

## TI Designs

# IEC 61850 Demonstration of Substation Bay Controller on Beaglebone Cape and AM335X Starter Kit

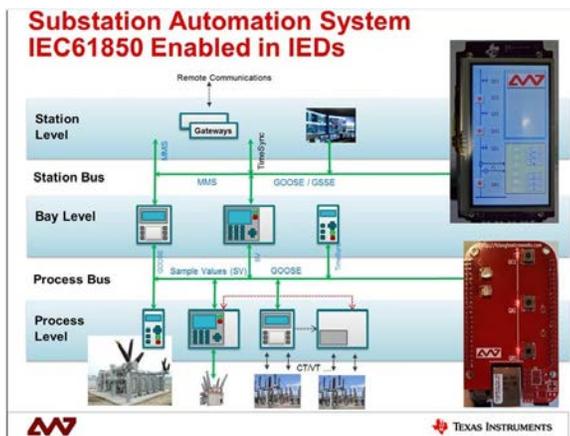


## TI Designs

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### Design Description

A low cost, simplified implementation of an IEC 61850 Substation Bay Controller is demonstrated by running the Triangle MicroWorks IEC 61850 stack efficiently on the TI AM335X platform with a Linux target layer definition. Many different substation automation applications can be built on top of the AM335X platform and IEC 61850 stack demonstration.



### Design Resources

[TriangleMicroWorks](#)

More information on Triangle MicroWorks

[BeagleBone](#)

More information on BeagleBone

### Design Features

- A Substation Bay Controller including one circuit breaker, two disconnectors, and an IEC 61850 Server is implemented on a Beaglebone Card with the Triangle MicroWorks Demo Cape
- The IEC 61850 Client application is run on the AM335X Starter Kit, implementing a Human Machine Interface (HMI) that sends IEC 61850 operate commands to the Substation Bay Controller
- The Client application automatically discovers the available services and Object Model of the Server application
- The Bay Controller includes an interlocking function which does not allow the disconnectors to switch current while the breaker is closed
- The Client HMI sends operate commands to the Bay Controller Server and displays status of the Bay Controller
- This sub-system is for demonstration purposes and includes AM335X Starter Kit based application, Beaglebone based application, and Design Guide



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IEC 61850 Demonstration of Substation Bay Controller

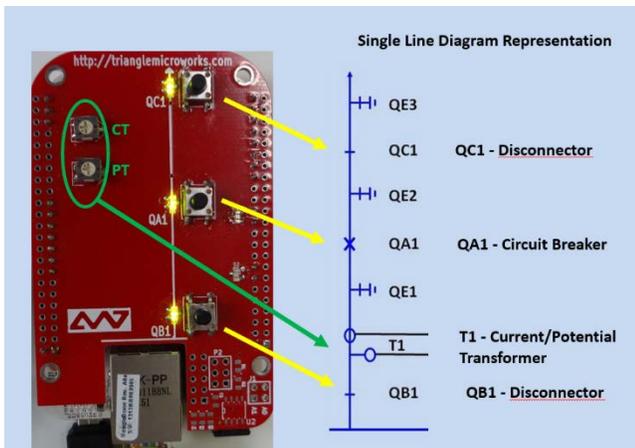
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## Bay Controller Server Application

The Bay Controller Server application simulates protection equipment consisting of one breaker and two disconnectors. A real device that performs this type of function is commonly referred to as an Intelligent Electronic Device (IED). The Bay Controller Server runs as an IEC 61850 Server device, runs on the TI Beaglebone platform and implements the [IEC 61850 Server Source Code Library](#) from Triangle MicroWorks.

Figure 1 shows the Beaglebone Cape and the corresponding single line diagram for the Bay Controller Server. The switches QC1 and QB1 represents the disconnectors, and switch QA1 represents the circuit breaker. The LEDs next to each switch indicates the position of the disconnectors and circuit breaker.

The Current and Potential Transformer (CT/PT) T1 is represented by the potentiometers in the top left corner of the board. Adjusting the potentiometers will adjust the current and voltage measured at T1.

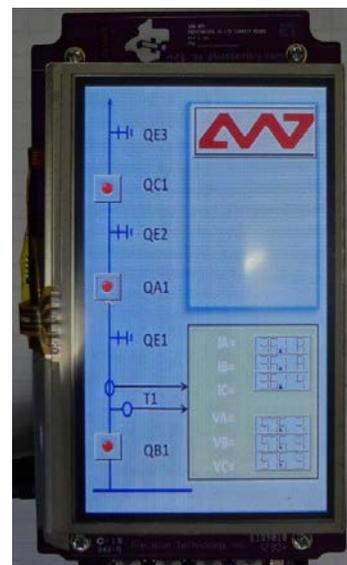


**Figure 1: Single Line Diagram Representation**

The disconnectors (QB1 and QC1) are not capable of switching current, so the application implements an interlocking function. The disconnectors can only be operated when the breaker (QA1) is open in order to guarantee that no current is flowing.

## Client Application

Monitoring and control of the Server is performed by the Bay Controller Client, an IEC 61850 Client, which discovers the Server's available data and services. The Client application implements the Triangle MicroWorks [IEC 61850 Client Source Code Library](#) on the AM335X Starter Kit (shown in Figure 2). Alternatively, it is also possible to monitor the Bay Controller Server with other IEC 61850 compliant Clients, such as the Hammer test Client in the [Triangle MicroWorks IEC 61850 Test Suite](#).



**Figure 2: Client on AM335X Starter Kit**

## IEC 61850 Configuration

The IEC 61850 standard differs from previous utility standardization efforts in that it covers technologies ranging from low-level Ethernet VLAN to very high-level modeling techniques. It specifies not only messages and protocol, but also communications architecture and substation engineering and configuration.

### *System Configuration Language*

IEC 61850 defines a System Configuration Language (SCL) for the design, configuration, and management of large scale systems. The SCL is a vendor-independent language for exchanging information between engineering tools. The SCL file for a device includes the full description of all models, services, and communication capabilities supported by the device. IEC 61850 also includes the capability of 'self-description', in that all of the information contained in the SCL file of a device is also available at run-time through other protocols through the communications network. This means that the actual configuration of the device and the mapping of all data through the system can be validated in real-time against the SCL file, which provides for highly automated commissioning.

IEC 61850 Servers use an IED Configuration Description (ICD) file to configure and describe the communications, object model, services, and control blocks supported by the device.

### *Server Object Model*

The object model used in the Bay Controller Server includes logical nodes defined by the IEC 61850 standard. This object model is a simplified version for demonstration purposes. A complete substation automation and protection solution would typically consist of several logical nodes that each cover different aspects. There are two logical nodes that the Bay Controller Server uses to represent the state of the switches, current, and voltage of the device:

- **CSWI** – Switch Controller – There are three instances of this logical node, for the circuit breaker QA1 and the two disconnectors QB1 and QC1. Each instance is named with a prefix for the switch as follows: QA1CSWI1, QB1CSWI2, and QC1CSWI3. CSWI has both control and status for the position of the switches. Pos.Oper.ctlVal is the control for operating the breaker. Control of the switch follows a Select Before Operate (SBO) control model. Pos.stVal is the status value for

breaker position. For example, when QA1 is closed, Pos.stVal="on" and the LED is red. When QA1 is open, Pos.stVal="off" and the LED is green.

- **MMXU** – Measuring – This logical node is used to measure currents, voltages, and power in a three phase power system. Data Objects A and PhV indicate the current and voltage of the circuit.

### *Mapping from Beaglebone Cape to Object Model*

In the Bay Controller Server application, data from the Object Model is mapped to/from the Beaglebone Cape as follows:

Circuit Breaker switch QA1 -> QA1CSWI1.Pos

Disconnector QB1 -> QC1CSWI3.Pos

Disconnector QC1 -> QB1CSWI2.Pos

Voltage Potentiometer (PT) -> T1MMXU1.PhV

Current Potentiometer (CT) -> T1MMXU1.A

### *Report Control Blocks*

The Data Objects listed above can be monitored through Report Control Blocks (RCBs) with an IEC 61850 Client, either with an HMI or a test tool. The IEC 61850 Test Suite from Triangle MicroWorks is one such test tool. In order to see the Object Model, use an IEC 61850 Client to connect to the Bay Controller and enable the following Report Control Blocks:

bcrbSTAT01 – this RCB contains the Data Objects QA1CSWI1.Pos, QC1CSWI3.Pos, and QB1CSWI2.Pos

bcrbMEAS01 – this RCB contains the Data Objects T1MMXU1.PhV and T1MMXU1.A

## Client-Server Connection

The Bay Controller Server and Client communicate through Manufacturing Message Specification (MMS) based communications, which is the communication protocol stack specified by the IEC 61850 standard.

### Discovery of Server

The Bay Controller Server supports discovery services which allows an IEC 61850 Client to discover the capabilities of the Server including the Object Model, supported services, and available control blocks. When an IEC 61850 Client connects to the Server, the Client builds the Object Model for the Server and subscribes to Report Control Blocks in the Server in order to receive updates when Data Objects change. The Bay Controller Client does not use discovery, but instead uses the Server ICD file to build the Object Model and configure the Client.

### Viewing Server Object Model with Client

The Bay Controller Client application displays data from the Bay Controller including status of the circuit breaker as well as current and voltage measurements. This type of application is commonly referred to as a Human Machine Interface (HMI).

The Client subscribes to the following Report Control Blocks (RCB's):

"bcrbSTAT" – this RCB reports the position (Pos) of the three Switch Controllers (CSWI) for QA1, QB1, and QC1

"bcrbMEAS" – this RCB reports the voltage (PhV) and current (A) from the MMXU logical node

The entire Server Object Model can be viewed with an IEC 61850 Client tool like the [IEC 61850 Test Suite](#) from Triangle MicroWorks. The Hammer test Client, within the Test Suite, can connect to the Bay Controller Server and automatically load the Server Object Model as shown in Figure 1. In this example, the position of Circuit Breaker QA1 is shown to be closed ("on") in the Data Object found at QA1CSWI1.Pos.stVal. As positions of the switches and potentiometers on the Bay Controller Cape are changed, changes to Data Object values can be viewed. See the above section on Report Control Blocks for a list of Data Objects that can be monitored through an IEC 61850 Client.

Name	Value	Type
BayControllerQ		
LLNO		
LPHD1		
QA1CSWI1		
Data Sets		
Report Control		
Log Control		
Log		
Mod		
Beh		
Health		
NamPit		
Pos		
origin		Struct
SBOw		Struct
Oper		Struct
Cancel		Struct
stVal	on	Dbpos
q	[000000000000]	Quality
t	08/18/2014_14:58:41.877.[00000000]	Timestamp
stSeld	False	BOOLEAN
ctlModel	sbo-with-enhanced-security	Enum
sboTimeout	30000	INT32U
sboClass	operate-once	Enum
QA1XCBR1		

Position of Circuit Breaker QA1



**Figure 3: Bay Controller Object Model Shown in IEC 61850 Test Suite**

### Client Commands to Server

The Bay Controller Client is also capable of sending control commands to the Server. This allows the Client to duplicate the functionality of the buttons on the Beaglebone Cape. These commands are sent through MMS and follow a Select Before Operate (SBO) control model. For example, Pos.Oper.ctlVal is the control for issuing an open/close command to the breaker QA1.

### Learn More about IEC 61850

Triangle MicroWorks has IEC 61850 training videos available for free, including the following topics:

[IEC 61850 Introduction and Training](#)

[IEC 61850 Data Modeling Part 1](#)

[IEC 61850 Data Modeling Part 2](#)

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