

1 IEC6499 based Control development of Advanced Manufacturing and HVAC solutions Alessandro Brusafferri

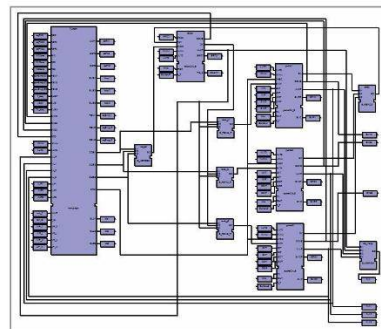


Istituto di Tecnologie Industriali e Automazione
Consiglio Nazionale delle Ricerche

SYNESIS

IEC61499 based Control development of Advanced Manufacturing and HVAC solutions

Alessandro Brusafferri

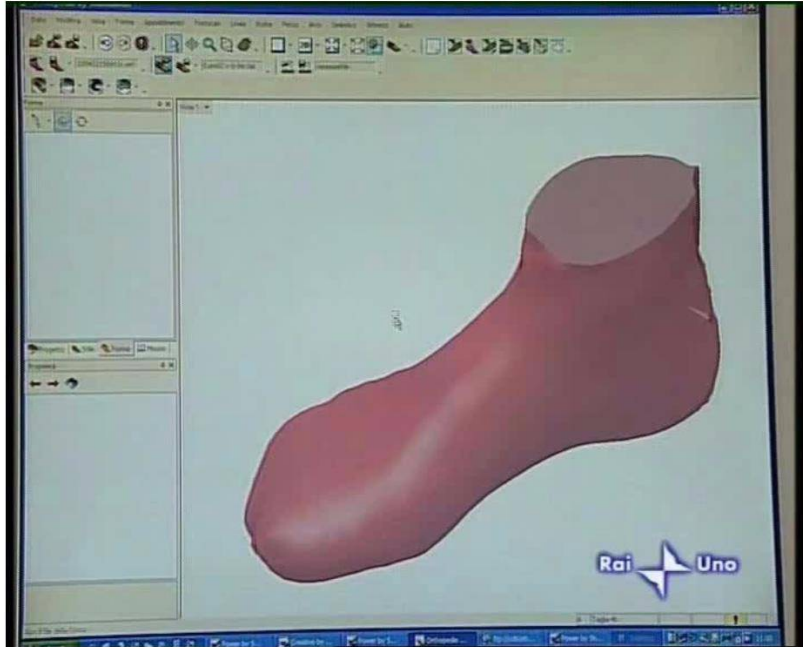


2 About ITIA-CNR and Synesis

ITIA-CNR, as a promoter of Industrial Innovation, performs strategic activities of Scientific Research and Technological Development for the Competitiveness and Sustainability of Italian and European Manufacturing Industries. The focus of the research activities concerns the following issues: - Machine/System control solutions - Intelligent robot systems - Enterprise engineering and virtual applications Synesis, as an European Public-Private technology development consortium, acts on a spectrum of enabling technologies for production systems: from innovative operating machines to adaptive factories from design and optimization of production systems to energy efficient and green manufacturing processes Solutions Requirements MARKET

3 Innovative Shoe Manufacturing Plant Responsive Manufacturing Plant

Innovative Shoe Manufacturing Plant



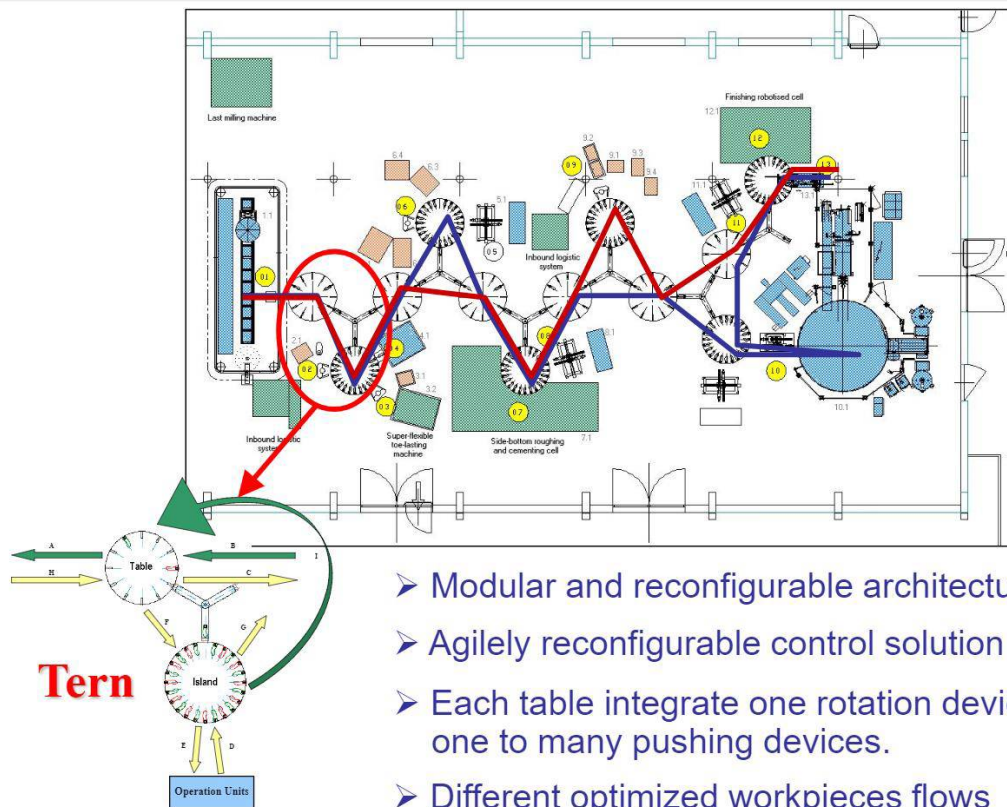
Responsive Manufacturing Plant



4 Molecular Line Architecture

A H B C I Modular and reconfigurable architecture Tern F E G D Agilely
reconfigurable control solution required Each table integrate one rotation device and
one to many pushing devices. Operation Units Different optimized workpieces flows

Molecular Line Architecture

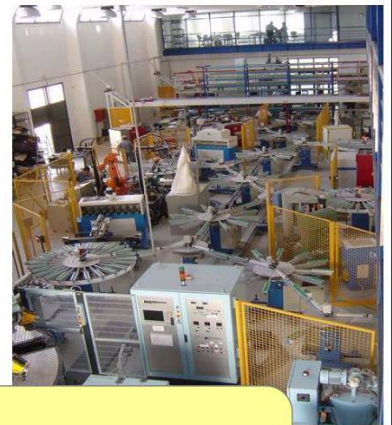


5 Mechanical Design Control Development

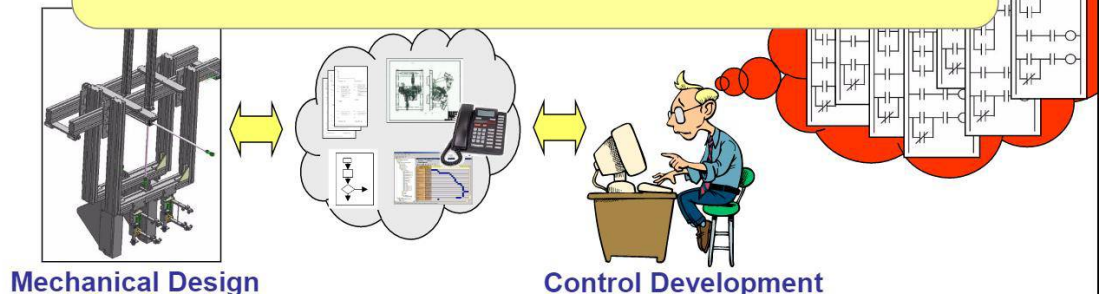
Advanced Manufacturing Systems requirements Automation systems increasing complexity Growing product variety and shorter lifecycle Agile solutions reconfiguration required Not properly structured control application Difficult to maintain and re-adapt Need to formalize and reuse knowledge Avoid starting from scratch Reduce time/costs How of to properly control software structure the development control application in order to satisfy such requirements?

Advanced Manufacturing Systems requirements

- ❑ Automation systems increasing complexity
- ❑ Growing product variety and shorter lifecycle
- ❑ Agile solutions reconfiguration required
- ❑ Not properly structured control application
- ❑ Difficult to maintain and re-adapt
- ❑ Need to formalize and reuse knowledge
- ❑ Avoid starting from scratch
- ❑ Reduce time/costs



How to properly structure the control application in order to satisfy such requirements?



EC 63 FBD: Explicit modules interactions IEC 63 ST: Complex algorithm support
IEC 63 SFC: Structured logic organization IEC 63 LD: Easy Boolean rules

IEC 61131 FBD: Explicit modules interactions

The diagram shows three function block instances labeled TR_FAULT, connected via their inputs and outputs to a central output block.

IEC 61131 ST: Complex algorithm support

```

(* Referencement instruction Cutting Condition On *)
Instr_iRefInCutConOn(IfCMD_ENCLENCHREMENT,
    Instr_iCutConOn,
    PUB_EneCuttingConOn,
    PUB_EneMeasuringConOn,
    Sys_RetVide,
    Sys_RetVide,
    Sys_RetVide,
    Sys_RetVide,
    Sys_RetVide,
    Sys_RetVide);
IF INSTR_iRefInCutConOn.CadPut
THEN
  IF ((NVR_inWirePanelCoverOpened (* Porte platine fil fermée *)
      AND NVR_iBigSpoolDoorClosed) OR Instr_iSignal) THEN
    Instr_iCutConOn.Cad := TRUE;
  ELSE
    IF NOT NVR_inWirePanelCoverOpened (* Platine fil ouverte *) THEN
      Instr_iPlatineFilOuverte := TRUE;
    END_IF;
    IF NOT NVR_iBigSpoolDoorClosed (* Grosse bobine ouverte *) THEN
      Instr_iGrosseBobOuverte := TRUE;
    END_IF;
    Instr_iCutConOn.Cad := FALSE;
    Instr_iCutConOn.Err := TRUE;
  END_IF;
ELSE
  END_IF;
END

```

IEC 61131 SFC: Structured logic organization

The diagram shows a sequence of steps (S1, T1, S2, T2, S3, T3, S4) connected by transition lines, representing a state machine logic.

IEC 61131 LD: Easy Boolean rules

```

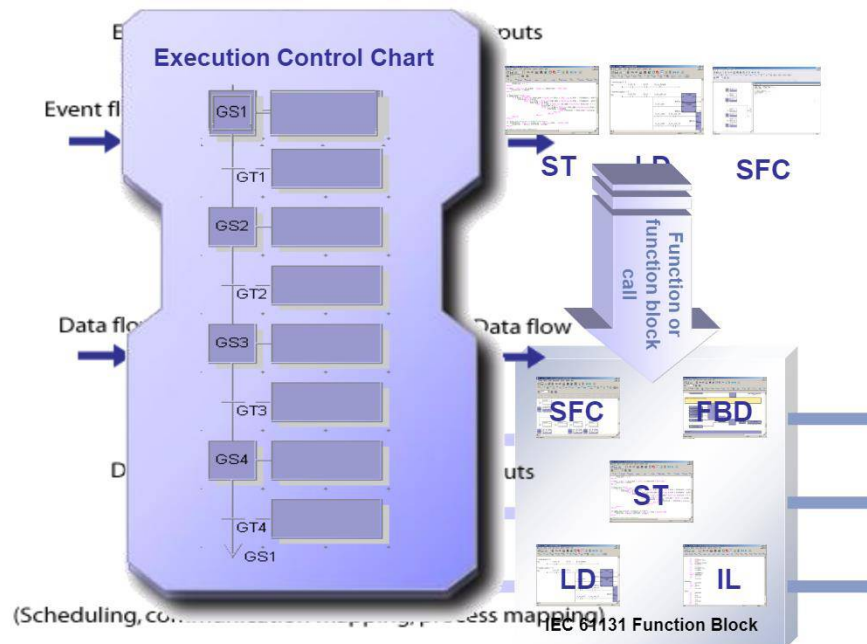
(* CONTROLE CIRCULATION DES MAIL BOXES Mail boxes VO (B & T) *)
[1] IN_D_128
|> OUT_D_128
|> [2]
(* Mail box i / insertion sortie à chaque cycle VM *)
OUT_D_161
|> [3]
(* DETECTION DU PREMIER PASSAGE SYS_PremierPassage peut être lu par tous les modules *)
SYS_PremierPass
|> [4]
(* Compteur cycles VM : publiée pour TrVMR pour déterminer si la VM tourne *)
[4] EN 1.gain END Done
SYNA_CYCLE -> PUB_VM_CYCLES
Collection du premier cycle VM lors du premier PowerOn de la machine, utilisé pour initialiser des variables non-volatiles
Sys_VariAlte
|> [5]

```

7 IEC 6499 Structured design formalism

Execution Control Chart ST LD SFC Function or function block call SFC FBD ST
LD IL IEC 63 Function Block

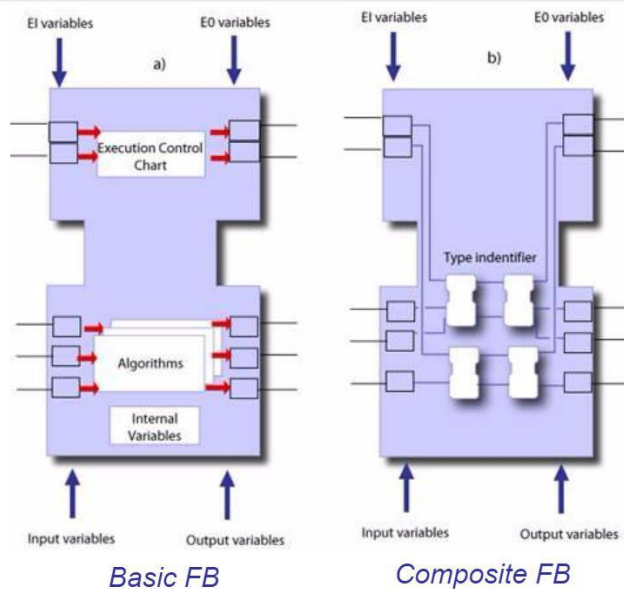
IEC 61499 – Structured design formalism



8 IEC 6499 Structured design formalism

Basic FB Composite FB Structured approach supported by Composite Function Blocks: A Composite Function Block includes many Basic and/or Composite Function Blocks

IEC 61499 – Structured design formalism



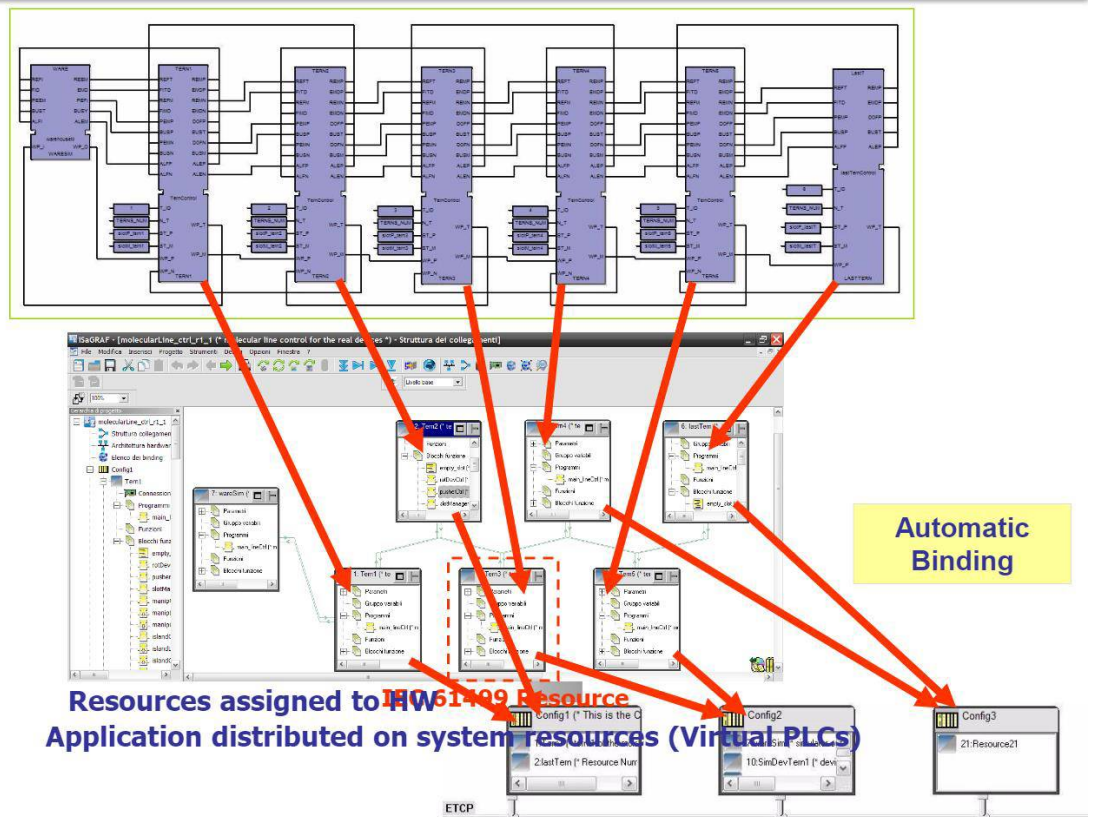
Structured approach supported by Composite Function Blocks:

A Composite Function Block includes many Basic and/or Composite Function Blocks

9 IEC 6499 Distributed Control Solutions

Automatic Binding 05/0/20 HVAC BRAIN Diapositiva 9 di X Resources assigned to IEC HW 6499 Resource Application distributed on system resources (Virtual PLCs)
Table Control

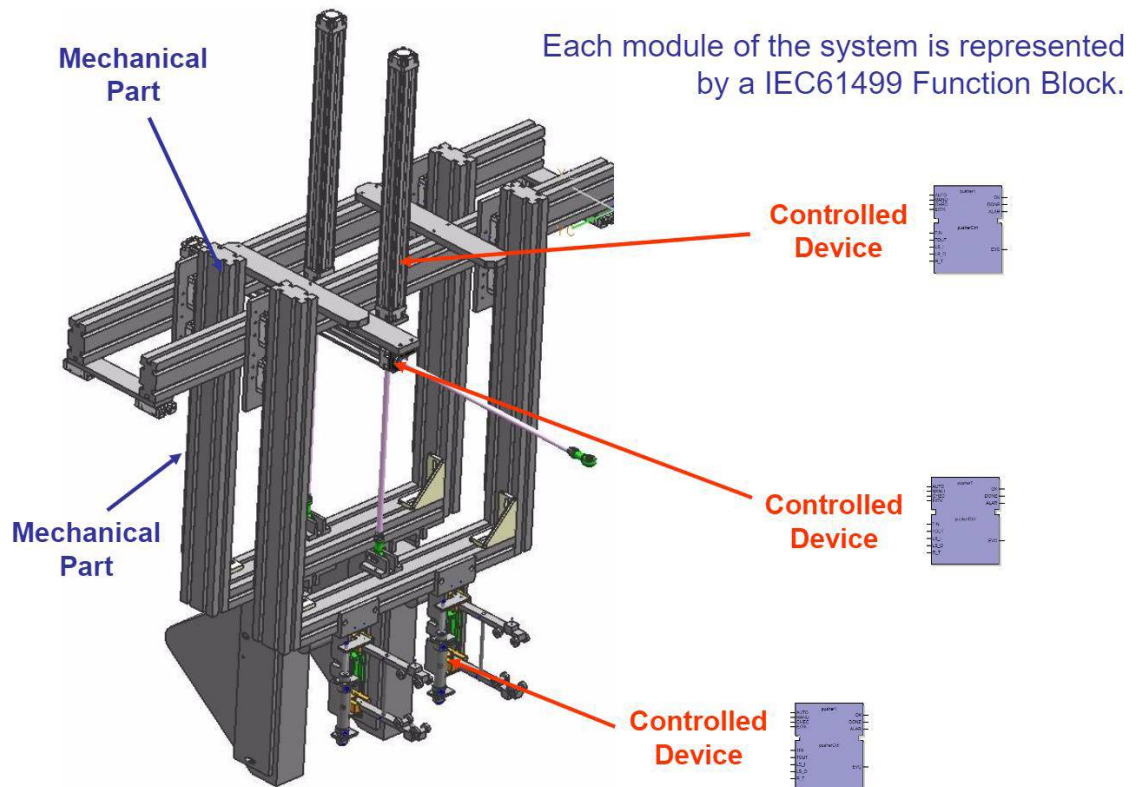
IEC 61499 – Distributed Control Solutions



10 Control software modularization

Mechanical Part Each module of the system is represented by a IEC6499 Function Block. Controlled Device Mechanical Part Controlled Device Controlled Device

Control software modularization

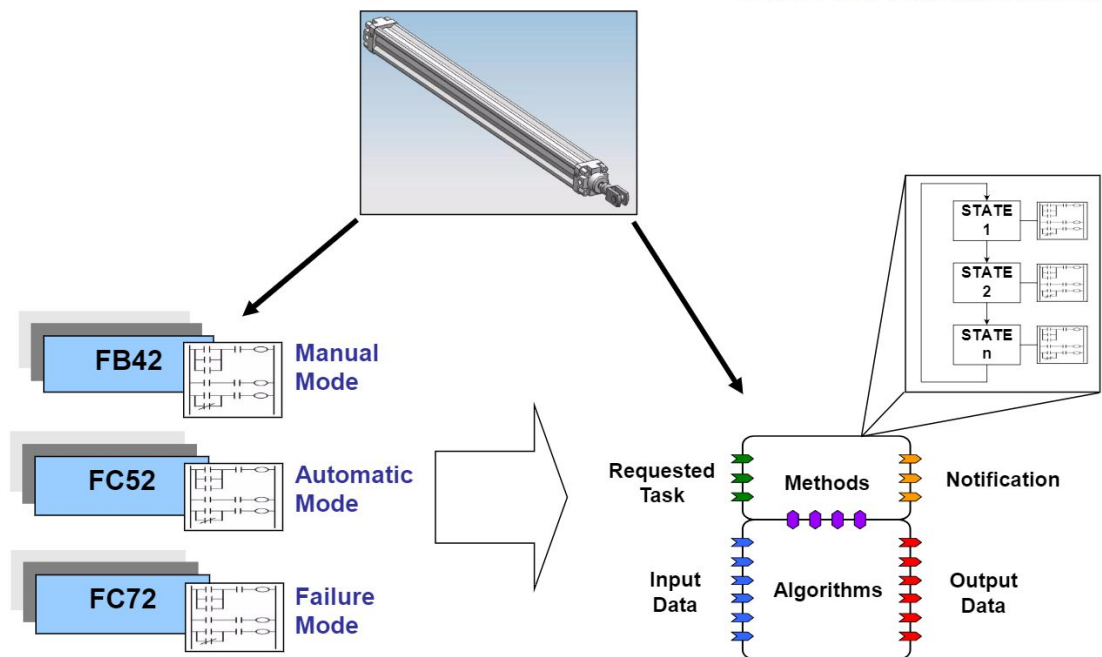


11 Control software modularization

Structure control logic organization in a IEC6499 Function Block. STATE STATE 2
FB42 Manual Mode STATE n FC52 Automatic Mode Requested Service invocations
Task METHODS Methods Notification Event notifications FC72 Failure Mode Input
Data Input Parameters PROCESSES Algorithms Output Data Output Parameters

Control software modularization

Structure control logic organization in a IEC61499 Function Block.



12 Control Solution Design

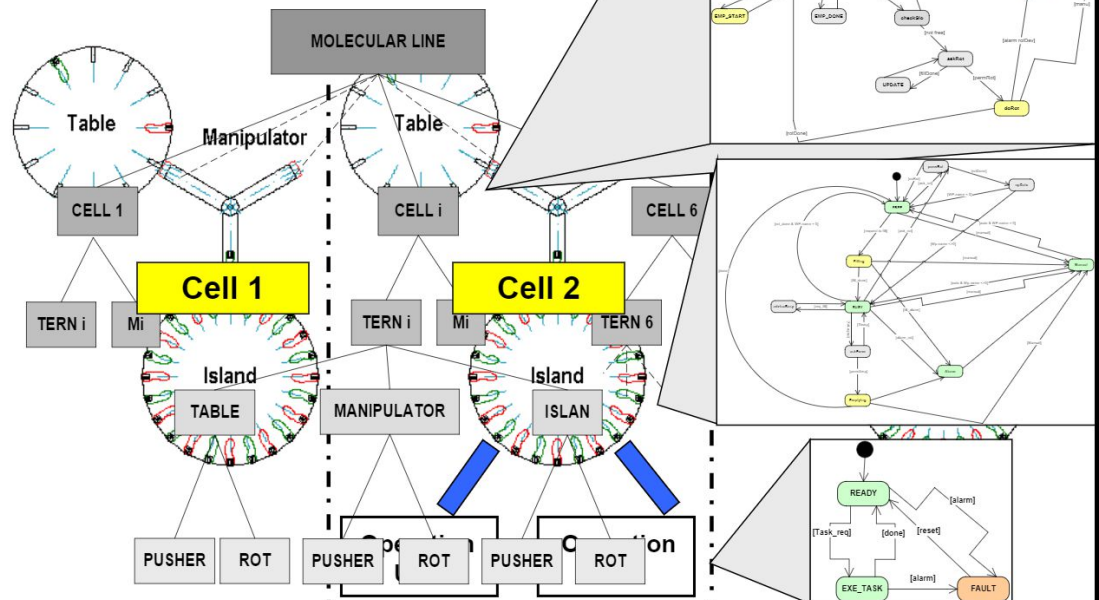
First step: FREE Process top down analysis: [filldone] [auto & free] [manu] Modular system decomposition Identification of modules functions [filldone] [WP_TO_EMP] UPDATE [auto & not free] [free] [manu] CHECK_TK [alarm pushers] [emdone] [NOT EMP & NO filldone] manual alarm [manu] EMP_START EMP_DONE checkslo MOLECULAR LINE [not free] [alarm rotdev] askrot UPDATE [filldone] [permrot] dorot [rotdone] permrot [rotdone] [norot] [ask_rot] update CELL CELL i CELL 6 [rot_done & WP.name = 0] FREE [WP.name = 0] [auto & WP.name = 0] [request to fill] [ask_rot] [manual] [Wp.name <>0] TERN i Mi Cell Cell 2 Cell k TERN i Mi TERN 6 M6 [done] [manual] Filling [fill_done] advisebusy [req_fill] BUSY [fill_alarm] [Tbusy] [doempty] [alarm_rot] [auto & Wp.name <>0] [manual] [Manual] Manual askperm [permemp] Alarm TABLE MANIPULATOR ISLAN Emptying READY [alarm] Operation ROT Unit PUSHER ROT PUSHER PUSHER Operation ROT Unit [Task_req] [done] [reset] [alarm] EXE_TASK FAULT

Control Solution Design

First step:

Process top down analysis:

- Modular system decomposition
- Identification of modules functions



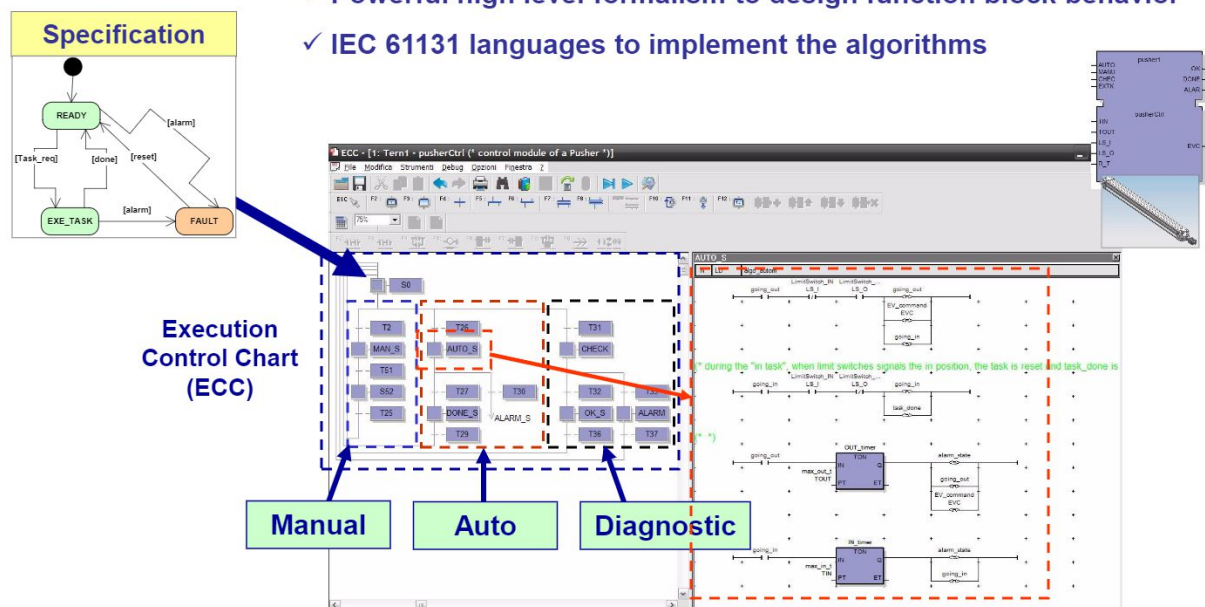
13 IEC 6499 based Control Development

The IEC6499 basic function block content: Agile specification to control code phase
Function block logics structured into a State Machine (ECC) Specification Powerful
high level formalism to design function block behavior IEC 63 languages to
implement the algorithms READY [alarm] [Task_req] [done] [reset] EXE_TASK
[alarm] FAULT Execution Control Chart (ECC) Manual Auto Diagnostic

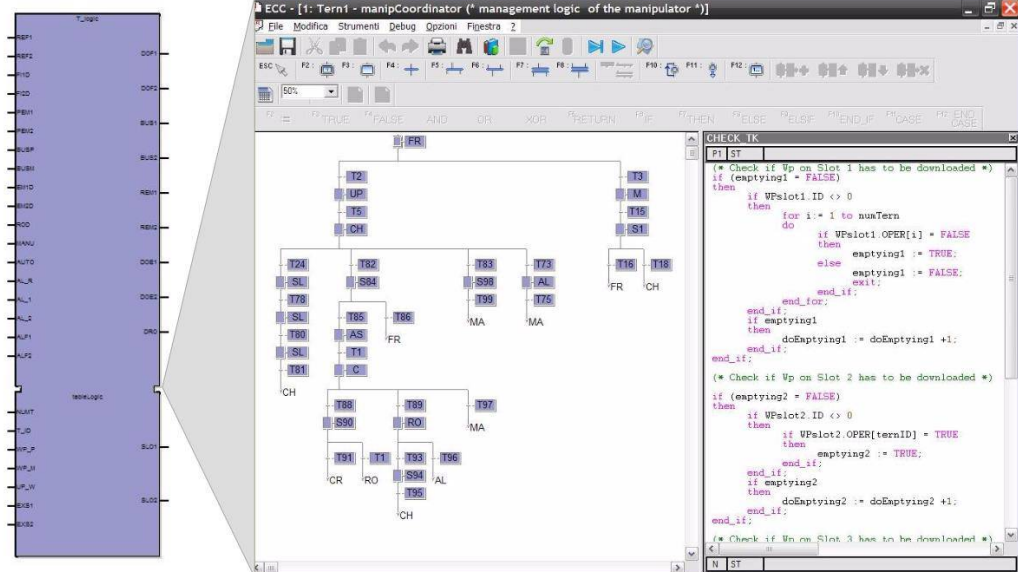
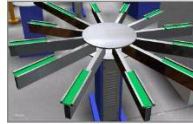
IEC 61499 based Control Development

The IEC61499 basic function block content:

- ✓ Agile specification to control code phase
- ✓ Function block logics structured into a State Machine (ECC)
- ✓ Powerful high level formalism to design function block behavior
- ✓ IEC 61131 languages to implement the algorithms



- Table Manager IEC 61499 Function Block -



15 IEC 6499 based Control Development

The IEC6499 composite function block content: Network of connected function blocks
Event based blocks interaction policy
Separated event/data function block interfaces
Faster application build-up (Plug & Play)
Extensive approach by hierarchical encapsulation
Events Data

IEC 61499 based Control Development

The IEC61499 composite function block content:

- ✓ Network of connected function blocks
- ✓ Event based blocks interaction policy
- ✓ Separated event/data function block interfaces
- ✓ Faster application build-up (Plug & Play)
- ✓ Extensive approach by hierarchical encapsulation

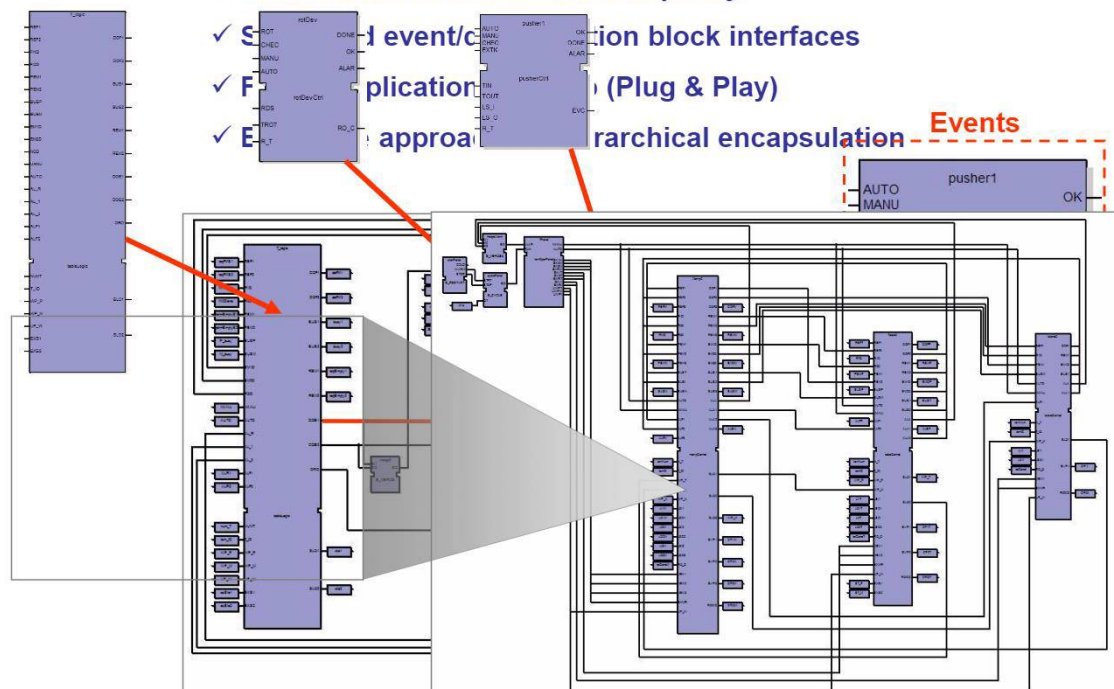
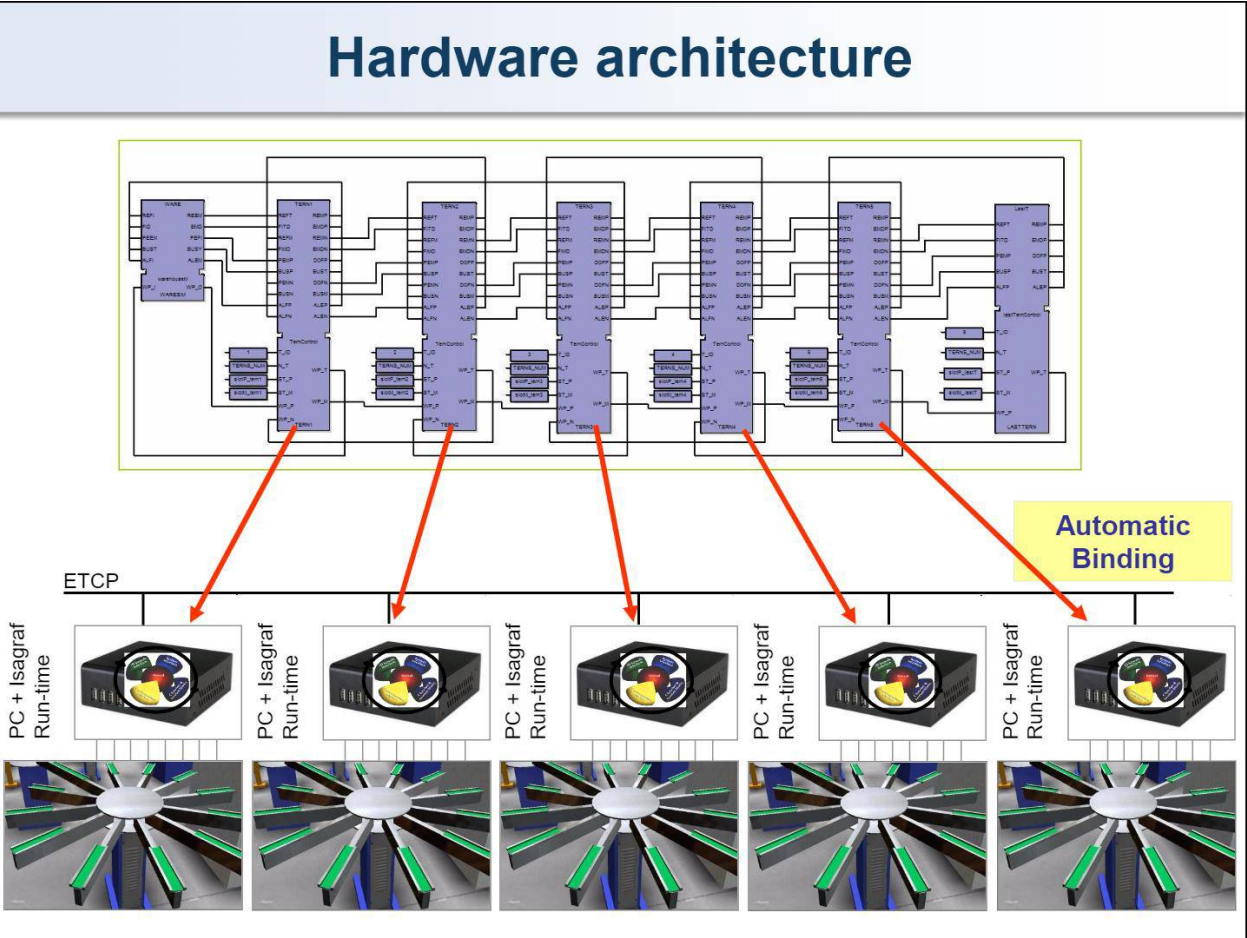
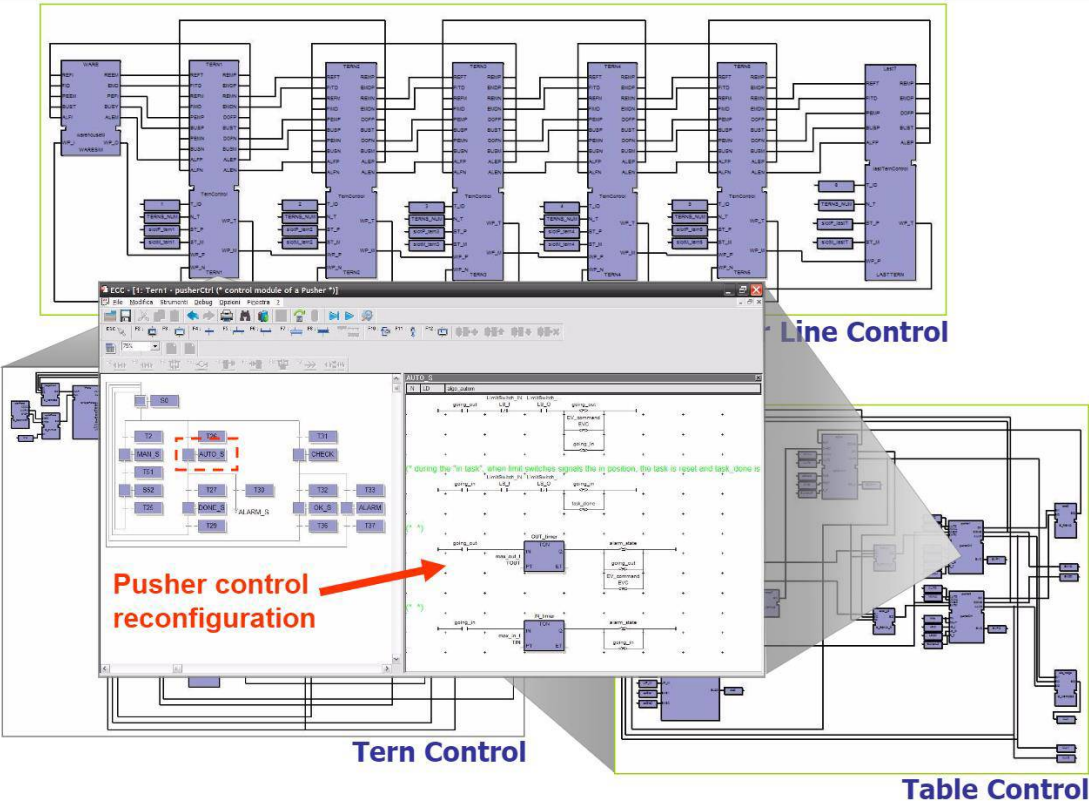


Table Control

PC + Isagraf Run-time PC + Isagraf Run-time Hardware architecture PC + Isagraf Run-time PC + Isagraf Run-time PC + Isagraf Run-time ETCP Automatic Binding



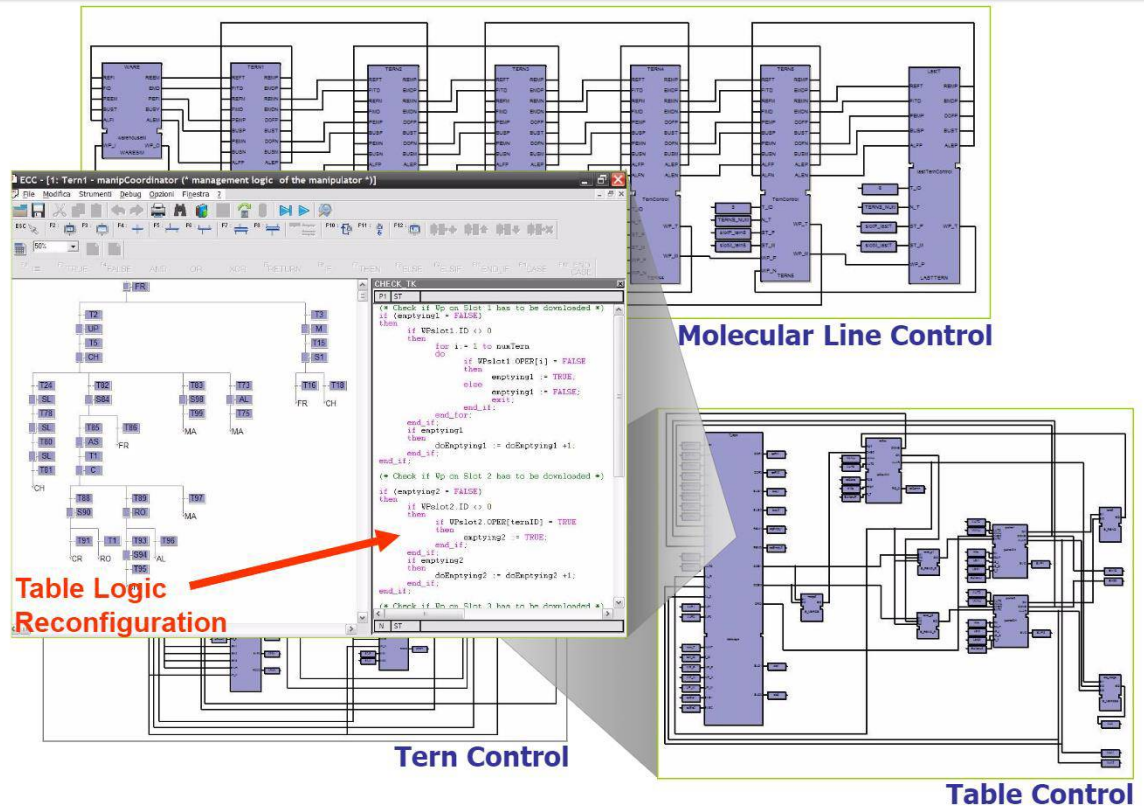
Control solution reconfigurations



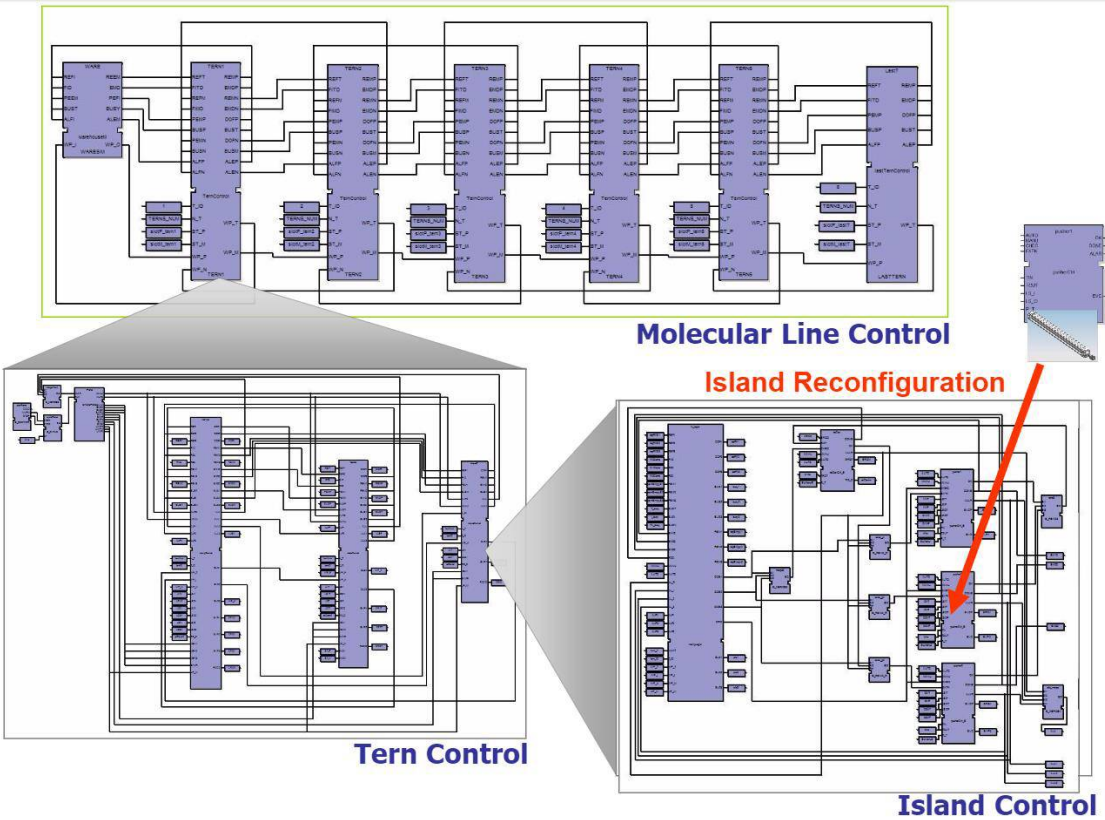
19 Control solution reconfigurations

Molecular Line Control Table Logic Reconfiguration Tern Control Table Control

Control solution reconfigurations



Control solution reconfigurations

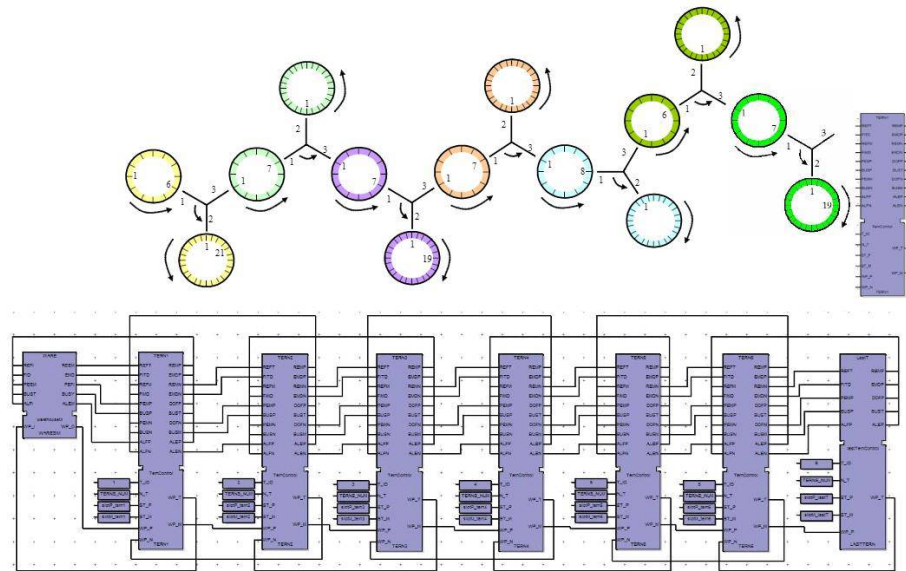


21 New cell integration

- Add FB Instance into the application, connect & play Control solution reconfigurations

Control solution reconfigurations

- New cell integration -



→ Add FB Instance into the application, connect & play

22 Main emerged benefits

Enhanced control code readability and maintainability Reduction in time and effort during control development Less control solutions validation effort Increased control solutions re-usability Faster application distribution Agile reconfiguration of control solution NEXT: IEC6499 based control of a Pilot Remanufacturing Plant

Main emerged benefits

- ☐ Enhanced control code readability and maintainability
- ☐ Reduction in time and effort during control development
- ☐ Less control solutions validation effort
- ☐ Increased control solutions re-usability
- ☐ Faster application distribution
- ☐ Agile reconfiguration of control solution

NEXT: IEC61499 based control of a Pilot Remanufacturing Plant

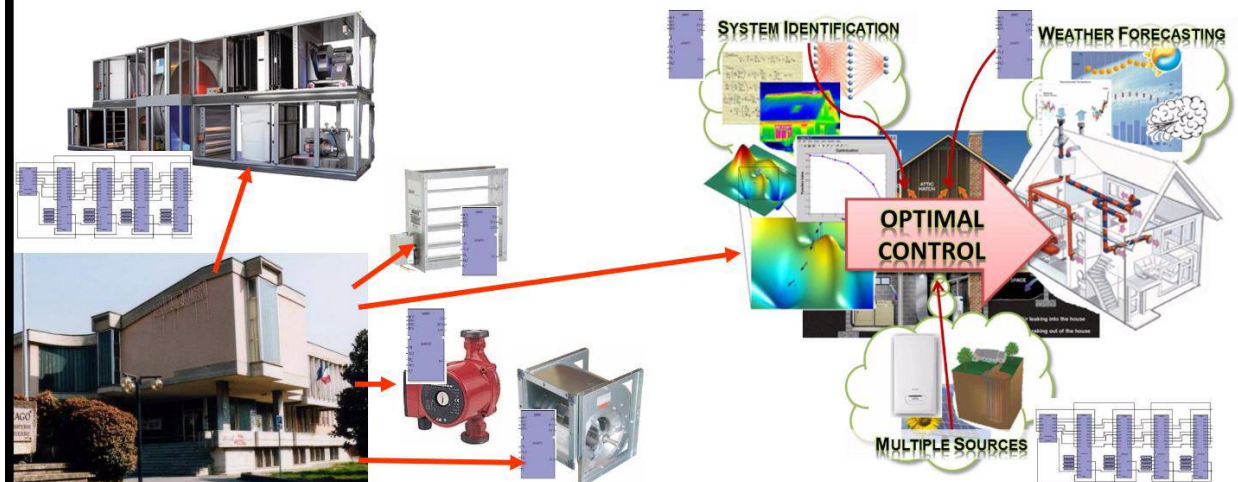
23 HVAC Brain Solution

Library of Function Block for HVAC control oriented to the reduction of Building energy consumption (EN5232): Distributed Building HVAC Intelligence Demanded Predictive control and optimal sources commitment Peak Energy demand reduction, oriented to Smart Grids.

HVAC Brain Solution

Library of Function Block for HVAC control oriented to the reduction of Building energy consumption (EN15232):

- ❑ Distributed Building HVAC Intelligence
- ❑ Demanded Predictive control and optimal sources commitment
- ❑ Peak Energy demand reduction, oriented to Smart Grids.



Library of Function Block for HVAC control oriented to the reduction of Building energy consumption (EN5232): Distributed Building HVAC Intelligence Demanded Predictive control and optimal sources commitment Peak Energy demand reduction, oriented to Smart Grids. Already Installed on two Pilot Buildings in Italy. Validation ongoing! In collaboration with:

HVAC Brain Solution

Library of Function Block for HVAC control oriented to the reduction of Building energy consumption (EN15232):

- ❑ Distributed Building HVAC Intelligence
- ❑ Demanded Predictive control and optimal sources commitment
- ❑ Peak Energy demand reduction, oriented to Smart Grids.

