PCCN: From Concept to Realisation

C. Boisnault, J.F. Brisset, A. Pinget (EDF)
L. Hossenlopp (ALSTOM), H. Libens (ICE), C. Souchère (SCHNEIDER ELECTRIC)

1. Introduction

The aim of the PCCN Project, set up by the management of the EDF GDF Services Division is to implement a new technical generation of control systems for the HV/MV substations.

Following a feasibility study carried out between 1993 and 1995, it was decided that entirely digital technology should be used. Since January 1996, the project has been at the realisation stage: after the creation of the Technical Specification Requirements, a European bid was set up. Six manufacturers were selected and are now working on the development phase.

The first part of the paper explains the strategic aims of the project. The advantage of the digital technology will then be detailed in term of architecture, configuration, functions and tests.

2. Strategic aims

The policy of the EDF GDF Services Division is based on general principles including improvement of the quality of service and the reduction of costs. These factors are implying technical decisions.

2.1 Quality of supply

At present, almost 16% of customers' loss of supply are due to a failure of the control and protection system. Above all, current protection systems give no indication when they have failed. When there is a fault on the network, protection devices located upstream are activated, causing a loss of supply to a greater number of customers.

The failure of the protection systems is a function of time which bears no relevance to the number of network faults. Improved continuity of supply means that the control systems are responsible for an increasing proportion of cuts. Thus, if no improvements are made, control systems will be responsible for around 25% of permanent cuts by the year 2000.

2.2 Adaptation to network changes

The use of underground networks will continue to grow because of environmental constraints and in order to avoid the consequences of widespread incidents. The parts of the network which are underground will require the neutral earthing and the corresponding protection plan to be modified.

2.3 Upgradeability

The current control systems of the HV/MV substations are frequently reconfigured. This currently represents 16% of spending on substations, and 40% of the installations which are more than ten years old have been upgraded since they were installed. The emergence of new methods, the implementation of operation support systems to reduce the time taken to restore the system and the specification of new functions (defence plan etc.) mean that allowances will have to be made for technical modification of the control systems.

3. The digital generation

3.1 The advantages of digital technology for quality of supply

One of the primary objectives of the PCCN generation is to improve the quality of electrical power in terms of continuity of supply.

This is in line with the demands of the market and represents a general trend among the major suppliers of electrical power in industrialised countries.

Improved in the quality of supply requires both a reduction in network faults and a considerable reduction in the number of incidents involving loss of supply due to HV/MV substation control and protection systems.

The objective is that the performance in terms of reliability, availability and maintainability of equipment involved is increased. Only a generalised use of digital technology makes it possible.

3.1.1 Impact of greater availability

The advantage of digital technology over older generations is particularly interesting when availability is considered:

All the equipment monitor themselves by means of a series of self-tests, making it possible to determine the operating state of the equipment in real time (in service or out of service).

This also allows to switch to a back-up strategy when the failure of an equipment has an impact on the continuity of supply.

The best example of this is the "back-up of the outgoing feeder by the incoming feeder":

- With the PCCN generation, when a network fault occurs on an outgoing feeder whose digital protection system is shown to be out of service, the incoming feeder orders the circuit breaker of the outgoing feeder in question to open as a back-up. Thus, loss of power supply is limited to a single output.
- On the other hand, with previous generation technology, when a network fault occurs, the failure of the outgoing feeder protection systems causes the circuit breaker of the incoming feeder to open, cutting off the power of half a busbar.

3.1.2 Easier maintenance

Aside from triggering timely troubleshooting operations, the self-tests and self-diagnoses also represent an advantage for maintenance as they reduce the time spent working on equipment and make it considerably easier to locate faults.

3.1.3 Reliability leading to more efficient operation

Another advantage of digital technology, essential to the desired objective, is the fact that equipment reliability is not directly related to the number of functions it provides (whereas in the case of the earlier technology, reliability is inversely proportional to the number of functions).

This advantage of digital technology has been widely exploited in the PCCN generation.

Therefore, whilst observing the reliability constraints of the Technical Specification Requirements with regard to the desired objective, it is possible to implement numerous functions and mechanisms which make operation safer, faster and better suited to requirements, above all service resumption operations.

An example of this is the automatic load transfer without interruption in the event of an alarm.

3.2 The advantages of digital generation for upgradeability

The PCCN generation will be installed on EDF supply networks and used for ten to fifteen years. During this period, user needs and industrial realities will change, making it essential to modify solutions designed and installed at the start of the project.

From the user's point of view, requirements may be:

* addition of a new busbar to a substation,
* addition of a new line,
* modification of an existing item:
  - addition of input and/or output signals,
  - modification of functions,
  - modification of man/machine interface,
  - modification of messages exchanged between devices.

From the manufacturer's point of view, requirements may be:

* technological changes (i.e. component becoming obsolete),
* reduction in manufacturing costs.

3.3 Compatibility with current generation

The digital generation takes into account the importance of developing and modernising existing substations,

Compatibility with the current generation means that it must be possible to install the digital generation in current HV/MV substations (corresponding to two technical generations known as the conventional generation and Generation 86). This is essential to allow for a gradual installation of this generation.

3.4 Architecture principles

3.4.1 Conventional alternative in the supply of a substation control system

Electrical substation control systems are usually supplied in the following way:

* either a single supplier provides everything (turnkey basis), in which case the supplier must provide the various hardware and software components, and carry out engineering work to assemble these components and install them in the substation infrastructure (switchgear and civil engineering work),
* or different suppliers provide individual items such as protection devices, automatic controllers or man-machine interfaces, in which case the engineering work is carried out by the user or a third-party.

The strategy of separate equipment suppliers is generally used by utilities which own a large number of substations, justifying the expense of having specialised engineering teams working on all the substations.

3.4.2 PCCN packaging

A compromise was decided upon for the PCCN project, in order to take advantage of the good items of both these solutions. The supply consists of packages which are homogeneous from an electrical point of view, making it possible to decrease the amount of equipment to be procured without sacrificing EDF's technical control:

* The substation is split in five packages (busbars, transformers, supervision, substation automation, billing), as opposed to around twenty products when separate equipment is used (see Figure 1). Each package optimises the integration of the individual devices that it contains.
* Each of the five packages has its own specifications (configuration, cables, installation, etc.). EDF installs these packages using a communication network and a software configuration management system.
* Each package can be procured from different suppliers. The compatibility of these packages is ensured by the test process described in Section 5.

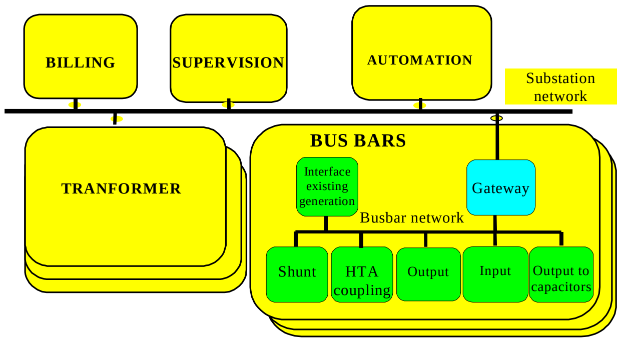

Figure 1 - The five PCCN project packages

3.4.3 Cohabitation principle

The ability to *cohabit* of PCCN generation digital package in an existing substation which still has to be modernised is one of the main characteristics of the busbar, transformer and billing packages.

This coexistence meets two of the operator's major requirements:

* Maintaining and ensuring flexible term investments. It is not necessary to replace the whole of the substation control system immediately to install the PCCN packages. For example it must be possible to add a new transformer of the PCCN generation installation without having to change the existing transformer equipment or the corresponding feeders. Eventually, this same package must be able to operate with the rest of the entirely digital control system, and optimise the corresponding functions.
* Minimising the unavailability of the substation. Modification of a busbar must not prevent the other busbars from operating. Repairs are made on one busbar at a time, unavailability being limited to the busbar which is being repaired.

* The concept of coexistence requires that boolean interfaces be created in order to provide connections with existing equipment (RTU, SOE, Mimic, etc.) via conventional marshalling cubicles (Figure 2).

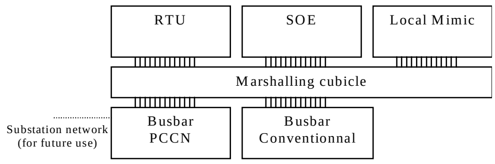

Figure 2 - Coexistence principle

3.4.4 Communication principles

Communication between a PCCN package and the rest of the system is based on two principles:

* Conventional physical connections in cohabitation phase (see section above).
* Communication network when all the packages have become digital. This network can be used to retrieve event files created by protection systems and set parameters.

The communication network is based on the Ethernet, UDP/IP, SNMP and TFTP standards. Remote signalling, remote control, remote measuring and file objects have been described. Services derived from the future standard IEC 61850 have also been specified for the transfer of these objects.

The network is completed by conventional wiring to transfer:

* Inter-package data with critical time constraints, for example, activation orders from the incoming feeder between the busbar and transformer packages.
* Safety data. A bus alarm which integrates the critical fault data is set up by each of the packages to allow emergency processing in the event of network communication failure inside the package.

3.5 <u>Configuration principles</u>

3.5.5 The configuration system

This integrates all the resources used to:

* Adapt standard equipment for the requirements of the substation,
* Improve the functions of the system without changing the hardware components.

Digital technology means that operation and parameter setting are more flexible.

However, this flexibility can only be guaranteed by using user-friendly configuration support tools. PCCN package configurators fall within this category.

3.5.6 Domains of configuration

The configurator works in four domains:

* The electromechanical architecture, which governs the single-line diagram of the substation.
* The system control architecture, which governs the substation automation and protection equipment.
* The operating functionality.
* The data files exchanged.

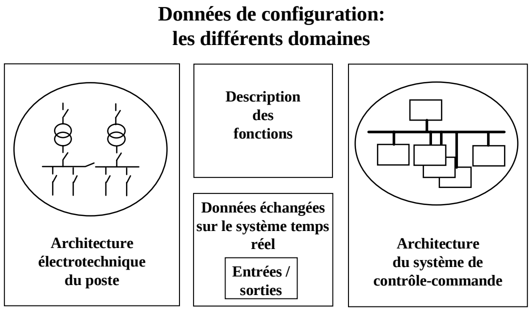

Figure 3 : Configuration fields

3.5.7 Concepts and library

Using the following objects makes it easier to adapt a substation:

* Standard objects.
* Identification rules.
* Standard formats for exchanges between the system configurator and the package configurators.

The repetitive nature of the configuration procedures naturally leads to the prior description of a standard objects library: standard plant, standard equipment, standard devices, standard functions, etc. The package configurator is used to create real objects by instantiating standard objects.

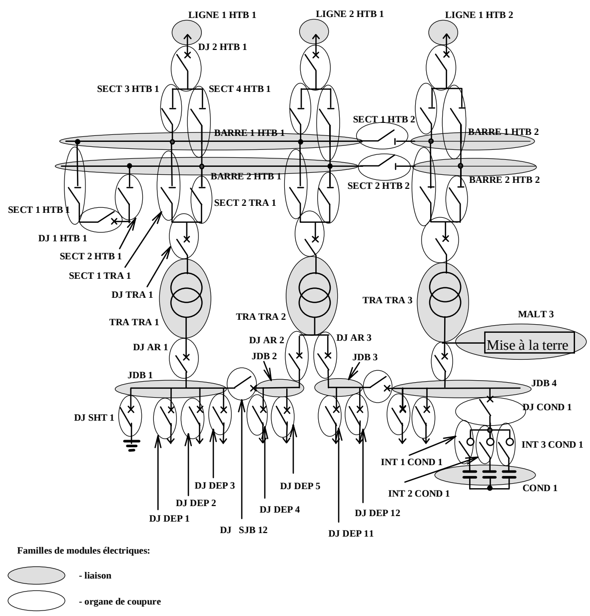

Figure 4 : Standard objects

3.5.8 Service functions

Each package executes the functions assigned to it. There are three types of functions:

* *Basic functions* do not require any parameters.
* *Standard configurable functions*. These functions are put into service or taken out of service and are adapted to the requirements of the substation network. These functions cannot be modified.
* *User functions*, which are created or modified using package configurators.

Each equipment of a package executes "*basic functions*".

The electromechanical architecture and the requirements of adaptation to the process lead to implementation of

"*Standard configurable functions*" and to the setting of parameters for them. An example is the type of earthing connection.

The specific features of the substation and its network, the obligatory coexistence with the preceding generations and the upgradeability requirements are handled by the "*user functions*". These functions are created functional block library. These functional blocks make it possible to install complex sequential boolean functions, safely and simply without computer experts. Programming by the end user means that the operating flexibility of digital technology can be used to full advantage.

• 3.5.9 Data coherency

Configuration flexibility can sometimes cause data incoherency as a result of a lack of traceability of successive parameter settings. The installation of an integrated parameter setting management tool ensures overall coherence of both data and functions.

• 3.5.10 Outlook

The current phase of the package configurator development is the first step towards EDF developing the "System Configurator", covering substation control systems and remote control systems.

• 4. The functions of the various packages

· 4.1 The busbar package

The busbar package is the only PCCN package for which decentralised architecture was mandatory (each cubicle is equipped with a control device). The safety requirements for people and property, associated with the quality service requirements, have led to EDF keeping the current structure, that is to say, the protection and automation equipment, as close to the circuit breaker as possible.

The different equipment (incoming feeders, outgoing feeders, capacitors, etc.) will therefore be connected to a local communication network.

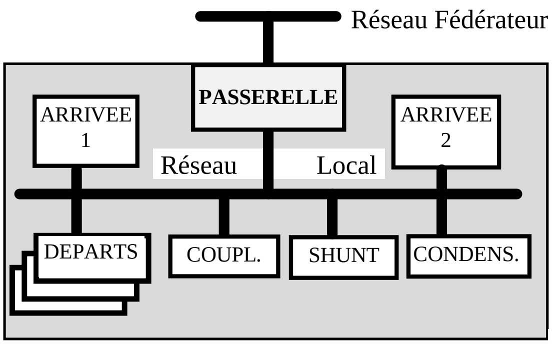

Figure 5 : Busbare package

New functions, made possible by adopting digital technology, will be added to the current protection and automation functions:

* logical selectivity of feeders and coupler,
* backup by logical selectivity of outgoing feeder by the incoming feeder and of the input by the connection,
* modification of the basic protection plan in order to take into account the imminent implementation of the new MV neutral earthing .
* parameter trouble recording back-up for all equipment.

On the front panel of each piece of equipment there is an integrated man-machine interface, which is automatically triggered in the event of loss of the communication network, the local network or the supervision package.

The choice of the local network to be used for the busbar package is left to the manufacturer.
The package shall be equipped with a coexistence interface whose architecture is also left to the manufacturer.

· 4.2 The transformer, automation, billing and supervision packages

The internal architecture of these packages is not imposed. As in the case of the busbar package, the transformer and billing packages are designed to be used in conventional substations or Generation 86 substations and are therefore manufactured with coexistence interfaces.
The package functions are as follows:

in the case of the supervision package:

* remote operation,
* local operation,
* SOE and archive,
* retrieve and store event files,
* allow remote reading: the remote read mode from a distant station (not to be confused with the remote control mode) means that, as in local mode, latest event files, parameter setting functions and event files can be accessed.

in the case of the transformer package:

* operation of internal protection systems,
* operation of external protection systems,
* voltage regulation,
* control the neutral point coil (for networks which change neutral configuration and use compensated neutral earthing).

in the case of the automation package:

* transformers automatic transfer,
* automatic switchover without transformer cut-off,
* frequency-metric load shedding/load restoration,
* VARmetric control,

in the case of the billing package:

* manage and transmit tariff signals at 175 Hz and at 188 Hz.

• 5. The PCCN test platform

· 5.1 A new testing problem

The introduction of digital technology not only means that ever more modular, upgradeable and powerful systems can be developed, but also that operating tests to check that equipment are interacting correctly are becoming increasingly complex (even more so when the equipment is supplied by different manufacturers).

These validation tests require tools to be developed to simulate, simultaneously and in real time, the digital exchange process between different items of equipment particularly for functions shared by different items of equipment.

The following sections describe the test tool developed for the PCCN project.

· 5.2 Acceptance platform

The platform has 4 parts:

* A PC which configures the system: generation of control system database structure and transfer to the control workstation.
* The dedicated control workstation supports the following functions:
    1. preparation of test scenarios (print out, compiling, import/export of files);
    2. test execution control (simulation device loading, establishing a common start time, monitoring the test as it is carried out, monitoring the behaviour of the back-up network, test sequencing conditions etc.);
    3. analysis of test results (merging the operation traces produced by each simulation device, archiving and advanced filter and search functions to facilitate rapid result analysis).
* A VXI rack which contains as many CPU cards as packages to be simulated and an input/output card to simulate the operating process (position of circuit breakers, faults etc.).
* A simple language for describing complex automation packages which simulate the behaviour of a package which receives and sends signals to other packages or the process. The engine can be based on any protocols and communication networks. It can therefore take into account all types of messaging software.
* The process simulation carried out using boolean equations is flexible and upgradeable. Generally, it makes it possible to simulate circuit breakers, currents and voltages representing electrical network faults, and all types of boolean states in real time.
* Different components simulate the signals (three-phase and single-phase current and voltage sources, direct current, etc.) as well as a junction box for connecting the control system packages to be tested (more than a hundred boolean and analog inputs/outputs available).

The entire platform is contained within a standard cabinet.

Furthermore, an analyser which decodes messages up to the application level allows non-specialists to follow all the exchanges, in real time or on-line, between packages and to diagnose the problems associated with improper message formats or improper message sequences between packages.

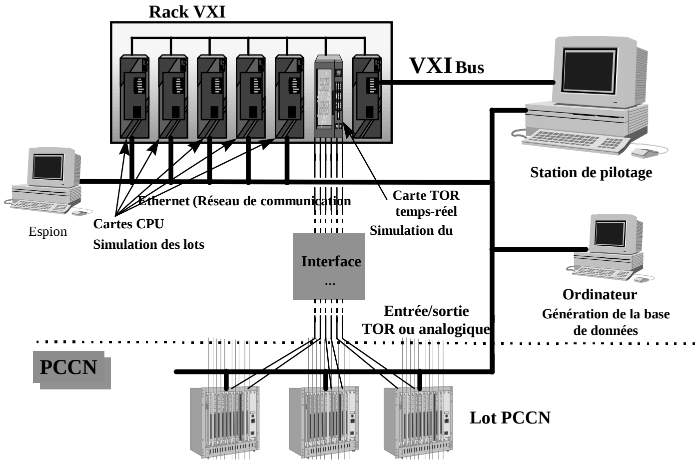

Figure 6 : PCCN tests plateform

· 5.5 A complex but fruitful development process

The development options selected make it possible not only to test the developed control system but also for a full-scale prototype of the control system to be produced even before the test stage. This is particularly effective for developing messaging software (type of message to be implemented, volume of exchanges etc.).

The same platform then makes it possible to validate each package individually, and then to check the inter-operation of all the packages, by a gradual integration process.

It should be noted that this is a general problem affecting many digital products with shared functions.

From a simple experiment, EDF has found a solution which is open and adaptable to different requirements. In particular, the communication module can be replaced by a different one on request and the simulation of different types of process by a simple modification of boolean equations and the development of an *ad hoc* interface.

• 6. Conclusion

The "PCCN - Development" project should reach its conclusion towards the year 2001 with different control packages being made available to EDF. These PCCN packages will then be able to be installed both in existing substations (to renovate or extend them) and in new structures.

The ability of various items of equipment to be used together will enable the operating organisation to develop its substation at a pace which suits it and with the equipment it chooses.