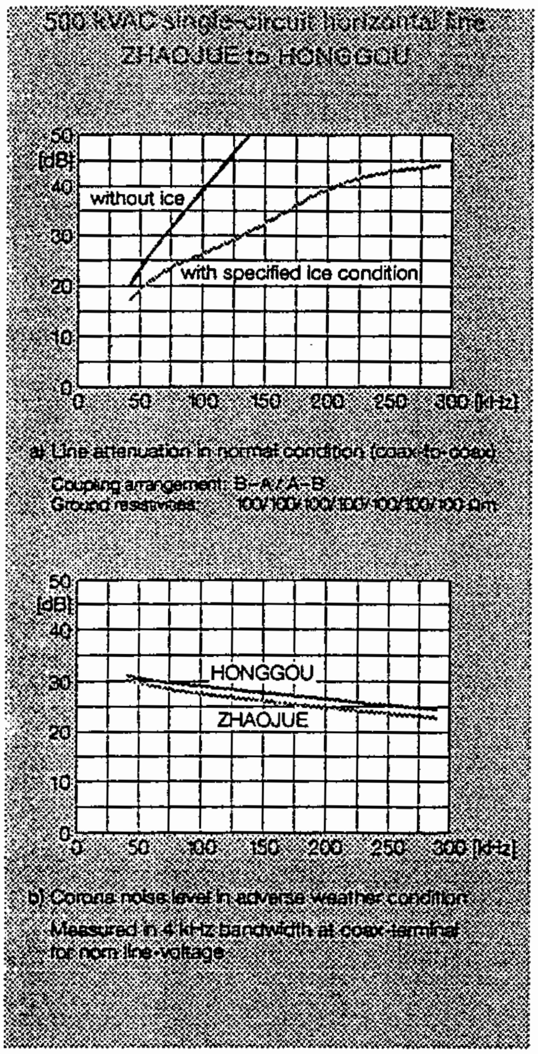


Fig. 2: a) Line attenuation and b) corona noise level as a function of frequency.

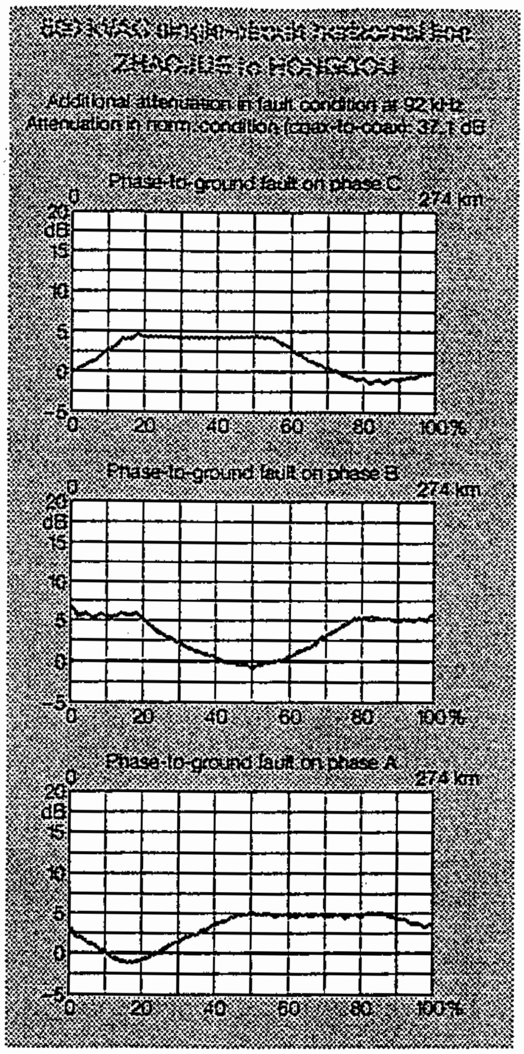


Fig. 3: Additional attenuation for a phase-to-ground fault in relation to fault location.

Figure 2a shows the line attenuation in relation to frequency for the prescribed method of coupling and a specific ground resistance of 100 Wm. The influence of conductor icing on signal attenuation can be clearly seen (curves 1 and 2).

The corona noise level as a function of frequency calculated for a bandwidth of 4 kHz and applicable for poor weather conditions is given in Fig. 2b. The small difference between the noise levels at the two ends of the line (curves 1 and 2) is due to the slight asymmetry of the transmission path.

The additional attenuation resulting from a ground fault for a frequency of 92 kHz is shown in relation to fault location and the phase concerned in Fig. 3. The considerable influence of fault location is clearly visible.

The magnitude of the additional attenuation was limited to a maximum of 8 dB by choosing a system with coupling onto two phase conductors. This value would have been significantly exceeded for a ground fault close to the end of the line had single-phase coupling been employed.

The full power of the transmitter is made available for a short time while a protection signal is being transmitted (signal boosting). This ensures that the signal is reliably received at the remote end in spite of the increased attenuation of the line.

PLC link no. ... 92 + 4 kHz HONGGOU to ZHAQUIE

Loading of channel 1

Speech 300 ÷ 2000 Hz + NSD 50/4 | D1 | Pilot

300 900 1500 2100 2700 3300 3900

Channel performance		Adverse weather	+ Con-ductor icing	+ Line fault
Testtone level at Tx coax-terminal	dBm	39.7	39.7	39.7
Line attenuation (coupling loss included)	dB	25.8	37.7	45.7
Testtone level at Rx coax-terminal	dBm	13.9	2.0	– 6.0
Corona noise level at Rx coax-terminal	dBm	–22.0	–22.0	–22.0
Burning arc noise level at Rx coax-terminal	dBm	—	—	–15.0
S/N ratio speech channel without compander	dB	39.3	27.5	—
S/N ratio data channels	dB	38.9	27.0	—
S/N ratio NSD 50	dB	—	—	15.2
S/N ratio ETL pilot channel	dB	43.9	32.0	—

PLC link no. ... 88 + 4 kHz ZHAQUIE to HONGGOU

Loading of channel 1

Speech 300 ÷ 2000 Hz + NSD 50/4 | D1 | Pilot

300 900 1500 2100 2700 3300 3900

Channel performance		Adverse weather	+ Con-ductor icing	+ Line fault
Testtone level at Tx coax-terminal	dBm	39.7	39.7	39.7
Line attenuation (coupling loss included)	dB	25.4	36.5	44.5
Testtone level at Rx coax-terminal	dBm	14.3	3.2	– 4.8
Corona noise level at Rx coax-terminal	dBm	–20.6	–20.6	–20.6
Burning arc noise level at Rx coax-terminal	dBm	—	—	–15.0
S/N ratio speech channel without compander	dB	38.4	27.3	—
S/N ratio data channels	dB	38.0	26.9	—
S/N ratio NSD 50	dB	—	—	18.2
S/N ratio ETL pilot channel	dB	43.0	31.9	—

Tables 3 and 4: Resulting signal-to-noise ratios for 88 and 92 kHz PLC channels.

The two Tables 3 and 4 give the performance data for the 88 and 92 kHz channels. The signal-to-noise ratios calculated include the transmitter power, the actual channel load, the line attenuation determined previously and the line noise level at the receiver input. It can be seen that with the degree of icing assumed, the signal-to-noise ratio is about 11 to 12 dB worse than the bad weather case without icing. A signal-to-noise ratio appreciably higher than 45 dB can be expected in good weather conditions. The signal-to-noise ratio of >15 dB during a fault which takes the additional attenuation and the noise level of the fully ionized arc into account is more than adequate to ensure reliable reception of a transfer tripping signal.

Communication on HVDC systems

A further example of the application of computer-based engineering tools is the synthesis and optimization of noise suppression filters for HVDC lines. PLC is often used as a means of communication on HVDC systems. The converter stations in such systems are powerful sources of interference having high spectral components in the PLC frequency band. These have to be significantly suppressed before PLC operation is sufficiently free of interference. Linear filters are used for this purpose. Their design, however, is made more difficult by the fact that only a limited number of standard values are available for the main L/C components. Additional tuning circuits are thus necessary to achieve an optimum from the point of view of technical performance and cost.

The attenuation characteristic of a noise suppression filter is shown in Fig. 4. In the frequency range 36 to 80 kHz of consequence for PLC, the rejection is >80 dB.

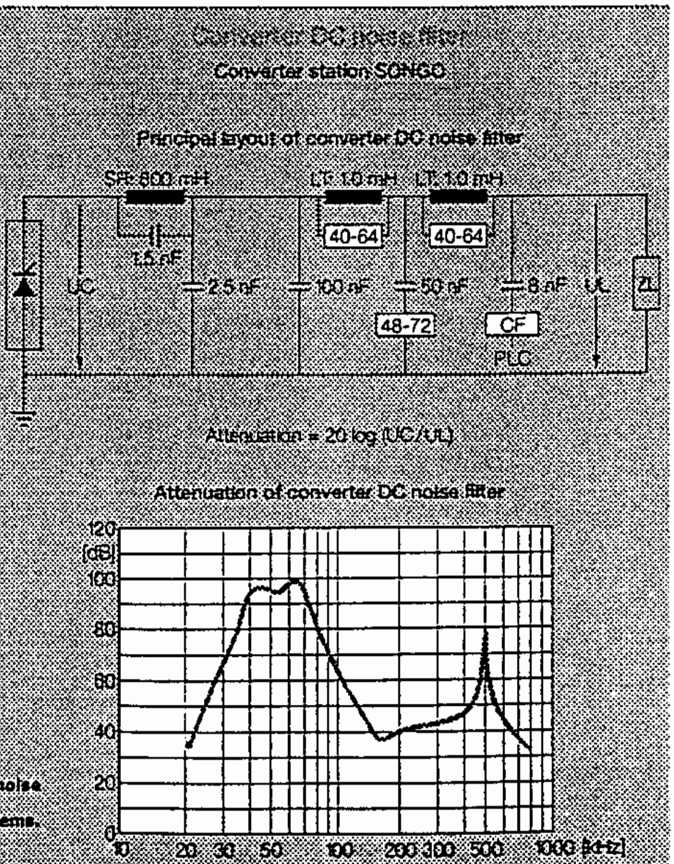


Fig. 4: Circuit and characteristic of a noise suppression filter for HVDC systems.

Advantages of an ABB PLC system solution:

- All-inclusive system solutions
  Long years of experience in the development of optimized systems, products, and services for the management, automation, control, and protection of power networks allow ABB to deliver all-inclusive system solutions for its customers.
- Understanding customer's needs
  As a result of the detailed knowledge of the processes for power system control, station control and protection, ABB is able to provide solutions even for the most diverse customer problems.
- A full range of products
  ABB offers a complete range of products, such as PLC equipment, coupling devices, wave-traps, transfer tripping devices, data modems, and telephone exchange equipment.
- Engineering know-how
  The invaluable engineering expertise that ABB has acquired over many years of experience in the field guarantee every conceivable support in the search for the best possible customer solutions.
- Computer-based project management
  An integrated data processing system supports our sales and system engineers in the preparation of tenders, system design, system engineering, contract administration, production, assembly, testing, shipping, and accounting.

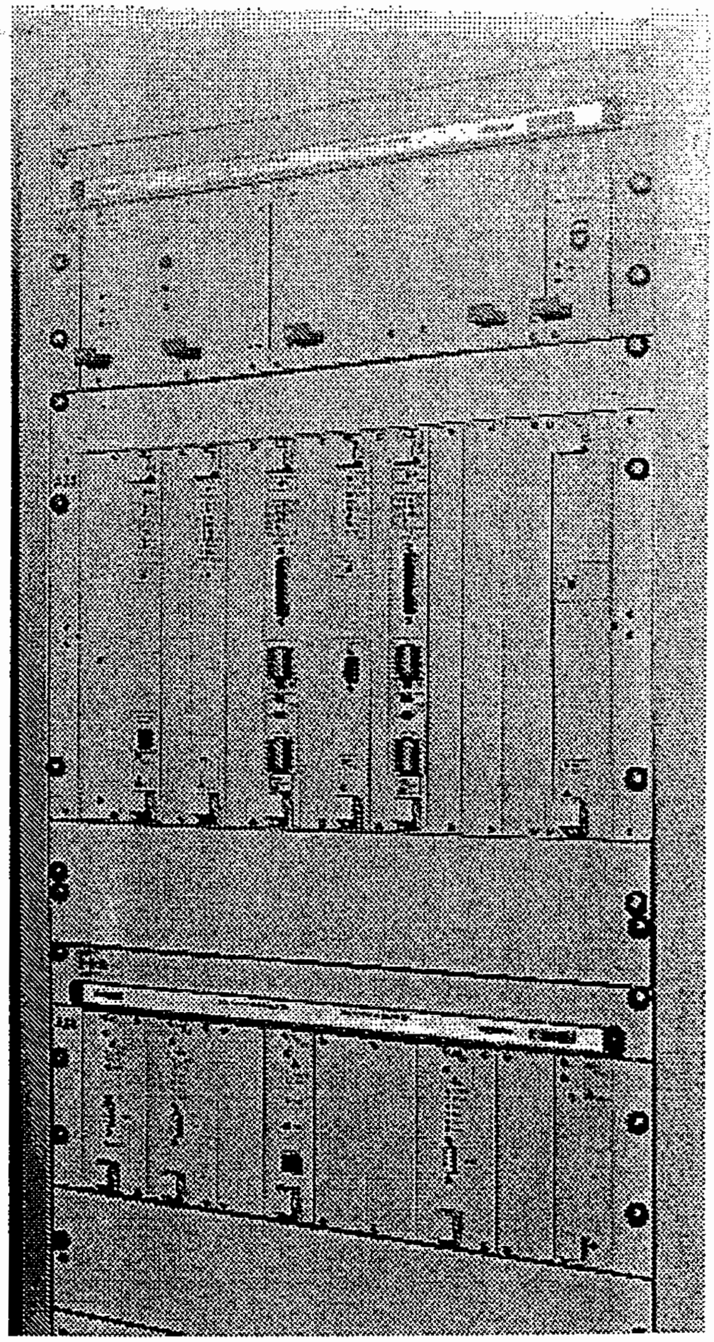


ABB Switzerland Ltd
Utility Automation Systems
Brown Boveri Strasse 6
CH-5400 Baden/Switzerland
Phone +41 - 58 589 37 35
or +41 - 844 845 845 (Call Center)
Fax +41 - 58 585 16 82
e.Mail utility.communication@ch.abb.com

www.abb.com/utilitycommunications

1KHA-000 547-SEN
2000 03.03 Printed in Switzerland

Lima, Octubre del año 2004.