

Innovación: Regulación del Sistema Eléctrico.

Caso: Controlador de nivel y
generación Tilawa

ING. JOSÉ FREDDY ROJAS CH.

Proyecto de innovación y desarrollo

Sector Electricidad

- Ingeniería y Construcción.
 - Centro de Servicios Investigación y Desarrollo
- Negocio de Generación Eléctrica
 - Complejo Hidroeléctrico Plantas Arenal, Dengo, Sandillal.
- Centro de Control de Energía.

Ing. Marvin Montero Montero.

Ing. Fabio Jaramillo Cordero.

Ing. Andrés Fernández

Ing. Oscar Vargas Fallas

Ing. Freddy Rojas Chavarría

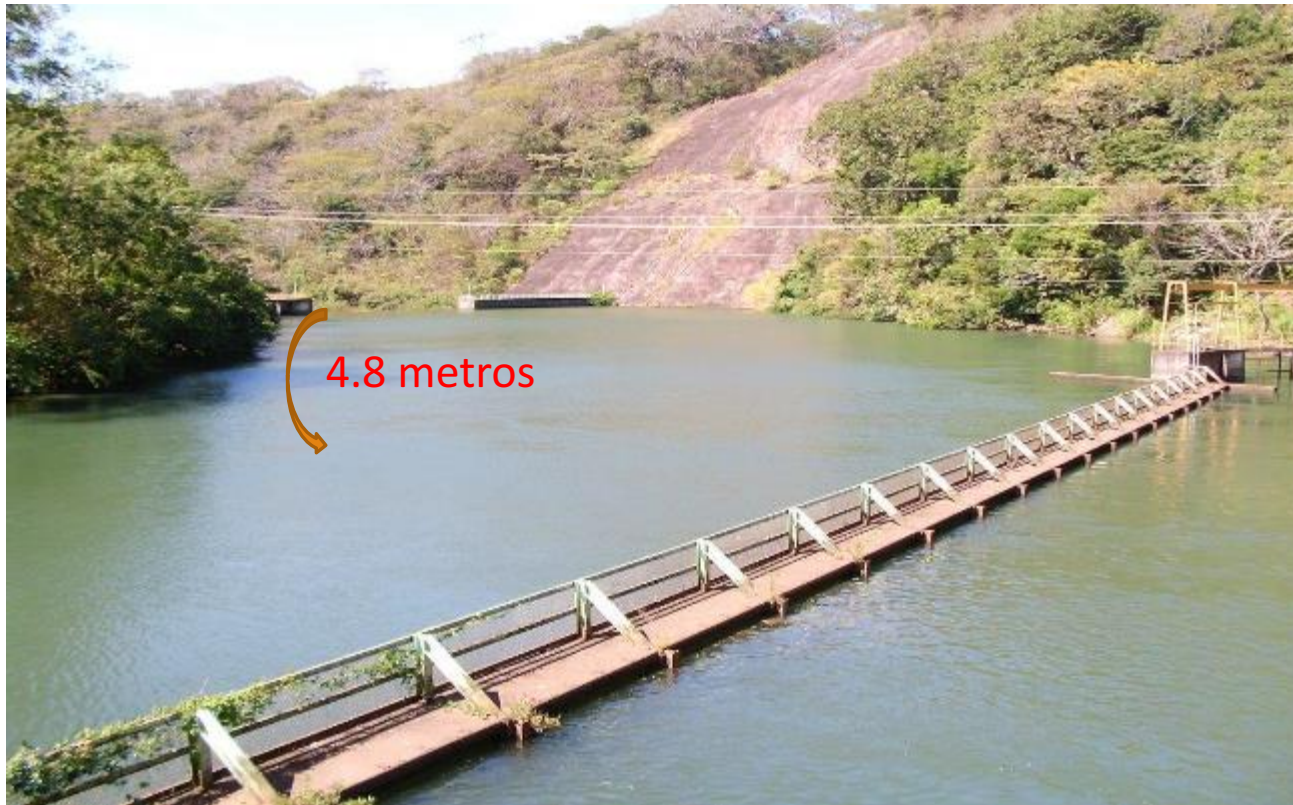
Ubicación



4.8 metros

Objetivo General

Desarrollar un sistema de control de lazo cerrado para el nivel del embalse Santa Rosa, mediante estrategias de desvío de la potencia final de las plantas Arenal y Dengo del complejo ARDESA, manteniendo la potencia total requerida por el Sistema Automático de Generación (AGC) del Centro de Control de Energía.



Tilawa

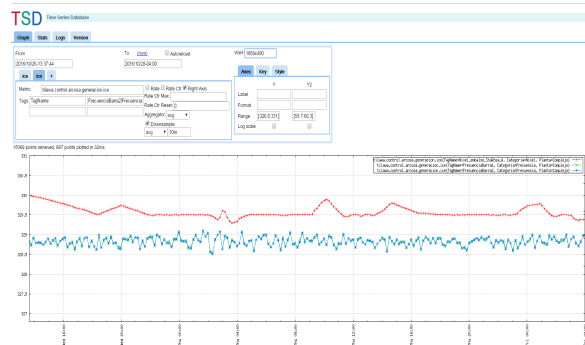
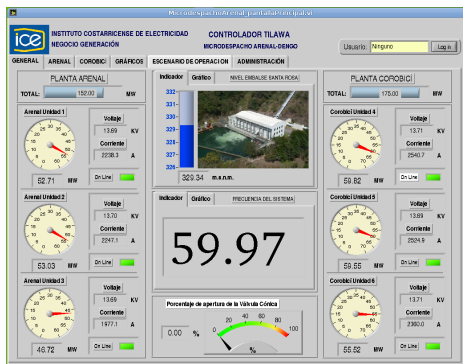
Nombre indígena asociado con las lluvias intermitentes y ventosas (tilawas) de la Zona de Tilarán, de donde se deriva el nombre de la localidad.

Historia

Años 70 Controlador Cibertec



Nuevo milenio 2000 Controlador SIAHC



2016 Controlador Tilawa

Historia

Años 70 Controlador Cibertec



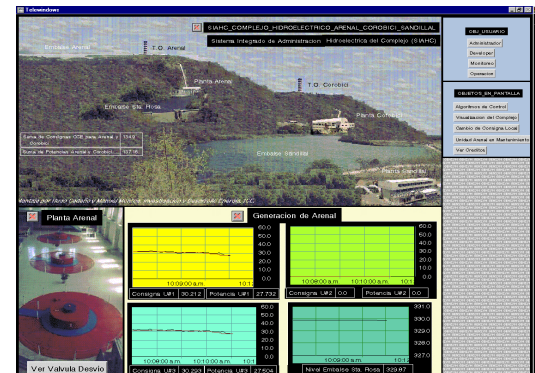
- Computador Cromenco
- Ensamblador Z80
- Recibe consigna total y reparte consignas para garantizar nivel del embalse.

Historia

Nuevo milenio 2000 Controlador SIAHC



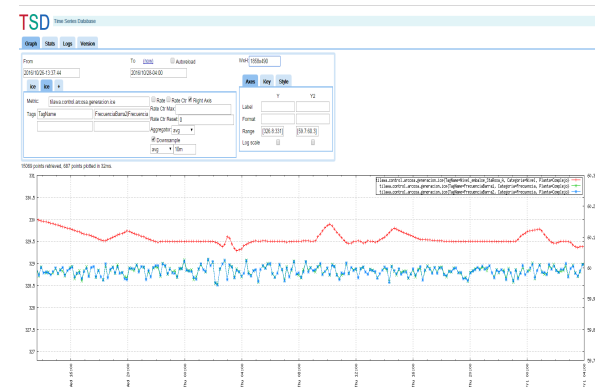
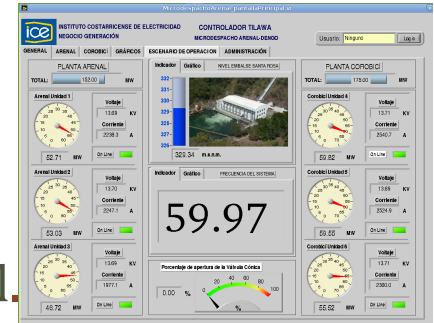
- Primer proyecto I+D y se desarrolla entre 1998 y 2000
- PLC Siemens S5
- Sistema Operativo Solaris
- G2 www.gensym.com



Historia

2016 Controlador Tilawa

- Control del nivel mediante ajustes por unidad individual.
- Restricciones del Mercado Eléctrico Centroamericano
- Todo el diseño es nacional en C++/C, sobre Linux.
- Uso maximizado de código abierto.
- Integración comercial con Simulink y LabView
- Interoperabilidad siguiendo estándares Smart Grid.
- Ningún alambrado.
- Integra simulación en tiempo real 7x24 durante meses.



Alcance

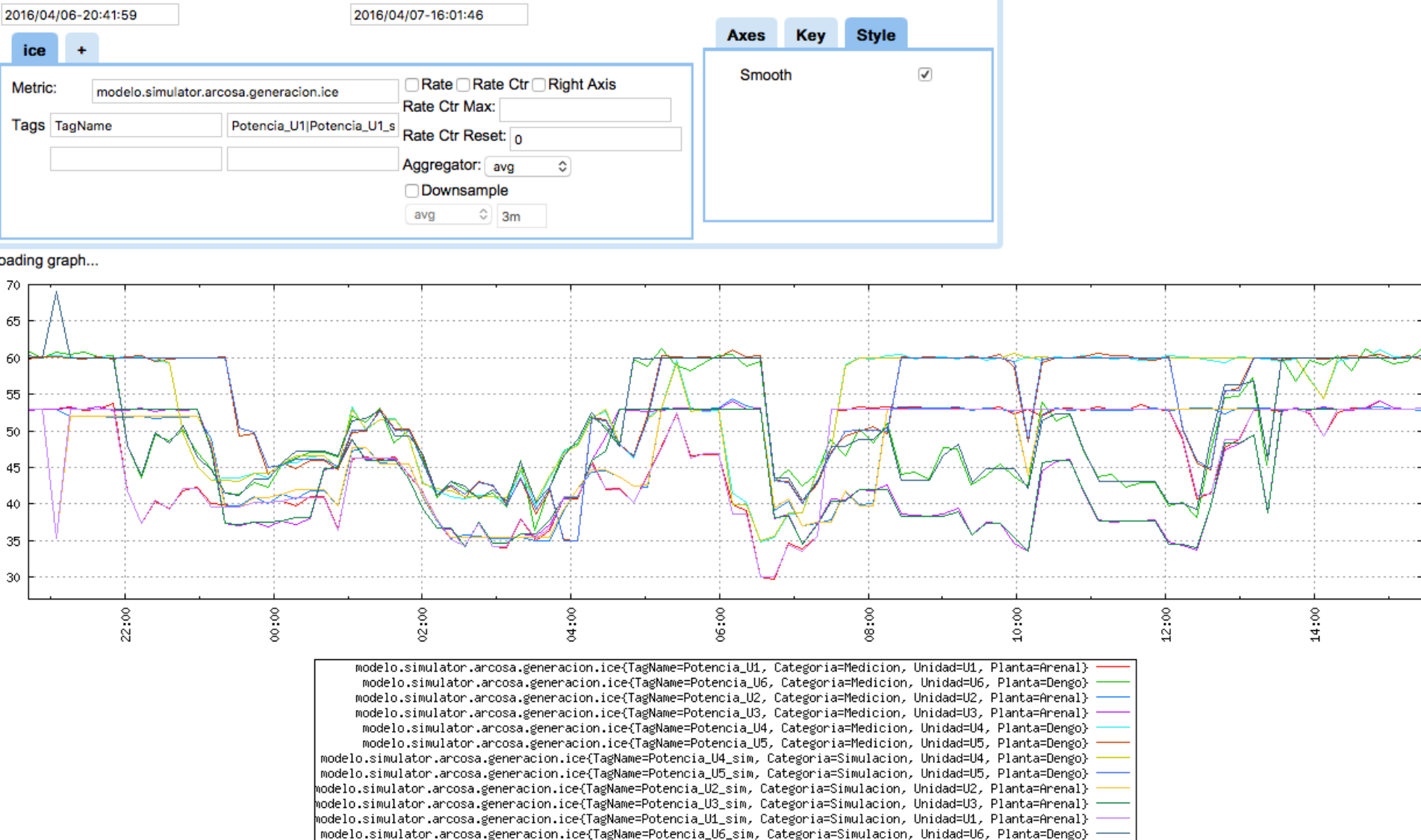
Realizar el **despacho** del **nivel** del embalse **Santa Rosa** del Complejo Hidroeléctrico Arenal Dengo Sandillal, mediante **telemando** y **control automático** en forma integrada con el negocio Generación y el Centro de Control de Energía (CENCE)

Mantener las **consignas** de **potencia** enviadas por el Centro de Nacional de Control de Energía que garanticen el **control primario** y **secundario**, en **forma conjunta** con el **control de nivel** del embalse Santa Rosa.

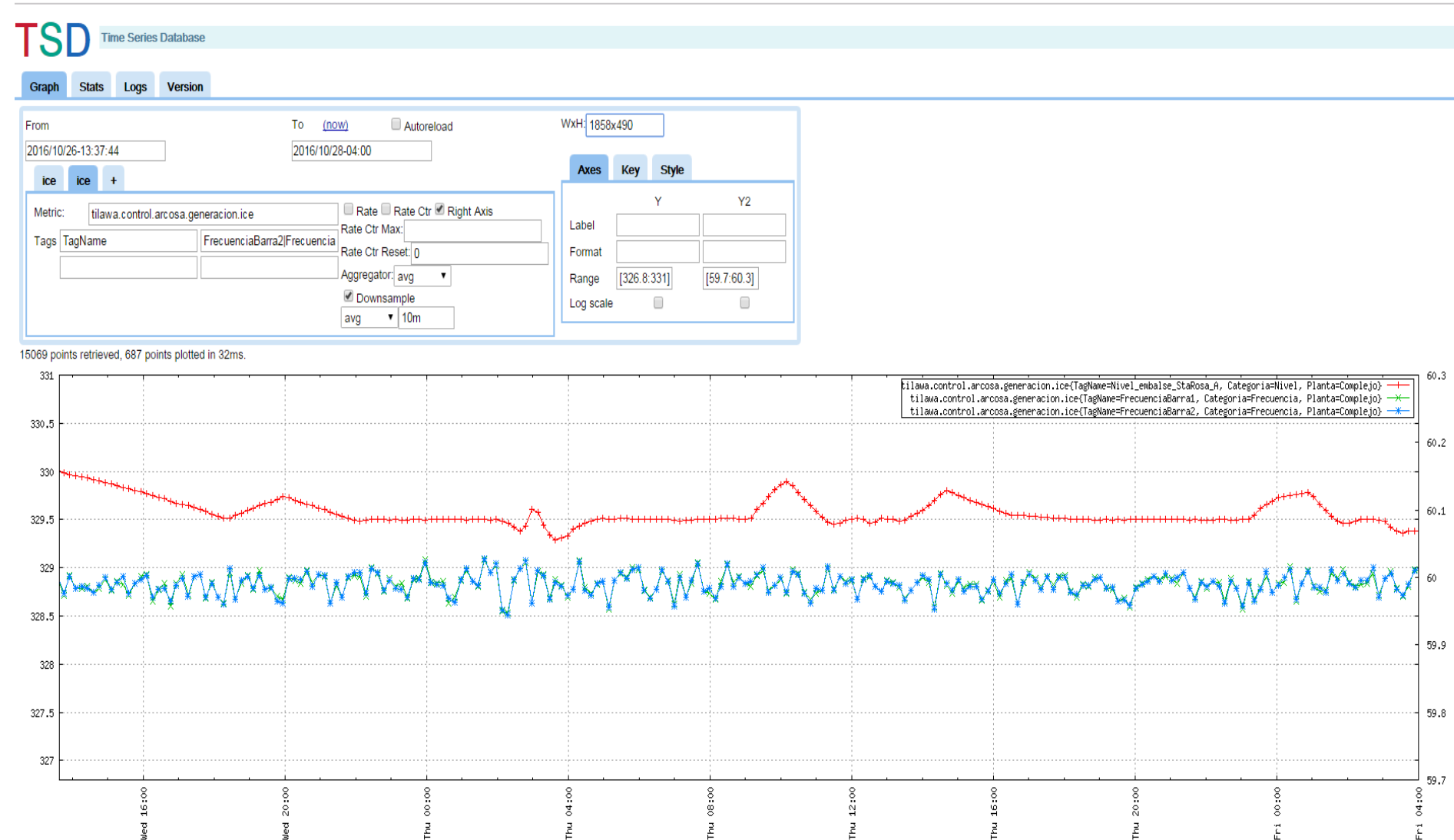
Permitir el **control manual** del embalse Santa Rosa por parte de los **operadores** de Planta Arenal mediante la intervención de las unidades de Plantas Arenal y Dengo.

Desarrollar el sistema con un **mínimo** de **indisponibilidades**.

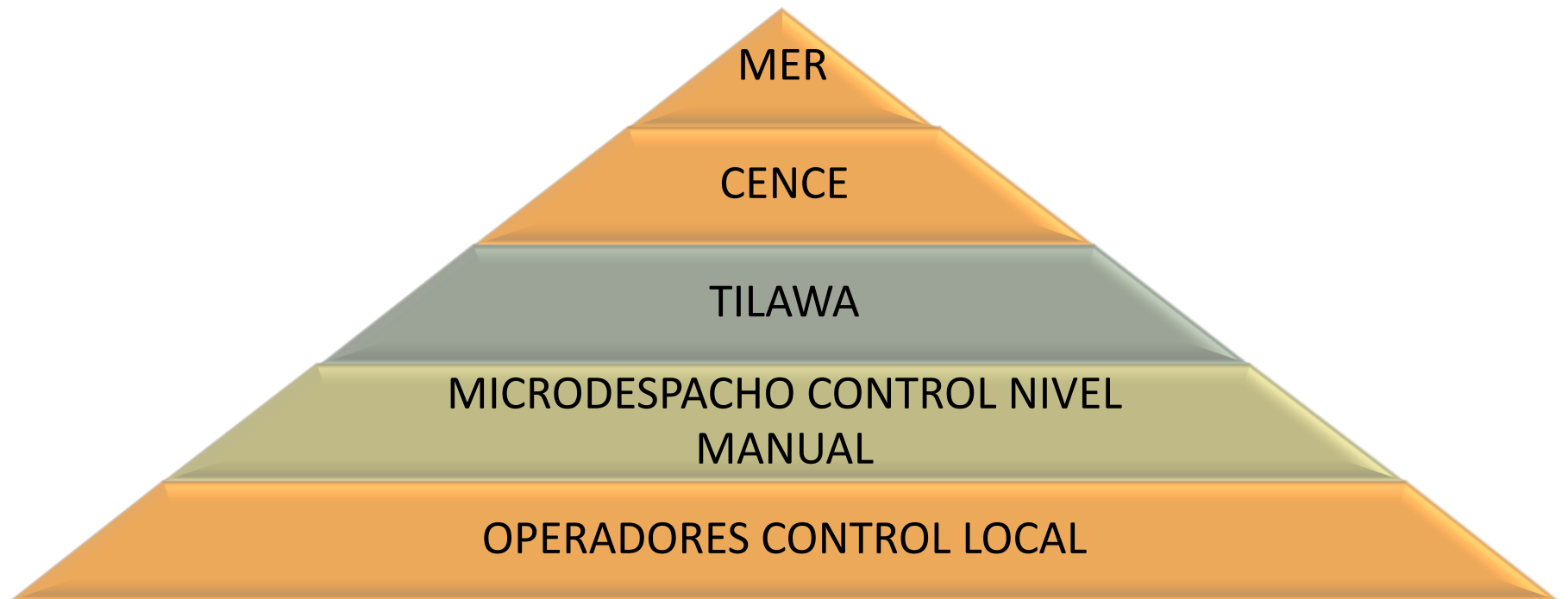
Cómo controla



Cómo controla



Precedencia de Control



Estándares

NIST

Search NIST

NIST MENU

PUBLICATIONS

NIST Framework and Roadmap for Smart Grid Interoperability Standards, Release 3.0

Published: October 01, 2014

RECENT PUBLICATIONS

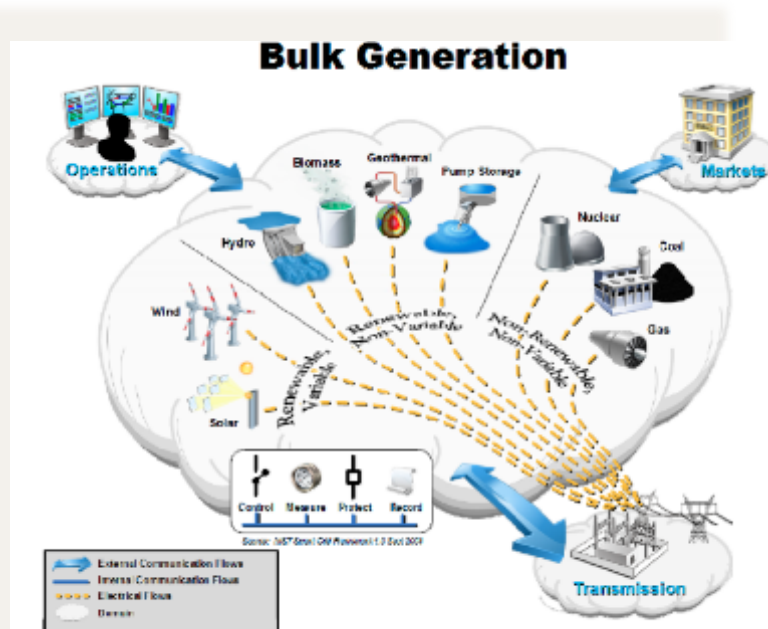
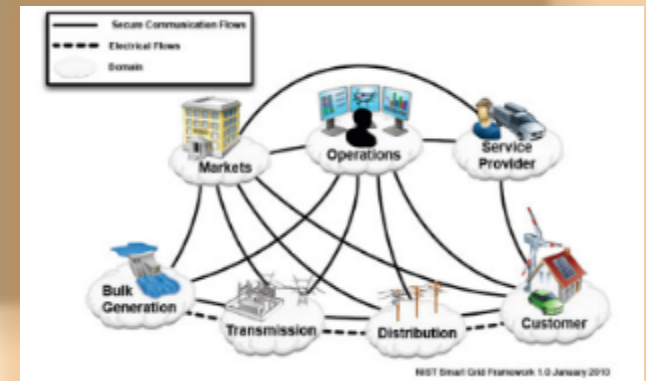


Figure 9-6. Overview of the Bulk Generation Domain.



NIST:
<http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.1108r3.pdf>

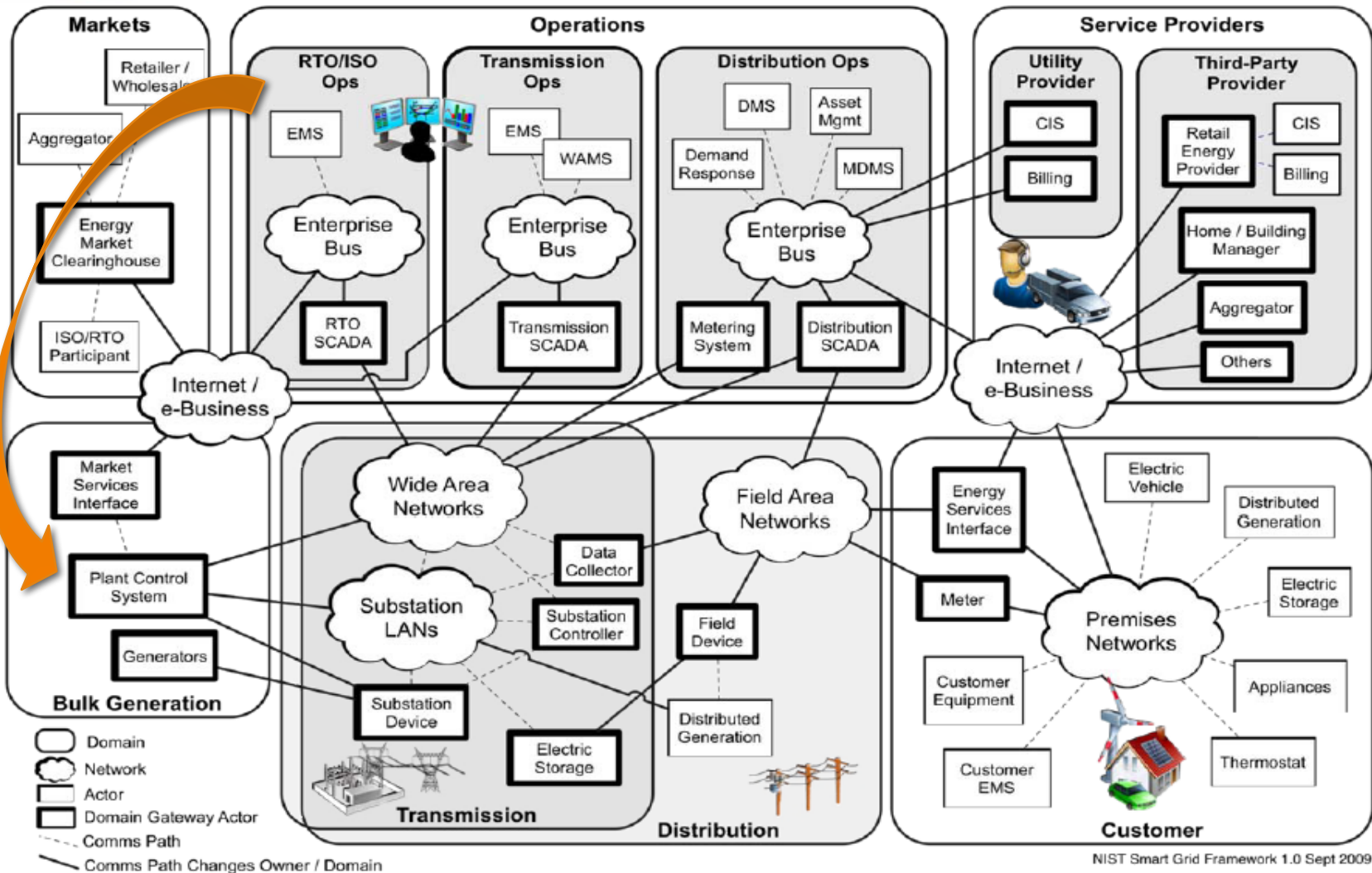
May, 2013

1. List of Standards that include Cybersecurity

- ANSI C12.18-2006/IEEE P1701/MC1218 Protocol Specification for ANSI Type 2 Optical Port
- ANSI C12.19-2008/IEEE 1377/MC1219 Utility Industry End Device Data Tables
- ANSI C12.21/IEEE P1702/MC1221 Protocol Specification for Telephone Modem Communication
- ANSI C12.22/IEEE P1703/MC1222 Protocol Spec for Interfacing to Data Comm Networks
- ANSI/ASHRAE 135-2010/ISO 16484-5 BACnet
- ANSI/CEA 709.1-B-2002 Control Network Protocol Specification
- CEA 852.1:2009 Enhanced Tunneling Device Area Network Protocols
- IEC 15118 Road vehicles — Vehicle to grid communication interface
- IEC 60870-5 Telecontrol equipment and systems: Transmission protocols
- IEC 60870-6 Telecontrol Application Service Element 2 (TASE.2) (references IEC 62351)
- IEC 61850 Suite of standards on Communication Networks and Systems for Power Utility Automation (references IEC 62351)
- IEC 61850-90-5 for exchanging synchrophasor information
- IEC 61968 System Interfaces for Distribution Management (references IEC 62351)
- IEC 61970 Energy management system application program interface (EMS-API) (references IEC 62351)
- IEC 62056 COSEM: COmpanion Specification for Energy Metering (COSEM)
- IEC 62541 OPC Unified Architecture
- IEC PAS 62559 Methodology for Requirements Development



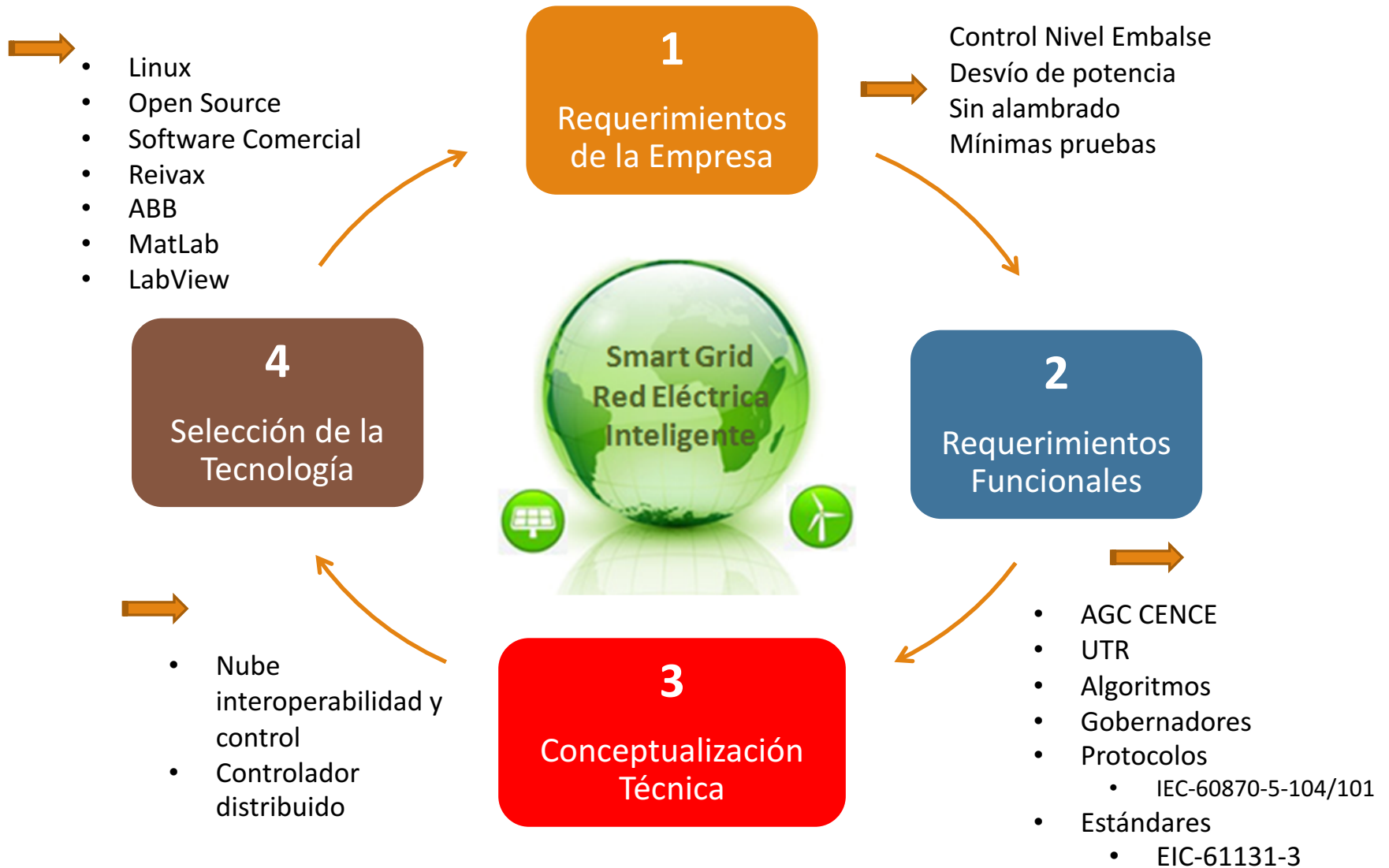
Gestión de la Energía



NIST Smart Grid Framework 1.0 Sept 2009

Interoperabilidad en la cadena de valor

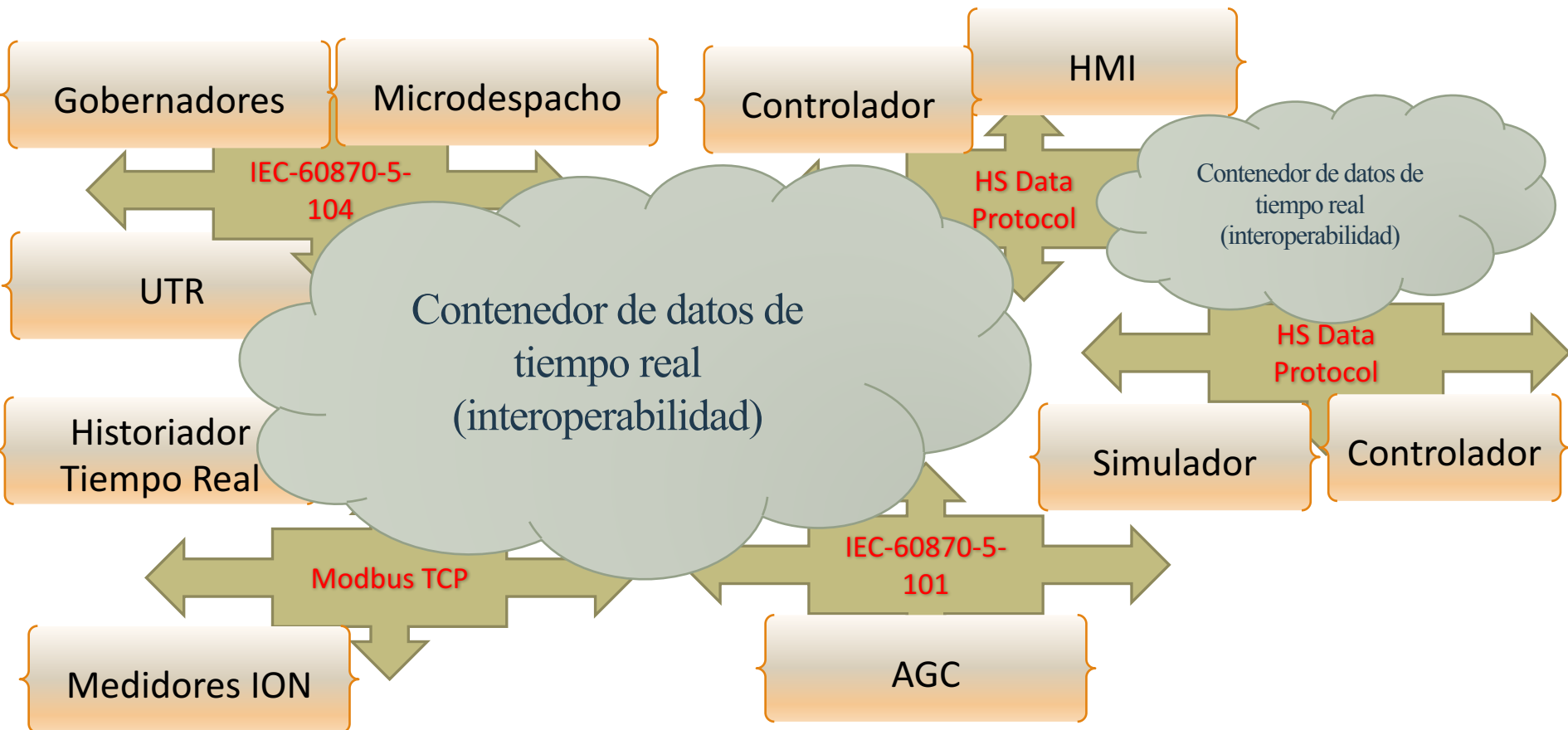
Pasos Implementación SG ... un proceso iterativo

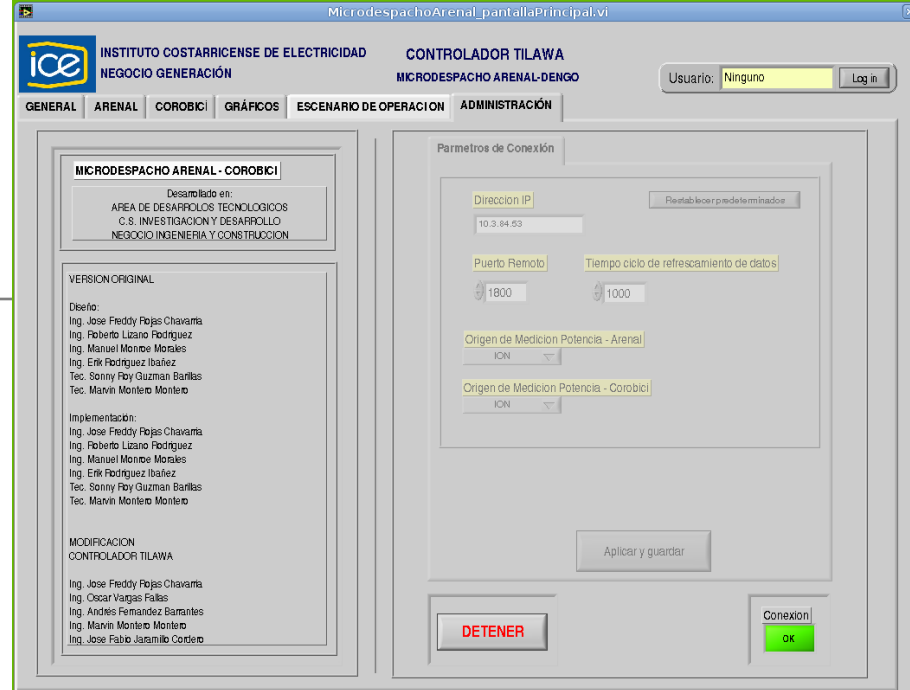
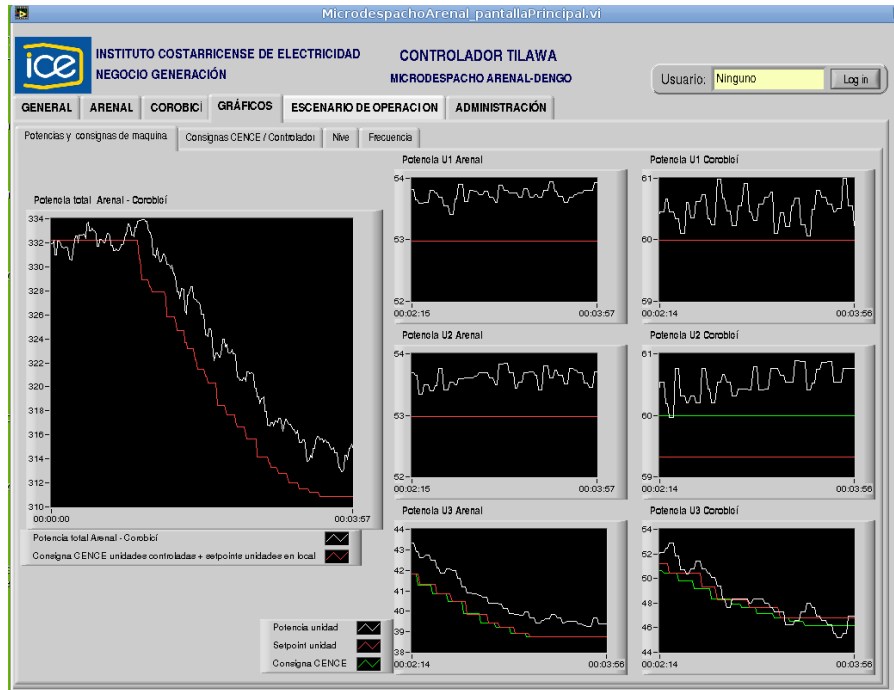
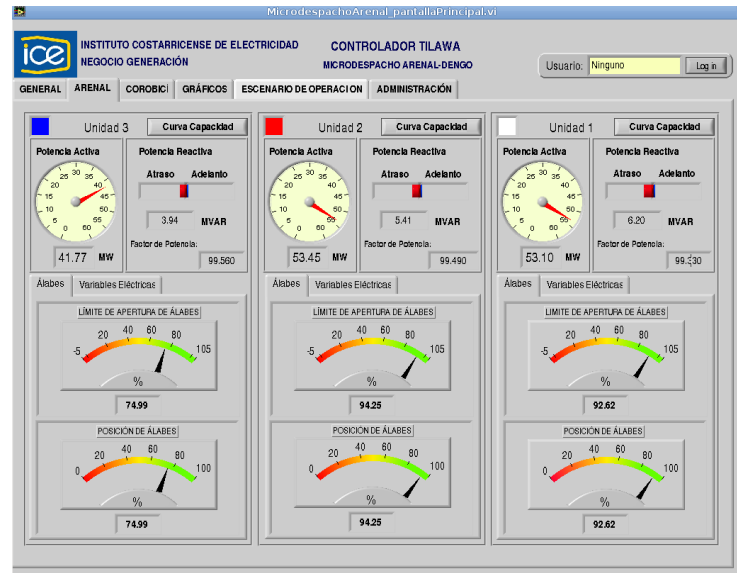
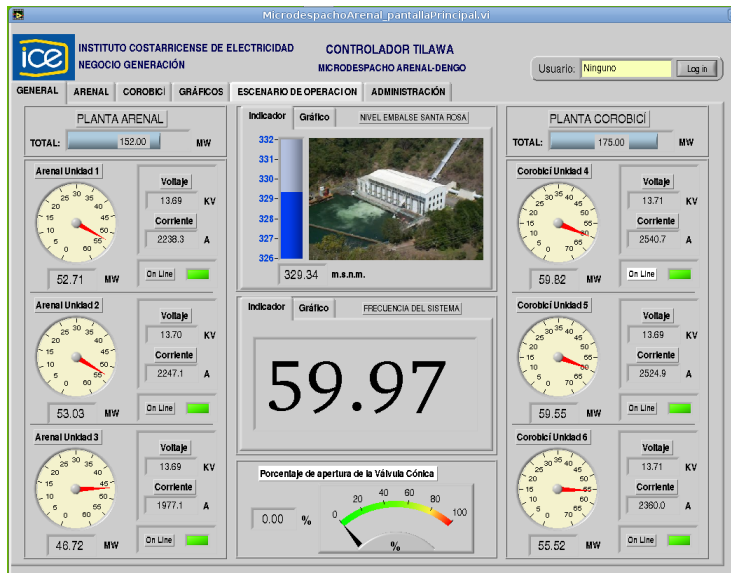


Nube de datos

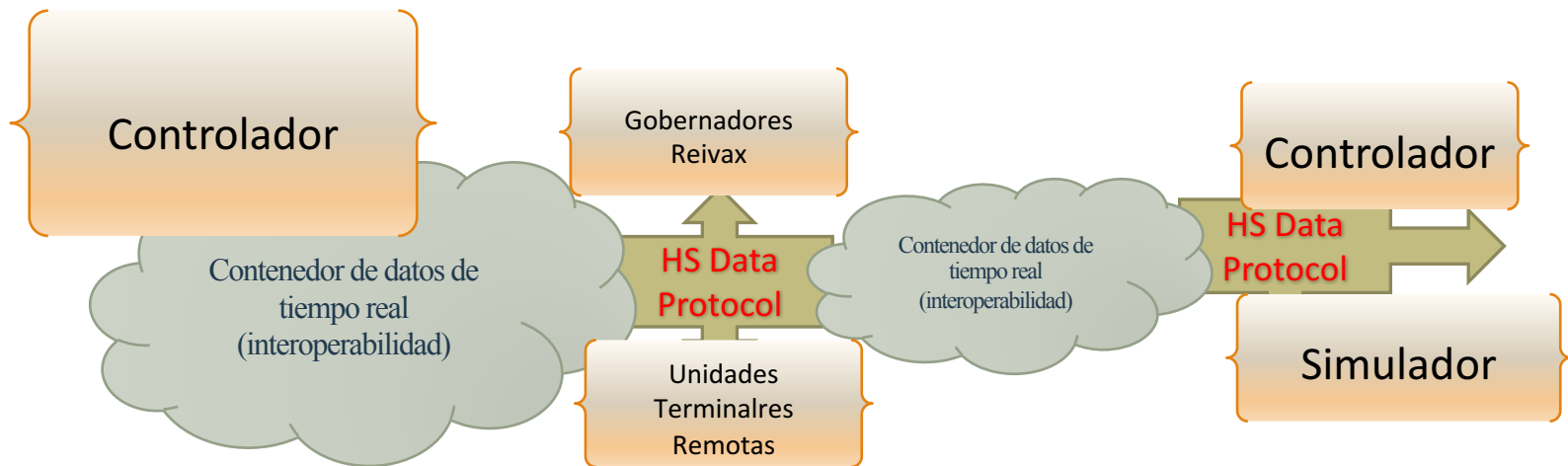
Servidor de comunicaciones

Internet de las cosas industriales

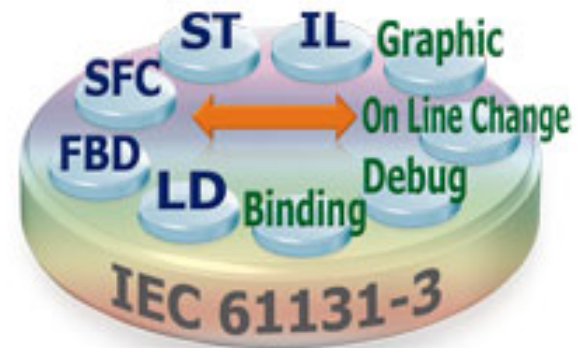




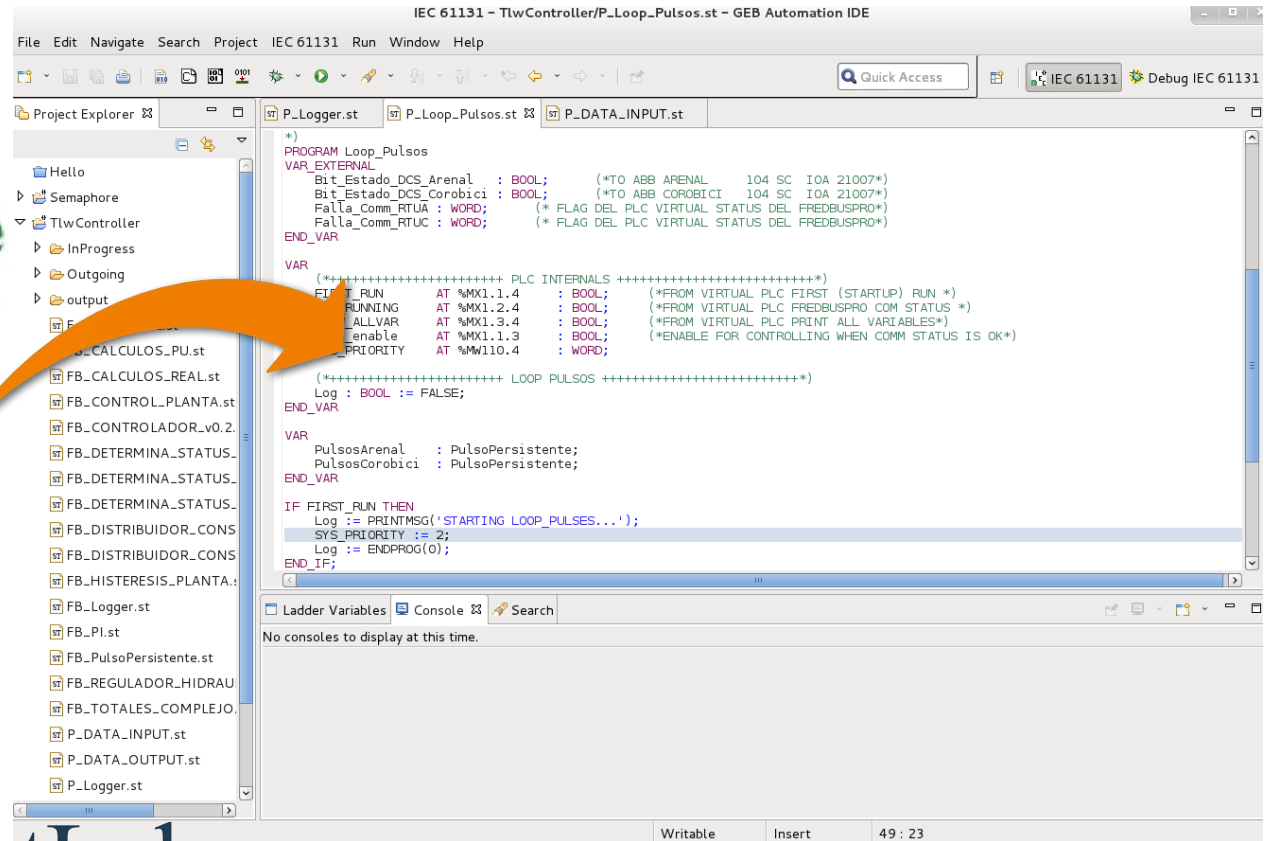
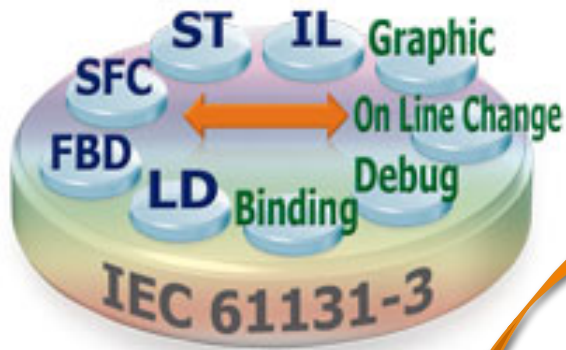
Controlador Servicio de control



- Control de eventos discretos
- Control de Lazo cerrado de nivel



Controlador Servicio de control



Simulink/MatLab

Advances in Industrial Control

German Ardul Munoz-Hernandez
Sa'ad Petrous Mansoor
Dewi leuan Jones

Modelling and Controlling Hydropower Plants

AIC

 Springer

TSD

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global>

main(int size, char* arg[]) int

gemenet

projectsSymbolsResources

TwlSimulator

Smulink_eval

TwlRuntime

VisualScada

VisualSimulator

Simulator

Sources

Headers

Simulator Controller

matlab\tw\ModelComplete.m

Simulator.cc

main_simulator.cpp

172 ChangeEventDialog Causal_US_Sim Causal_US_Sim_99_99_0_00;

173 ChangeEventDialog Causal_US_Sim Causal_US_Sim_99_99_0_00;

174 ChangeEventDialog Causal_US_Sim Causal_US_Sim_99_99_0_00;

175

176 ChangeEventDialog Factor_CargaDelmal_FactorCargaDelmal_100_0_0_1;

177 ChangeEventDialog Factor_CargaDelmal_FactorCargaDelmal_100_0_0_1;

178 ChangeEventDialog Factor_InferenciaFactorInferencia_100_0_0_1;

179 ChangeEventDialog Nivel_Embalse_SantaRosa_Nivel_Embalse_350_0_0_0;

180

181 class changeEventBinary_INO_REMOTO_UI(getBinaryElement<"INO_REMOTO_UI");

182

183 while(enable_getdata) thmsleep(1);

184

185 while(true)

186 {

187 //Frecuencia

188 if(FrecuenciaBarra_Test()) {T_RT_Tag Info(FrecuenciaBarra,"Frecuencia","Complejo"); Queue.inserteInfo();

189 =====

190 //Nivel Actual

191 if(Nivel_Actual_Test()) {T_RT_Tag Info(Nivel_Embalse_SantaRosa,"Nivel_actual","Medicion","Nivel","Complejo"); Queue.inserteInfo();

192 =====

193 //Consigna

194 if(Consigna_CC_U1_Test()) {T_RT_Tag Info(Consigna_CC_U1,"Consigna_U1","Medicon","U1","Arena"); Queue.inserteInfo();

195 =====

196 if(Consigna_CC_U2_Test()) {T_RT_Tag Info(Consigna_CC_U2,"Consigna_U2","Medicon","U2","Arena"); Queue.inserteInfo();

197 =====

198 if(Consigna_CC_U3_Test()) {T_RT_Tag Info(Consigna_CC_U3,"Consigna_U3","Medicon","U3","Arena"); Queue.inserteInfo();

199 =====

200 if(Consigna_CC_U4_Test()) {T_RT_Tag Info(Consigna_CC_U4,"Consigna_U4","Medicon","U4","Bengo"); Queue.inserteInfo();

201 =====

202 if(Consigna_CC_U5_Test()) {T_RT_Tag Info(Consigna_CC_U5,"Consigna_U5","Medicon","U5","Bengo"); Queue.inserteInfo();

203 =====

204 if(Consigna_CC_U6_Test()) {T_RT_Tag Info(Consigna_CC_U6,"Consigna_U6","Medicon","U6","Bengo"); Queue.inserteInfo();

205 =====

206 //Potencia Actual

207 if(Potencia_Gob_U1_Test()) {T_RT_Tag Info(Potencia_Gob_U1,"Potencia_U1","Medicon","U1","Arena"); Queue.inserteInfo();

208 =====

209 if(Potencia_Gob_U2_Test()) {T_RT_Tag Info(Potencia_Gob_U2,"Potencia_U2","Medicon","U2","Arena"); Queue.inserteInfo();

210 =====

211 if(Potencia_Gob_U3_Test()) {T_RT_Tag Info(Potencia_Gob_U3,"Potencia_U3","Medicon","U3","Arena"); Queue.inserteInfo();

212 =====

& others

Code: Blocks

CppCheck

CppCheck messages

DoyBlocks

Debugger

Valgrind

Valgrind messages

Closed files list

Cccc

Build log

Build messages

Line Message

-- Build: Release_linux in PreDebugPre_client_dynamic (compiler: GNU GCC Compiler) ---

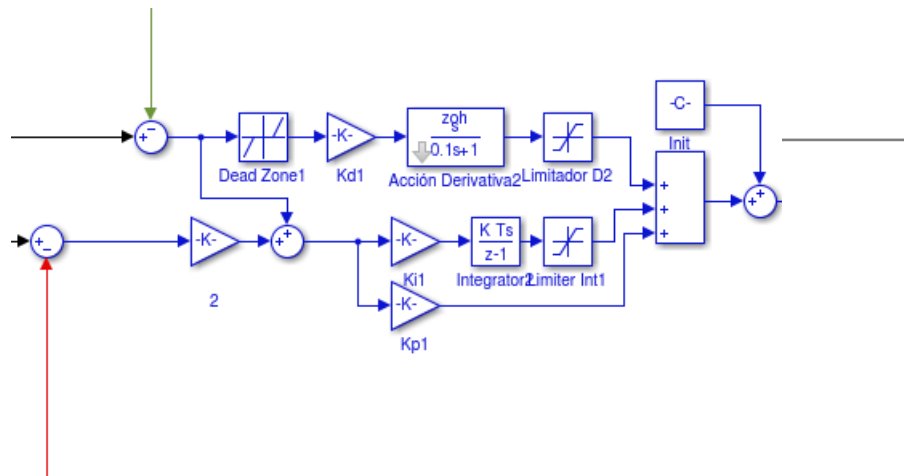
-- Build: Release_linux in PreDebugPre_client_wsl (compiler: GNU GCC Compiler) ---

a/freddy/d... -- Build: Release_linux in TwlSimulator (compiler: GNU GCC Compiler) ---

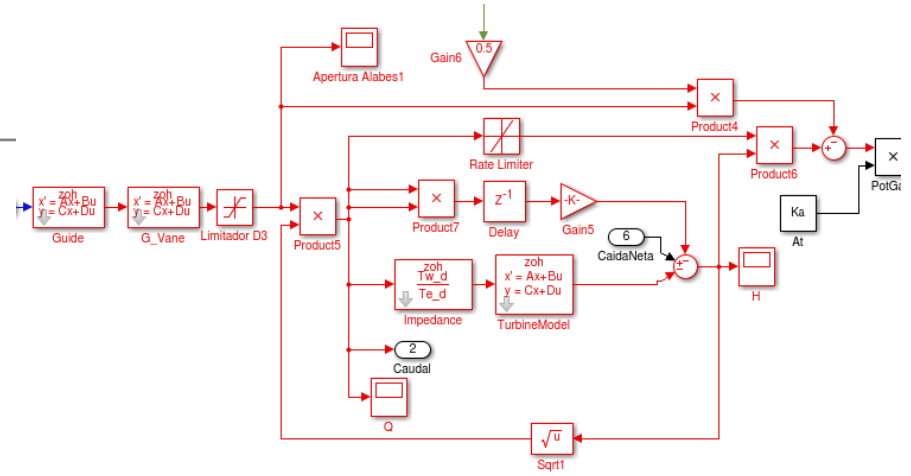
n/freddy/d... In member function 'size_t __gnu_cxx::strlen(const char*)' [warning: unused variable 'size' [-Wunused-variable]]

warning: unused variable 'size' [-Wunused-variable]

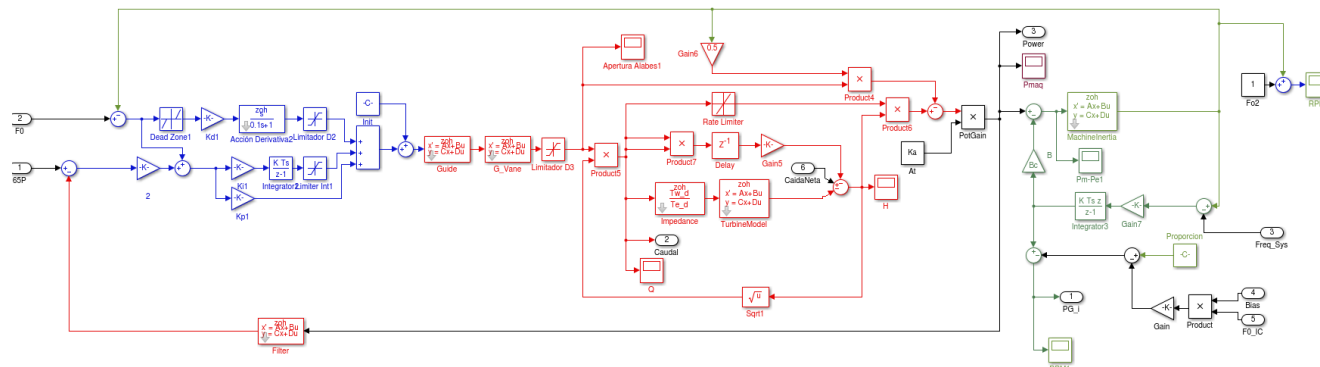
Modelado generado



Gobernador

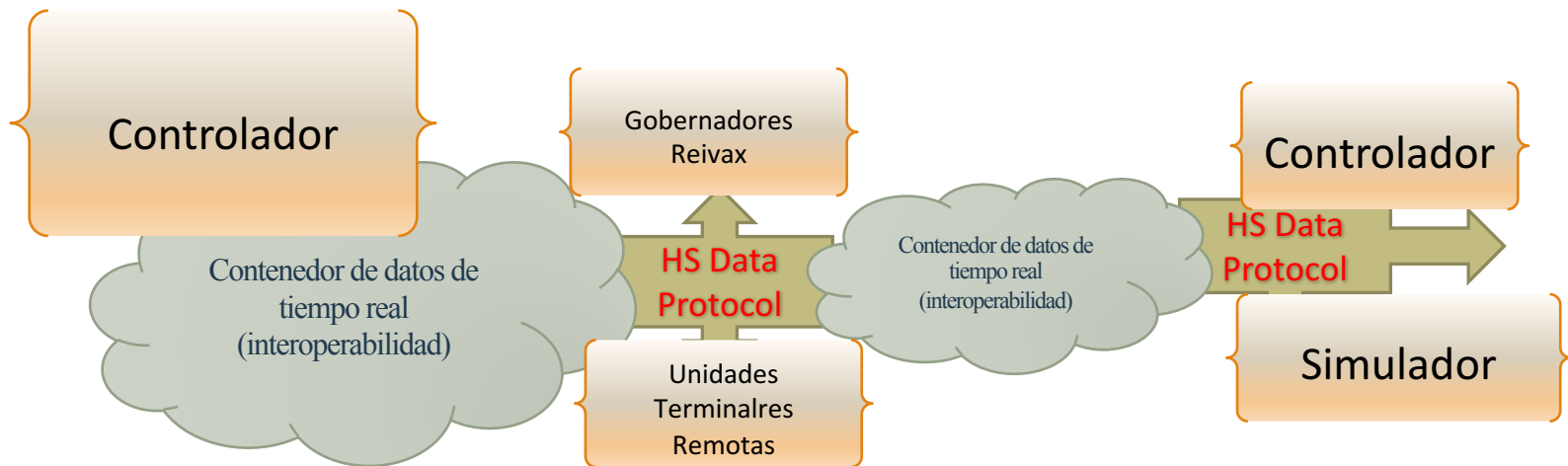


Turbina, tubería de presión

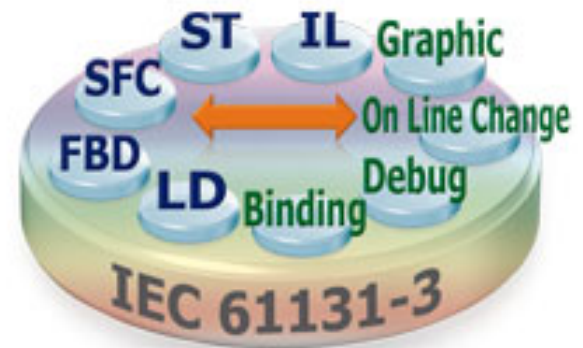


Generador completo

Controlador Servicio de control



- Control de eventos discretos
- Control de Lazo cerrado de nivel



Comparar simulación y realidad

2016/05/12-14:39:30

2016/05/12-15:45:54

iceice+

Metric:

tilawa.control.arcosa.generacion.ice

Rate

Rate Ctr

Right Axis

Rate Ctr Max:

Rate Ctr Reset:

0

Aggregator:

avg

Downsample

avg

10m

Tags

TagName

Consigna_CENCE_U2|Poter

Axes

Key

Style

Y

Y2

Label

Format

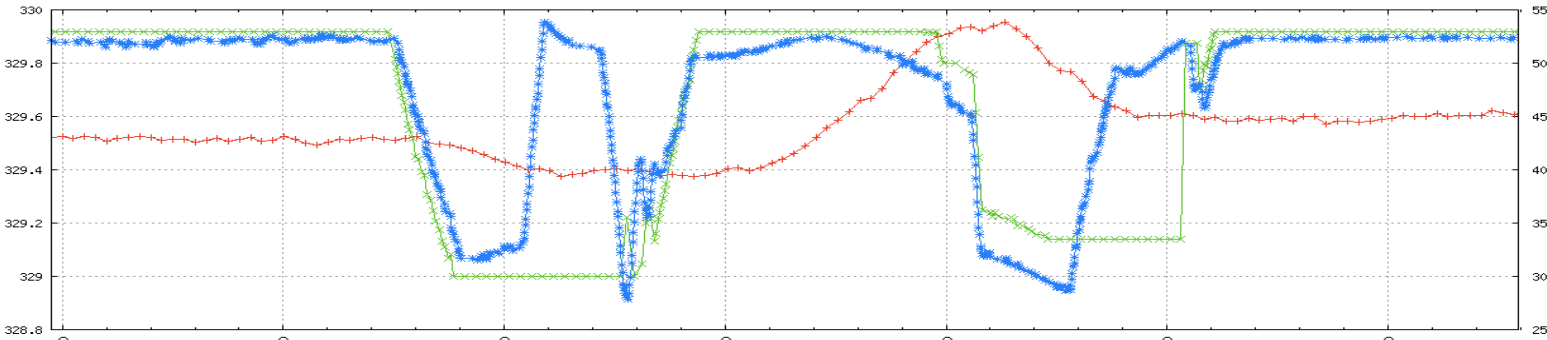
Range

328.8

Log scale

2414 points retrieved, 959 points plotted in 31ms.

tilawa.control.arcosa.generacion.ice{TagName=Nivel_embalse_StaRosa_A, Categoria=Nivel, Planta=Complejo} +
tilawa.control.arcosa.generacion.ice{TagName=Consigna_CENCE_U2, Categoria=Consigna, Unidad=U2, Planta=Arenal} x
tilawa.control.arcosa.generacion.ice{TagName=Potencia_U2, Categoria=Potencia, Unidad=U2, Planta=Arenal} *



2016/05/12-14:39:30

2016/05/12-15:45:54

iceice+

Metric:

controlador.simulator.arcosa.generacion.ice

Rate

Rate Ctr

Right Axis

Rate Ctr Max:

Rate Ctr Reset:

Aggregator:

sum

Downsample

avg

10m

Tags

TagName

Consigna_CENCE_U2|Poter

x

Categoria

x

Planta

Unidad

Axes

Key

Style

Y

Y2

Label

Format

Range

329.1

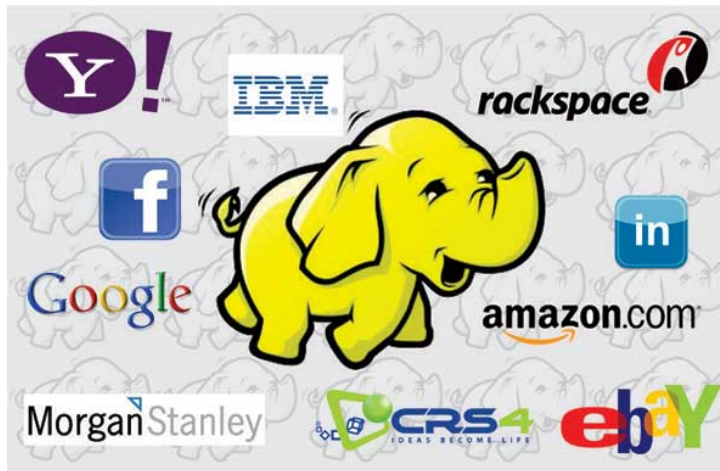
Log scale

1102 points retrieved, 401 points plotted in 40ms.

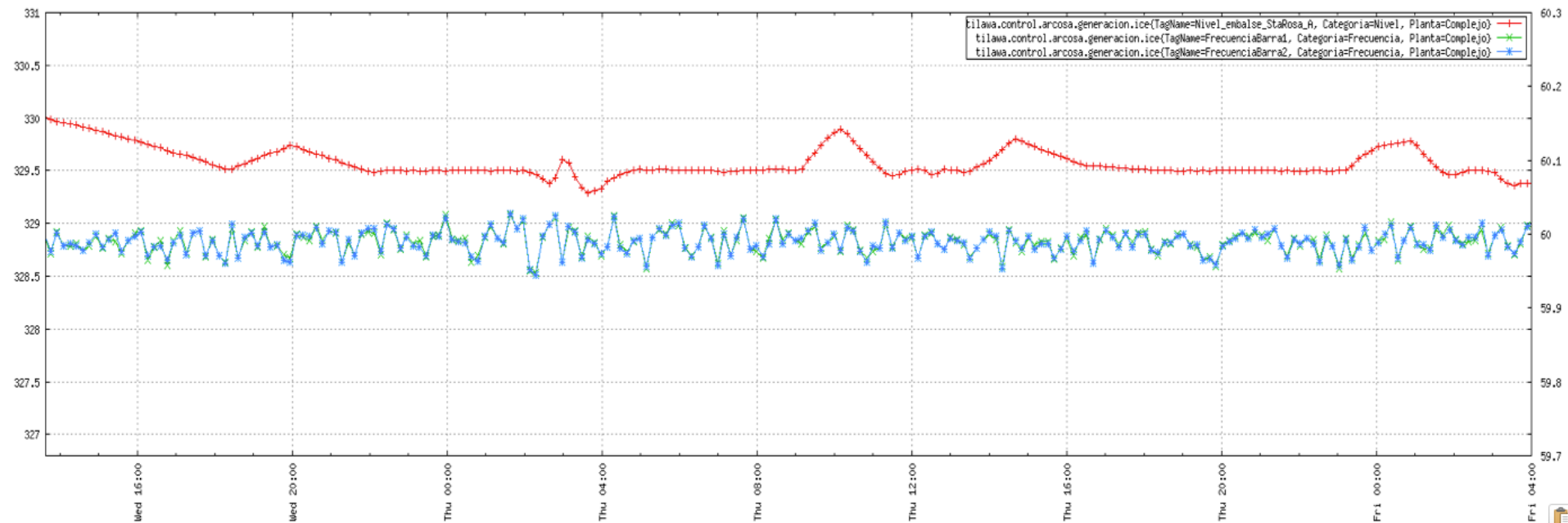
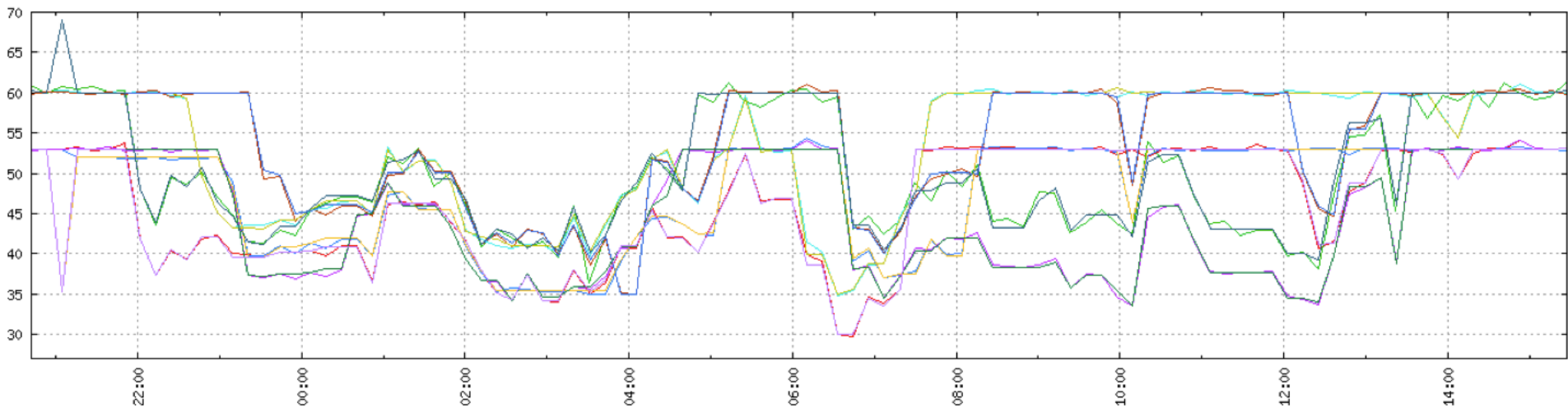
controlador.simulator.arcosa.generacion.ice{TagName=Nivel_actual, Categoria=Medicion, Unidad=Nivel, Planta=Complejo} +
controlador.simulator.arcosa.generacion.ice{TagName=Nivel_sim, Categoria=Simulacion, Unidad=Nivel, Planta=Complejo} x
controlador.simulator.arcosa.generacion.ice{TagName=Consigna_CENCE_U2, Categoria=Medicion, Unidad=U2, Planta=Arenal} *
controlador.simulator.arcosa.generacion.ice{TagName=Potencia_U2, Categoria=Medicion, Unidad=U2, Planta=Arenal} □

This line chart displays four data series over time from 14:40 to 15:40. The left y-axis ranges from 329 to 330, and the right y-axis ranges from 25 to 55. The red line with '+' markers represents the actual level of the Sta Rosa A embalse, fluctuating between 40 and 50 on the right axis. The green line with 'x' markers represents the simulated level, which is relatively stable around 35 on the left axis. The blue line with '*' markers represents the command for the U2 unit, showing a step-like pattern between 30 and 35 on the left axis. The purple line with '□' markers represents the power of the U2 unit, which also shows a step-like pattern between 30 and 50 on the right axis. The chart compares simulation data from 'controlador'.

Historiador open source OpenTSDb/Hadoop



Resultados

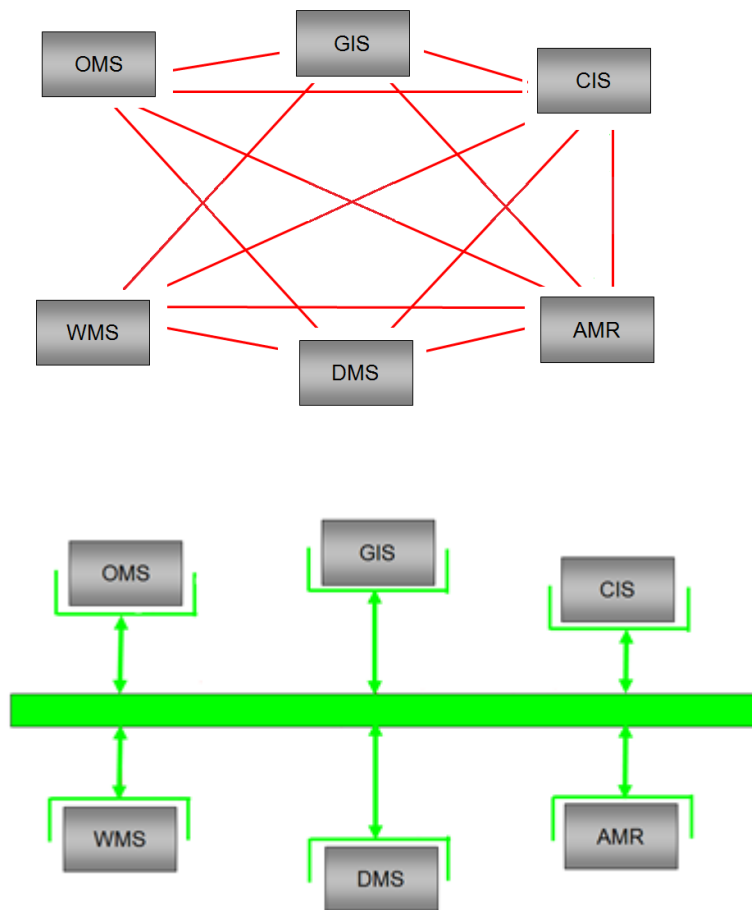


Resultados

- Inversión cercana a un millón de dólares.
 - Compra de Unidades Terminales Remotas.
 - Tarjetas 104 Prosoft.
 - Costos indirectos.
 - Mano de obra.
- En servicio desde el 21 de Julio 7x24.
 - Control de Unidades Arenal y Dengo.
 - Control automático de válvula cónica.
 - Integración Microdespacho.
- Aplicativos
 - Nube de interoperabilidad
 - Controlador
 - HMI
 - Historiador OpenTSDB

Prospectivas

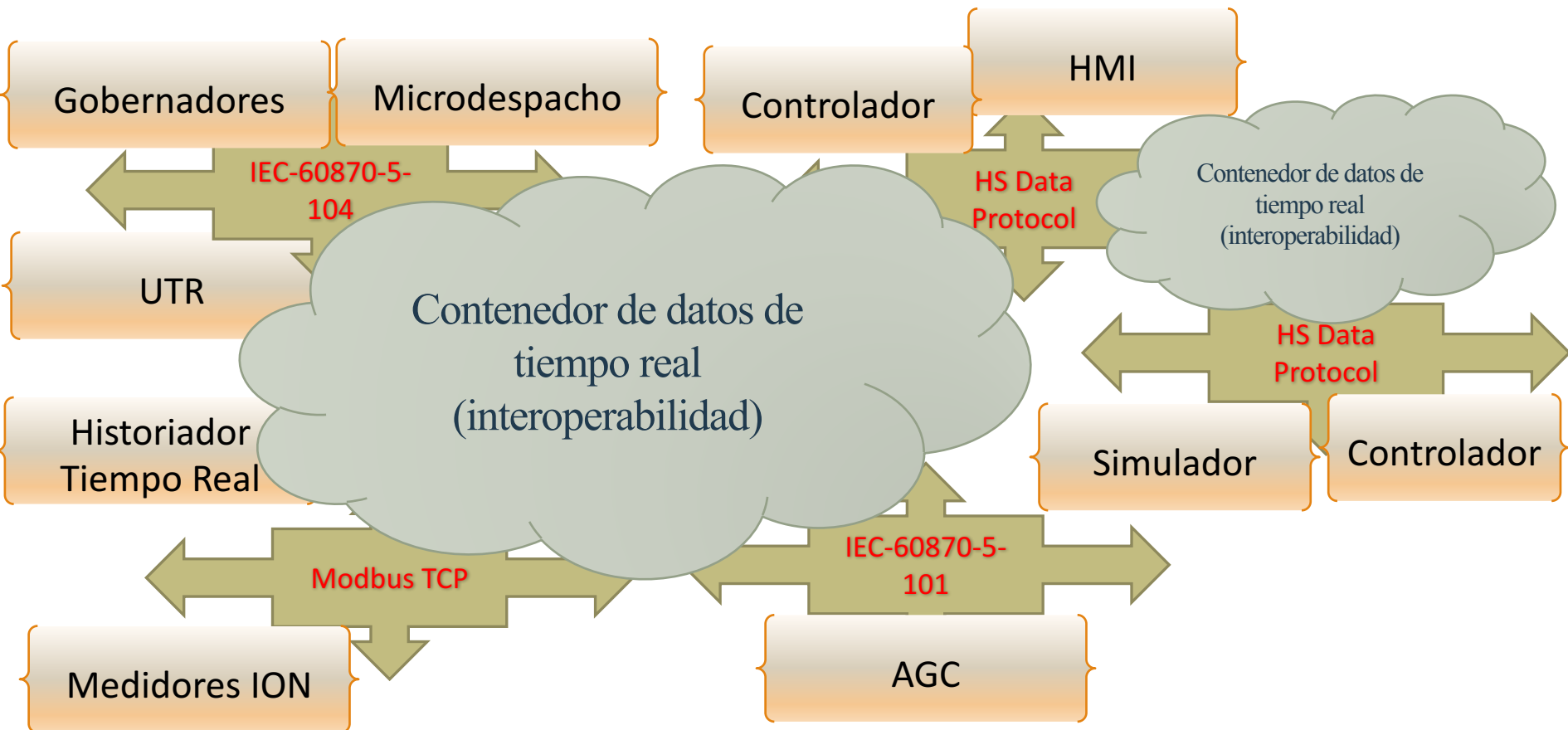
Interoperabilidad



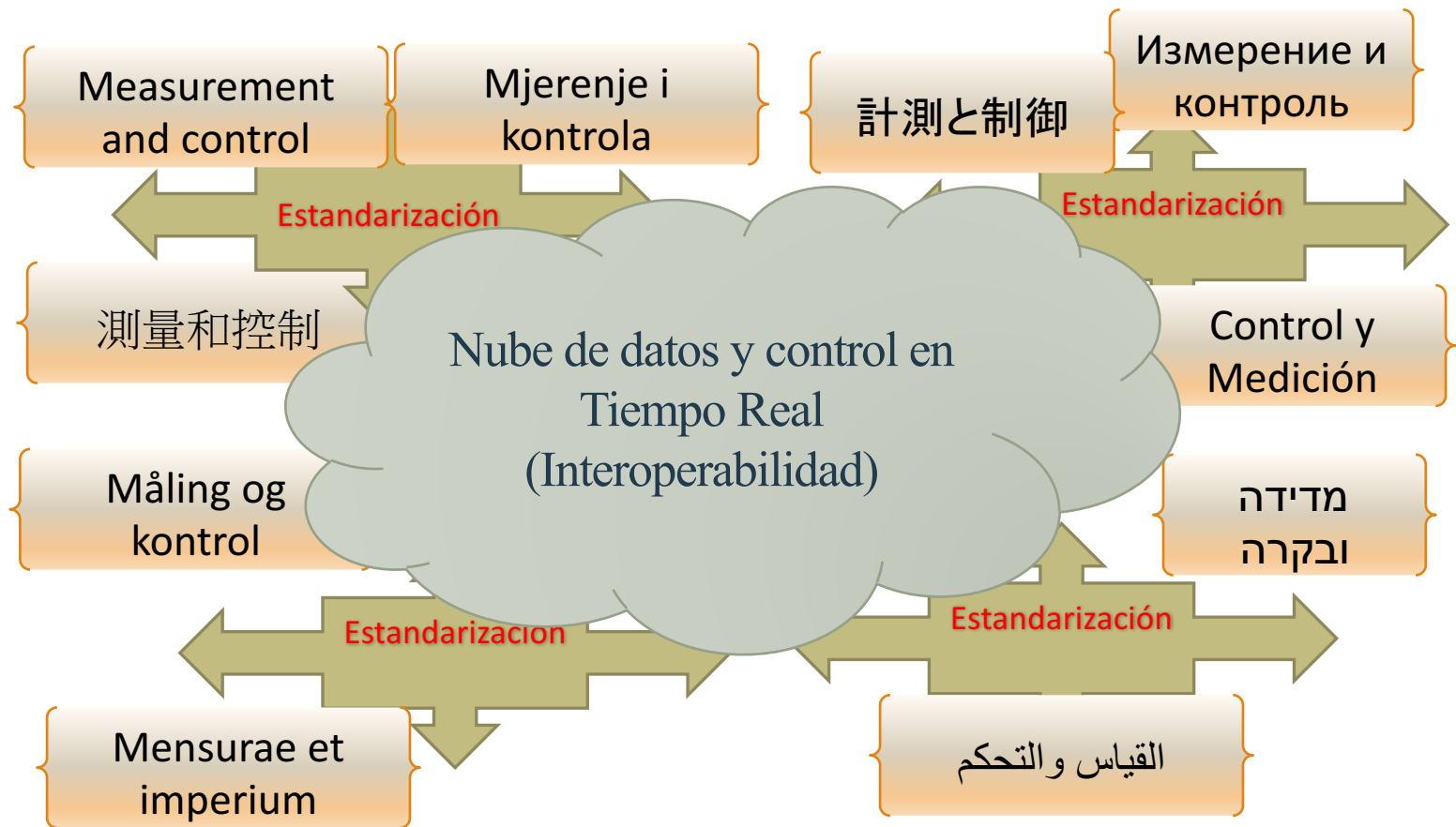
iOS 6



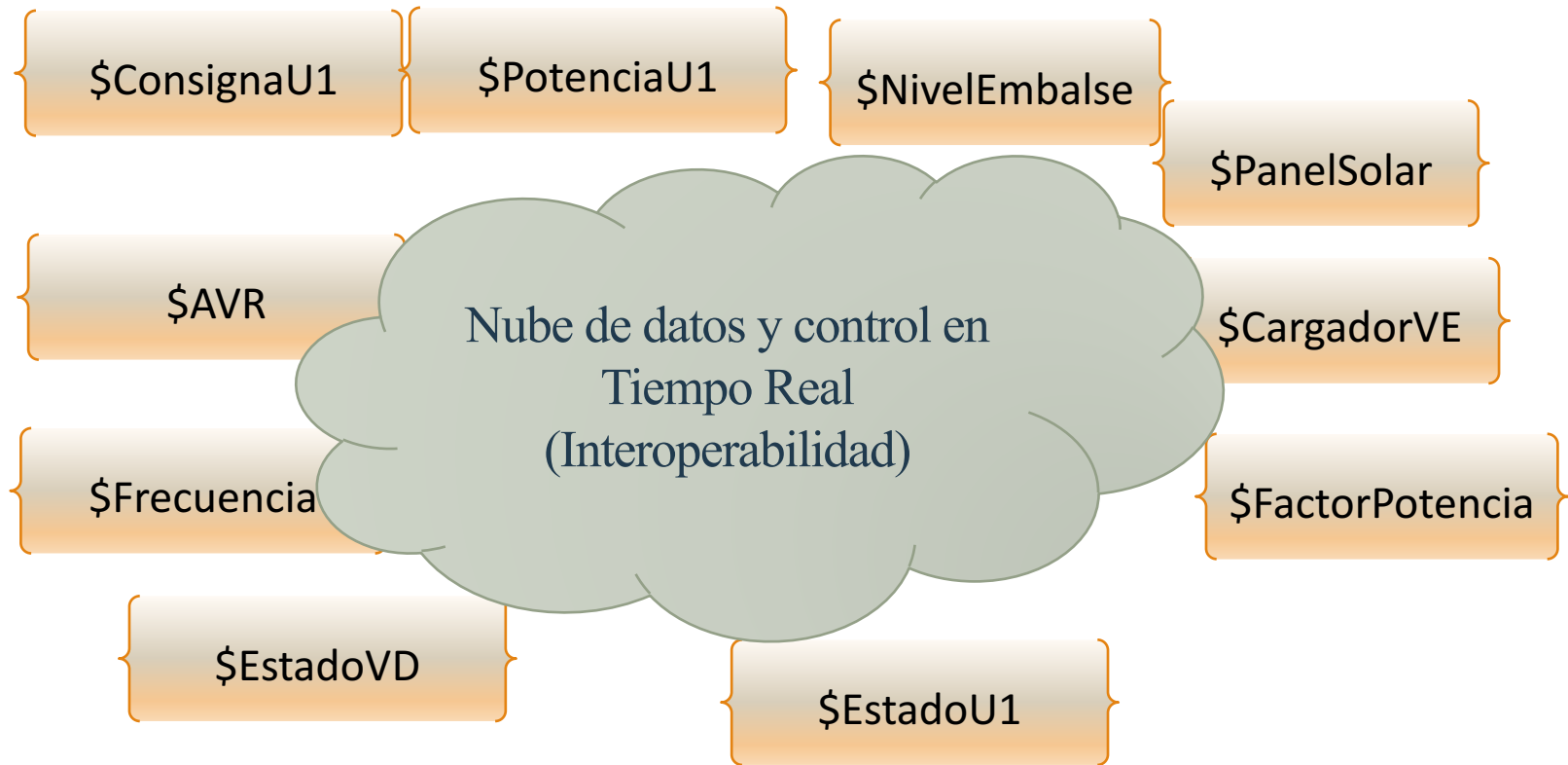
Nube de Datos y Control en Tiempo real



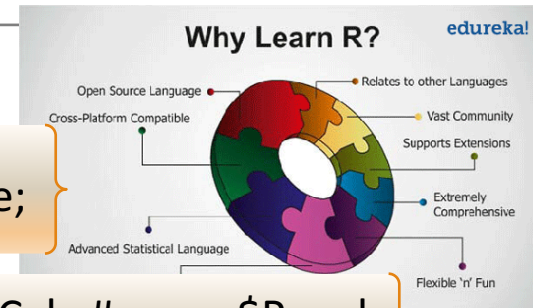
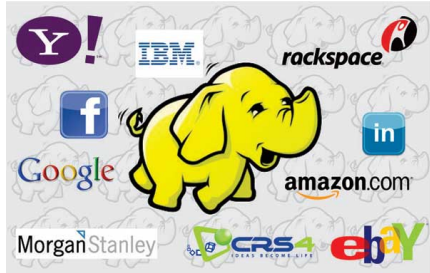
Nube de Datos y Control en Tiempo real



Nube de datos en lenguaje común



Nube de información y control en lenguaje común



Cmd:\$ConsignaU1,30;

Get:\$PotenciaU1;

Get:\$NivelEmbalse;

Calc:#mean,\$Panel Solar;



Cmd:\$AVR,OFF;

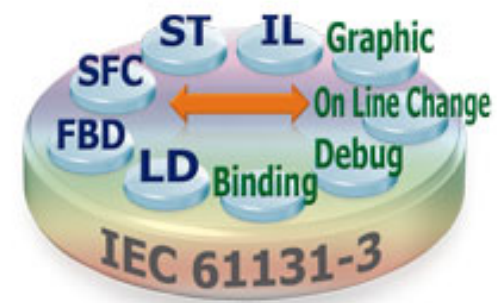
SBO Cmd:\$CargadorVE,ON;

Get:\$Frecuencia;

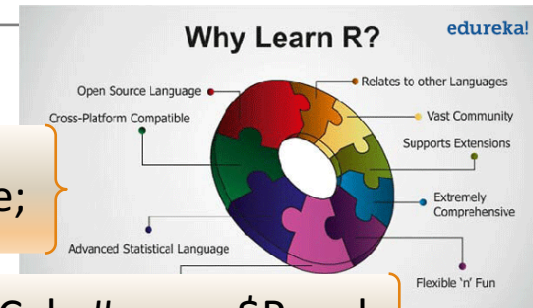
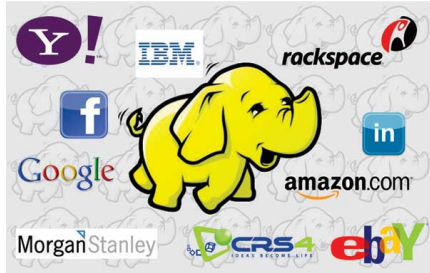
Get:\$EstadoVD;

Read:\$FactorPotencia;

Get:\$EstadoU1;



Nube de interoperabilidad



Get:\$PotenciaU1;

Get:\$NivelEmbalse;

Cmd:\$ConsignaU1,30;

Cmd:\$AVR,OF

Get:\$Frecuencia;

Get:\$EstadoVD;

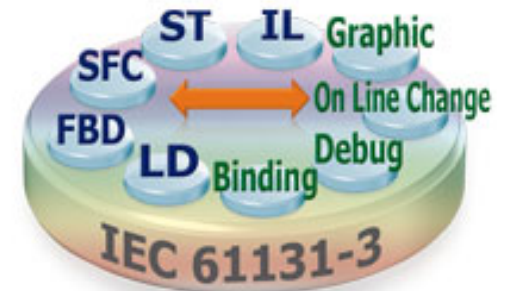
Read:\$FactorPotencia;

Get:\$EstadoU1;

Calc:#mean,\$Panel
Solar;

SBO Cms:\$CargadorVE,ON;

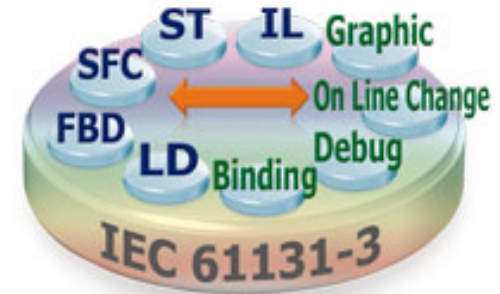
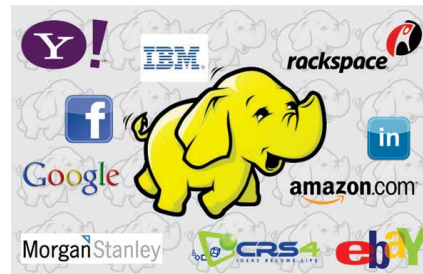
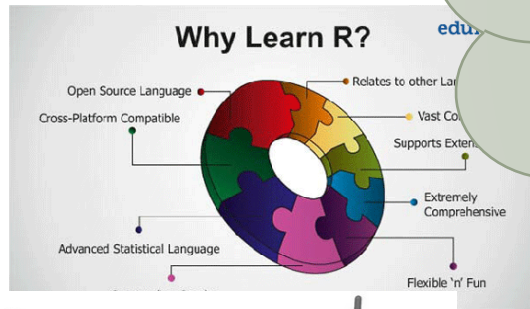
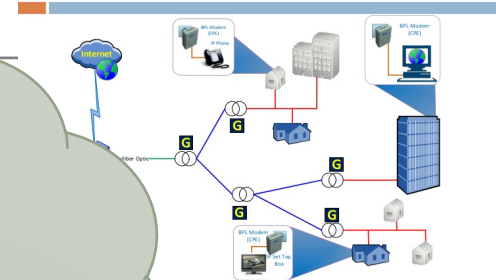
EN OPERACIÓN 7x24



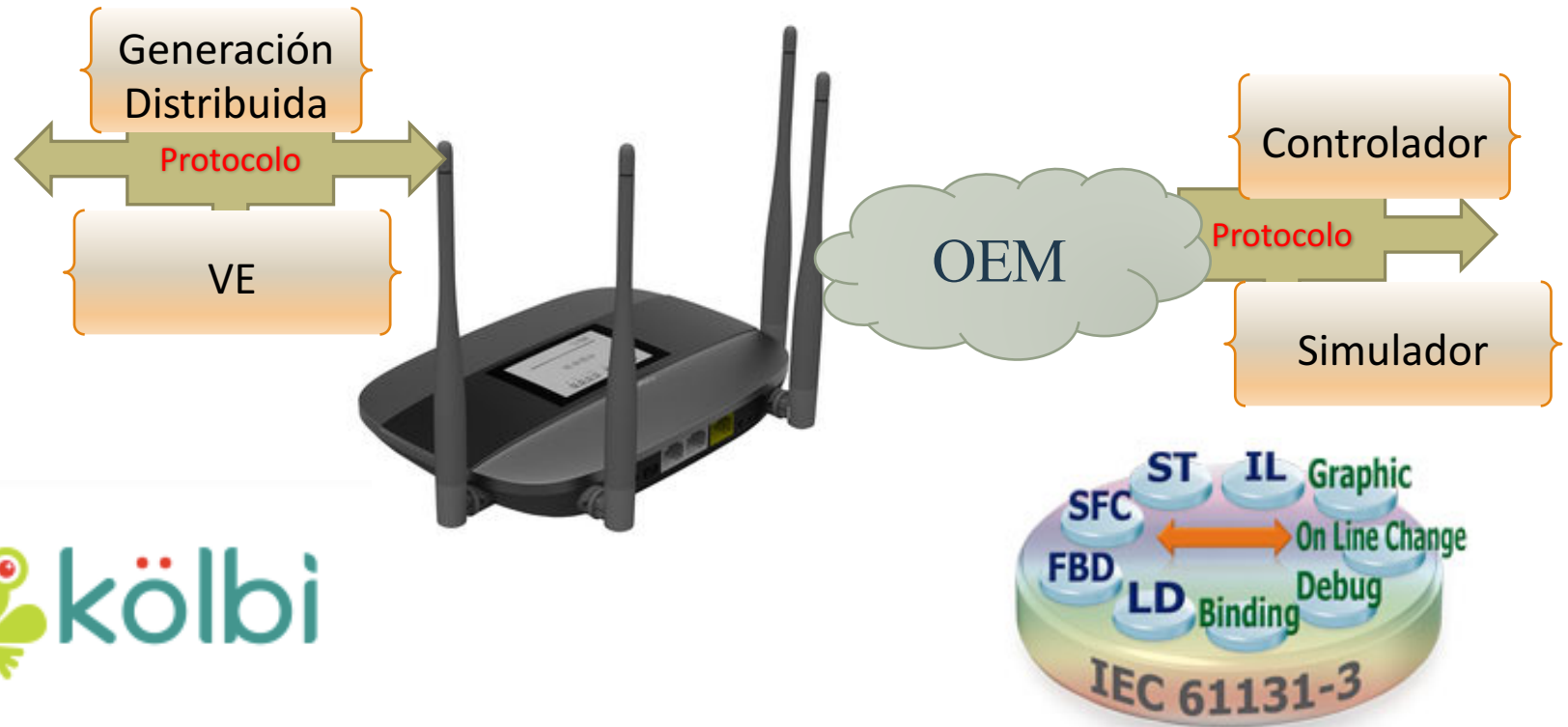
Nube de Internet



TALURUS esCom BPL Deployment Architecture



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Home

Raspberry Pi

With the addition of an RFM69Pi expansion board, the Raspberry Pi is able to receive data via wireless from other OpenEnergyMonitor modules such as an emonTx or emonGLCD. A Raspberry Pi can forward data to an emoncms sever, and/or log data locally to an SD card or hard drive.

[Shop](#)

[Hardware \(RFM12Pi\)](#)



RFM69Pi Adapter Board

The RFM69Pi adapter board is compatible with all models of the Raspberry Pi. The board enables a Pi to transmit and receive data from other OpenEnergyMonitor modules such as emonTx/emonTH via an RFM12B or RFM69CW radio. The RFM69Pi will fit inside a standard Raspberry Pi case.

Energy Monitoring through a Raspberry Pi

Made by [Control Everything](#) - Published in [ControlEverything.com](#), [Home Automation](#), and [Raspberry Pi](#)



ABOUT THIS PROJECT

In this application we will setup a CE current monitor with a Raspberry Pi and display current readings for circuits through a web interface

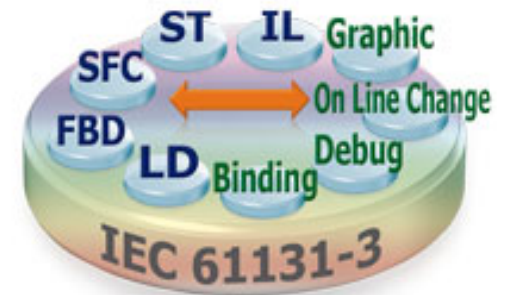
energy monitoring | controleverything

PROJECT INFO

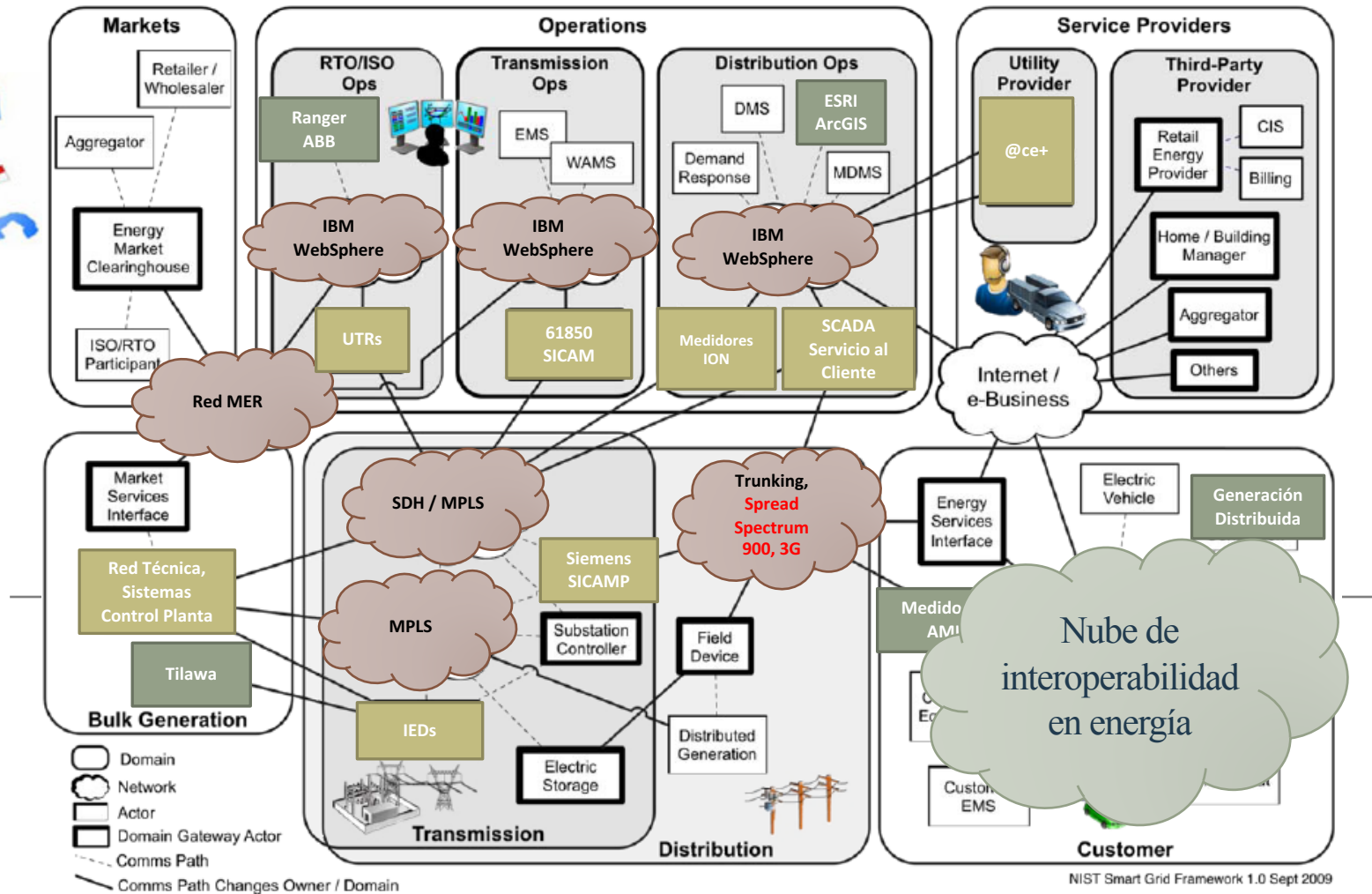
Type	Full instructions provided
Difficulty	Easy
Estimated time	4 hours
Published	April 11, 2016
License	GPL3+

4,266 | 18

[Respect project](#) [I made one](#)



Interoperabilidad en la cadena de valor



Muchas Gracias

