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Integration of New IEC 61.850 Based SAS to Legacy Systems

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1 INTRODUCTION

The electric power industry is experiencing important changes in the implementation of SAS (Substation Automation System) by using new standards and protocols. IEC 61.850 standard has become adopted worldwide by many utilities in communication networks and systems for their new substations. However, many legacy IEDs (Intelligent Electronic Devices) and communication protocols still exist and will last for many years in their applications. Moreover, these systems might be expanded or might have some IEDs retrofitted later, with impacts on their architecture. Therefore, strategies for adapting legacy SAS to the future are also very important.

This paper is about the integration of new IEC 61.850 based SAS, accommodating existing legacy systems, as it happens in expansions or refurbishments. A practical challenge of major interest is optimizing the exchange of information among these different technologies. But there are many natural obstacles, such as: new paradigms, new technologies, diversity of protocols, network topology, distributed protection schemes, interlocking philosophy definitions, use of hard wires versus goose messages, Human Machine Interfaces etc. Such constraints need to be well known and managed.

Integration approach is analyzed in a practical application described in this article, with a legacy IEC 60.870-5 protocol based 230 kV substation at Chesf (Companhia Hidro Eletrica do Sao Francisco), that was expanded with new transformer bays based on IEC 61.850 standard. New Protection and Control IEDs were added in the new LAN to the original SAS, with impacts on redundancy, interlocking, supervision and protection schemes. Significant changes were necessary for retrofitting the substation SCADA (Supervisory Control and Data Acquisition) system, in order to achieve both communications, assuring the desired functionality and performance requirements. There was a migration plan for the overall solution with detailed stages of transient topologies and testing strategies, designed for connecting the operational legacy SAS to the new one. That experience turned out to point important difficulties found in the integration process. On the other hand, actual benefits could be achieved. In addition, longer term benefits are also expected, by exploring the potential of the new standard. A special issue after integration is the capability for new expansions at the substation, although there may be problems with multi-vendor interoperability.

Lessons learned with the above mentioned experience and other SAS migration processes have helped build implementation guidelines for new expansions. This paper is started with the analysis of a real migration application and is concluded with a description of some practical difficulties and benefits of system integrations.

2 NEW IEC 61.850 BASED SUBSTATION AUTOMATION SYSTEMS

2.1 The use of IEC 61.850

Brazilian utilities have different levels of local automation in substations, ranging from decreasing conventional use of old electromechanical relays and control buttons up to increasing complete digital substations.

IEC 61.850 standard was first available in the year of 2004. There is a huge change in paradigms, for it is based on standardized information models, semantic of data, common use of SCL (Substation Configuration Language), functional virtualization and advanced communication services for information exchange.

The use of IEC 61.850 standard at Chesf started in 2006, with the technical specification of new SAS. The first one of them was integrated to the electrical system in 2007. It has been adopted in the station bus of all new SAS specifications for substations up to 500 kV. Before that decision, many different vendors had supplied SAS for several substations, using specific proprietary and some standardized protocols, such as: Conitel, EFIP, K-Bus, Modbus, Profibus, Fieldbus, IEC 60.870-5-101/103/104, IEC 60.870-6, DNP 3.0 etc. These legacy SAS may often need to be expanded with new bays and functionalities. SAS expansion with same type of IEDs and protocols collide with the increasing unavailability of expensive obsolete components. Furthermore, it would require direct contract with the same original vendor, facing economic limitations and contract law restrictions, especially for the national utilities.

Adapting legacy SAS to integrate IEC 61.850 standard based SAS is a must for managing the limitations of legacy SAS and interconnecting them to new technologies, providing an easy way for next expansions with updated products and solutions. One option is the use of gateways to reach those IEDs that are not compatible to IEC 61.850, resulting in additional intermediate devices, latency, complexity and additional costs. Another possibility is to implement the local SCADA server acting as a substation concentrator, communicating with both legacy SAS and the new IEC 61.850 based SAS, throughout the Ethernet network. Of course, specific solutions will depend on the particularities of the plant.

2.2 A real application

This article presents a real example of a 7 year old IEC 60.870-5-101/103 protocol based 230 kilovolts substation at Chesf, which was expanded with new transformer bays based on IEC 61.850 standard.

THE LEGACY SYSTEM

The legacy SAS is briefly showed in figure 1, on the light blue background part. It is formed by multifunctional protection IEDs and control IEDs, interconnected by serial communication paths to the central control units. These concentrators have the role of data acquisition from the IEDs, station level interlocking, local communication to the WinCC SCADA system HMI (Human Machine Interface) servers and communication to the COR (Remote Operation control Center). So far, several reports had already mentioned difficulties with spare parts, protocol implementations, IEDs maintenance etc.

THE IEC 61.850 BASED SAS AND THE LEGACY SYSTEM

As illustrated in the topology with the red dotted lines in the Figure 1 above, the new transformer bays were implemented with basis on IEC 61.850 standard. There is an Ethernet ring formed by redundant switches, with connections to the IEDs and the new local SCADA system. A new SCADA system was supplied for communication to both legacy SAS and the IEC 61.850 based SAS. It was implemented with the SAGE (Sistema Aberto de Gerenciamento de Energia) solution, that was developed by CEPEL (Electric Power Research Center). Within this solution, there are redundant servers performing real time database management and advanced applications, besides regular HMI functionality. It substituted the legacy WinCC based SCADA system, communicating at the same time through the Ethernet network, by:

- IEC 60.870-5-101 protocol, with the existing central control units, from the legacy SAS;
- IEC 61.850 based protocols (TCP/IP, MMS and Goose), with the new transformer's IEDs;
- DNP 3.0 protocol, with the COR system.

The integrated architecture is briefly shown in figure 1.

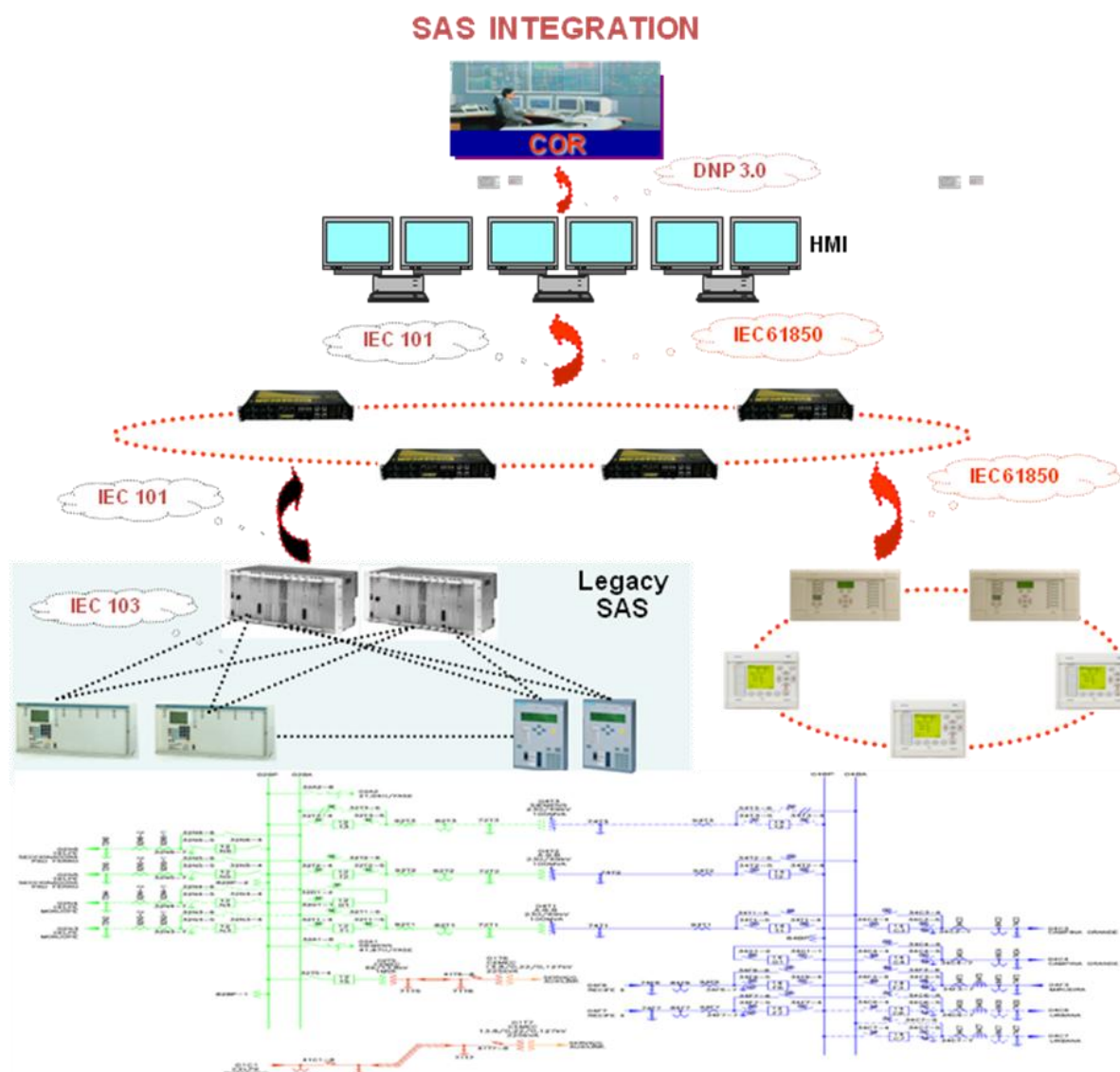


Fig. 1: The IEC 61.850 SAS and the Legacy system

MIGRATION

The migration process was not an easy task. Integration of the new transformer bays and SAS migration should be carried on without any electrical interruptions or major operational disturbances. So a very detailed migration plan was elaborated, covering the main tasks, strategies, stages, SAS transition topologies, check lists, tests, safety issues, schedule and mitigating contingency plans.

New data objects were configured for the new HMI on its new platform. So the data point routing on the new topology. Commissioning tests also covered these modified objects, always keeping the regular supply of electrical energy. A hybrid SAS was established in the substation. All tests were successfully performed.

The plan was later adapted for other next similar migrations, one of them with another different legacy system. Integration to legacy SAS based on Remote Terminal Units (RTUs) are also other successful processes that have been carried on in the electrical system.

A special feature from that integration must be always emphasized. After the hard work and asset investment, there is now an IEC 61.850 based Ethernet network that can accommodate new or retrofitted bays, including those from legacy SAS.

DOCUMENTATION

Information of Goose messages are scattered through traditional insufficient documentation, different IED tools and specific descriptions. So, a virtual wiring map called "Goose Map" was

developed, with the information flow, sources, destinations, descriptions, addresses etc, as shown in Figure 2. It associates the publishers and the subscribers, their messages, links and descriptions.

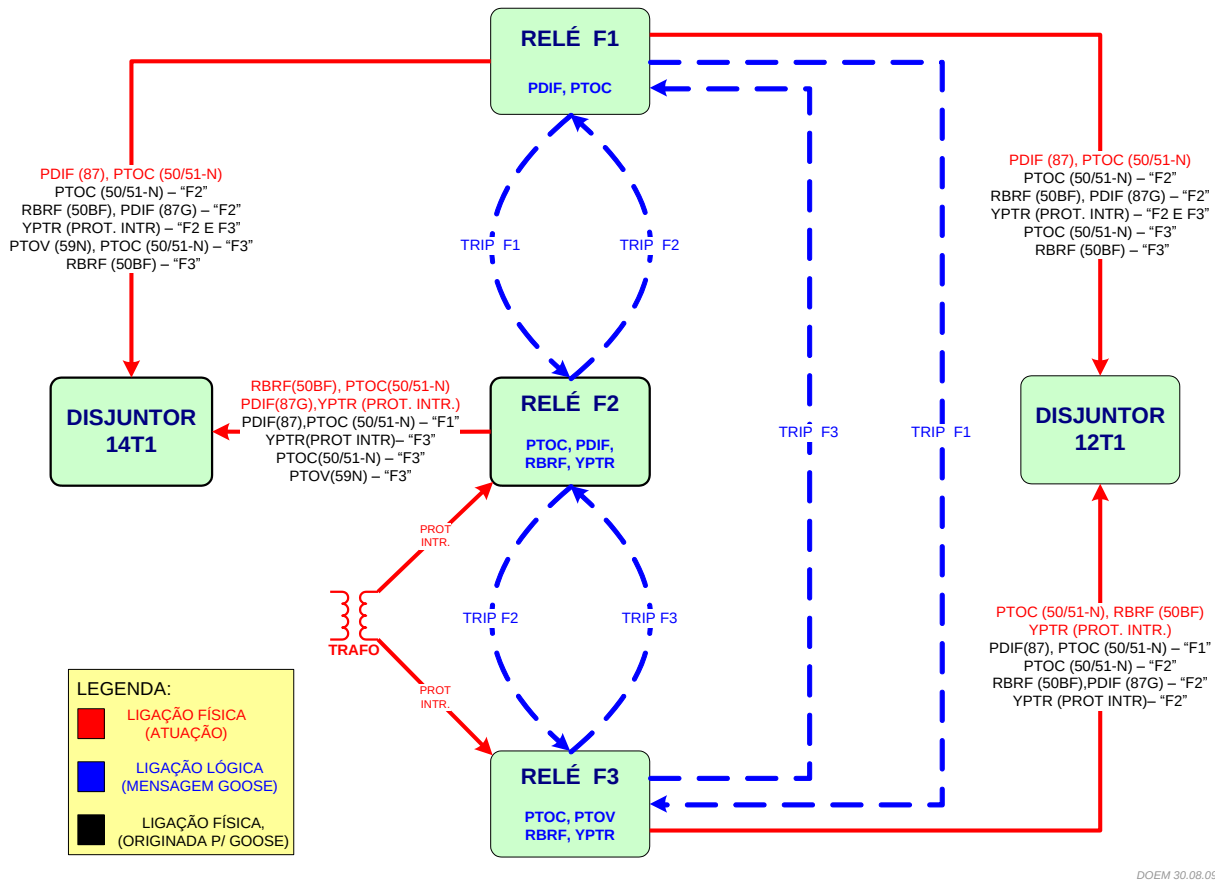
Mapa de Goose SE-PCD paper.xls [Modo de Compatibilidade] N												
Início Inserir Layout da Página Fórmulas Dados Revisão Exibição												
Área de Tr... Fonte Alinhamento Número Estilo Células Edição												
A93 F2												
A B C D E H I J K L M												
41	GOOSE OUT			GOOSE IN								
42				UB1		F1		F2		F3		
43	UB2	IEC	SCE	Ind	Gl	Ind	Gl	Ind	Gl	Ind	Gl	
46	SOBRECORRENTE DO COMUTADOR	ind10	Goose Out 2									
47	BLOQUEIO/REARME FALHA DISJUNTOR	ind11	Goose Out 3							ind5	Gl 10	
48	POSICÃO DJ52 FECHADO CONSISTIDO	ind12	Goose Out 4							ind7	Gl 6	
49	POSICÃO DJ52T FECHADO CONSISTIDO	ind13	Goose Out 5							ind9	Gl 7	
50	DJ 52 BAIXA PRESSÃO SF6 2o EST	ind14	Goose Out 6							ind11	Gl 8	
51	DJ 52T - BX PRESSÃO SF6 2o EST	ind15	Goose Out 7							ind13	Gl 9	
52	VÃO 69kV ABERTO	ind16	Goose Out 8					ind15	Gl 5	ind15	Gl 12	
53	43N 69kV	ind17	Goose Out 9				ind17	Gl 4		ind17	Gl 1	
54	43T 69kV	ind18	Goose Out 10				ind19	Gl 5		ind19	Gl 2	
56	DISJUNTOR 69kV ABERTO OSCILOGRAFIA	ind2	Goose Out 12	GO12 (UB2)								
64	BLOQUEIO DE SINCRONISMO DJ 230kV	ind27	Goose Out 20	GO20 (UB2)								
78												
79	GOOSE OUT			GOOSE IN								
80				UB1		F1		F2		F3		
81	F1	IEC	SCE	Ind	Gl	Ind	Gl	Ind	Gl	Ind	Gl	
82	ATUAÇÃO PROTEÇÃO F1	ind1	Goose Out 1					ind1	Gl 7	ind1	Gl 3	
83	TRIP 50/51 230kV	ind15	Goose Out 15	ind15	Gl15(F1)							
84	TRIP 50/51N 230kV	ind16	Goose Out 16	ind16	Gl16(F1)							
85	TRIP 50/51 69kV	ind17	Goose Out 17	ind17	Gl17(F1)							
86	TRIP 50/51N 69kV	ind18	Goose Out 18	ind18	Gl18(F1)							
87	TRIP 87 FASE A	ind30	Goose Out 30	ind30	Gl30(F1)							
88	TRIP 87 FASE B	ind31	Goose Out 31	ind31	Gl31(F1)							
89	TRIP 87 FASE C	ind32	Goose Out 32	ind32	Gl32(F1)							
90												
91	GOOSE OUT			GOOSE IN								
92				UB1		F1		F2		F3		
93	F2	IEC	SCE	Ind	Gl	Ind	Gl	Ind	Gl	Ind	Gl	
94	ATUAÇÃO PROTEÇÃO F2	ind1	Goose Out 1			ind1	Gl 6			ind1	Gl 4	
96	LIBERA SECCIONADORAS	ind3	Goose Out 3	ind3	Gl3(F2)							
97	FALHA DISJUNTOR 230kV	ind4	Goose Out 4	ind4	Gl4(F2)							
98	VÁL. SEGURANÇA / 63 TANQUE / 63 COMUT	ind5	Goose Out 5									
108	TRIP 87G	ind7	Goose Out 7	ind7	Gl7(F2)							
109	TRIP TEMPERATURA NÃO ATIVADO	ind15	Goose Out 15	ind15	Gl15(F2)							
122	TRIP PROTEÇÕES INTRÍNECAS (UB1 P/R)	ind28	Goose Out 28	ind28	Gl28(F2)							
124	TRIP 50/51 FASES 230kV (I<2 OU I>3)	ind30	Goose Out 30									
125	TRIP 50/51N VÃO TRAF 230kV (IN2>1 OU IN>3)	ind31	Goose Out 31									
126	TRIP SOBRETEMPERATURA	ind32	Goose Out 32									
GOOSSES SD-PCD Plan2 Plan3												
Pronto Contagem: 16 60%												

Fig. 2: An example of a “Goose Map”

In addition, a functional “Protection Diagram” was also developed, explicitly showing the protection functional intercommunication among IEDs and circuit breakers, like the example shown in Figure 3. In this case, the transformer protection scheme uses 3 (three) protection relays F1, F2 and F3, that can issue trip commands to the 2 (two) circuit breakers, called 14T1 and 12T1.

The blue dotted lines indicate the Goose messages flow to and from all different IEDs. They are used for status information, interlocking functions, breaker failure protection scheme and inter trip. The red lines indicate the physical connections, like the ones between each IED and a circuit breaker, for trip functional purposes. One can notice that the trip commands can be originated from the protection device itself or from an inter trip source, coming from another IED.

The protection diagram is very helpful in integration and commissioning tests, fulfilling the lack of documentation that is usually unavailable in a single document. Maintenance may find it very helpful too, during future work, avoiding long time research on functional drawings and different vendor tools.



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Fig. 3: An example of a "Protection Diagram"

Important difficulties and benefits are reported on the next section.

2.3 Difficulties and Benefits

The need for integration is clearly understood, but a lot of work must be done to achieve good results. Some difficulties should arise in advance, due to the new concepts and the complexity brought by the new features of the IEC 61.850 standard. On the other hand, many benefits could be expected with the potential of the standard.

Real applications implemented in high voltage transmission substations at Chesf have showed up many difficulties and benefits that were already predicted, but they have added some others that should be highlighted.

Some important additional **difficulties** found in the SAS integration process are described below:

- There is a lack of technical knowledge on the standard, computer networks, monitoring and supporting tools. Traditional documentation is missing in detailed specification and data point routing;
- Very important system functions have been implemented using Goose messages and they must flow on very reliable networks. There is a need to specify better supervision functionalities in the HMI implementation;
- Technical specification must be well detailed, including additional supervision points and HMI objects for monitoring the network and the information exchange. Additionally, it should establish more detailed functional and performance tests.
- There is an exaggerated use of generic GGIO objects, with loss of semantics. IEC 61.850 new edition, new IEDs and more appropriate implementations will hopefully attenuate that problem;

- Goose mapping is critical. Generic tools and better handling software for SCL files are needed to achieve successful importing or exporting;
- A very detailed migration plan is essential, covering the main tasks, strategies, stages, SAS transition topologies, check lists, functional tests, safety issues, schedule and mitigating contingency plans.

Many benefits of IEC 61.850 standard applications are already known, such as: standardization, interoperability between different vendor IEDs, topology flexibility, cabling reduction, distributed automation, low costs etc.

The SAS integration process showed up additional **benefits** as described below:

- At first, functional testing seemed to become harder. However, by using network analysis software (e.g. Wireshark), it provides good views of messages through network ports. Independent and vendor tools let software perform traditional physical checks, without influencing the running system;
- The use of Goose messages, instead of limited digital outputs and inputs, presents great logical implementation flexibility with lower costs;
- Goose messages on-line monitoring can turn protection schemes more reliable and they can add logic redundancy with protection inter trip commands;
- The hybrid SAS can be seen as if it were IEC 61.850 compliant, because the new SCADA servers can act as gateways when connected to other IEDs, substations or control centers. It is already a possibility and new editions of the standard will cover these issues;
- After integration with IEC 61.850 compatible network, the whole substation becomes prepared for retrofitting the legacy SAS or for new expansions, thus reducing dependence on multiple protocols.

3 CONCLUSION

IEC 61.850 is already a reality in electrical systems, with increasing acceptance and so many successful practical applications around the world. Most of them have been done in new substations by single vendors. Some multi-vendor applications are already in operation too.

Migration options from legacy systems to new IEC 61.850 based SAS is a very recurrent discussion. The new technology itself leads to that. Integration of new IEC 61.850 based SAS to legacy systems requires detailed plans and they must be analyzed beforehand.

A special issue after integration is the capability for new expansions at the substation, although there may be problems with multi-vendor interoperability. The entire engineering process of SAS is enhanced with the new standard.

The work presented some experiences gained from initial use of IEC 61.850 and integration to legacy SAS. The implementation of practical applications with IEC 61.850 highlighted important features. Lessons were learned. New difficulties appeared and full benefits will certainly be acquired. By planning and managing these aspects, an expertise can be built to identify best practices, providing useful roadmaps for such integrations.

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