Utility Communications
MCD80 - Power Line Carrier Coupling Devices
ABB coupling device type MCD80 – a reliable component for PLC communication

Power Line Carrier (PLC) links supplied by ABB form the backbone of power utility communication systems in all parts of the world. As an economical means of transmitting information and data, PLC has made an important contribution to power system control for many years.

PLC is mainly used to reliably transmit speech, energy management data and power system protection signals. In order to meet the varying requirements of power utilities when constructing a new power system or extending an existing one, PLC equipment must be compatible and of modular design.

MCD80 – advantages and features

- **High degree of modularity**
  Compact unit with variable complement of modules

- **Maximum personnel protection**
  Insulated enclosure and special design features minimize electrical hazards

- **Programmable**
  One high-pass version for different system parameters, programmable on site

- **Weather-proof and tropicalized**
  Corrosion inhibited by fiberglass reinforced polyester enclosure

- **High carrier power rating**
  Up to 1000 W PEP

- **ISO 9001 quality**

- **Simple integration in PLC system**
  As a supplier of complete PLC systems, ABB knows what is required of a coupling device

Fig. 1: Coupling device A9BT for phase-to-phase and inter-system coupling
Frequently, the coupling device is referred to as a coupling filter. Its purpose is to permit the PLC signal to pass, but reject the power system frequency and protect the communications equipment from the power system voltage as well as transient over-voltages caused by switching operations and atmospheric discharges.

**Coupling device functions**
- Injection and extraction of PLC signals on high voltage (HV) overhead lines and cables
- Through connections in intermediate stations
- Matching of HV line and PLC equipment impedances
- Electrical insulation between HV plant and PLC equipment

**The modular MCD80 series**
The MCD80 modular coupling devices form the interface between the HV transmission line and the PLC equipment and fully comply with the previously listed requirements with respect to compatibility and flexibility.

The units of the MCD80 series provide optimum PLC end-to-end links, RF through-connections and junction networks on all HV transmission systems.

All MCD80 devices conform to the latest IEC and ANSI recommendations.

**Task performed by a coupling device**
A PLC coupling device together with the associated coupling capacitor (CC) or capacitive voltage transformer (CVT) form a filter, which accepts the carrier frequency signals and rejects the power system frequency.

The following explanation of the principle of the coupling device assumes a single-phase coupling (PLC signals can be coupled to one or more phases of the power system). The basic circuit diagram is shown in Fig. 2.

A complete coupling comprises a line trap, to prevent the PLC signals from being short-circuited by the substation, and a coupling filter formed by the coupling capacitor and the coupling device.

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**Fig. 2: Principle of PLC communication**

Transport of Electrical Energy

Substation | Line trap | HV line impedance $Z_L$ | Line trap | Substation

Coupling capacitor or CVT

PLC equipment

Transmission of Data, Speech and Protection Signals

$Z_1$

$Z_2$

MCD80

Coupling device

$Z_1$

$Z_2$
Programmable high-pass filter – the optimum solution for most coupling problems

**Basic considerations**

**Single-phase coupling**

Since a single phase to ground fault close to the station (on the phase used for the PLC link) can short-circuit the signal, PLC signals may only be coupled to just one phase of the power system when transmission reliability in the event of a power system fault is of secondary importance.

Depending on the lower cut-off frequency, the high-pass coupling unit can be used with all coupling capacitance higher than 1.5 nF.

**Phase-to-phase coupling**

Coupling to two phases of the power system is much more reliable than coupling to just one phase. A single phase to ground fault in this case will normally cause an additional attenuation of the PLC signal by about 6 dB only.

A phase-to-phase coupling scheme consists of two coupling devices, one of which includes a hybrid module.

Sometimes the PLC signals can also be coupled to all three phases (three-phase coupling) or, in case of double-circuit HV lines, to one phase of circuit 1 and one phase of circuit 2 (inter-system coupling).

In practice, PLC coupling is a more complex problem since the units at both ends of the HV line have to be optimized for the conditions prevailing there. In the case of long lines with high attenuation, an analysis of the line is necessary to determine the arrangement with the most preferable transmission characteristics. ABB has years of experience in conducting such analyses. Analysis is generally not necessary for short or non-transposed lines. For a horizontal conductor configuration, the center phase is chosen for single-phase coupling and two adjacent phases for phase-to-phase coupling. In case of configurations with a vertical distribution, phases as high and as close as possible should be chosen. How many phases are used is largely a question of the reliability specified for the PLC link.
**Mechanical design**
A PLC coupling device consists of the equipment housing, the filter module, a drain coil, a surge arrester and an external earth switch.

In a phase-to-phase or inter-system coupling, one of the two coupling devices includes a hybrid transformer.

The MCD80 enclosure is of fiberglass reinforced polyester and meets the protection class requirements IP54 according to IEC 60529. The color of the enclosure is grey. There is no possibility of rust or corrosion.

The door is fitted with a synthetic seal and pressed firmly against the housing by two latches so that it is hermetically sealed. The latches are opened and closed by using a special key which can be removed to prevent unauthorized access to the unit.

The terminals for the connections to the coupling capacitor and to system ground are M10 bolts on the left of the unit.

The connections to the PLC equipment enter via four polyester cable glands (2x M20 and 2x M25) at the bottom of the housing.

A screw terminal is provided for the center of the coaxial cable and a clamp for the outer braiding.

In the bottom of the housing there are also two breathing vents.

All the components are tropicalized and therefore heaters or dehumidifiers are not required.

**Special versions**
A fully insulated version of the coupling device with the earth switch inside the housing is also available.

In yet another version, the earth switch is interlocked in such a way that the door of the coupling device can only be opened when the earth switch is closed.

There is also a special version for Extra High Voltage (EHV) systems with additional spurious protection inside the housing as well as at the end of the coaxial cable (in the communication room).

**Device protection**
A surge arrester limits voltage surges arising from switching operations and lightning strikes.

The matching and isolating transformer is designed for a test voltage of 10 kV for 1 minute which provides an adequate safety margin for the insulation between the line-side terminal and the PLC equipment terminal.

The reactive component of the power system current is conducted to ground by a drain coil. Because of the coil’s low impedance at power system frequency, it has high continuous and short-time current ratings.

It is safe to work on the device, providing the earth switch fitted externally on the left of the unit is closed.

Safety with respect to electrical hazards is further enhanced by the use of the electrically insulating fiberglass reinforced polyester enclosure.

**Modularity**
The modular MCD80 series of coupling devices has been designed to provide the best cost-effective solutions for a wide variety of coupling applications. To keep the stocks of essential spares to a minimum and facilitate future system extensions, the standard units do not have any components which have to be tuned (A9BS, A9BT).

For special applications, tuned units of the MCD80 series are available (A9BP, A9BR, A9CA, A9CG).
The system of MCD80 comprises the following components:

**High-pass coupling device A9BS**
This is a fourth-order high-pass filter and protective device housed in a fiberglass reinforced polyester enclosure. The filter can be programmed for various values of coupling capacitance and for two line-side and two PLC equipment-side impedances. Where the desired impedance is not covered by the standard programming range, a special programming range is available on request. In conjunction with the coupling capacitor or capacitive voltage transformer, the unit constitutes a complete coupling system for phase-to-ground coupling. There is space available in the enclosure for ancillary modules.

**High-pass coupling device A9BT with hybrid transformer**
Phase-to-phase or inter-system coupling requires push-pull signal injection onto the HV lines. For this purpose, a hybrid transformer A1AC is added to the high-pass filter described above. The unit then has the type designation A9BT. A full scheme for phase-to-phase or inter-system coupling thus comprises one A9BS and one A9BT at each end.

**Band-pass coupling device A9BP**
The individually manufactured, fixed tuned band-pass filter A9BP has to be used for applications where the frequency band which can be achieved with the programmable high-pass filter is inadequate.

Examples of such applications are coupling to HV cables (low line-side impedance) and cases in which relatively low frequencies have to be coupled via small capacitances.

The filter and its associated protective device are accommodated in the standard fiberglass reinforced polyester enclosure.

**Band-pass coupling device A9BR with hybrid transformer**
This unit is the same as A9BP but with the hybrid transformer A1AC. As before, phase-to-phase or inter-system coupling requires one A9BP and one A9BR at each end.

**Components for network branches**
These are three- or four-port network junctions for decoupling carrier frequencies. They are generally used in radial or in-line networks. A distinction must be made between directional decoupling and unidirectional decoupling. Wherever possible, directional decoupling is preferred, because it prevents the propagation of spurious carrier signals and exhibits the lowest signal attenuation.

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Fig. 5: In-line network configuration
Universal hybrid transformer A1AC
The universal hybrid transformer can be used for the following:
- push-pull signal generation and decoupling for phase-to-phase and inter-system coupling
- unidirectional coupling network in PLC transit stations
- paralleling two PLC units with little frequency separation

Figure 5 shows an in-line network which includes hybrids. The control station at point A is linked to all three substations. The hybrid is selective and unidirectional so that the substations cannot communicate with each other.

Separating filter A9CA/A9CG
This is used to directionally separate PLC channels where an especially low through attenuation is required. The cross-band attenuation of the filter is high. High-pass / low-pass and band-pass / band-stop versions are available. The filter is specifically designed for each application.

The A9CA version is supplied in a separate MCD80 enclosure.

The A9CG version, with same electrical characteristics as A9CA, is mounted on a plate with 4 UHF-sockets and intended for indoor use inside the PLC cabinet.

Matching components
Matching transformer A1AE
The matching transformer A1AE matches 75 Ω unbalanced impedance to 50 Ω unbalanced or 150 Ω balanced impedance. The module can be incorporated in the coupling device enclosure.

Attenuator A1AD
Matching can be improved by inserting an attenuator in the transmission path. Typical applications are couplings in short lines and in systems with input impedance largely dependent on frequency (e.g. combined HV cable and overhead line systems).

Attenuators can also be deployed if a coupling has to have a broadband termination at nominal impedance. Without the attenuator, the termination of a coupling is only matched within the frequency band of the PLC equipment connected to it. PLC equipment exhibits high impedance outside its own frequency band to enable other equipment to be connected in parallel. The module has to be incorporated in the coupling device enclosure.

Figure 6 illustrates an application of this kind for a T-line with a PLC system linking the three terminals. The possibility of an open-circuit (e.g. when the PLC equipment at one of the terminal stations is disconnected), which would be seen as a short circuit at the junction, has to be eliminated, because this would additionally attenuate signals transmitted between the other two terminals.

The purpose of the attenuators shown in Figure 6 is therefore to maintain the impedance at the junction close to nominal in the entire PLC frequency range.
Systems engineering and planning
The following points are of special interest with regard to systems engineering:

HV line impedance
Characteristic impedances of HV lines typically lie in the range from 350 to 450 Ω per phase for single conductor and from 250 to 350 Ω per phase for bundle conductors. In order to terminate the coupling filter correctly for average operating conditions, the shunting effect of the line trap and the station impedance has to be taken into account. The line traps, which are inserted to compensate as far as possible the shunt impedance of the substation, are designed in such a way that the minimum blocking resistance is 1.41 times the line impedance. So the effective shunt impedance can be varied during operation between this value and infinity. Accordingly, the lineside impedance of the coupling filter varies between 240 and 400 Ω for single conductor and between 180 and 300 Ω for bundle conductors. A compromise has to be chosen in these ranges for the line-side impedance of the coupling filter. For single conductor, this is typically 320 Ω, for bundle conductors 240 Ω. Where a mismatch still remains, a lower coupling filter impedance is better than a higher one.

A phase-to-phase coupling is essentially a combination of two single-phase couplings, and therefore the same line-side impedances apply for the filters. The corresponding line-side impedance for HV cables has to be calculated in each individual case.

RF through connections
RF through connections is a low-cost way of establishing PLC links extending over a number of line sections. Their main drawback is their relatively high transit attenuation. The signal-to-noise ratio of the over-all link must therefore be considered when engineering the system. However, since the signals do not pass through filters with high selectivity, they have a more favorable frequency response (lower amplitude and group delay distortion) and shorter signal delays than AF through connections.

It is therefore quite likely for a data channel to perform better via a link with an RF through connection in spite of its lower signal-to-noise ratio than via an AF through connection.

Another advantage is the saving in frequency bandwidth due to the fact that the same frequency is used on all sections of the link.

Through connections using transit networks
Figure 7 shows a solution for the following problem:

There are HV lines from B to A and from A to C. At A, the PLC link from B to C has to be connected through and a local unit has to be connected for transmitting between A and B. To keep the attenuation of the through connection as low as possible, a directionally selective separating filter is installed.

Lower frequencies have better transmission characteristics and therefore they are used for the longer link between B and C and the higher frequencies are used for the shorter link between A and B.

Two coupling devices and a separating filter from the MCD80 series are needed. The separating filter can be installed either in the PLC equipment room or – if fitted in the MCD80 enclosure – in the switch yard.

Figure 8 shows a similar arrangement, but with phase-to-phase couplings and with local units to establish communication from A to B and from A to C.
Phase-to-phase RF through connection

Fig. 8: Phase-to-phase RF through connection

Dimensions [mm]

Fig. 9: Dimensions [mm] (subject to change without notice)
The attainable frequency ranges of band-pass coupling devices can be calculated by using the following formula:

$$ f_2' = \frac{f_1'}{1 - \frac{2.5 \cdot 10^{-7} \cdot \pi \cdot f_1' \cdot C_k \cdot Z_1}{C_k' + 1.0 \cdot 10^{-7}}} $$

- $f_2'$: upper frequency limit [Hz]
- $f_1'$: lower frequency limit [Hz]
- $C_k$: coupling capacitance [F]
- $Z_1$: line-side impedance [Ω]

Formula valid for positive denominator, upper frequency limit $f_2' = 1000$ kHz, return loss $\geq 12$ dB.
### High-pass filter A9BS/A9BT

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal impedance PLC equipment-side $Z_2$</td>
<td>75 Ω and 125 Ω, unbalanced</td>
</tr>
<tr>
<td>Nominal impedance transmission line-side $Z_1$</td>
<td>240/320 Ω</td>
</tr>
<tr>
<td>Range of coupling capacitance</td>
<td>1.5 to 13 nF</td>
</tr>
<tr>
<td>Composite loss within passband</td>
<td>≤ 1.0 dB typical</td>
</tr>
<tr>
<td>Return loss within passband</td>
<td>≥ 12 dB typical</td>
</tr>
</tbody>
</table>

### Band-pass filter A9BP/A9BR

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nominal impedance PLC equipment side $Z_2$</td>
<td>as desired</td>
</tr>
<tr>
<td>Nominal impedance transmission line side $Z_1$</td>
<td>as desired</td>
</tr>
<tr>
<td>Range of coupling capacitance</td>
<td>min. 0.5 nF</td>
</tr>
<tr>
<td>Composite loss within passband</td>
<td>≤ 1.0 dB typical</td>
</tr>
<tr>
<td>Return loss within passband</td>
<td>≥ 12 dB typical</td>
</tr>
</tbody>
</table>

### Common filter properties

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average continuous power (frequency dependent)</td>
<td>200 W typical</td>
</tr>
<tr>
<td>Nominal peak power P.E.P. at 50 kHz</td>
<td>≤ 400 W</td>
</tr>
<tr>
<td>Nominal peak power P.E.P. at 100 kHz</td>
<td>≤ 1000 W</td>
</tr>
<tr>
<td>Non-linear distortion</td>
<td>2-tone test P.E.P. 400 W, $f_1 = 54$ kHz, $f_2 = 66$ kHz</td>
</tr>
<tr>
<td>Intermodulation 3rd &amp; 5th order</td>
<td>≥ 80 dB</td>
</tr>
<tr>
<td>Harmonic distortion</td>
<td>≥ 80 dB</td>
</tr>
<tr>
<td>Power frequency test voltage</td>
<td>Transformer (primary/secondary)</td>
</tr>
<tr>
<td>Hybrid (windings/windings)</td>
<td>5 kV$_{max}$, 1 min</td>
</tr>
<tr>
<td>Impulse test voltage</td>
<td>Transformer (input line-side to ground)</td>
</tr>
<tr>
<td>Hybrid (inputs against ground)</td>
<td>5 kV$_{peak}$</td>
</tr>
<tr>
<td>Crossover attenuation of hybrid A1AC</td>
<td>≥ 20 dB</td>
</tr>
</tbody>
</table>

### Drain coil

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-pass A9BS/A9BT</td>
<td>Inductivity adjustable depending on selected programming</td>
</tr>
<tr>
<td>Impedance at mains frequency</td>
<td>≤ 1.5 Ω</td>
</tr>
<tr>
<td>Band-pass A9BP/A9BR</td>
<td>Inductivity</td>
</tr>
<tr>
<td>Impedance at mains frequency</td>
<td>≤ 20 Ω</td>
</tr>
<tr>
<td>Common features</td>
<td>Continuous current</td>
</tr>
<tr>
<td>Short-time current</td>
<td>≤ 50 A, 0.2 s</td>
</tr>
</tbody>
</table>

### Earthing switch

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated current</td>
<td>300 A$_{max}$, continuously</td>
</tr>
<tr>
<td>Short-time current</td>
<td>16 kA, 1 s</td>
</tr>
</tbody>
</table>

### Surge arrester (type ABB RV 0.66)

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
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<tbody>
<tr>
<td>Rated voltage</td>
<td>660 V</td>
</tr>
<tr>
<td>Max. 100% impulse spark-over voltage (1.2/50 μs)</td>
<td>3300 V$_{peak}$</td>
</tr>
<tr>
<td>Rated discharge current (8/20 μs)</td>
<td>5 kA$_{max}$</td>
</tr>
</tbody>
</table>

### Connections

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment side</td>
<td>Terminal blocks for max. cross section</td>
</tr>
<tr>
<td>Line side and earthing</td>
<td>4 cable glands (2 x M20 and 2 x M25) for cable diameter</td>
</tr>
<tr>
<td>Connecting bolts with metric threading</td>
<td>M10</td>
</tr>
</tbody>
</table>

### Permissible ambient temperature range

<table>
<thead>
<tr>
<th>Property</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Designed and manufactured in accordance with requirements and recommendations of IEC 60481, SEV 3052 and ANSI C93.4.</td>
<td></td>
</tr>
</tbody>
</table>

Designed and manufactured in accordance with requirements and recommendations of IEC 60481, SEV 3052 and ANSI C93.4.
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