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. 1) 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: ...

<table>
<thead>
<tr>
<th>Section Nr.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Section length (km)</td>
<td>46.0</td>
<td>91.0</td>
<td>91.0</td>
<td>3.0</td>
<td>19.0</td>
<td>17.5</td>
<td>6.5</td>
</tr>
<tr>
<td>Geometry No. 1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Type of tower configuration</td>
<td>H11</td>
<td>H11</td>
<td>H11</td>
<td>H11</td>
<td>H11</td>
<td>H11</td>
<td>H11</td>
</tr>
<tr>
<td>Kind of section termination</td>
<td>TR</td>
<td>TR</td>
<td>TR</td>
<td>NG</td>
<td>NG</td>
<td>NG</td>
<td>CE</td>
</tr>
<tr>
<td>Average ground resistivity (Ωm)</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Designation of phase conductor 1</td>
<td>C</td>
<td>A</td>
<td>B</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
<tr>
<td>Designation of phase conductor 2</td>
<td>B</td>
<td>C</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Designation of phase conductor 3</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>Designation of phase conductor 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of phase conductor 5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of phase conductor 6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of phase conductor 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of phase conductor 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of groundwire 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Designation of groundwire 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Specification of phase conductors</th>
<th>Groundwire No. 1</th>
<th>Groundwire No. 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conductor designation</td>
<td>LgJ-400/50</td>
<td></td>
</tr>
<tr>
<td>Number of conductors in the bundle</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Conductor distance within the bundle D (cm)</td>
<td>45.0</td>
<td></td>
</tr>
<tr>
<td>Conductor diameter D0 (mm)</td>
<td>27.6</td>
<td></td>
</tr>
<tr>
<td>Number of outer strands</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Diameter of outer strands D1 (mm)</td>
<td>3.1</td>
<td></td>
</tr>
<tr>
<td>Material of conductors</td>
<td>ACSR</td>
<td></td>
</tr>
<tr>
<td>Thickness of ice layer T1 (mm)</td>
<td>7.5</td>
<td></td>
</tr>
<tr>
<td>Horizontal displacement (m) of conductor No. 1:</td>
<td>–14.0</td>
<td>4: 7: 10</td>
</tr>
<tr>
<td>Horizontal displacement (m) of conductor No. 2:</td>
<td>0.0</td>
<td>5: 8: 11:</td>
</tr>
<tr>
<td>Horizontal displacement (m) of conductor No. 3:</td>
<td>14.0</td>
<td>6: 9: 12:</td>
</tr>
<tr>
<td>Suspension height (m) of conductor No. 1:</td>
<td>27.0</td>
<td>4: 7: 10:</td>
</tr>
<tr>
<td>Suspension height (m) of conductor No. 2:</td>
<td>27.0</td>
<td>5: 8: 11:</td>
</tr>
<tr>
<td>Suspension height (m) of conductor No. 3:</td>
<td>27.0</td>
<td>6: 9: 12:</td>
</tr>
<tr>
<td>Maximum sag (m)</td>
<td>17.5</td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Basic data of high voltage line data

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

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

Fig. 1: 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.

500 kVAC single-circuit horizontal line
ZHAOJUE to HONGGOU

Figure 2a 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. 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 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.

![Graphs showing line attenuation, corona noise level, and additional attenuation for different fault conditions.]

**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
Pilot (teleprotection).

quate to ensure reliable reception of a transfer tripping signal level of the fully ionized arc into account, is more than ade-
a fault, which takes the additional attenuation and the noise weather conditions. The signal-to-noise ratio of >15 dB during ratio appreciably higher than 45 dB can be expected in good than the bad weather case without icing. A signal-to-noise
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 ade-

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, au-
tomation, control and protection of power networks allow ABB to deliver all-inclusive system solutions for its cus-
tomers.

- **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 tele-
phone 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, pro-
duction, assembly, testing, shipping and accounting.

---

Table 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 ade-

---

Power Line Carrier Communication Design and Engineering | 7