IEC 61850-9 Process Bus Line Protection Performance Test and Comparative Methodology
Process Bus Solution

Background

- Natural technological evolution of the Control and Protection systems of high and extra high voltage substations.
- Wide acceptance of communication solutions based on the IEC61850 standard.
- Simplification of signal and data acquisition from the high voltage equipment to the control and protection intelligent devices (IED’s).
- Expansion of the communication solutions according to IEC 61850-9-2 standard, taking it up to the switchyard.
- Permanent search of HMV Engineers of innovative ideas, by the use of new technologies, which allows to develop better and cost-effective solutions to the Clients.
Connectivity Plus: HMV’s Solution

• HMV Engineers has developed, tested, and implemented a Process Bus Solution, based on the installation of a Digital Marshalling Kiosk, adjacent to the switchyard equipment, which collects all analog and digital signals in a “Merging Unit”, and connects to the Control and Protection Panels via fiber optics.

Custom made solutions according to Client’s preferences and needs

Multi-Brand Integration Capability of Control and Protection Equipment

HMV Engineers: Innovative Solutions Developers
Process Bus Solution

Basic Concept

Digital Marshalling Kiosk:

• Its development is based on the adoption and practical application of the “Process Bus” technology (IEC 61850-9) for the implementation of Control & Protection systems of medium, high, and extra high voltage substations.

• The Standard sets forth the implementation of a Data Bus on fiber optics, between control level 0 (Process Level) and level 1 (Bay/Unit Level), allowing for higher data availability in the substation, as well as lower installation cost and commissioning time.

• HMV Engineers has already used this solution in several of the substations developed by the company, having verified and confirmed all the fore-mentioned benefits.
Process Bus Solution

Basic Concept

Hard-wired connections (Analog and Digital Signals) from the H.V. equipment to the Merging Units

STATE OF THE ART: DIGITIZING OF THE HARD WIRING
Process Bus Solution

Basic Concept
Fiber Optic connection from the Merging Units to the Control & Protection Panels
Process Bus Solution

HMV’s Experience in its Application

- Since the arrival of the first solutions and equipment based on IEC 61850 standards, HMV has implemented Protection and Control systems and Digital Substations, even integrating different brands of IED’s
- As innovators in the industry, HVM has implemented several process bus solutions according to IEC 61850-9-1 and IEC61850-9-2LE

HMV has designed, manufactured, tested, and commissioned, three process bus systems using different vendors and technologies

- The implemented solutions have allowed HMV to carry out, for several years, a detail follow-up of their performance and draw conclusions about the considerations and multiple advantages of this technology
Process Bus Solution

HMV’s Experience

SAN LORENZO SUBSTATION 110 kV

110/13.2/13.2 kV

SAN MIGUEL POWER PLANT 42MW

MOLINOS POWER PLANT 20MW

SW: Communication Switch
DMU: Digital Merging Unit
AMU: Analog Merging Unit
MU: Analog and Digital Merging Unit
Process Bus solution utilizing Alstom (GE) equipment and a simple star switched network model, according to IEC 61850-9-2LE, with one Merging Unit for analog signals and another for digital signals (Parallel Redundant Protocol network).

San Miguel 110 kV substation, 2015

Digital MK with Merging Units installed in the switchyard

Fault Recorder of analog and digital signals via the process bus

Connection Topology
Process Bus Solution

San Miguel 110 kV substation

Digital MK
Installed in the Switchyard

Control & Protection Panels
In Control Room

Line protection system:
- ALSTOM (GE) P446 relay with Process Bus concept
- Conventional hard-wired SEL 421 relay
Process Bus Solution

El Molino 110 kV substation, System 1 - 2017

A/D Merging Unit 1
A/D Merging Unit 2

Digital MK with Merging Units installed in the switchyard

Process Bus utilizing GE (Multilin) Solutions in a Point-to-Point network, according to IEC 61850-9-1, with combined-redundant Merging Units for the analog and digital signals.
Process Bus Solution

El Molino 110 kV substation, System 2 - 2017

Process Bus utilizing NR equipment connected in a simple star, switched network, according to IEC 61850-9-2LE, with one Merging Unit for analog signals and another for digital signals.
Process Bus Solution

Testing with CMC
Different types of faults were simulated during the testing; tripping time was recorded in the test equipment both for the process bus protection and for the conventional protection.

### FAT’s Operation Comparison - San Miguel 110 kV System

<table>
<thead>
<tr>
<th>Relay</th>
<th>Z1(Ω)</th>
<th>t(s)</th>
<th>Z2(Ω)</th>
<th>t(s)</th>
<th>Z3(Ω)</th>
<th>t(s)</th>
<th>Z4(Ω)</th>
<th>t(s)</th>
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<tbody>
<tr>
<td>Alstom P446 (Process Bus)</td>
<td>0.32</td>
<td>0</td>
<td>0.67</td>
<td>0.3</td>
<td>2.34</td>
<td>1.2</td>
<td>0.63</td>
<td>0.8</td>
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<tr>
<td>SEL 421 (Conventional)</td>
<td>0.32</td>
<td>0</td>
<td>0.67</td>
<td>0.3</td>
<td>2.34</td>
<td>1.2</td>
<td>0.63</td>
<td>0.8</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Type of fault</th>
<th>Z2 (P-G)</th>
<th>Z2 (P-G) PUTT</th>
<th>Z2 (P-P)</th>
<th>Z2 (P-P) PUTT</th>
<th>67N</th>
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<tbody>
<tr>
<td>Nom. oper. Time (ms)</td>
<td>300</td>
<td>0</td>
<td>300</td>
<td>0</td>
<td>3267</td>
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<tr>
<td>Relay</td>
<td>ALSTOM</td>
<td>SEL</td>
<td>ALSTOM</td>
<td>SEL</td>
<td>ALSTOM</td>
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<tr>
<td>Oper. time GOOSE (ms)</td>
<td>317.7</td>
<td>NA</td>
<td>24.9</td>
<td>NA</td>
<td>317.3</td>
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<tr>
<td>Oper. time. Dig. output (ms)</td>
<td>322.4</td>
<td>323</td>
<td>29.7</td>
<td>26.3</td>
<td>321.9</td>
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<tr>
<td></td>
<td>3335</td>
<td>3306</td>
<td>3330</td>
<td>3306</td>
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<td>Nominal oper. time (ms)</td>
<td>300</td>
<td>0</td>
<td>300</td>
<td>0</td>
</tr>
<tr>
<td>Relay</td>
<td>GE D60</td>
<td>NARI</td>
<td>GE D60</td>
<td>NARI</td>
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<tr>
<td>Operation time Dig. output (ms)</td>
<td>328.1</td>
<td>337.7</td>
<td>30.8</td>
<td>38.1</td>
</tr>
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</table>
Process Bus Solution

San Miguel 110 kV Substation - Operational Report

The system of the San Miguel 110 kV substation has been monitored for almost three years, and has operated correctly with similar performance of the two systems.

During this period of time, several high voltage system faults have occurred and the process bus-based line protection has operated correctly, detecting the fault conditions and acting with times very close to the conventional system.

Example: San Miguel – San Lorenzo 110 kV line P-G fault. Record taken from the fault recorder installed at the substation which gets the signals both through hard wiring and 61850 protocol based process bus.
In this case, the conventional relay operated faster than the process bus relay with differences in the 67N function of 11.5 ms, and trigger operating difference of 16.2 ms.

The operation of the process bus line protection with point-to-point communication technology and conventional hardwiring had very similar operation times with some differences originated in the algorithms of the manufacturers.

Both protection systems performed adequately under the functional and real fault events.
Process Bus Solution

Key Aspects for the Implementation

- Independent implementation of process bus at the station and process level
- Reliability of the time synchronization system
- Redundancy for the data network
- Redundancy for the merging units
- Utilization of software tools suitable for process bus technology implementation
- Cyber-Security measures that are required to be taken
- Reliability of the solution
- Complexity level
- Interoperability
- Different testing procedures are required for the Process Bus
- Differences between point-to-point network (IEC 60850-9-1) and switched network (IEC 60850-9-2LE) should be considered in order to select the best solution for each application.
**Process Bus Solution**

**Benefits**

- Significant reduction in hard-wiring, resulting in an important reduction in cost and installation time
- Reduction in P&C cubicles manufacturing time
- Cable trenches can almost be eliminated, reducing cost and construction time
- Fewer terminal blocks and less internal wiring in the P&C cubicles
- Simpler operation and maintenance of the substation throughout its lifecycle
Authors

• **Camilo E. López**: Electrical Engineer graduated from Universidad Nacional de Colombia, Medellin Campus in 2004, specialized in Industrial Energy Management from Instituto Tecnológico Metropolitano (ITM) in 2009. Started his career in industrial automation programming and design with PLC equipment; in addition to it, in industrial system maintenance before joining HMV Engineers. In his seven years at HMV, he has performed in design, setup, tests, and commissioning, of control and protection systems associated to medium and high voltage and power plants in different countries. Currently, he performs as a specialized engineer in the control and protection area. [celopez@h-mv.com](mailto:celopez@h-mv.com)

• **Juan David Garcia**: Electrical engineer graduated from Universidad Pontificia Bolivariana in 1994; started his career in substation maintenance and power plant design before joining HMV Engineers. In his 22 years at HMV, he has performed in design, tests, and direction of projects associated to medium and high voltage and power plants. Currently, he performs as director of the control and protection area and as control, protection, and low voltage system manufacturing and procurement leader. [jgarcia@h-mv.com](mailto:jgarcia@h-mv.com)

• **Edgar Poveda**: Electric Engineer from Pontificia Bolivariana University. He is an Analysis and Protection of Power Systems Specialist from GEC Alsthom, England. Energy Management in the Small and Medium Scale Industry Specialist from University of Twente, The Netherlands and High Voltage Substations specialist. He has an overall experience of 37 years and he currently serves as the Strategy and Growth Vice President of HMV Engineers. [epoveda@h-mv.com](mailto:epoveda@h-mv.com)
Thank you!

HMV Engineers LLC. Orlando, Florida
7380 W. Sand Lake Road Suite 576E
Orlando, FL. 32819
Tel: (+1 407) 3523960