Developing IEC61499 in Industrial Processes, Measurement and Control Systems (IPMCS)

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Abstract: - Increasing marketing competition with globalization force companies to expand diversity of the production lines which in turn improve the ability of choosing customizable products, improve the flexibility of system design and maintenance costs lead to a strong trend towards automation and distributed control systems. The plant is constantly adapted to the differences of products to achieve the highest production quality in a shortest possible time and so the automatic control have to be adapted, developed and upgraded based on changes in the plant conditions. Traditional production has typically relied upon a PLC as a Centralized hierarchy of Programmable Logic Controllers which is usually fixed or "hard-wired". For developing the system it should be shut-down and completely rewired which leads to a high cost and time consumption may last at least several weeks in often cases in production process.

A new design methodology with open architecture for modeling industrial control systems has been developed. New international standard "IEC 61499", defines event driven functional modules called function blocks which can be distributed to field devices and interconnected across multiple controllers. It used for intelligent and agile control with more Portability, interoperability and configurability adds the system flexibility by adaption and reconfiguration basing on environment changes. It can be used for reducing the cost and complexity of industrial automation process.

In this approach IEC61499 Function Blocks concept, Function Block Development Kit (FBDK), Function Block Run Time Environment (FBRT), Netmaster and Automatic Iron Cutting Device using IEC61499 FBs Editor will be discussed.

Key-Words: - IPMCS , DCS, PLC, IEC 61499, Function Block, FBDK, FBRT, Netmaster, JVM, SIFB

1 Introduction

By developing the manufacturing production lines and increasing marketing competition, the Distributed measurement and Control System with distributed hardware and software modules is the case that nowadays has been widely used in industrial manufacturing control systems.

As manufacturing control becomes more distributed, encapsulation and reuse of control algorithms by end users, the new system must be designed to easily reconfigure in the face of changing conditions and deploy in a wide Varity of situation in different manufacturing systems. This could be achieved by direct linking to resources, devices and communication systems with distributing the code through available devices and integrating the communicated code.

Distributed control is distinguished from purely hierarchical control by the fact that the decision processes associated with an application are not running under a single processor and divided among several processors, each having their own thread of control. However, in order to execute the application, these processors must exchange data and state information with each other.

Modular, hierarchical and device independent control application is now so essential in marketing industrial products.

Following the extension of IEC 61131-3 programming languages, IEC 61499 is developed to support distributed control System not only encapsulation of algorithms but also sub application or even system application so that system designer is able to design applications and reuse them to simplify design procedures. Central control systems will be replaced by smart field devices and distributed controllers. Heterogeneous systems with components from different hardware and software manufacturers will be possible. IEC 61499 provides schema for realizing distributed application, in which interface for network protocol and configuration are both considered.

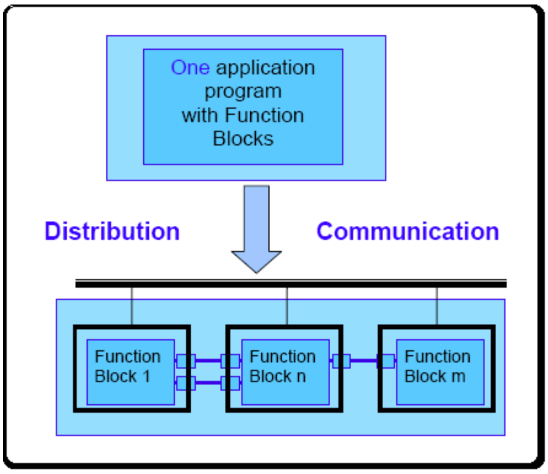


Fig. 1. IEC 61499 Distributed Function Blocks among Smart Field Devices

The future of DCS is directed towards full network functionality. Networks can save wiring costs and offset the cost of the intelligent devices. Software modules called function blocks are applied to lessen the complexity and high engineering cost of a distributed system.
IEC 61499 is a developed standard that defines how function blocks can be used in distributed industrial process, measurement and control systems. Function blocks are an established concept for defining robust, re-usable software components.

Fig. 2 is illustrative of a distributed control development platform for IEC 61499.Components on the network are intelligent devices with their own microprocessor and network drivers.

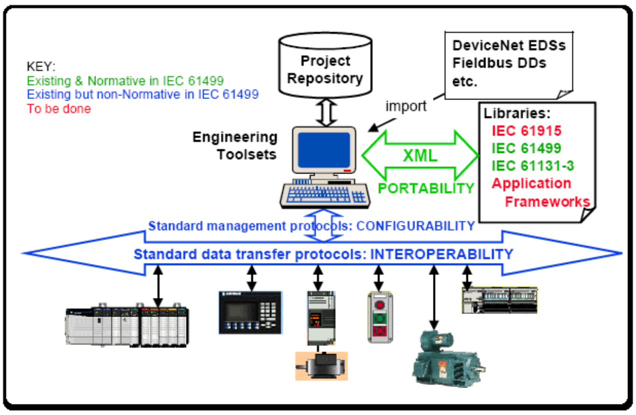


Fig. 2. Open Distributed System base on IEC 61499

Function blocks allow industrial algorithms to be encapsulated in a form that can be readily understood and applied by people who are not software specialists. Each block has a defined set of input parameters, which are read by the internal algorithm when it executes. The results from the algorithm are written to the block's outputs. Complete applications can be built from networks of function blocks formed by interconnecting block inputs and outputs.

IEC61499 concept with FBs model is introduced in the next section. Section 3 and 4, elucidates the Function Block Development Kit and Function Block Run Time Environment. Section 5, 6 and 7 introduce the Automatic Iron Cutting Device by IEC61499 FBs Editor, simulation of the system and Netmaster. In the last section conclusion with presenting the prospective features has been shown.

2 IEC 61499 standard

IEC 61499 international standard comes to facilitate world trade by removing technical barriers to trade, leading to new markets and economic growth providing the following features:
Interoperability of devices from multiple suppliers;
Portability of software between software tools of multiple suppliers and configurability of devices from multiple vendors by software tools of multiple suppliers.

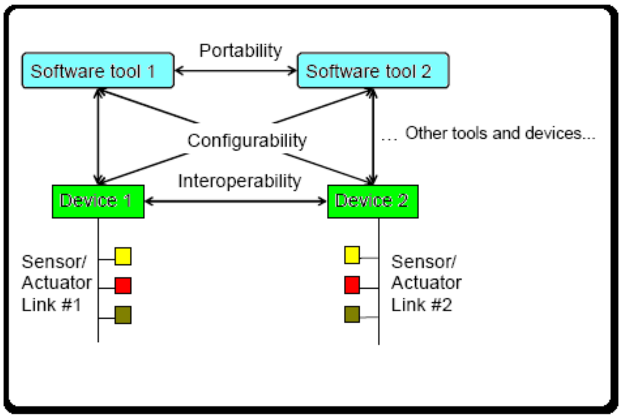


Fig. 3. Interoperability, Portability and configurability; IEC 61499 features

IEC61499 is an open architectural standard defines component based on Function Block (FB) provides a high level approach to design distributed IPMCS (Industrial Processes, Measurement and Control Systems). It goes beyond the PLC Function Blocks (IEC61131-3) and DCS Function Blocks (IEC 61804) describes a model that can be created through the interconnection of event driven software modules with distributed applications over multiple resources. It provides communication function blocks, which are easily implemented and distributed over field devices and controllers by accessing to different networks. It enables a modular and hierarchical control application design with direct links to devices, resources, and communication systems.

Device, application and resource are the key elements of a distributed control system under IEC 61499 architecture. A device is a control unit with interfaces to the physical I/Os, consisting at least one processor and communicates to other devices on the network. An application is a set of function blocks communicating to each other to fulfill a control task. A resource is a logical subdivision (processor) within the structure of a device, which has independent control of its operations and the part of a distributed application is run on it.

IEC 61499 defines a general model and methodology for describing functions blocks in a format that is independent of implementation. The methodology can be used by system designers to construct distributed control systems. It allows a system to be defined in terms of logically connected function blocks that run on different processing resources. This standard emphasizes formal methods based on Unified Modeling Language and object oriented concepts. It makes a separation between events, data, and algorithms. The programming is done using function blocks, a modeling formalism originally proposed under the standard IEC 1131-3, but extended under the IEC61499 standard.

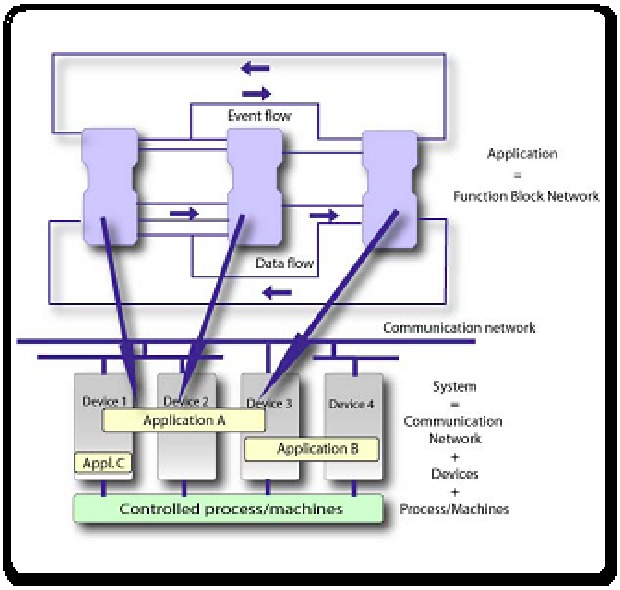


Fig. 4. Distributed System in IEC 61499

General concept of a distributed system in IEC 61499 is illustrated in Fig.4. As it is shown, Applications could be distributed among one or more devices. Devices will communicate over one or more communication links and may interface to controlled machines and processes. This can be recognized as an abstract art of distributed IPMCS.

Function block (FB) model consist of the Executed Control Chart that is an event driven state machine, event input variables (EI), event output variables (EO), Data input variables (DI) and Data output variables (DO).

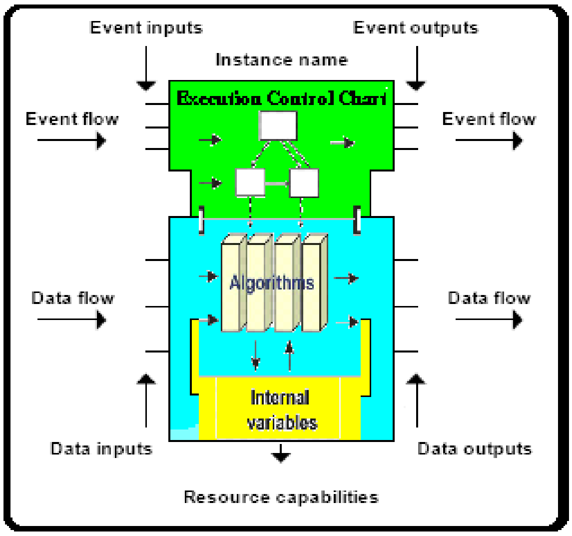


Fig. 5. IEC 61499 Function Block concept

Execution of Algorithm code is initiated by arrival of events and accomplished using current data at the time the events occurred. Data inputs will be provided from physical devices or the other function blocks. Different scenarios could be executed by triggering the individual event input. Output events will be enabled after it executed and output data is available to other function blocks for executing the application. A control application is represented in the form of network of FBs which can be allocated and run on different resources and devices.

IEC 61499 defines three types of function blocks: basic, composite and service interface function blocks (SIFB). A basic function block executes an elemental control function, such as reading a sensor or setting the state of an actuator.

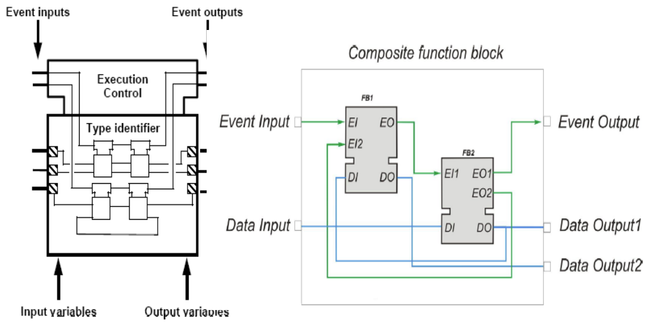


Fig. 6. Composite function block

Composite function block is a conglomerate of basic function blocks gathers to encapsulate a higher-level of control function.
The service interface function block provides the communication services among devices like sensors, actuators and microcontrollers. It performs the task of interfacing multiple IEC 61499 resource models.

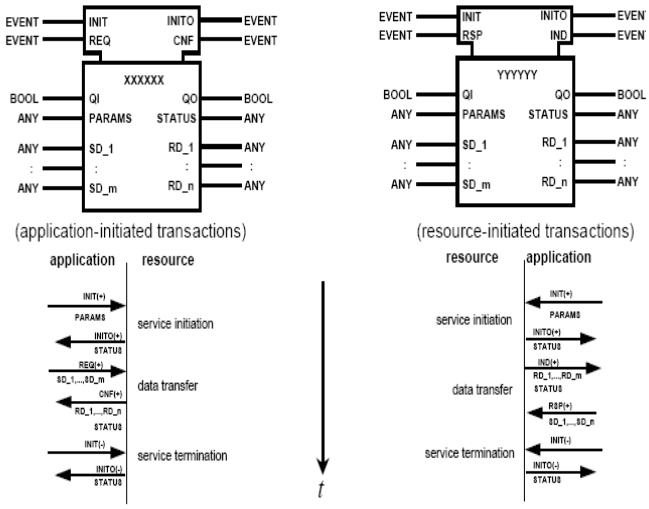


Fig. 7. Service Interface Function Block

By properly connecting more than one FB, a distributed application can be defined. The sequencing of algorithm invocations is defined in the FB type specification using a variant of state charts called Execution Control Chart (ECC).The event flow between ECCs of FBs determines the scheduling and execution of the FB algorithms and thereby the behaviors of the complete control application.

An ECC of FB is shown in fig. 8. It consists of EC states, EC transitions and EC actions.

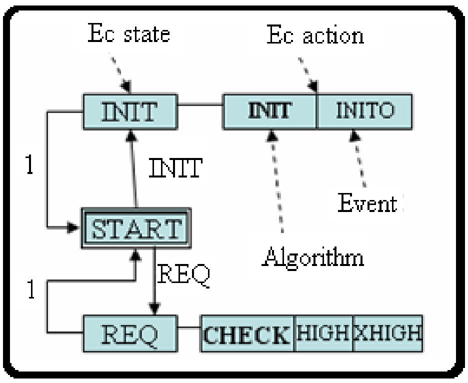


Fig. 8. IEC 61499 ECC of Function Block

Except from the initial state that shall have no associated EC actions, An EC state may have zero or more associated EC actions, may have an associated algorithm and an event that will be issued after the execution of the algorithm. EC transitions are directed links that represent the transition of the FB instance from one state to another. An EC transition is enabled when the associated Boolean expression becomes true.

3 Function Block Development Kit

The most widely used tool in the development of Function Block Systems is Function Block Development Kit [FBDK, 2006]. FBDK is an effort of Holonic Manufacturing System consortium. Creation of function blocks have been facilitated by Rockwell Automation through the Holobloc IEC 61499 prototyping software.

FBDK provides a graphical interface through which IEC 61499 compliant systems can be created and tested. It creates FB using Java Developer Kit. A software tool was developed for a visual creation of this function block network. Using this tool allows users to define, reuse built-in and/or user defined function blocks in designing the DCS applications.

Control software could be configured using a standard library of function blocks (FB) that would be assembled in a plug-and-play fashion to develop the control programs. It will run on the individual devices. Standard function blocks for communication among devices enable peer-to-peer communication.

4 Function Block Run Time Environment

Function Block Run Time Environment (FBRT) is a runtime platform. This allows systems created with FBDK to be run on any Java enabled platform. It provides the running platform for remotely configurable devices where FB based applications can be executed. So it works coherently with FBDK. By installing FBRT on any micro controller, they could run function block systems.

As a result, the FBRT system is a step towards middleware in industrial automation. Linked to this is the notion of portability. There is no need for proprietary languages and development systems which can only be run on one type of controller. This also facilitates the intercommunication between different micro controllers such that larger and more complex intelligent systems can be developed.

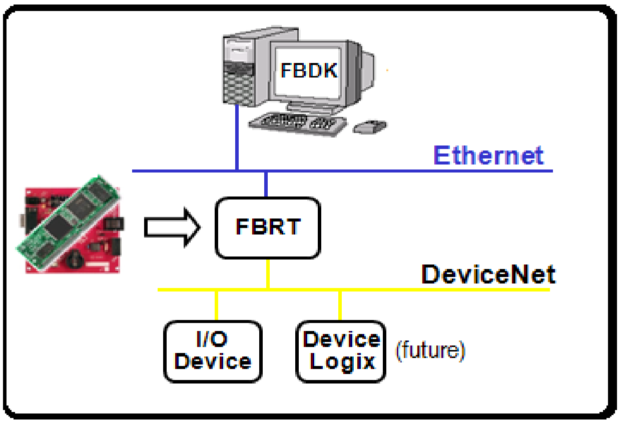


Fig. 9. FBDK and FBRT in creating IEC 61499 Function Blocks Environment

5 Automatic Iron Cutting Device using IEC61499 FBs

Consider the automatic Iron Cutting Device with two controllers. The first controller (Device1) runs a master panel with three buttons: Cutting Project on / off and Electronic Eye read start. The second controller (Device2) runs the operating cycle of the Cutting Project. Two controllers must communicate with each other. The two lights on operating panel (1- Cutting Project On "indicate whether the Cutting Project has been started or not" and 2-Electronic Eye Detect "indicate whether the Electronic Eye has been read the map or not") need the data coming from the master panel, Device 1 done this by latching these two data and sending them to Device 2. While the data outputted from the latch normally would go to an output function blocks, the second device-the operating panel-needs that data.

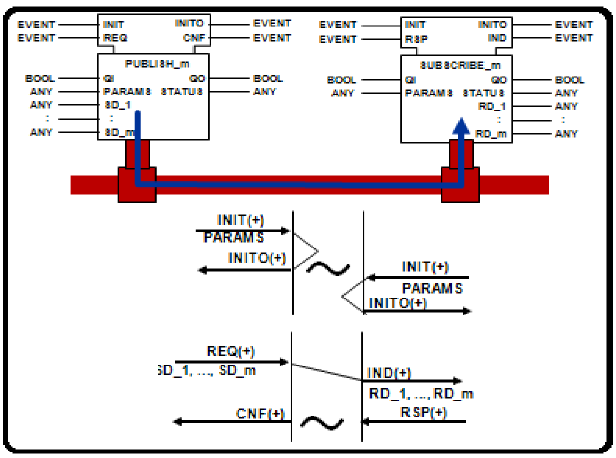


Fig. 10. Communication Service Interface using Publish subscribe Function Block

As a result, device 1 will publish that data output. That is, this device will always take the data coming from the latch available to any subscribers-devices that read data from the publisher. Publish function blocks need an IP address and a port so data can be written to a specific address. the IP address 225.0.0.1 and the port 0001 is used for cutting project On and IP address 225.0.0.2 and the port 0002 is used for Electronic Eye read, to keep the data being written to and read from a local address. To receive data from a publish function block, there needs to be a subscribe function block. Exactly like the publish function block, the subscribe function block need IP address and a port to read data from. The IP address and port defined for the Subscribe function block shall exactly be the same as those that defined on the Publish function blocks.

Control panels is shown in Fig. 11

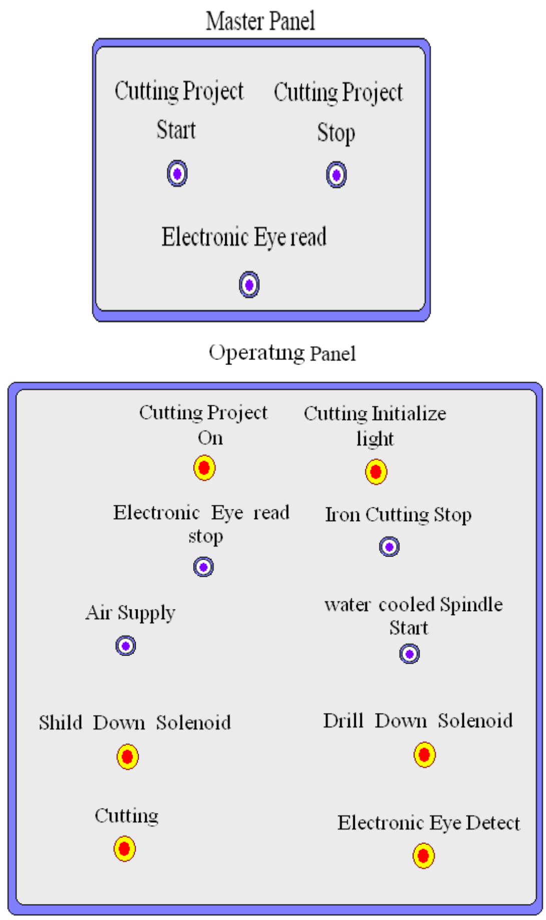


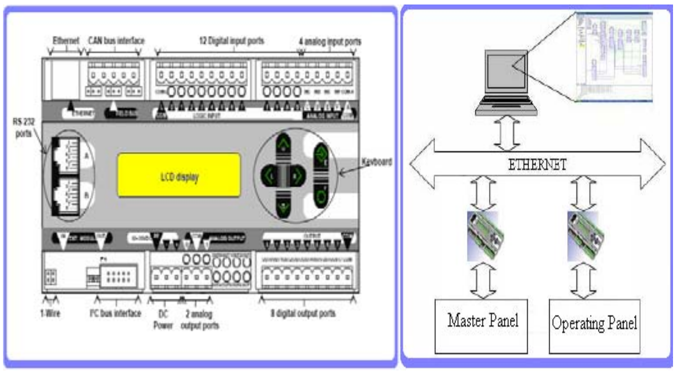
Fig. 11 Cutting Device Control Panels

The operating System done as follows:

Cutting Project Start button turns the Cutting Initialize light on. Operator shall place the part to be cut under the spindle. Then he must press both the Air Supply and Water cooled spindle start buttons simultaneously. This automatically leads the shield to come down. The shields down Limit switch is enabled when the shield is down completely and stop the shield coming down more. At this time the Electronic Eye read shall be pressed for reading the cutting map which determines the shape of cutting. The drill spindle starts to cut and the drill head comes down. When the drill head is completely down, Drill Down limit switch is activated. If at any time operator hit the Cutting Project Stop button or an Electronic Eye read stop or Iron Cutting stop button, the operating cycle should be shut down.

6 Netmaster

Netmaster is an Italian microcontroller produced by Elsist.s.r.l can be used in implementing the wide variety of DCS applications.



(a) (b)

Fig. 12. (a) Netmaster Hardware

(b) Re-configurability for this project

Netmaster bi Processor structure is constructed of TINI (Tiny Internet Interface) CPU or DS80C390 of Dallas semiconductor as the central processor and ADuC812 as the Analog Device comprising of the 12 bit data accusation system on chip, managing the Analog I/O Functionality. TINI microprocessor contains the static RAM and flash ROM memories with 1-Wire, RS232 and 10-base-T Ethernet interfaces. It is compatible with both C and Java languages with the well defined software environment. Both the field bus and Ethernet communication services through the TCP/IP protocols enable the connectivity of a group of equipments. Netmaster software environment comprise the operating system and command shell, native codes executed by microcontroller and Java Virtual Machine (JVM). Flexible and reconfigurable manufacturing Model can be deployed on this module by changing the elements or reconfiguring the system with lunching the new application. Using FBDK, each function block could be translated into Java code (FBT) and could be configured on Netmaster by FBRT.

7 Simulation

Simulation of the whole system with IEC 61499 Editor with considering two devices and two resources are shown in fig 13.

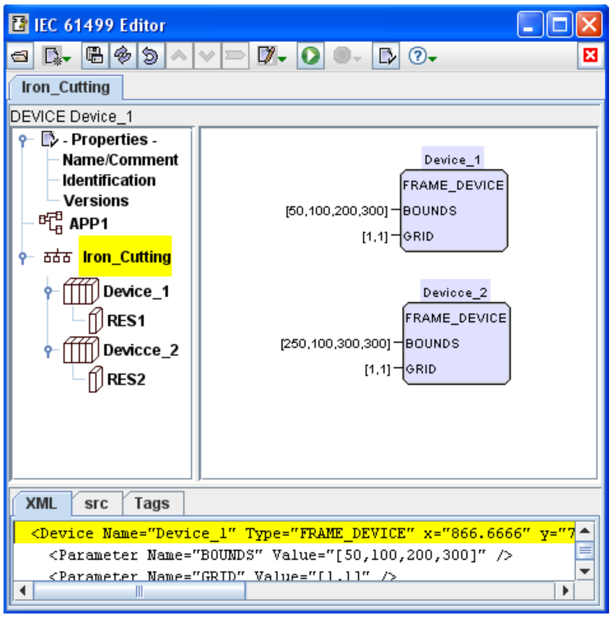


Fig. 13. Two Devices in Iron Cutting System

The application with the FB defined in the process is shown. Publish and subscribe are defined in two resources (RES1 and RES2) for communicating tow devices.

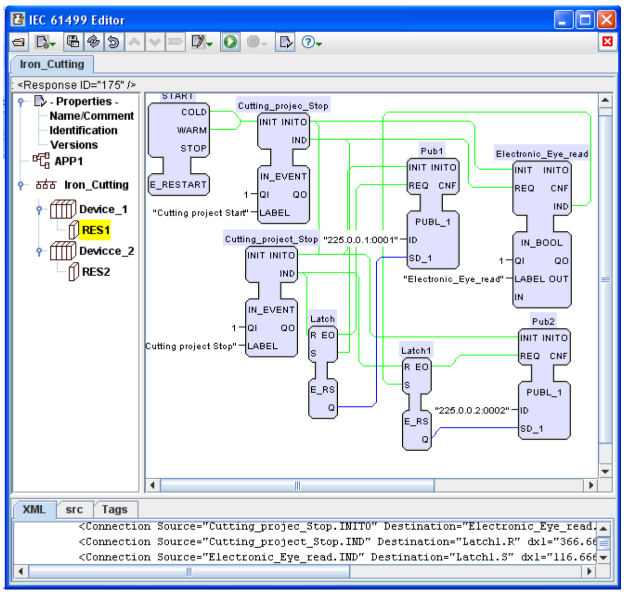


Fig. 14. Iron Cutting Resource 1 Application

The logic of the control process are made by mathematical library exist in the IEC 61499 Editor Math library. Input and Output FBs are defined by the FBs found on the library. Connections between events are in green line. Data Connections are shown in blue line (Fig. 14, Fig. 15). Simulation results are shown in fig 14. library. Connections between events are in green line. Data Connections are shown in blue line (Fig. 14, Fig. 15). Simulation results are shown in fig 16.

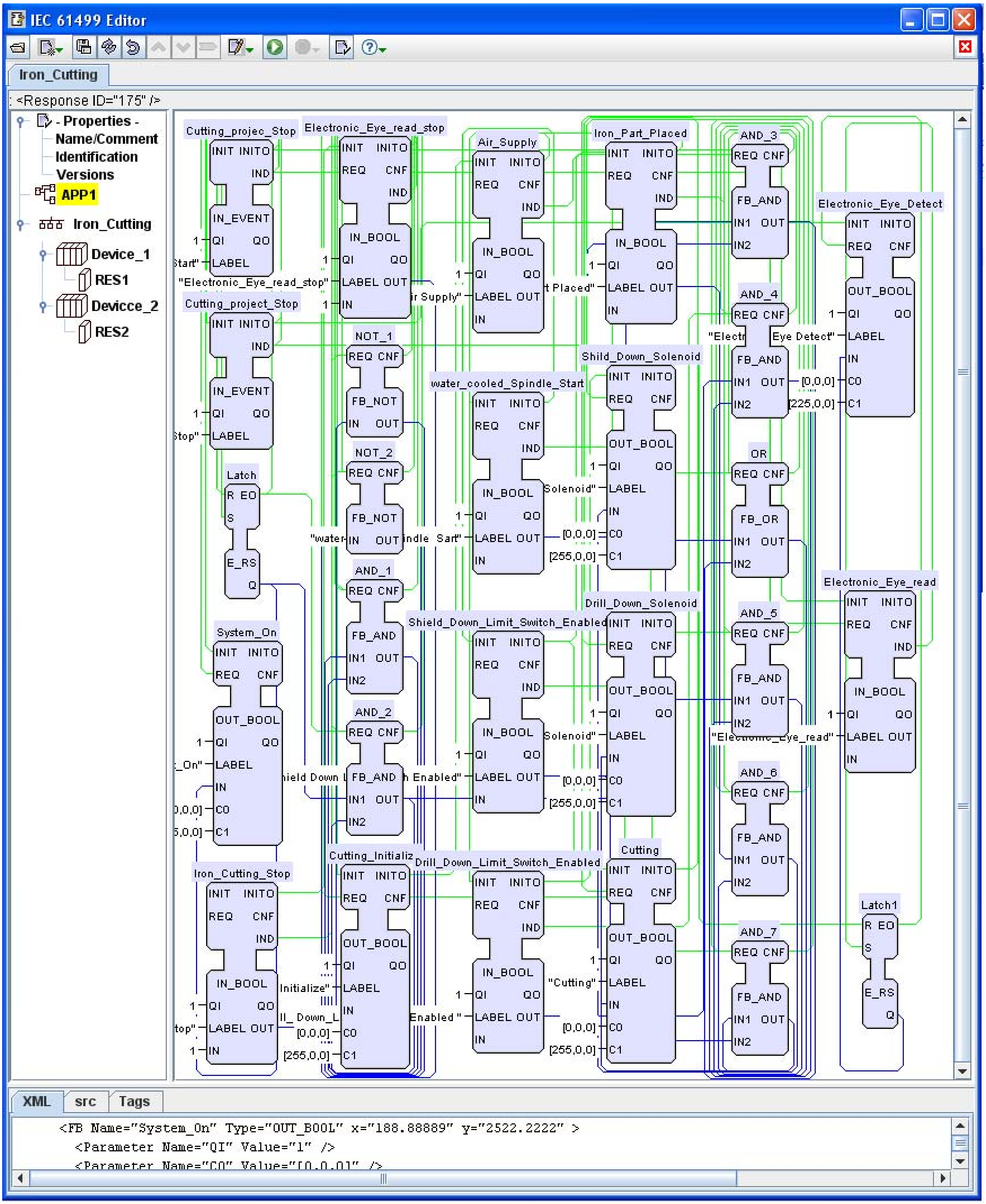


Fig. 15. IEC 61499 Iron Cutting Application

Fig. 16. IEC 61499 Iron Cutting Device Application:
(a) Cutting Project Start and Electronic Eye read buttons on device 1 are pressed. Cutting Project on, Cutting Initialize and Electronic Eye detect lights on device 2 are turn on and Shield Down Solenoid, Drill Down Solenoid and Cutting Lights are turn off.
(b) Cutting Project Start and Electronic Eye read buttons on device 1 are pressed. Air Supply and Water cooled Spindle Start are pressed on device 2 and Iron Part Place Sensor and Drill Down Limit Switch are activated and Cutting Project on, Cutting Initialize and Electronic Eye detect lights on device 2 are turn on and Shield Down Solenoid, Drill Down Solenoid and Cutting Lights are turn off.
(c) Condition on (b) plus considering that the Drill Down Limit Switch is enabled. So Cutting Project on, Cutting Initialize, Shield Down Solenoid and Electronic Eye detect lights are turn on and Drill Down Solenoid and Cutting Lights are turn off.
(d) Condition on (c) plus considering that the Shield Down Limit Switch is enabled. So Cutting Project on, Cutting Initialize, Shield Down Solenoid ,Electronic Eye detect, Drill Down Solenoid and Cutting Lights are turn on.
(e) Condition on (d) plus considering that the Iron Cutting Stop Button is pressed So Cutting Project on, Cutting Initialize Lights are turn on and Shield Down Solenoid ,Electronic Eye detect, Drill Down Solenoid and Cutting Lights are turn off.
(f) Condition on (d) plus considering that the Iron Cutting Project Stop Button is pressed So Cutting Project on, Cutting Initialize , Shield Down Solenoid ,Electronic Eye detect, Drill Down Solenoid and Cutting Lights are turn off.

4 Conclusion

The knowledge of IEC 61499 is deepened through this article and benefits of using IEC 61499 are fully described. IEC 61499 provides easy communication via network. A design pattern for developing the Iron cutting device distributed in two devices based on IEC 61499 was explicated on this paper.

A model is flexible with reconfigurable design by IEC 61499 Editor FBs. Communications between two devices has provided by publish and subscribe FBs with an exclusive IP address and a port so that data can be written to and read from a specific address.

One special approach in this research is the device independent control application design followed by the code distribution among available devices and the communication code integration.
Modularity is typically introduced into a manufacturing operation to increase the flexibility of the operation both in terms of its range of functions and also its ability to be easily reconfigured in the face of changing conditions. It is achieved on new architectural design on DCS by IEC 61499 standard that describe the common modeling paradigm of programming distributed applications by utilizing and interconnecting elementary function blocks residing on DCS devices.

Function block PUBLISH and SUBSCRIBE take care of internet protocol and network communications. Software reuse and reconfigure ability of IEC 61499 are the especial features enable system designers make changes to application or reconfigure application to perform other functions, without redesigning the whole system again. Software encapsulation allows the number of function block used in an application to reduce thus reducing number of connections thus reduces the chances of making an error and make debugging of application very easy. Therefore, by using IEC 61499 concepts, design time is greatly reduced, engineering cost is expected to reduce and system will be more flexible and maintainable.

Future industry solutions will demand system engineering for integration and seamless communication between different components in the system.

However, to realize such a distributed system in today's industry is complicated and requires high engineering cost, by producing a common interface of execution platform, network protocol and system configuration.

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