DISLOCATING I/O-S AND CPU-S ON THE LAN ENABLES NEW FEATURES OF THE SUBSTATION PROTECTION AND CONTROL SYSTEM

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INTRODUCTION

Emerging technologies in the filed of information technology (IT) influence secondary equipment in power system, since more and more IT is included in secondary equipment. The new systems use technological solutions, which are already available on the market of IT. Recent development in IT technology offers now processing capacity concentrated in one processor exceeding needs of substation automation system (SAS) units and better, much more powerful communication technologies.

New standardization brought by IEC 61850 is first systematic attempt to cope with these inevitable changes on the international level. It will definitely not solve all the problems in interoperability and maintainability of the SAS in the future. But, it still brings a lot of advantages and very important, it offers guidelines for further development without loosing interoperability.

Unfortunately, the standard is result of top-down approach regarding voltage level of the substation and associated SAS architecture and available founds. Therefore, this process is opening a lot more new possibilities and questions regarding SAS systems for distribution substations, than is at the moment answering them. Beside that, it is questionable, how fast will it move in following new IT developments and these are some important questions for the future of SAS development in distribution.

Some of them are specially investigated in this paper, since they are related to the further system architecture development, and foundation of the new 3 level SAS is what is specified in the standard IEC 61850. a possibility to provide redundant protection and control functionality with less CPU-s, what is compared to existing systems not imaginable.

NEW POTENTIALS FOR SAS ARCHITECTURE DEVELOPMENT

Only some potential advantages for SAS architecture brought by IT development and encouraged by IEC 61850 standard are discussed here. The reason is foundation of 3 level SAS that is specified in the standard [1,2]. Recent development in IT technology offers now processing capacity concentrated in one processor exceeding needs of SAS units. With new standard, there are no formal limitations set to the number of functions in the bay level unit. With increased processing capacity, one unit can control and protect more bays and so the number of needed intelligent electronic devices (IED) is reduced essentially. The big thing about IEC 61850 is, that it enables and defines separation of I/O and processing units in a way, that they can be physically located a part from one another, although this is not yet commonly used. This is by our opinion the major and the only break through of the 61850 and the biggest change in SAS concept after late 80's. So, new SAS architecture is defined.

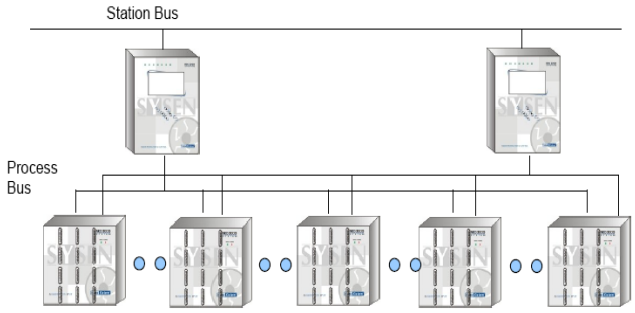

Figure 1: Bay and process level units on process bus

Possibility to use dislocated input/output (I/O) units offers in combination with pairs of CPU-s a possibility to provide redundant protection and control functionality with less CPU-s, what is compared to existing systems not imaginable. So, changes brought by IEC 61850 offers us more reliable systems for lower investments.

Since the substation is not to be controlled by one redundant pair of CPU-s only, more possibilities are open for what we call 'clustering of redundant CPU pairs'.

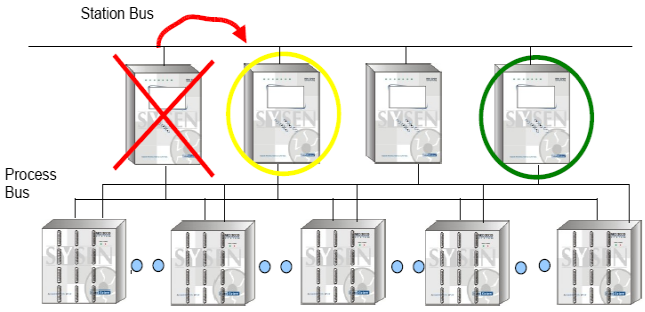

Figure 2: Clustering of redundant pairs of CPU-s.

That means, that more than two CPU units have access to I/O unit's data, but two only operate in parallel. Other CPU units are executing functions for other bays. In case of

failure of one CPU, it's functions are automatically distributed among other CPU-s and so even in the case of failure of one unit after short non-redundant operation, redundant parallel operation is granted again and means another step in improved reliability.

Further, all CPU units are connected to the same IP based network, that enables almost unlimited possibilities for communication and data exchange among them. This network is actually WAN (wide area network) of the utility and it spreads all around the power system network. Two substations can be treated as one and control center network and substation network merge into one single network avoiding bottlenecks on communication between relay and control center.

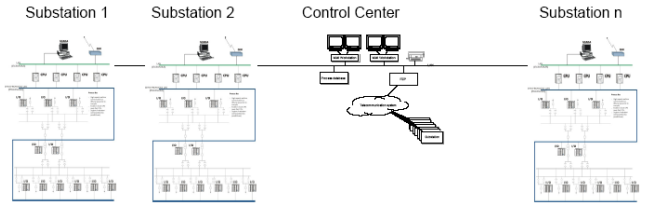

Figure 3: Substations and control centers on the station (utility) bus.

There is another important option now open to be used since the CPU-s can be divided from the I/O -s. CPU-s (bay units) can be set up in better EM protected environment in the substation, since there is no need for CPU to follow I/O to be close to the primary equipment. CPU is now connected to the rest of the system by communication only. So, there are no reasonable constrains any more not to use general purpose hardware for this, what means price reduction potential. We can conclude here, that new architectures of SAS are offering many potential improvements in operation and investment for distribution companies as well, although IEC 61850 was dictated and originally introduced for transmission purposes .

EXAMPLE OF APPLICATION NEW POTENTIALS FOR SAS ARCHITECTURE DEVELOPMENT

There are two pilot projects discussed in this paper. One is installed in small substation Balos owned by Elektro Gorenjska utility. In this case, no dislocated I/O units are used, so we use classic approach with I/O and CPU in one box per bay. The main purpose of the project is to evaluate possibility, that all relays (IED-s) in substation communicate directly to each other and to the control center using Ethernet technology and IP based protocol. Since IEC 61850 does not specify this kind of communication to the control center yet, protocol IEC 60870-5-104 was implemented in the IED-s. So the bottleneck in the form of the concentrator or central unit was avoided. Additionally, some connections to the other parts of utility computer network were established, as automatic upload of the disturbance or power quality related oscylographs to the protection engineer workstation for example and automatic transfer of power quality related data to the office dealing with these problematics.

Second project is going on in substation Črnuče owned by Elektro Ljubljana utility.

Figure 4: Substation Črnuče in Ljubljana

Here, dislocated I/O-s are used and configuration concept can be seen on the next figure.

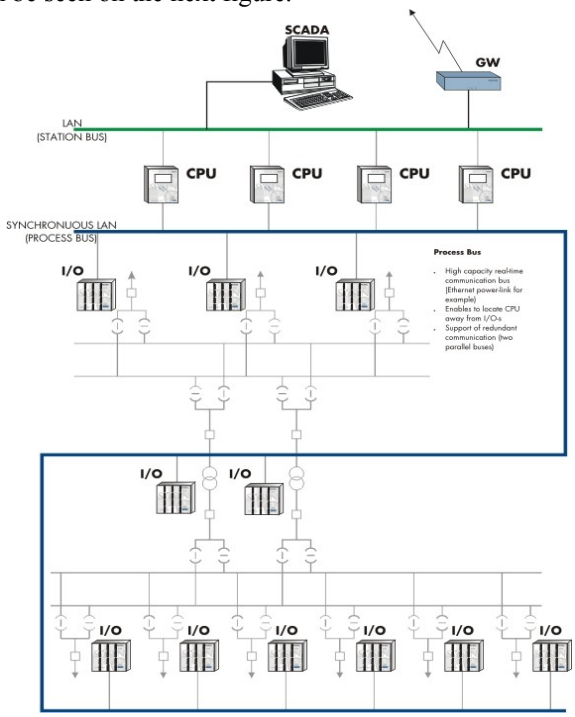

Figure 5: SAS architecture princip scheme of the system under evaluation.

I/Os are dedicated for physical signal acquisition, conversion into digital form and transmission to the bay level by means of hard real time communication. I/O units perform all necessary input signal pre-processing, such as debounce, A/D conversion. But they in this case do more, like digital filtering, phase calculation etc. FPGA-s in I/O do not execute only fast communication but can also do the

signal pre-processing, normally performed by DSP (Digital Signal Processor). Mathematically transformed data flow through the high-speed real-time process bus to the upper level. For this purpose, evaluation of special double shielded TP cables is going on at the project, since laboratory tests showed sufficient EM immunity. They are essentially cheaper, than FO cables.

Figure 6: Dislocated I/O unit installed in the substation Črnuče.

Bay level units are processing these signals and perform actually the real time functions as protection, interlocking, time tagging and similar. The bay level units contain an extensive range of protection and control functions, which represent the heart of the system functionality. Their main feature is a very high processing capacity. Each unit can simultaneously manage several bays and work in parallel to provide increased redundancy. Housing of dedicated CPU has already space for two units, that are completely independent with own supply units.

Figure 7: Dedicated CPU installed in substation Črnuče

CPU is connected to the rest of the system by communication only, which can be and in reality is standardized. So, it is very simple to add new CPU with new functionality to the system. And what is important, standards enable any vendor to do it. Additionally, big advantage of such approach is, that it is possible to move CPU's to the locations in the substation, where it can be well protected against electro magnetic disturbances. Therefore, general purpose hardware can be used and beside other advantages proved during operation, essential investment and maintenance cost reduction was proved. Such systems are in trial operation for some years already [3,4] and in presented project the use of general purpose HW is evaluated as well.

Figure 8: General purpose CPU unit used for pilot project

As a precondition the software must be designed to be extremely hardware independent and easily portable to support a variety of hardware platforms. Using a popular and well accepted operating system (OS) LINUX with its real-time extension RTAI is a guarantee that software will run on a wide range of processors and will have good support in the future. [5,6] Recently, we have achieved and proved, that with this combination, we now have commonly accepted and freely available OS that can handle hard real-time requirements for SAS and which is hardware independent and portable and this combination is running in substations Balos and Črnuče.[7]

Portability, scalability and availability are issues to be met in modern designs. Stepping aside from own OS development, the gains are great when using General Purpose Operating System (GPOS) and Hard Real Time Operating System (HRTOS) already running on variety of platforms and yet more are expected to be supported in the

future. Expecting the same OS and its standard development tool chain to be used for at least two decades and hopefully more, the application code will hardly need to be rewritten soon just for the sake of porting to another platform. While such porting could be now done by means of simple recompile, development team could concentrate more on the function and quality of the application code. And this is another topic, that mentioned pilot projects are intended to prove it as reality and not as fiction.

Additionally, if the customer's staff is unfamiliar with programming C or similar language, functions can be developed and tested in so called 'fast prototyping' environment compatible with Matlab/Simulink©, and directly loaded into the system. This opens the software development system to be freely available, thus enabling the owner to add additional functions independently from the vendor .

LESSONS LEARNED SO FAR

Some lessons have been learned from project substation Balos already and are worth to mention, although project hasn't finish yet, are:

- In the future, at least some if not many more IP based protocols will be used on so called station level bus (one can say also system level utility wide bus) and not only ones specified in IEC 61850, if we want to use all benefits of IP based IT development in power sector.
- Special attention will have to be payed to the configuration of the network and to the control of the traffic on the network, when more substations and dislocated workplaces of the control center are connected to the bus in order to secure required performance.

Many more findings are expected from second project, which was started few months later. But some are already here:

- New architecture offers even with less processors enhanced reliability and availability built inside the protection and control systems. So, changes brought by IEC 61850 offers us more reliable systems for lower investments and by our opinion many more potentials advantages for distribution utilities, although standard was designed for transmission in the first place. Performed tests make us believe, that availability can increase and down times can be reduced for up to 10 times. Different redundancy and architecture schemes enable improvement in security and availability even with a less reliable hardware.
- Having platform independent software means that the customer will be able to buy HW on bay and station level independently from the SW. He will be able to choose between the whole system, software only or hardware only. Hardware taken for a certain project can be selected according to the needed performance and applied functions. If more functions are added or activated needing bigger processing capacity on the later stage, hardware can be replaced or additional CPU-s can be added to the system.
- Fast prototyping facility really works, but user needs to know well, what he is doing. As a test, transformer differential protection was implemented. This also opens questions of responsibility division between vendor and user, but praxis in industrial automation can be followed, where these questions are solved for years already.
- Since the system is modular in its software as well as hardware structure, it is very flexible in size and functionality. This enables the system to be well adapted to the project and this is advantage worth to be kept in the future.
- During pilot projects, we found out, that since the system based on web technology enables direct access from multiple points in the WAN. And more and more offices want and need this access to gather different data from the system. So, there is not only one control center any more but many offices are becoming 'control centers' as well. Standards for these connections are by our experience much more needed, than standards for communications inside substations, where systems are usually supplied by the same vendor under one contract. IT has these standards already and power industry should just select the most appropriate ones.
- Since fibre optical Ethernet is very expensive, we made experiments with special shielded coper cables and galvanically isolated chips on these projects. So far results are positive and we didn't detect any problems related to EMC.
- Because of paralel operation of units on the bay level, there is a double communication to the station level and SCADA for example needs some adaptation. SCADA can deal with two channels for commands, since only one is active at a time. But it is in general unable to deal with double information flow in signaling direction. We needed to modify local SCADA in this way and also control center should be adjusted a little bit.
- Security is discussed a lot in relation with moving from serial to network communication. However, we didn't encountered problems related to this topic. May be this is because pilot projects are on distribution substations, not so critical for the system. One reason is also good security on the utility WAN of companies and good separation of segments of the network, where the pilot projects are taking place. But we also came to conclusion, that hacker can do much more harm by entering billing system than switching on or off some circuit breakers and practical approach to this problem is missing a lot.

CONCLUSION

New IT technologies offer many possibilities for new solutions in protection and control system development. There are some important changes in the system architecture and performance in view for the near future initiated by IEC61850 standard. Although, the standard is driven by transmission point of view in the sense of top down approach, it offers many advantages for distribution utilities.

CPU is separated from I/O unit and can manage several bays at the same time. Several CPU-s can work in parallel and increase availability of the system. Software becomes hardware independent and different kinds of hardware can be used for protection and control. Separate markets can be established for hardware and software components, which will speed up development.

So, with IEC 61850 and further development based on it, the road is open towards distributed web based software applications running on network of hardware components combined of special and general purpose units, performing power system automation and protection.

And finally, there are systems of that kind already under test and in operation in several places. Here, another example of modern system of that kind is given in two substations in Slovenia, where such systems are in operation. Technical and economical evaluation has shown so far advantages of such approach. They have also proved through pilot installations that such approach can save a lot of investments and offer at least competitive functionality and reliability, if not better. It is also expected to prove lower total life cycle cost in the next years. Described example is with some others the proof, that this topic is not only a speculation any more, since there are such kind of SAS systems commercially available on the market already.

BIBLIOGRAPHY

[1.] W. Baass et al: 'Automation of new and existing substations: why and how' (Cigre working group B5.07, report, Cigre, 2004)
[2.] IEC 'IEC standard 61850', 2003
[3.] M.J.M. Van Riet, F. Provoost, F. van Erp: 'New Intelligent features during refurbishment of substations', (IEE symposium on Developments in Power Systems Protections, 2004)
[4.] M.J.M. Van Riet et al: 'Alternative approach for total integrated secondary installation in MV substations covering all possible and required functions', (18th International Conference on Electricity Distribution CIRED - Torino, 2005)
[5.] Linux: http://www.linux.org http://www.linuxdevices.com
[6.] RTAI: http://ww.rtai.org
[7.] I.Kobal, D.Munda: 'Experiences with StrongARM/Linux/RTAI combination in Mission-Critical Systems', (7th Real-Time Linux Workshop, Lille, 2005)