

Servidor y cliente OPC UA usando software libre: Aplicación a un sistema fotovoltaico

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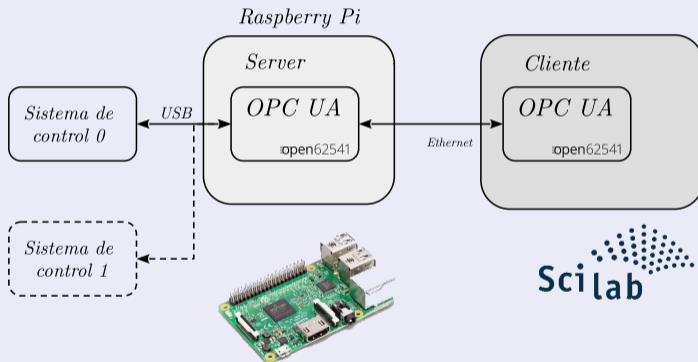
Índice

The background of the slide is a grayscale image of a vintage map. In the center-left, there is a round, metallic compass with a detailed face showing cardinal and intercardinal directions. To the right of the compass, a rolled-up map or parchment is visible. In the bottom right corner, there are drafting tools, including a pair of compasses and a large set square.

- 1 Introducción
- 2 Desarrollo del servidor y cliente OPC UA
- 3 Aplicación a un sistema fotovoltaico
- 4 Ensayos experimentales
- 5 Conclusiones

Desarrollo

Esquema del sistema



Herramientas (Software Libre)

- Slackware Linux
<http://www.slackware.com/>
- Librería de código abierto (Open62541)
<https://www.open62541.org/>
- Scilab/Xcos <https://www.scilab.org/>

Hardware

- Raspberry pi 3b
- Microcontroladores dsPIC33FJ32MC204.
- Convertidores electrónicos de potencia, paneles solares, baterías, etc.

Desarrollo del servidor OPC UA

Herramientas

- Compilador gcc.
- Librerías open62541, etc.

Servidor OPC UA

- 1: Declaración de librerías y variables.
- 2: Configuración del puerto serie 0 – n .
- 3: Creación de variables OPC UA.
- 4: Creación de *hlsusb0* – n .
- 5: **procedure** PRINCIPAL
- 6: Ejecuta hlsusb0 a n .
- 7: **while** (running) **do**
- 8: Ejecuta el servidor OPC UA.
- 9: Actualiza variables.
- 10: **end while**
- 11: Cierra 4,3,2 y finaliza.
- 12: **Return**

Hilo 0

```
1: procedure HLUSB0
2:     Creación de variables
3:     while do
4:         carácter ← leepuertoserie.
5:         if carácter == 10 then
6:              $n_1 \cdots n_4 \leftarrow buffer$ 
7:              $buffer_{pos} = 0$ ;
8:         else
9:              $buffer_{pos} = buffer_{pos} + 1$ .
10:             $buffer(buffer_{pos}) \leftarrow \text{carácter}$ 
11:         end if
12:          $/dev/ttyUSB0 \leftarrow V_{Pref}$ 
13:     end While
14: Return
```


Servidor

Servidor OPC UA. Versión 5.0

1

```
[2025-04-01 17:03:12.806 (UTC-0300)] info/eventloop Starting the EventLoop
[2025-04-01 17:03:12.807 (UTC-0300)] warn/server AccessControl: Unconfigured AccessControl. Users have all permissions.
[2025-04-01 17:03:12.807 (UTC-0300)] info/server AccessControl: Anonymous login is enabled
[2025-04-01 17:03:12.807 (UTC-0300)] warn/server x509 Certificate Authentication configured, but no encrypting SecurityPolicy. This ca
n leak credentials on the network.
[2025-04-01 17:03:12.818 (UTC-0300)] info/session TCP 0 | SC 0 | Session "Administrator" | AddNode (i=15303): No TypeDefinitio
n. Use the default TypeDefinition for the Variable/Object
[2025-04-01 17:03:12.844 (UTC-0300)] info/session TCP 0 | SC 0 | Session "Administrator" | AddNode (i=25451): No TypeDefinitio
n. Use the default TypeDefinition for the Variable/Object
[2025-04-01 17:03:12.938 (UTC-0300)] warn/userland ServerUrls already set. Overriding.
[2025-04-01 17:03:12.938 (UTC-0300)] warn/server AccessControl: Unconfigured AccessControl. Users have all permissions.
[2025-04-01 17:03:12.938 (UTC-0300)] info/server AccessControl: Anonymous login is enabled
[2025-04-01 17:03:12.938 (UTC-0300)] warn/server x509 Certificate Authentication configured, but no encrypting SecurityPolicy. This ca
n leak credentials on the network.
[2025-04-01 17:03:12.938 (UTC-0300)] warn/server x509 Certificate Authentication configured, but no encrypting SecurityPolicy. This ca
n leak credentials on the network.
[2025-04-01 17:03:12.940 (UTC-0300)] info/network TCP | Listening on all interfaces
[2025-04-01 17:03:12.942 (UTC-0300)] info/network TCP 6 | Creating listen socket for "0.0.0.0" (with local hostname "rpi3") on port 4
840
```

2

```
[2025-04-01 17:03:12.942 (UTC-0300)] info/server New DiscoveryUrl added: opc.tcp://rpi3:4840
[2025-04-01 17:03:12.942 (UTC-0300)] info/network TCP 7 | Creating listen socket for "::" (with local hostname "rpi3") on port 4840
[2025-04-01 17:03:13.507 (UTC-0300)] info/network TCP 8 | Connection opened from "192.168.10.173" via the server socket 6
[2025-04-01 17:03:13.507 (UTC-0300)] info/channel TCP 8 | SC 1 | SecureChannel created
[2025-04-01 17:03:13.607 (UTC-0300)] info/channel TCP 8 | SC 1 | SecureChannel opened with SecurityPolicy http://opcfoundation.org/U
A/SecurityPolicy#None and a revised lifetime of 600.00s
[2025-04-01 17:03:13.707 (UTC-0300)] warn/channel TCP 8 | SC 1 | ActivateSession: Session not found
[2025-04-01 17:03:13.838 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Ses
sion created
```

3

```
[2025-04-01 17:03:13.907 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Act
ivateSession: Session activated with ClientUserId ""
[2025-04-01 17:03:14.120 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Sub
scription 1 | Subscription created (Publishing interval 100.00ms, max 1000 notifications per publish)
[2025-04-01 17:03:14.208 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Sub
scription 1 | MonitoredItem 1 | Created the MonitoredItem (Sampling Interval: 0.00ms, Queue Size: 100)
[2025-04-01 17:03:14.232 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Sub
scription 2 | Subscription created (Publishing interval 500.00ms, max 1000 notifications per publish)
[2025-04-01 17:03:14.307 (UTC-0300)] info/session TCP 8 | SC 1 | Session "urn:Ramiro.unp.edu.ar:UnifiedAutomation:UaExpert" | Sub
```

Cliente OPC UA, Ua Expert

Unified Automation UaExpert - The OPC Unified Architecture Client - NewProject*

File View Server Document Settings Help

Project

- Project
 - Servers
 - open62541-based OPC UA Application
 - Documents
 - Data Access View

1

Data Access View

#	Server	Node Id	Display Name	Value	DataType
1	open62541...	NS1 String Vp	Tensión en los ...	6	Double
2	open6254...	NS0 Numeric 2257	StartTime	2025-04-01T13:...	DateTime
3	open6254...	NS0 Numeric 2259	State	0 (Running)	Int32

2

Attributes

Attribute	Value
NodeId	i=2259 [Serv...
NamespaceIndex	0
IdentifierType	Numeric
Identifier	2259 [Server...
NodeClass	Variable
BrowseName	0, "State"
DisplayName	"State"
Description	"State"
Value	
DataType	ServerState
ValueRank	-2 (Any)

References

Reference	Target DisplayName
HasTypeDefini...	BaseDataVariableType

Address Space

No Highlight

Root

- Objects
 - Corriente en el inductor
 - Corriente en el inductor, convertid...
 - Corriente en los paneles solares,
 - Corriente en los paneles solares,
 - Current time - data source
 - Current time - value callback
 - Server
 - Auditing

3

4

Log

Timestamp	Source	Server	Message
4/1/25 10:59:5...	DA Plugin	open62541-ba...	Found existing subscription for ServerId 0
4/1/25 10:59:5...	DA Plugin	open62541-ba...	Item [NS0 Numeric 2257]: SamplingInterval=250, QueueSize=1, DiscardOldest=1, ClientHandle=3
4/1/25 10:59:5...	DA Plugin	open62541-ba...	CreateMonitoredItems succeeded [ret = Good]
4/1/25 10:59:5...	DA Plugin	open62541-ba...	Item [NS0 Numeric 2257] succeeded : RevisedSamplingInterval=250, RevisedQueueSize=1, MonitoredItemId=2 [ret = Good]
4/1/25 11:00:0...	Attribute Plugin	open62541-ba...	Read attributes of node 'NS0 Numeric 2259' succeeded [ret = Good].
4/1/25 11:00:0...	Reference Plu...	open62541-ba...	Browse succeeded.
4/1/25 11:00:0...	AddressSpace...	open62541-ba...	QascAddressSpaceModel:mimeData
4/1/25 11:00:0...	DA Plugin	open62541-ba...	QascDaModel:dropMimeData
4/1/25 11:00:0...	DA Plugin	open62541-ba...	Found existing subscription for ServerId 0
4/1/25 11:00:0...	DA Plugin	open62541-ba...	Item [NS0 Numeric 2259]: SamplingInterval=250, QueueSize=1, DiscardOldest=1, ClientHandle=5
4/1/25 11:00:0...	DA Plugin	open62541-ba...	CreateMonitoredItems succeeded [ret = Good]
4/1/25 11:00:0...	DA Plugin	open62541-ba...	Item [NS0 Numeric 2259] succeeded : RevisedSamplingInterval=250, RevisedQueueSize=1, MonitoredItemId=3 [ret = Good]

Consumo de recursos del servidor OPC UA

```
root@rpi3:/home/ramiro# pgrep shyps45b_raspi
960
root@rpi3:/home/ramiro# pidstat -p 960 -t 10
Linux 6.6.16-v7-sarp13 (rpi3)    06/04/2025    _armv7l_    (4 CPU)

05:27:35 PM   UID      TGID      TID    %usr %system %guest   %wait   %CPU   CPU   Command
05:27:45 PM     0       960      -    0.40  0.70  0.00   0.00   1.10    2  shyps45b_raspi
05:27:45 PM     0       -      960    1.00  0.00  0.00   0.00   1.00    2  l__shyps45b_raspi
05:27:45 PM     0       -      961    0.00  0.20  0.00   0.00   0.20    2  l__shyps45b_raspi
05:27:55 PM     0       960      -    0.50  0.80  0.00   0.00   1.30    2  shyps45b_raspi
05:27:55 PM     0       -      960    0.90  0.10  0.00   0.00   1.00    2  l__shyps45b_raspi
05:27:55 PM     0       -      961    0.10  0.20  0.00   0.10   0.30    2  l__shyps45b_raspi
05:28:05 PM     0       960      -    1.10  0.50  0.00   0.00   1.60    2  shyps45b_raspi
05:28:05 PM     0       -      960    1.30  0.00  0.00   0.00   1.30    2  l__shyps45b_raspi
05:28:05 PM     0       -      961    0.00  0.20  0.00   0.10   0.20    1  l__shyps45b_raspi
05:28:15 PM     0       960      -    0.00  1.20  0.00   0.00   1.20    2  shyps45b_raspi
05:28:15 PM     0       -      960    1.00  0.00  0.00   0.00   1.00    2  l__shyps45b_raspi
05:28:15 PM     0       -      961    0.00  0.20  0.00   0.10   0.20    2  l__shyps45b_raspi
05:28:25 PM     0       960      -    0.10  1.10  0.00   0.00   1.20    2  shyps45b_raspi
05:28:25 PM     0       -      960    1.00  0.10  0.00   0.00   1.10    2  l__shyps45b_raspi
05:28:25 PM     0       -      961    0.00  0.30  0.00   0.20   0.30    2  l__shyps45b_raspi
^C
Average:      0       960      -    0.42  0.86  0.00   0.00   1.28    -  shyps45b_raspi
Average:      0       -      960    1.04  0.04  0.00   0.00   1.08    -  l__shyps45b_raspi
Average:      0       -      961    0.02  0.22  0.00   0.10   0.24    -  l__shyps45b_raspi
root@rpi3:/home/ramiro#
```

Promedio

Proceso	% usr	% system	% CPU
960	1,04	0,04	1,08
961	0,02	0,22	0,24

Desarrollo del cliente OPC UA para Scilab/Xcos

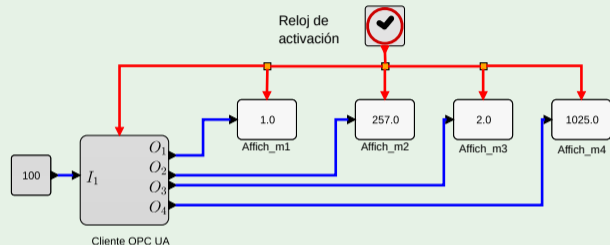
Función computacional (Cliente OPC UA)

```
1: procedure CLIENTEOPCUA(IP,PUERTO)
2:   Carga librerías.
3:   Definición de variables.
4:   if flag == 4 then                                ▷ Ini sim.
5:   |   Inicia conexión OPC UA.
6:   else if flag == 5 then                            ▷ final.
7:   |   Cierra la conexión OPC UA.
8:   else if flag == 1 then                            ▷ Calc. Salida.
9:   |   Lee y escribe variables OPC UA.
10:  end if.
11:  Return
```

Implementación

- Compilación con gcc.
- Enlace de la función computacional a Scilab.
- Creación de una nueva paleta de componentes para Xcos con el bloque nuevo.

Esquema en Xcos con el cliente OPC UA diseñado



Ejecución del servidor OPC UA y el registro de mensajes.

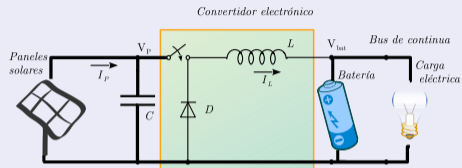
```
bash-5.1# ./shcps2
Servidor OPC UA, Versión 2.0
[2025-01-17 12:01:54.919 (UTC-0300)] warn/server
[2025-01-17 12:01:54.919 (UTC-0300)] info/server
[2025-01-17 12:01:54.919 (UTC-0300)] warn/server
[2025-01-17 12:01:54.919 (UTC-0300)] warn/server
This can leak credentials on the network.
[2025-01-17 12:01:54.919 (UTC-0300)] warn/userland
[2025-01-17 12:01:54.919 (UTC-0300)] info/network
Mensaje recibido: 0.0.0.0.0.0.0
data 0.000000, 0.000000, 0.000000, 0.000000
Mensaje recibido: 1.0,2.0,1.1,1.4
data 1.000000, 2.000000, 257.000000, 1025.000000
[2025-01-17 12:02:17.128 (UTC-0300)] info/network
[2025-01-17 12:02:17.226 (UTC-0300)] info/channel
[2025-01-17 12:02:17.324 (UTC-0300)] info/session
[2025-01-17 12:02:17.373 (UTC-0300)] info/session
[2025-01-17 12:02:18.897 (UTC-0300)] info/session
[2025-01-17 12:02:18.946 (UTC-0300)] info/channel
[2025-01-17 12:02:18.996 (UTC-0300)] info/network
[2025-01-17 12:02:25.714 (UTC-0300)] info/server
bash-5.1#
```

AccessControl: Unconfigured AccessControl. Users have all permissions.
AccessControl: Anonymous login is enabled
AccessControl: x509 certificate user authentication is enabled
Username/Password Authentication configured, but no encrypting SecurityPolicy.
This can leak credentials on the network.
AcceptAll Certificate Verification. Any remote certificate will be accepted.
TCP network layer listening on opc.tcp://romiro.unp.edu.ar:4840/

Connection 6 | New connection over TCP from 127.0.0.1
Connection 6 | SecureChannel 1 | SecureChannel opened with SecurityPolicy http://opcfoundation.org/UA/SecurityPolicyNone and a revised lifetime of 600.00s
SecureChannel 1 | Session ** | Session created
SecureChannel 1 | Session ** | ActivateSession: Session activated
SecureChannel 1 | Session ** | Closing the Session
Connection 6 | SecureChannel 1 | CloseSecureChannel
Connection 6 | Closed
received ctrl-c
Shutting down the TCP network layer

Aplicación a un sistema fotovoltaico

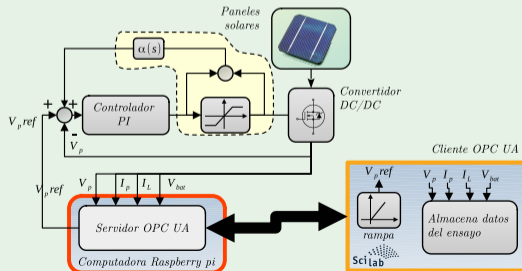
Circuito eléctrico del sistema fotovoltaico



Controlador PI

$$G_c(s) = k_p \left(1 + \frac{1}{T_i s} \right). \quad (1)$$

Esquema del sistema fotovoltaico



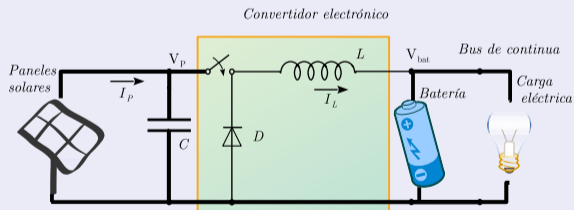
Fotografía del sistema.

Ensayos experimentales

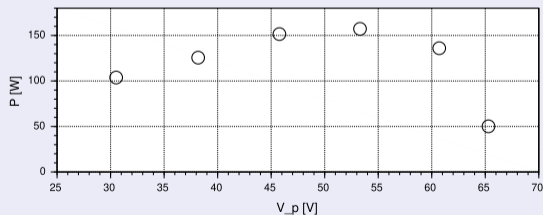
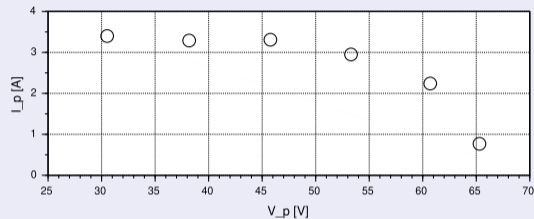
Ensayos

- Ensayos de las etapas de medición.
- Ensayos con Scilab/Xcos.

Sistema fotovoltaico

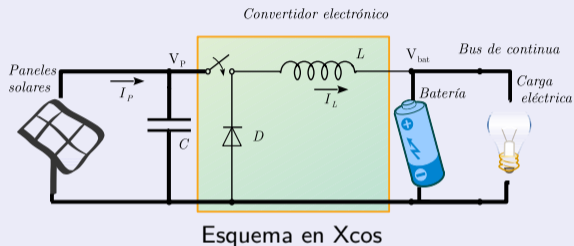


Esquema en Xcos y datos experimentales.

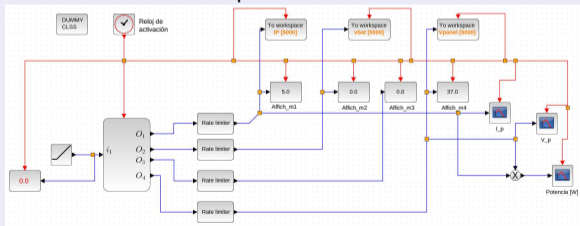


Ensayos experimentales

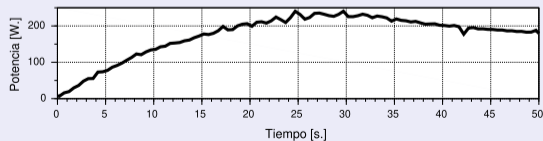
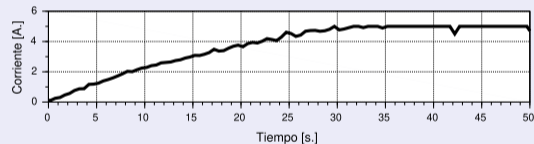
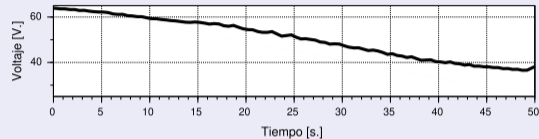
Sistema fotovoltaico y esquema en Xcos



Esquema en Xcos



Esquema en Xcos y datos experimentales.



Conclusiones

En este trabajo se presenta un servidor y un cliente para el protocolo de comunicación industrial OPC UA aplicado a un sistema fotovoltaico para la supervisión y control del sistema. El cliente OPC UA para el entorno gráfico Xcos puede tener múltiples aplicaciones, como por ejemplo la supervisión de sistemas, análisis de datos en tiempos real, etc. De esta forma, se agrega una nueva funcionalidad a Scilab/Xcos.

Por otra parte, el servidor OPC UA también está construido empleando la librería de código abierto open62541. Esto permite, una implementación económica del protocolo OPC UA en diferentes arquitecturas. Esto posibilita realizar la supervisión y control de más de un convertidor DC/DC conectado al sistema.

Los trabajos futuros incluyen la aplicación del cliente OPC UA en diferentes sistemas para tomar datos, implementación de algoritmos, aplicaciones en educación, etc.

¿Preguntas?



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¡Muchas gracias!