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Distribution automation using distribution line carrier systems - Part 1: General considerations - Section 1: Distribution automation system architecture

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Automatisation de la distribution à l'aide de systèmes de communication à courants porteurs - Partie 1: Considérations générales - Section 1: Architecture des systèmes d'automatisation de la distribution

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Automatisation de la distribution à l'aide de systèmes de communication à courants porteurs –

Partie 1:
Considérations générales –
Section 1: Architecture des systèmes d'automatisation de la distribution

Distribution automation using distribution line carrier systems –

Part 1:
General considerations –
Section 1: Distribution automation system architecture

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DISTRIBUTION AUTOMATION USING DISTRIBUTION LINE CARRIER SYSTEMS –

Part 1: General considerations – Section 1: Distribution automation system architecture

FOREWORD

1) The IEC (International Electrotechnical Commission) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of the IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, the IEC publishes International Standards. Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. The IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.

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The main task of IEC technical committees is to prepare International Standards. In exceptional circumstances, a technical committee may propose the publication of a technical report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;
- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;
- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

Technical reports of types 1 and 2 are subject to review within three years of publication to decide whether they can be transformed into International Standards. Technical reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

IEC 1334-1-1, which is a technical report of type 3, has been prepared by IEC technical committee 57: Power system control and associated communications.

The text of this technical report is based on the following documents:

Committee draft	Report on voting
57(SEC)196	57/240/RVC

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This series of IEC 1334, listed in annex B, concerns distribution automation systems supported by two-way communication channels using medium- and low-voltage distribution power mains as data transmission media.

Such communication channels will be referred to as "DLC", which stands for distribution line carrier.

Distribution automation systems are intended to provide a large amount of facilities related to two main applications, concerning network automation and customer service automation.

Table 1 summarizes the most important options concerning the above-mentioned applications. Requirements concerning these options will be included in the future IEC 1334-1-2.

As medium-voltage and low-voltage power mains have been designed for electric energy supply and, consequently, can only offer poor performances for data transmission, stringent requirements are necessary in order to ensure data integrity and transmission efficiency suitable to the application needs.

The aim of these publications is to provide adequate information for correct design and reliable operation of distribution automation systems using DLC.

INTRODUCTION

Distribution networks, in spite of being difficult channels for data communication because of signal attenuation, noise level and the fact that coupling side impedance can vary unpredictably with time, have always been considered by the electric utilities as the most attractive resource for supporting the introduction of automation techniques aimed at reducing operating cost and capital expenditure.

Compared to other communication media, distribution networks are owned by the electric utilities. This allows the creation of new services without requiring additional communication carrier costs or significant operational increase of costs.

Moreover, electric utilities can keep direct control over the transmission equipment, thus avoiding reliance on a third party.

For these reasons, a number of communication systems using distribution networks as a transmission medium have been already developed at industrial levels.

The first systems, due to the limited possibilities offered by technology, could only offer a one-way link from control centres towards the remote equipment to be controlled.

However, they opened the way to the implementation of distribution automation techniques suitable to satisfactorily respond to certain important needs, mainly related to the field of customer service automation, as for example:

- introduction of advanced tariff system (indirect load management);
- direct management of customer load.

In more recent years, due to the progress of electronics, two-way communication systems providing low data transmission speed (not more than a few bits/s) have been installed. They have been utilized to support network automation techniques requiring the acknowledgement of commands sent towards line switches, as for example:

- automatic sectionalizing of feeders affected by fault;
- remote operation of capacitor banks.

At present industrial development of very effective two-way communication systems can be envisaged. Their main feature is the ability to provide higher data transmission speed (from tens to hundreds of bits/s), so that a single channel can support most applications of distribution automation, thus allowing favourable cost/benefits evaluation.

In this way, a large number of facilities related to both network and customer service automation seems to be able to find a very comprehensive solution within the framework of integrated distribution automation systems.

It should be noticed that, even though the technique for transmitting communication signals on a distribution network is quite similar to that already well developed for high-voltage lines, stringent constraint for identifying cost-effective solutions is to be considered as a mandatory requirement.

Experience with high-voltage line carrier systems may not be directly applicable to distribution network line-carrier systems due to factors including cost considerations. Therefore, line carrier communication systems on distribution networks should be treated as a completely new application area in relation to what is already known for high-voltage networks.

DISTRIBUTION AUTOMATION USING DISTRIBUTION LINE CARRIER SYSTEMS –

Part 1: General considerations – Section 1: Distribution automation system architecture

1 Scope

This technical report of type 3, after a short description of the structure of distribution networks for both medium- and low-voltage levels, presents the architecture of a distribution automation system (DAS) using distribution line carrier systems.

It outlines and discusses the interaction between the distribution network structure and the configuration of the distribution automation system.

It provides an overview of the functional elements which constitute the basic structure and it deals with the main options concerning the coupling methods for the transmission signal injection.

It also identifies the ISO-OSI levels involved in the functional architecture of distribution automation systems.

2 Reference documents

IEC 38: 1983, *IEC standard voltages*

ISO 7498: 1984, *Information processing systems – Open Systems Interconnection – Basic reference model*

3 Structure of a distribution power network

A distribution power network includes two main power networks referred to as MV (medium-voltage) and LV (low-voltage).

Table 2 summarizes the values of standard and exceptional voltages of the distribution power network, according to IEC 38.

3.1 *MV power network*

MV power networks are supplied through HV/MV transformers, installed in HV/MV substations, typically as shown in figure 1.

Each HV/MV transformer whose MV winding neutral point can be either isolated or connected to earth by means of a suitable impedance supplies a section of busbar.

Each busbar section supplies a number of MV feeders through circuit-breakers with associated protection and possibly control (auto-reclosing) devices.

MV busbar sections in an HV/MV substation may be interconnected through a circuit-breaker to allow energizing all the MV feeders from one HV/MV transformer.

For power factor compensation, one switched capacitor bank per busbar section may also be installed.

MV feeders are an aggregation of several line sections delimited by switches, without any protection device associated, installed within an MV/LV substation. A typical diagram is shown in figure 2.

In relation to the operation of line switches, which can be either motorized or not, the resulting configuration of the MV power network is dynamic.

Each line section can be composed of one or more of the following main types: underground or overhead insulated cables, overhead lines with bare conductors.

Since most feeders rejoin MV busbar of adjacent HV/MV substations, the MV power network composed by MV feeders and MV/LV substations is a meshed network. A typical diagram is shown in figure 3.

In some cases, the MV network supplied by the same HV/MV substations, can include two different voltage levels, interconnected between themselves by means of suitable MV/MV transformers.

From the point of view of data transmission and network automation requirements, it is important to stress that this network can be operated in two different ways:

– radial scheme,

– interconnected scheme.

In the first case, each feeder is energized through a single circuit-breaker connected to a busbar section of an HV/MV substation, up to the end of the line sections where the final switch called "border line switch" is open.

In the second case, each feeder is energized by several circuit-breakers, normally belonging to different substations.

3.2 *LV power network*

LV power networks are supplied through MV/LV transformers, installed in MV/LV substations.

Each MV/LV transformer, whose LV winding neutral point is generally directly connected to earth, energizes a busbar section which supplies a number of LV lines through circuit-breakers with associated overload and overcurrent relays or fuses.

Since most LV lines coming out from an MV/LV substation rejoin LV busbar of neighbouring MV/LV substations, the structure of the LV network (whose typical diagram is shown in figure 4) is similar to that of the MV power network as far as meshing possibilities and radial or interconnected operation is concerned.

LV lines may also include line sections of different types: underground or overhead insulated cables, overhead lines with bare conductors. Each LV line is responsible for the supply of number of LV customers.

Since line switches can be operated for various reasons, the resulting configuration can also change dynamically.

4 Distribution automation system architecture

4.1 *Structure*

Figure 5 shows the general architecture of a distribution automation system (DAS), using a DLC system and providing both the facilities concerning network and customer automation.

This architecture, whose diagram is strictly dependent on the distribution power network structure, includes the following units:

– *central unit* (CU) which performs all the functions required by the applications needs. It may be connected to a number of central medium-voltage units (CMUs), installed in each HV/MV substation, and/or to a number of central low-voltage units (CLUs) installed in each MV/LV substation.

– *central medium-voltage unit* (CMU) which is located in HV/MV substations. It injects the transmission signal into the MV power network by means of an appropriate coupling device, establishing in this way a communication channel with the remote medium-voltage units (RMUs).

– *remote medium-voltage unit* (RMU), which is located at any MV distribution installation (typically an MV/LV substation, an MV customer, etc.). It injects the appropriate transmission signal into the MV power network by means of an appropriate coupling device. The RMU is connected at:

  - each energy delivery point supplying an MV customer, to the corresponding MV metering unit, performing energy measurement and data consumption processing;
  - each MV/LV substation to a central low-voltage unit (CLU) performing the functions required by network automation (telecontrol) and/or customer service automation;
  - typical points of MV networks to intelligent units performing other network automation applications (e.g. feeder switch selectors, fault detectors, reclosers, etc.);

– *central low-voltage unit* (CLU) which is located in each MV/LV substation. It provides the signal injection on the LV network in order to carry out a communication link with the remote low-voltage units (RLUs).

– *remote low-voltage unit* (RLU) which is typically located at the LV customer premises and connected to the LV metering unit.

Each of the above-mentioned units can be subdivided into a maximum of three functional components as shown in figure 6 and described below.

– *The communication unit* (xxCU) accepts messages with their destination addresses and delivers messages with their source addresses. Possible functions performed by the xxCU are: message routing, error handling, modulation, demodulation, signal injection, etc.

The xxCUs can communicate with each other (via the power mains) and with their processing units.

– *The processing unit* (xxPU) processes data in order to allow their transfer between the interfaces (to the outside of the DLC system) and the xxCUs.

Possible functions performed by the xxPU are: message interpretation, data compression, interface serving, etc.

– *The interfaces* (xxI) towards the outside of the DLC system perform the data transfer between the DLC system and the foreign system(s).

It can be stressed that the central unit (CU) does not contain a communication unit because it does not communicate via the mains. Access to other communication media is provided by a corresponding interface (CI).

The described architecture represents the most general functional model of a DLC system for distribution automation system applications.

When the aim of the distribution automation system concerns only customer service automation, it is possible to envisage alternative solutions, whose reference model depends on the extension of the facilities to be provided.

As an example, figure 7 shows a DLC system directly exchanging data between an HV/MV substation and the LV consumers supplied by an MV/LV transformer. In this case, it consists only of one CMU and of a number of RLUs. The function of the RMU and the CLU are performed by the CMU.

Figure 8 shows another example where a DLC system only allows house meter reading via the mains from a socket located in the street, to which a hand-held CLU can be connected.

In figure 9 a system is presented which uses DLC only within the LV network(s). The CLUs are connected to the CU via the public switched telephone network (PSTN).

4.2 *Identification of interfaces*

Table 3 lists the foreign systems and the DLC subsystems to which the DLC interfaces are connected. In a real system, some of them may be omitted, some are functionally implemented and some are physically reachable.

5 Interaction between network structure and automation system

5.1 *Signal injection*

The injection of the transmission signal into the MV power lines may be:

a) on MV busbar, upstream of the MV feeders' circuit-breakers or switches;

b) on MV lines, downstream of MV feeders' circuit-breakers or switches.