COMMUNICATION NETWORKS

Power Line Carrier Communication.
Design and Engineering.

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 fiber 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 backup to increase the availability of important new digital channels.

Over decades of successful involvement in the PLC and transfer tripping (teleprotection) 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.

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 (teleprotection) 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 fulfills the following essential requirements:

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

- **A full range of products**
  PLC equipment, coupling devices, line traps, transfer tripping devices (teleprotection equipment), 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 system 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 the manufacturing 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 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 teleprotection 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
  - Performance/cost optimization of communication networks
  - Recording, maintenance and management of PLC network data

Design example
The calculation of the parameters determining the performance of a PLC link is explained below for the example of a transposed 500 kV line (see Fig. 03) 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).

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.

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.

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: ...

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01 Basic data of high voltage line data

Section Nr.	1	2	3	4	5	6	7
Section length (km)	46.0	91.0	91.0	3.0	19.0	17.5	6.5
Geometry No. 1	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							

*The table is taken from a questionnaire that enables our partners to collect the line data needed.

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02 Geometry 1, conductor specification and co-ordinates

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)	17.5			

*The table is taken from a questionnaire that enables our partners to collect the line data needed.

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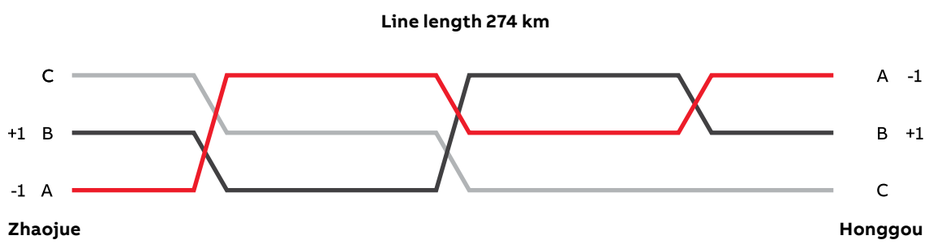
03 500 kV line transposed three times. PLC coupling: phase-to-phase A-B / A-B



The result of the HV line parameter calculation allow optimum coupling and best performance of the PLC links.

— 04 a) Line attenuation and b) corona noise level as a function of frequency

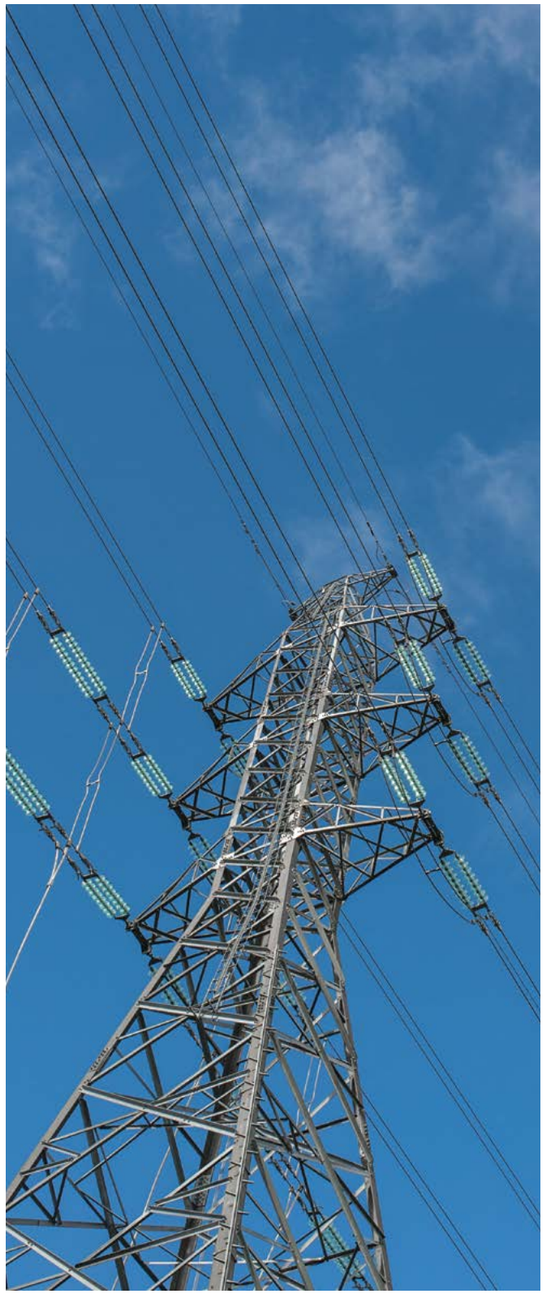
— 05 Additional attenuation for a phase-to-ground fault in relation to fault location

Figure 04a shows the line attenuation in relation to frequency for the prescribed method of coupling and a specific ground resistivity of 100 Ωm. 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. 04b. 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. 05. 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 if a single-phase coupling had been employed.

The full power of the transmitter is made available for a short time while a teleprotection 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.



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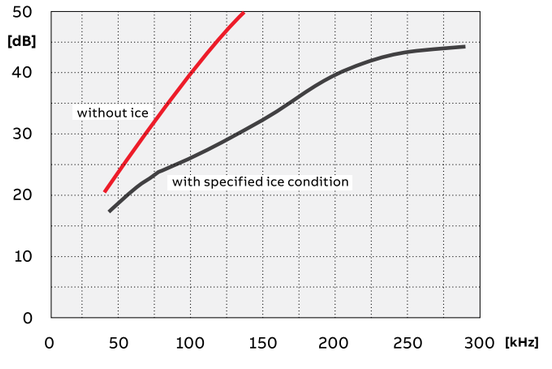
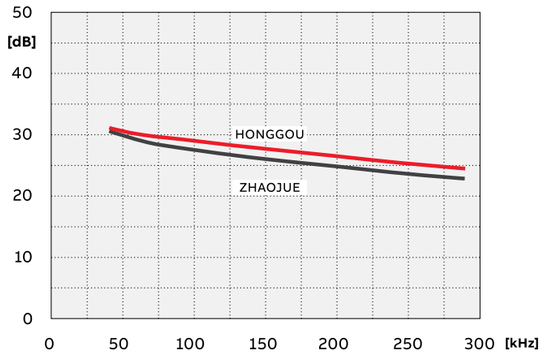
500 kVAC single-circuit horizontal line
ZHAOJUE to HONGGOU



a) Line attenuation in normal condition (coax-to-coax)

Coupling arrangement: **B - A / A - B**
Ground resistivities: **100/100/100/100/ 100/100/100 Ωm**



b) Corona noise level in adverse weather condition

Measured in 4 kHz bandwidth at coax-terminal for nominal line-voltage

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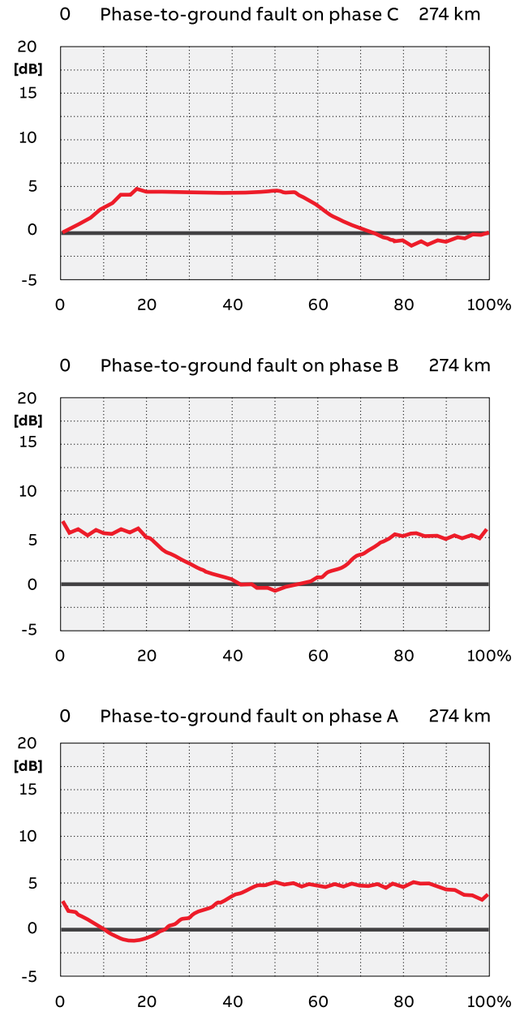
Additional attenuation in fault condition at 92 kHz
Attenuation in norm. condition (coax-to-coax): 37.1 dB



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06 Resulting signal-to-noise ratios for the 92 kHz PLC channel

PLC link no. ...: 92 + 4 kHz HONGGOU to ZHAOJUE

Loading of channel 1

Channel performance		Adverse weather	Conductor 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 Teleprotection	dB	-	-	15.2
S/N ratio PLC pilot channel	dB	43.9	32.0	-

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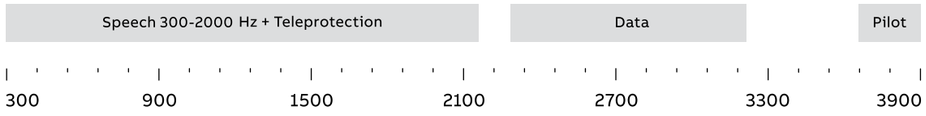
07 Resulting signal-to-noise ratios for the 88 kHz PLC channel

PLC link no. ...: 88 + 4 kHz ZHAOJUE to HONGGOU

Loading of channel 1



Channel performance		Adverse weather	Conductor 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 Teleprotection	dB	-	-	16.2
S/N ratio PLC pilot channel	dB	43.0	31.9	-

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08 ETL600-050: Compact single rack version, 50 Watts output power
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09 ETL600-100: Two racks version, 100 Watts output power

The two tables 06 and 07 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 (teleprotection).

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, line traps, transfer tripping devices (teleprotection equipment), 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 guarantees 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

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09

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