OPEN PLATFORM FOR PROTECTION, MONITORING AND CONTROL FOR OPTIMAL FLEXIBILITY IN GRID OPERATION

Frank BALDINGER	Omar MANSOUR	Bengt Almgren	Bo Almer
Locamation – Netherlands	Locamation – Netherlands	Fortum – Sweden	Protrol - Sweden
Frank.baldinger@locamation.nl	omar.mansour@locamation.nl	bengt.almgren@fortum.com	bo.almer@protrol.se

ABSTRACT

This paper describes an architecture for secondary systems in high and medium voltage substations. The system comprises protection, monitoring and control functionality as an integrated solution but with optimal modular realisation. The openness of the solution concentrates on the unconstrained functional possibilities, as perceived by customers, without jeopardizing cyber-security and system integrity. Application configuration by user definable Function Blocks and securely encapsulated within encrypted containers enable a manageable software maintenance process.

INTRODUCTION

The upcoming transition in the energy landscape and the application of yet unknown control of a Smart Grid enforce a different approach in the way we implement protection, control and monitoring technologies in the substations of electrical transmission and distribution grids.
The dilemma of introducing new innovative solutions, necessary to enable smart grids in a risk avoiding market, is impeding fast deployment.
Investments in electrical grids were traditionally based on a predictable planning horizon. Uncertainties in the future behaviour of a sustainable energy system disrupt the traditional planning principles. Network capacity based investments are costly, so alternative solutions, utilizing the capacity of the existing grid by means of advanced IT, are preferred. Uncertainty on what is required and how it should be implemented in protection, monitoring and control technology in the substations will not guide us towards the decisions that need to be taken for large-scale roll outs. Therefore, numerous pilots are underway to decrease the uncertainty on what is required and/or works successfully. The turnaround time of product development from concept to full-scale deployment might be far too long for network operators to react in a timely manner. In some geographic areas the market already requires a faster response. To enable fast responses a different approach is developed and presented in this paper.

PRESENT SITUATION

Protection, monitoring and control functionality today, is productized in dedicated devices for long-term usage in substations. New requirements will lead to additional or even new devices. The development, type registration and maturation cycle of new devices is long and deployment requires physical refurbishments in the grid. Unbundling of physical devices and the application functionality is a major step forward in accelerating the implementation. Reuse of the approved, type registered physical devices limits development work and risks. Only the newly developed protection, monitoring and control functionality need to be validated and released. These can be installed easily in the existing devices in the substations by using proven IT methodologies.

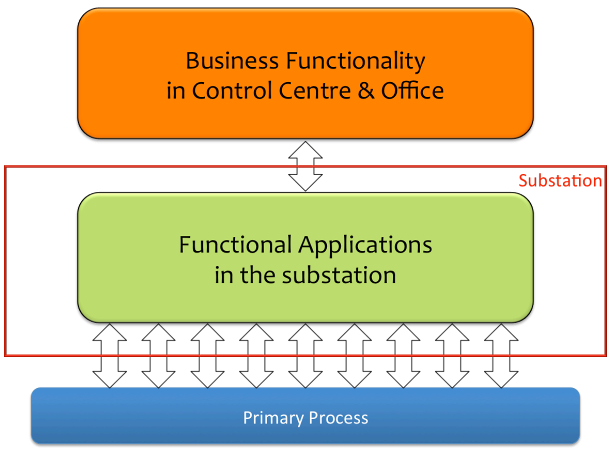

Figure 1: Business functions and process applications

SASENSOR PLATFORM

The platform concept consists of a software Application Suite and Computing & Process Interfacing hardware.

The Application Suite supports:

- Basic control and data acquisition functions, like alarm/event recording, telecontrol protocol support, graphical user interface for monitoring and control,

- Version and release management tools for all software,
- Fully embedded cyber security framework with authentication, authorisation, intrusion detection, encryption, etc,
- Configuration of Substation Automation Applications out of a repository of Function Blocks,
- Graphical application programming with Function Blocks,
- The ability and support to create your own Basic Function Blocks,
- Applications and/or Function Blocks can be encapsulated in 'encrypted containers' to ease version & release management and protect the intellectual property of the content as well as the integrity of the system.

Computing & Process interfacing with two groups of hardware families: *Control Units* & *Interface Modules*

- Full separation of functionality (application) and hardware implementation (computer & process interfacing).
- Process interfacing with long life design is separated from the fast moving world of computing and communication.

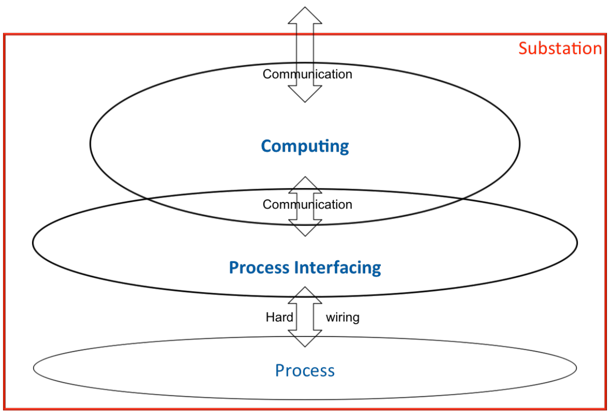

Figure 2: Separated computing and process interfacing

WHY TWO HARDWARE GROUPS?

Control Units & Interface Modules

The separation of computing from the process interface is driven by the wish for optimized life cycle management of the substation automation and protection system. High voltage components have a very long life and therefore the interface to the process should also have a long life. Particular interest is given to the constraint of working close to, or at the interface of the primary process, for which a primary outage is mandatory. Outage requirements are becoming stringent and sometimes very difficult to plan at any foreseeable moment. If the separated process interface is given a very long life -both technical and functional- it will help the network operator to optimize its operations and mitigate the risks of upgrading this interface during the life of the primary equipment. All associated engineering, installation and testing of the interface is reduced substantially.

The computing equipment is located at a less restricted area in the substation and can now be managed without getting close to the primary equipment and therefore do not require an outage. Risk for the work force is minimized. The replacement of computing devices is now characterized as low risk. Testing is limited to the functionality only, since no process cabling is touched. Testing can be done in a test office and not necessarily in the substation. The burden of costly life cycle management processes for the computing hardware is eased, resulting in better cost of ownership performance.

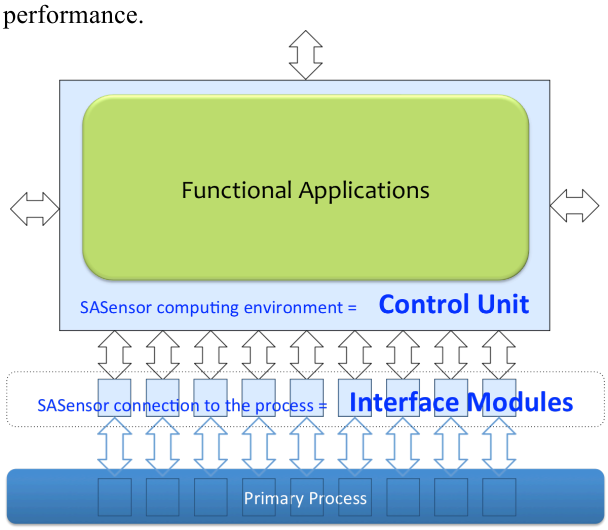

Figure 3: Control Unit and Interface Modules

WHY AN OPEN PLATFORM?

The world around us is changing. The transition to more decentralized generation in both medium as well as low voltage grids changes the operational behaviour of the grids. Functional elements in the grid such as protection, monitoring and control will most likely change over time to facilitate changes in grid utilization. Complete new functions will be required as well. If changed, or new functionality enable benefits for the network operator, it should be possible to implement them in a simple and economically sound manner. Most of today's protection relays and monitoring equipment are made more or less in a rigid manner. Existing equipment needs to be replaced and/or new function boxes need to be installed. An open application software suite that runs in the substations secondary system will bring benefits such as:

- Flexibility and functional freedom,
- Shorter cycle of development to roll-out,

- Faster evolution of new protection ideas,
- Faster maturation of functional applications,
- Increased productivity,
- One common development base,
- Invoke and validate developed applications of knowledge institutes or specialized third party software development companies,
- Optimize the Total Cost of Ownership of the system owner.

On the down side we have to introduce “Open" in a controlled manner:

1. Cyber security as main design starting point,
2. Encapsulation of the applications through ‘Containers’

REAL TIME PROCESS DATA

The open platform has a uniform representation for the process data and application functions. The data is mapped on a well-defined layer called Real Time Data (RTD). The information is structured in RTD-elements used for:

- Process measurements and indications,
- Processed information by application functions,
- Information exchange between applications,
- Graphical User Interface (GUI) for monitor and control,
- Exchange of information for Substation Automation protocols, like IEC60870-5-101/103/104, IEC61850, DNP3.

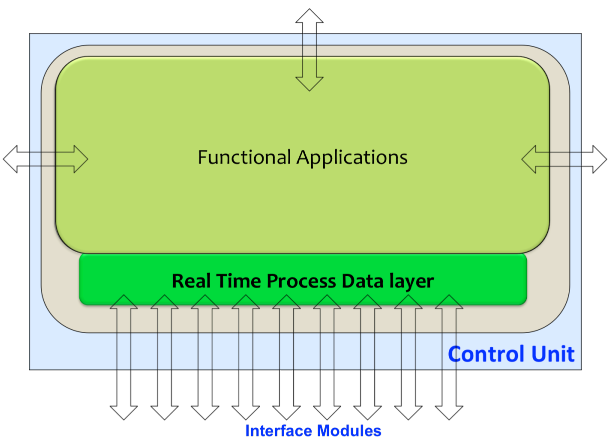

Figure 4: RTD as uniform data representation

FUNCTION BLOCKS

Applications like protections, interlocking, voltage controller or user definable functions are configured and instantiated with Function Blocks (FB). A Function Block is build with Basic Function Blocks and/or other FBs’. Basic Function Blocks cannot be decomposed into other Function Blocks

- A Graphical Programming Tools is used to create Function Blocks,
- (Basic) Function Blocks are available in a predetermined repository subject to user license agreements,
- (Basic) Function Blocks can be created by third parties and added to the repository,
- (Basic) Function Blocks enable advanced version and compatibility management and distribution mechanisms.

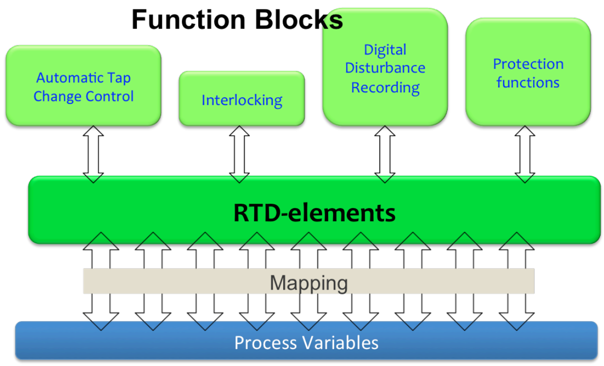

Figure 5: Function Blocks interact by using Real Time Data-elements

CREATION OF FUNCTION BLOCKS

The creation of a Function Block is done with a Graphical Programming Tool depicting the logical connections and data flow between the blocks. The tool visualizes the functionality as well as the real time information. The tool is an integrated part of the substation automation web server. The graphics are display with a generic web browser on an external connected PC.

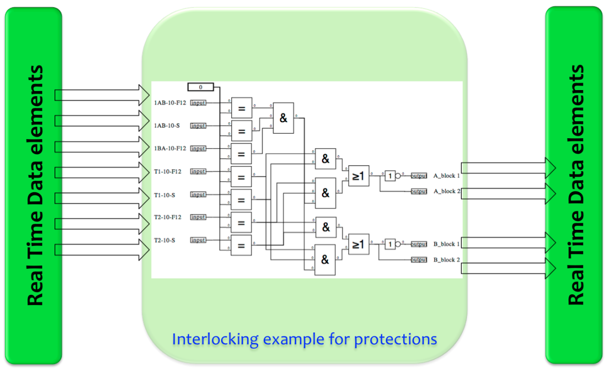

Figure 6: A Function block is created out of Basic Function Blocks and/or other Function Blocks

THIRD PARTY FUNCTIONS

The Swedish network operator Fortum requested protection functions that were not available in the existing Function Block repository of SASensor. A Swedish company Protrol developed algorithms that fulfilled the requirements of Fortum. The open platform is used to make the third party algorithms available for Fortum.

Directional Earth Fault protection (PDEF) is an earth fault protection function for safe detection of directional earth faults (DEF) with a special focus on intermittent (arcing) faults. An intermittent earth fault is characterized by repeated faults at voltage peaks. In cable networks it is commonly accepted that these types of faults are difficult to detect using conventional earth fault algorithms. Several manufacturers have tried to add intermittent fault detection methods to existing protective relays, with mixed success. The Function Block PDEF takes advantage of Protrols unique method for earth fault detection, which continuously performs an analysis of the phase currents. This method is used to accurately detect all kinds of earth faults and is a complement to the DEF function that identifies continued high impedance earth faults.

Neutral Voltage protection (PNV) is a residual overvoltage protection function for distribution networks, as a back-up protection for the earth fault protection of the line feeders or any other application where a non-directional general earth fault protection is used. It continuously measures the residual voltage of the system and has three overvoltage stages.

Over- and Under Voltage protection (POUV) is a three-phase over- and under voltage protection function primarily for distribution substations. It continuously measures the phase voltages of the system and has two overvoltage stages and two under voltage stages.

CONTAINERS

A container is used to protect and manage its content in an encrypted encapsulated manner. Containers help to protect the intellectual property of the third party developers using the open platform.

Containers:

- Are encrypted and uniquely identified,
- Can comprise a single Function Blocks, but also complete applications, operating system, protocols,
- Enable commercial license management,
- Simplify version and release management,
- Safeguard the integrity of the system and other applications.

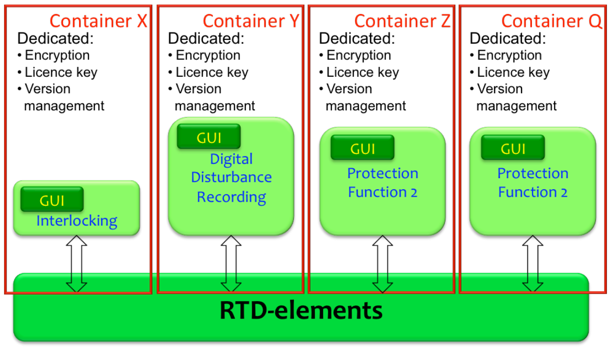

Figure 7: Containers with application software

Containers will be distributed to individual systems with advanced distribution tools. The integration of IT tools within the operational world is becoming a reality.

PRACTICAL EXPERIENCE

The Swedish network operator Fortum is currently introducing the SASensor Platform suite in their network. Their goal is to design a substation that is ready for the future. In the past substations were commissioned with a variety of different pieces of equipment. Asset managers perceive this way of working as an optimization of individual technical requirements; however, this is unmanageable from the long-term life cycle point of view. Changes to existing installations require individual engineered solutions, if even possible. The lack of a common flexible base slows down the introduction of Smart Grid functionality when it is required. The evaluation of a future proof design brought Fortum to an open and flexible architecture that is based on a common hardware platform. Special requirements of Fortum led to a solution where different solution providers worked together in teams to create a total solution, built out of independent Function Blocks. The development of new protection and control functions, inclusive the total time for functional maturation, has been shortened by a minimum of 50% when compared to traditional function box developments, as the hardware and basic system functionality doesn't need to be developed and type registered again.

The SASensor platform approach is being rolled-out at Fortum's Kyrkviken 70/10kV substation in Stockholm.

CONCLUSION

The modular and layered architecture of the SASensor Platform allows users to achieve a number of objectives. Fortum emphasized on one common base for all their secondary systems in their substations. Optimize the total cost of ownership by flexibility in the systems architecture, applications and product life cycle management. Create and facilitate independency for application development by third parties.
The concept of software Containers enables secure and simplified management of the substation protection, monitoring and control system software now and the long-term future.

REFERENCES

[1] B.Heerbaart, F.Kuijpers, F.Baldinger 2013, "i-Net the reality of an intelligent distribution grid", *CIRED Stockholm 2013*.

[2] O.Mansour, A.Jansen, F.Baldinger 2011, "Challenges in smart distribution grids", *CIRED Frankfurt 2011*.

[3] F. Baldinger, T. Jansen, M. van Riet, F. Volberda, 2010, "Nobody knows the future of Smart Grids, therefore separate the essentials in the secondary system", *DPSP Conference Manchester 2010*

[4] F. Baldinger, T. Jansen, M van Riet, F. Volberda, F. van Erp, M. Dorgelo, W.M. van Buijtenen, 2008, " Advanced secondary technology to evoke the power of simplicity", *DPSP Conference Glasgow 2008*.

[5] S. van Loon, F.Volberda, F.Baldinger, M. van Riet, 2009, "Challenge of managing organizational changes, necessary for new substation automation systems", CIRED Prague 2009.