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

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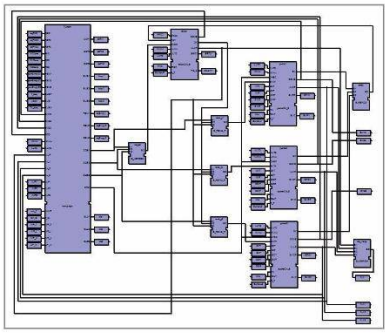
Consiglio Nazionale delle Ricerche

SYNESIS

IEC61499 based Control development of Advanced Manufacturing and HVAC solutions

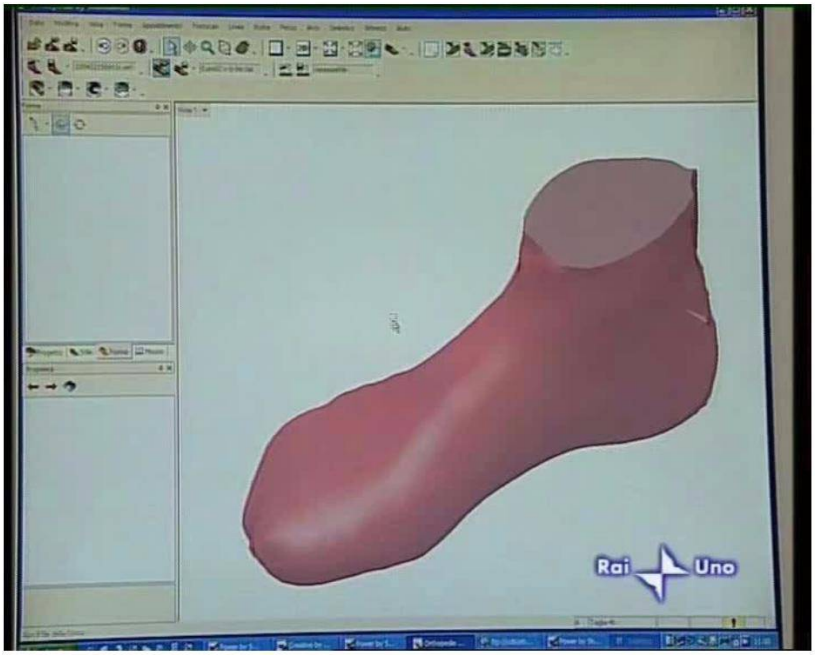
Alessandro Brusaferri



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

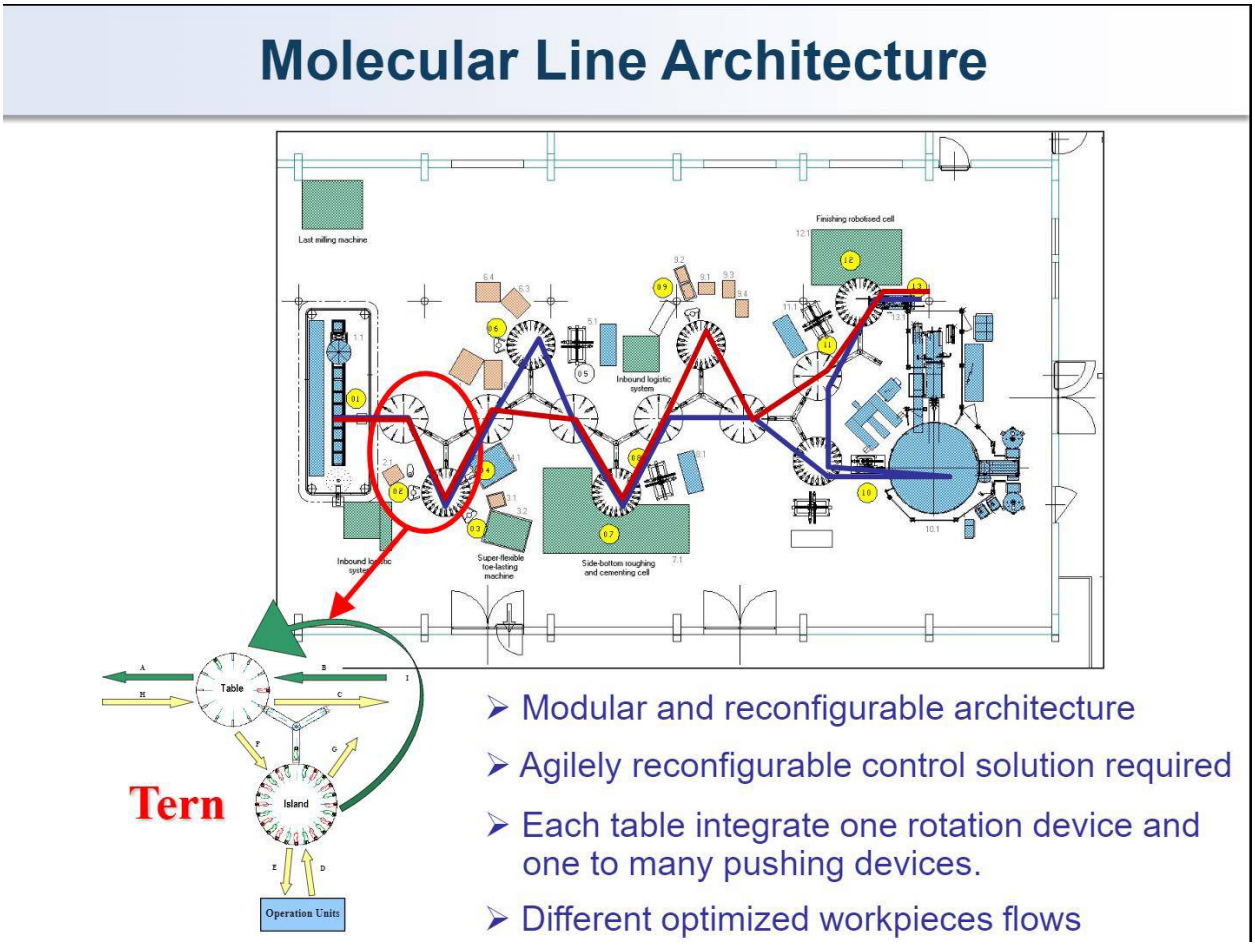
Innovative Shoe Manufacturing Plant



Responsive Manufacturing Plant

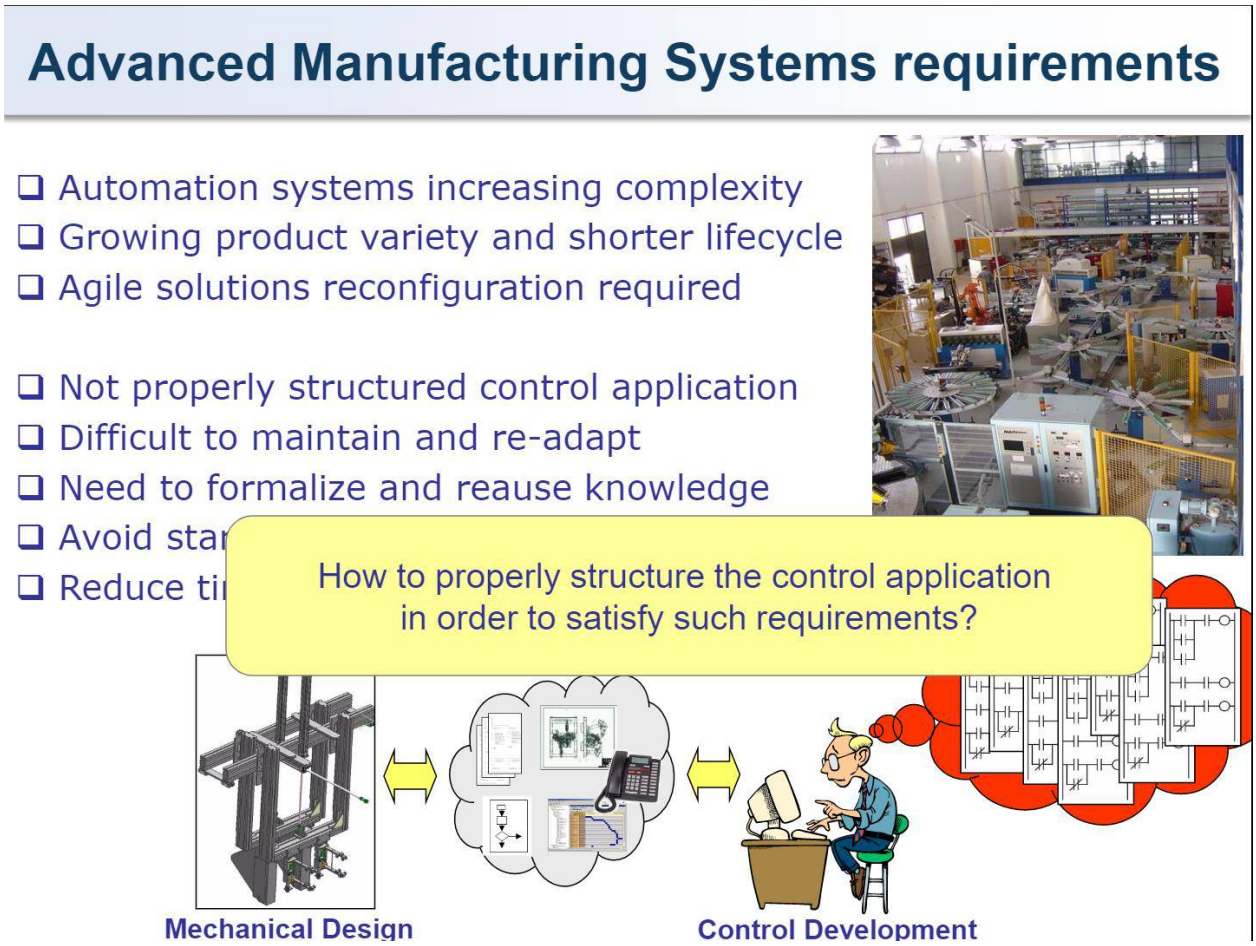
4 Molecular Line Architecture

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



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 reause 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?



6 IEC 6499 Structured design

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

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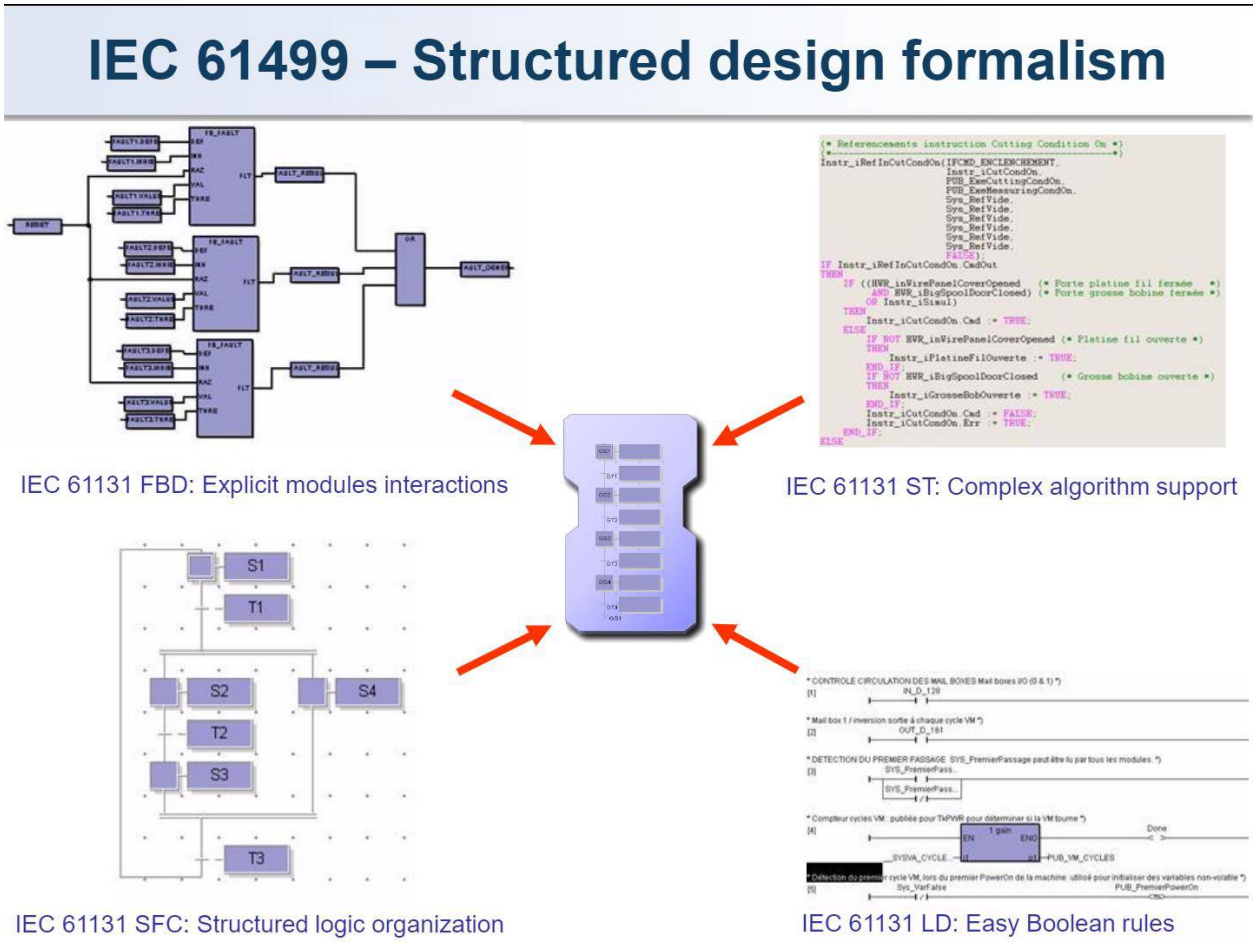

7 IEC 6499 Structured design formalism

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

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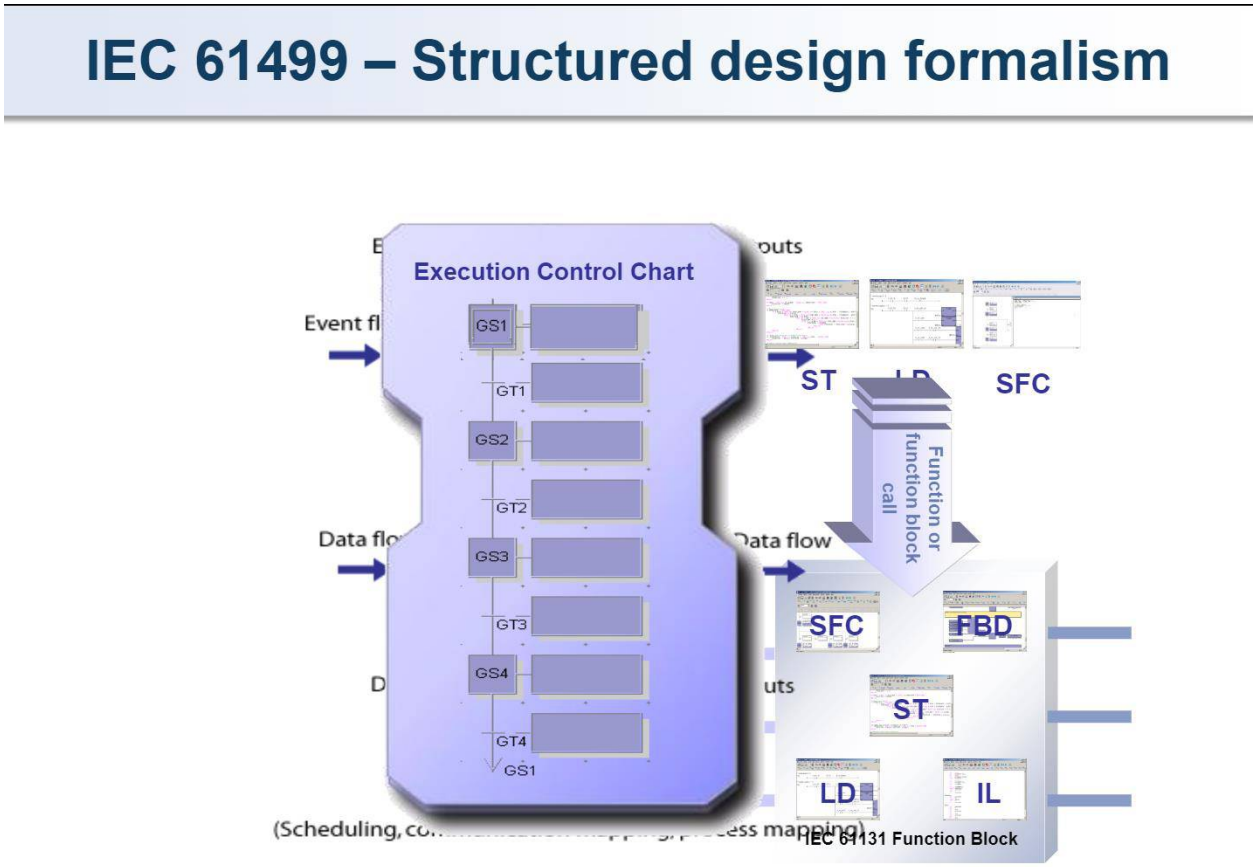

8 IEC 6499 Structured design formalism

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

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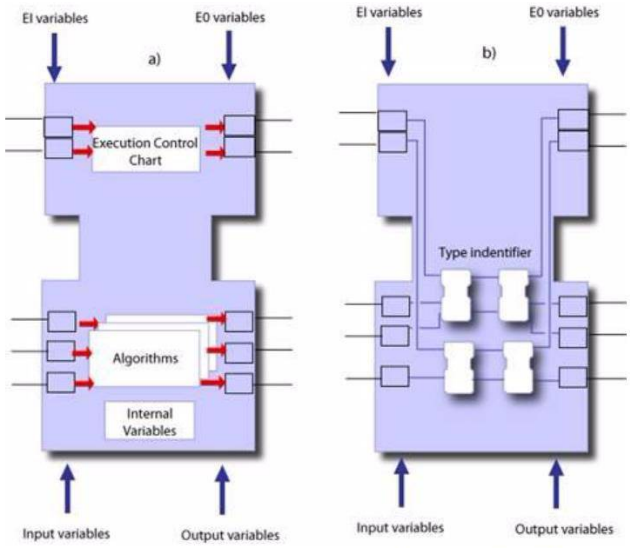
IEC 61499 – Structured design formalism



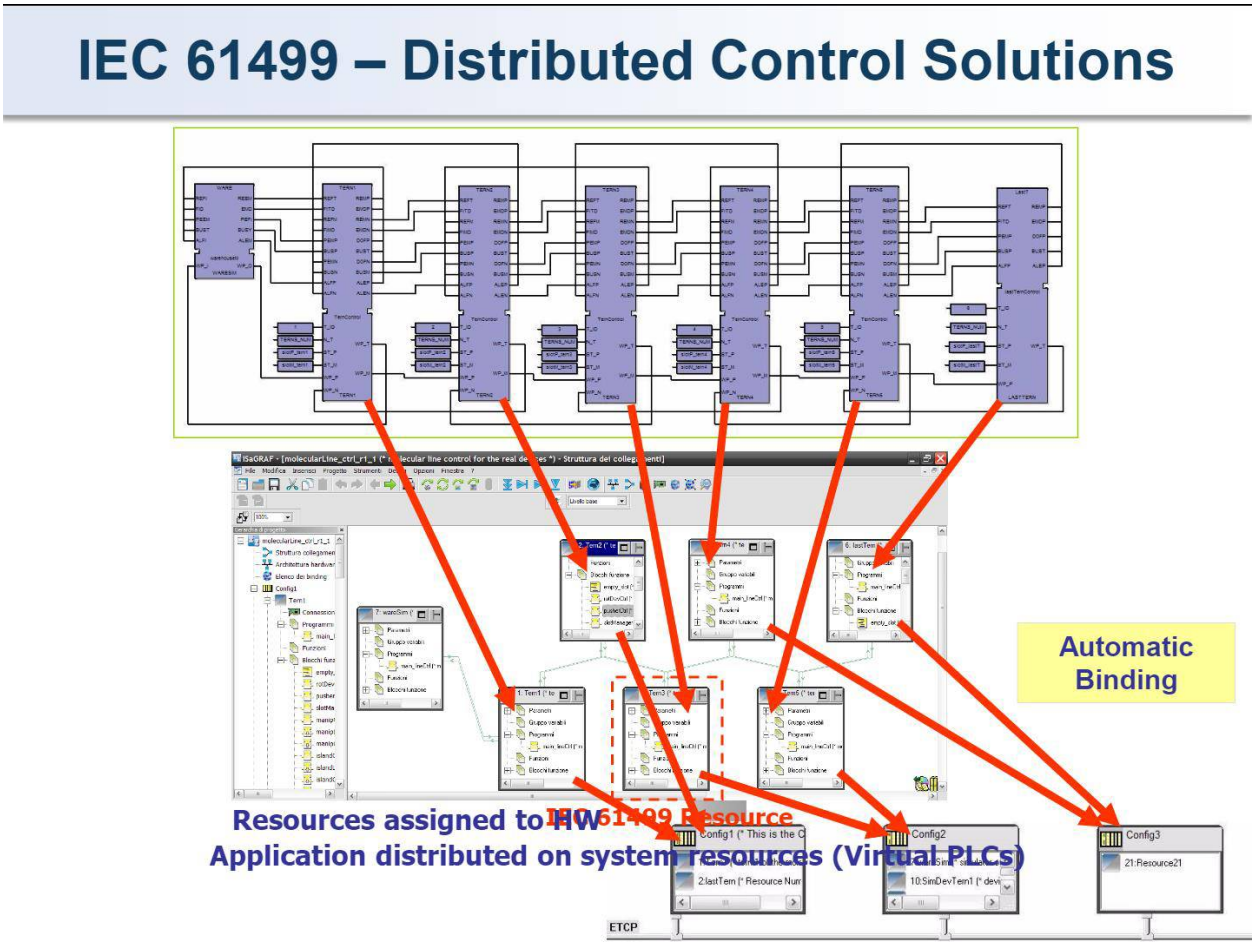
Basic FB *Composite FB*

Structured approach supported by Composite Function Blocks:

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

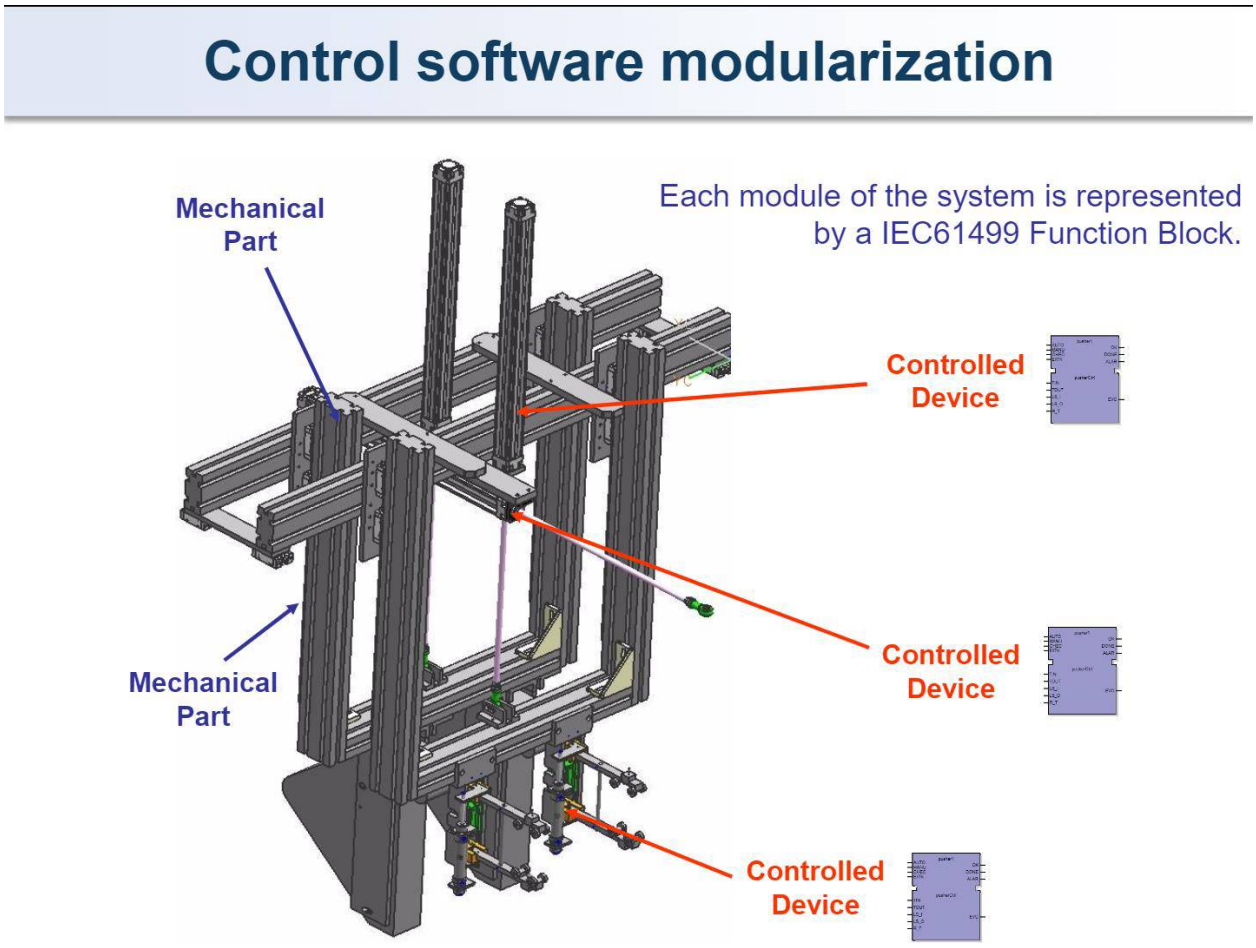
9 IEC 6499 Distributed Control Solutions

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



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



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 PROCCESSES Algorithms Output Data Output Parameters

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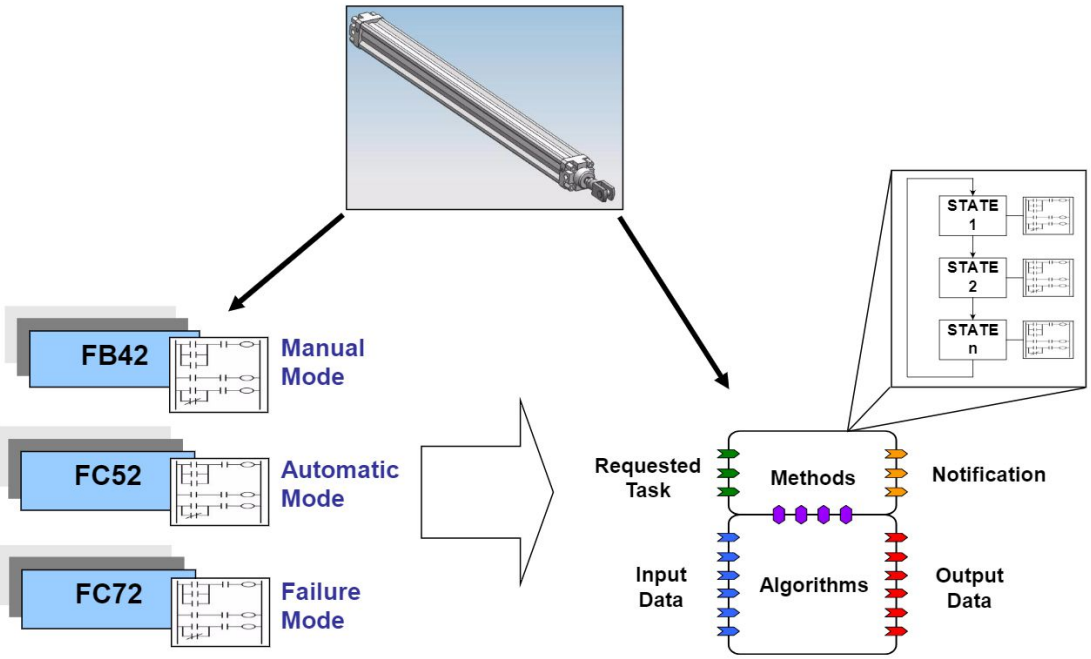
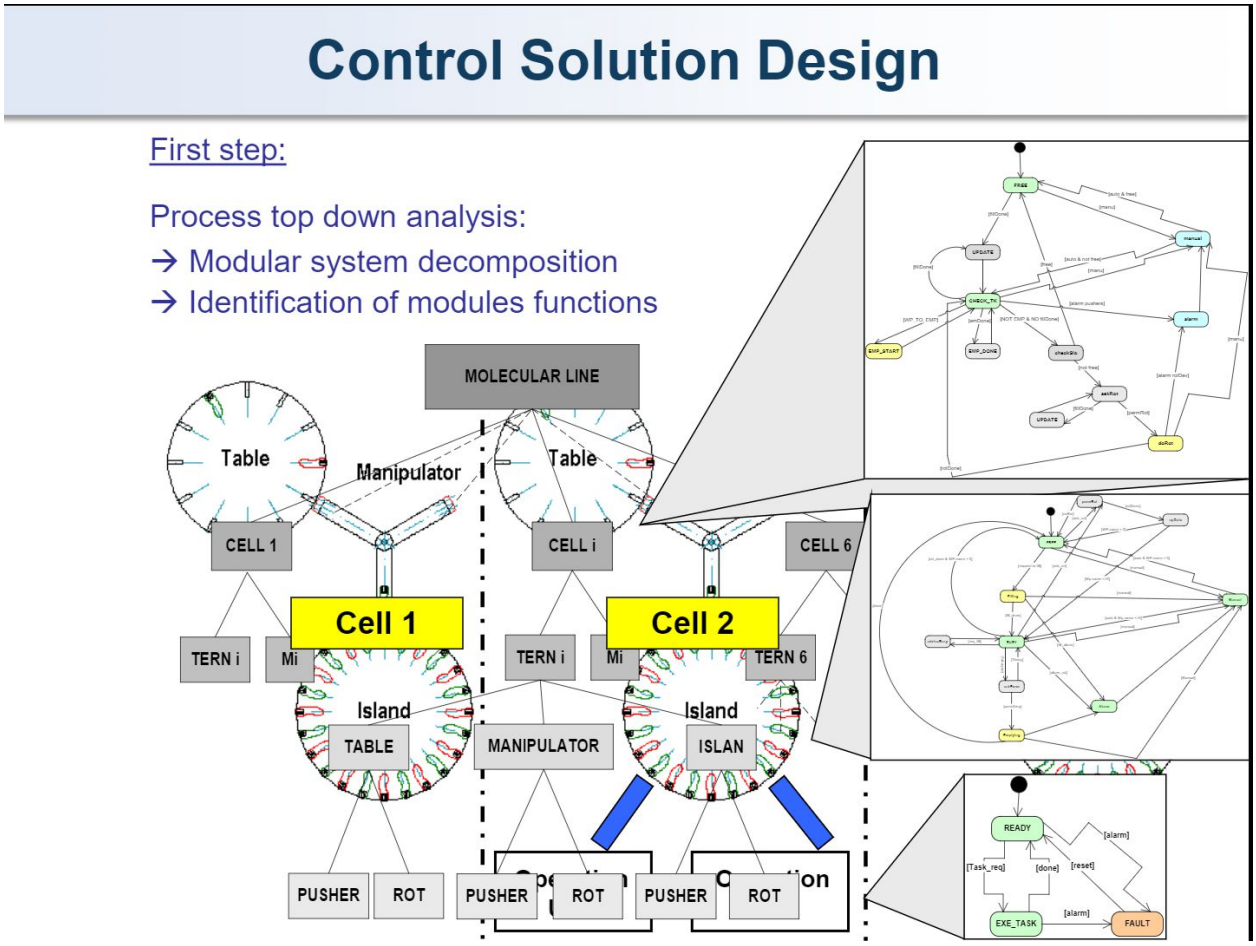
Control software modularization

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



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

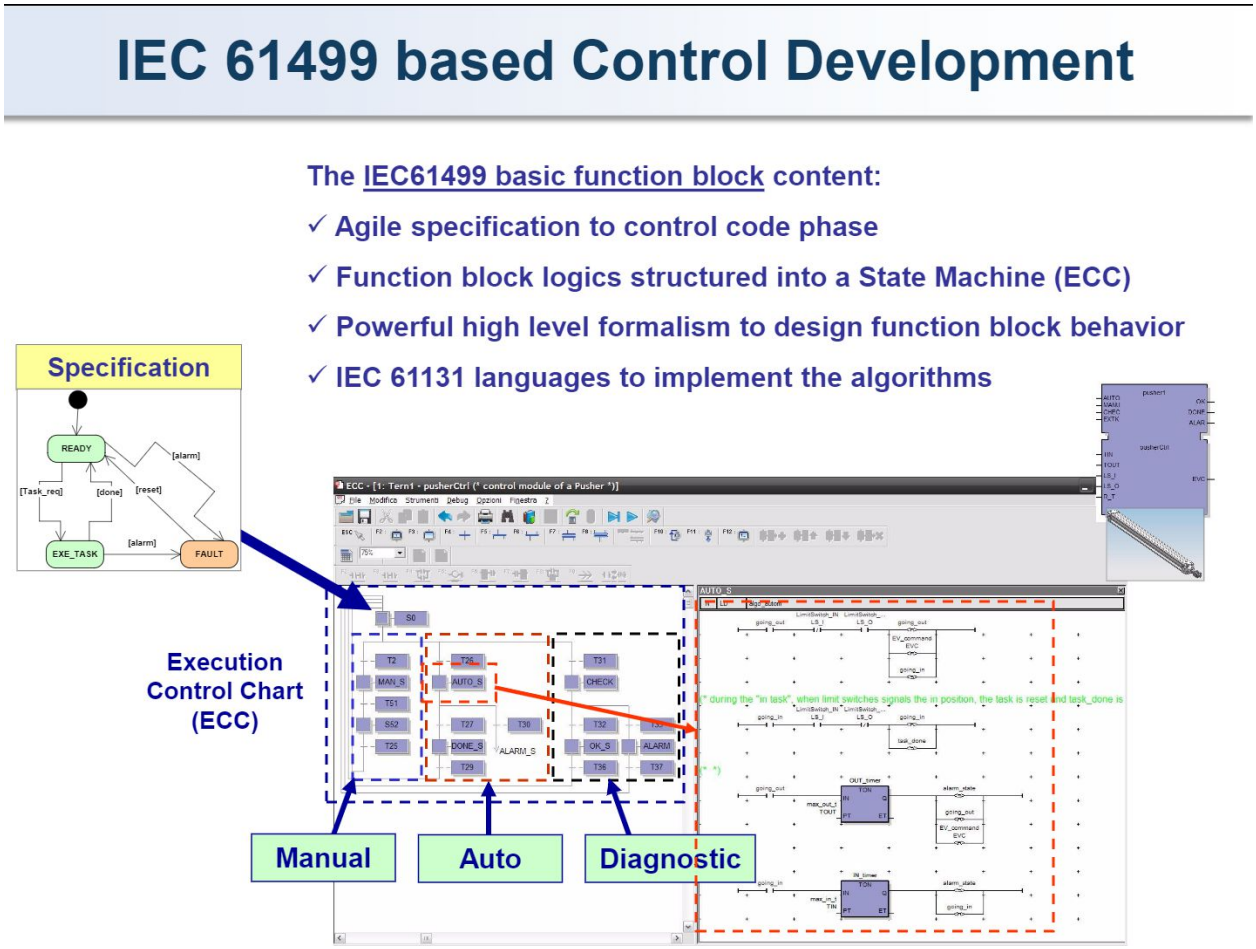
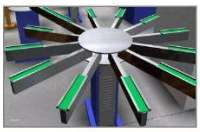
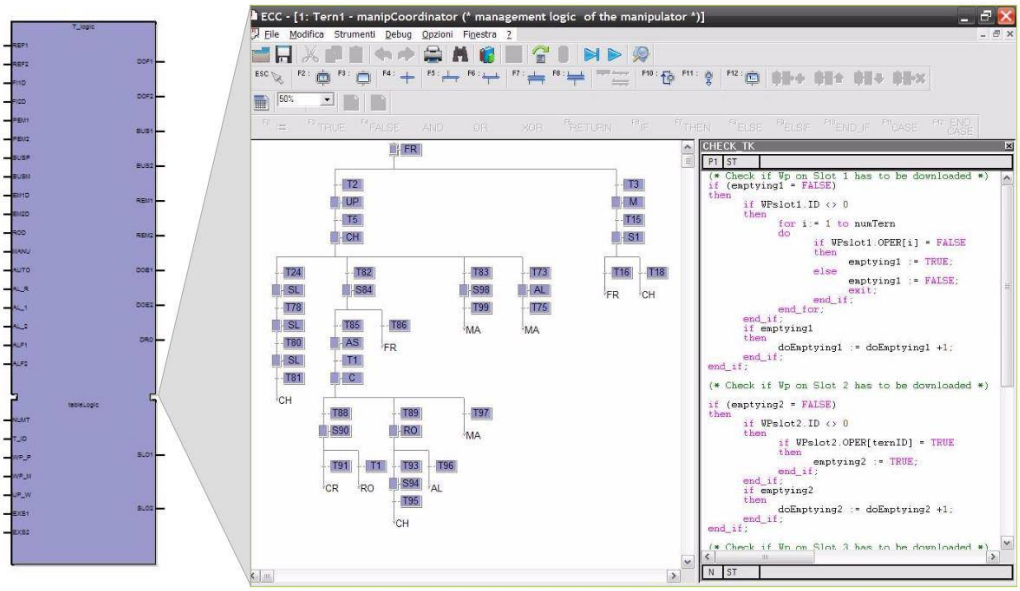


Table Manager IEC 6499 Function Block -

IEC 61499 based Control Development

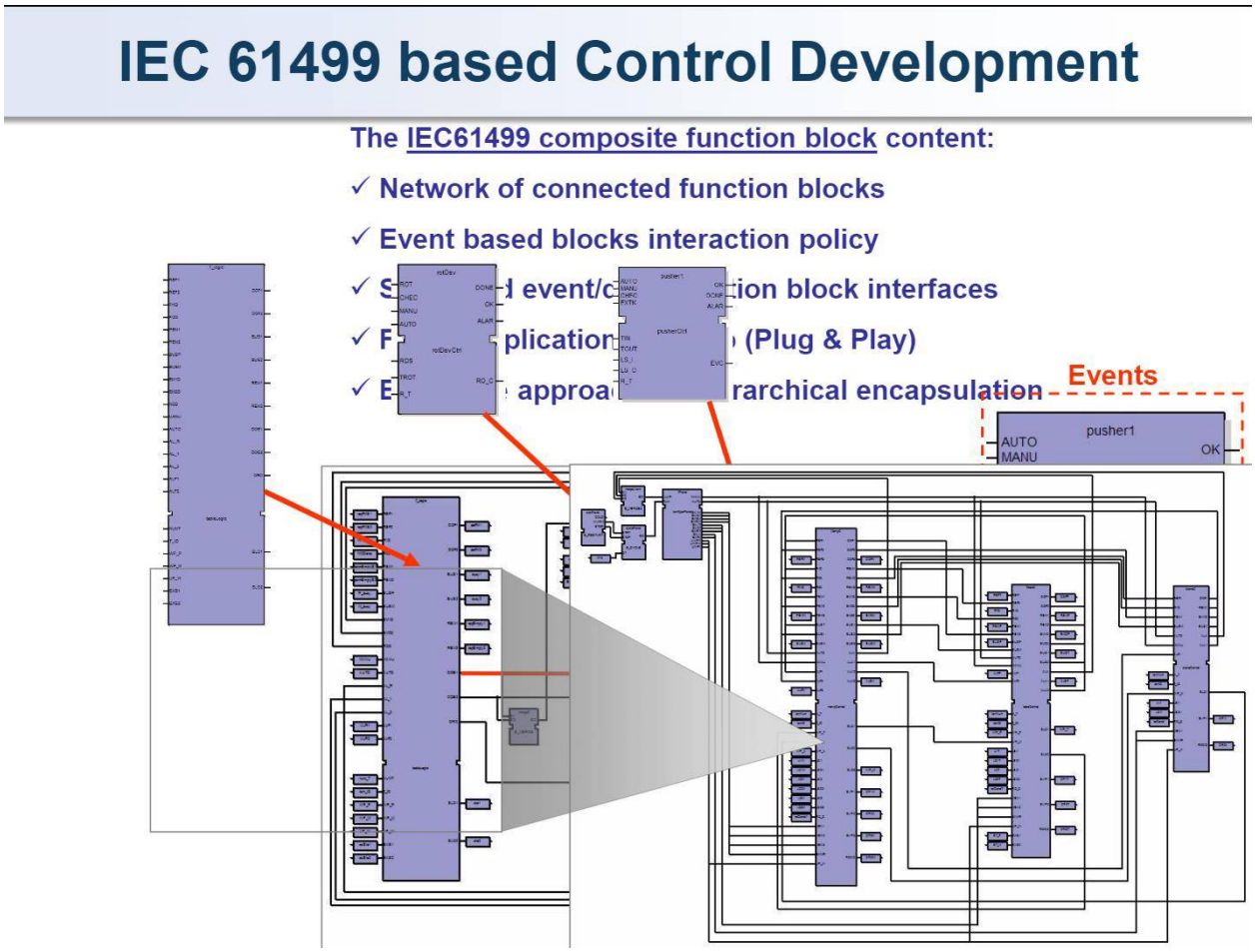
- Table Manager IEC 61499 Function Block -



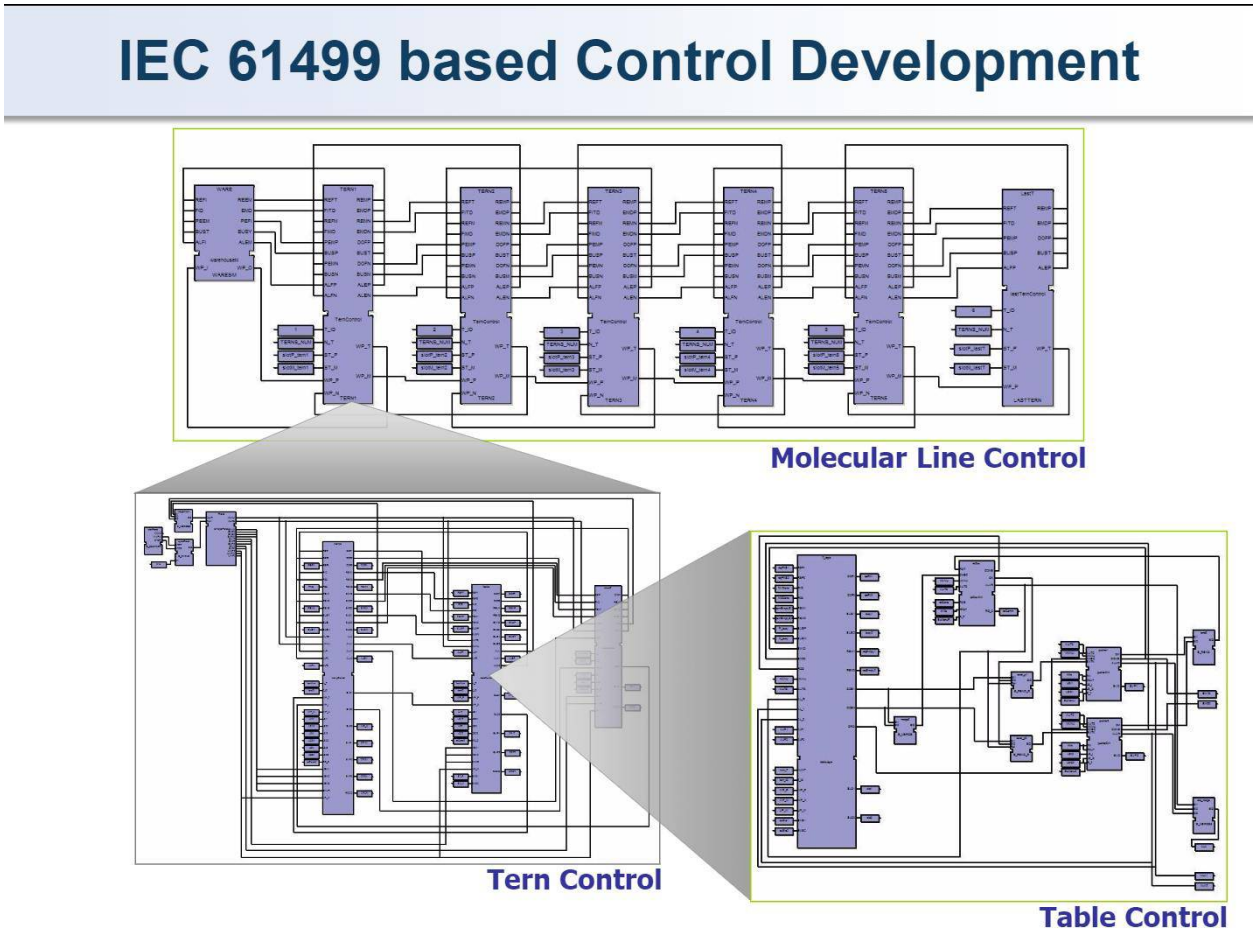


15 IEC 6499 based Control Development

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

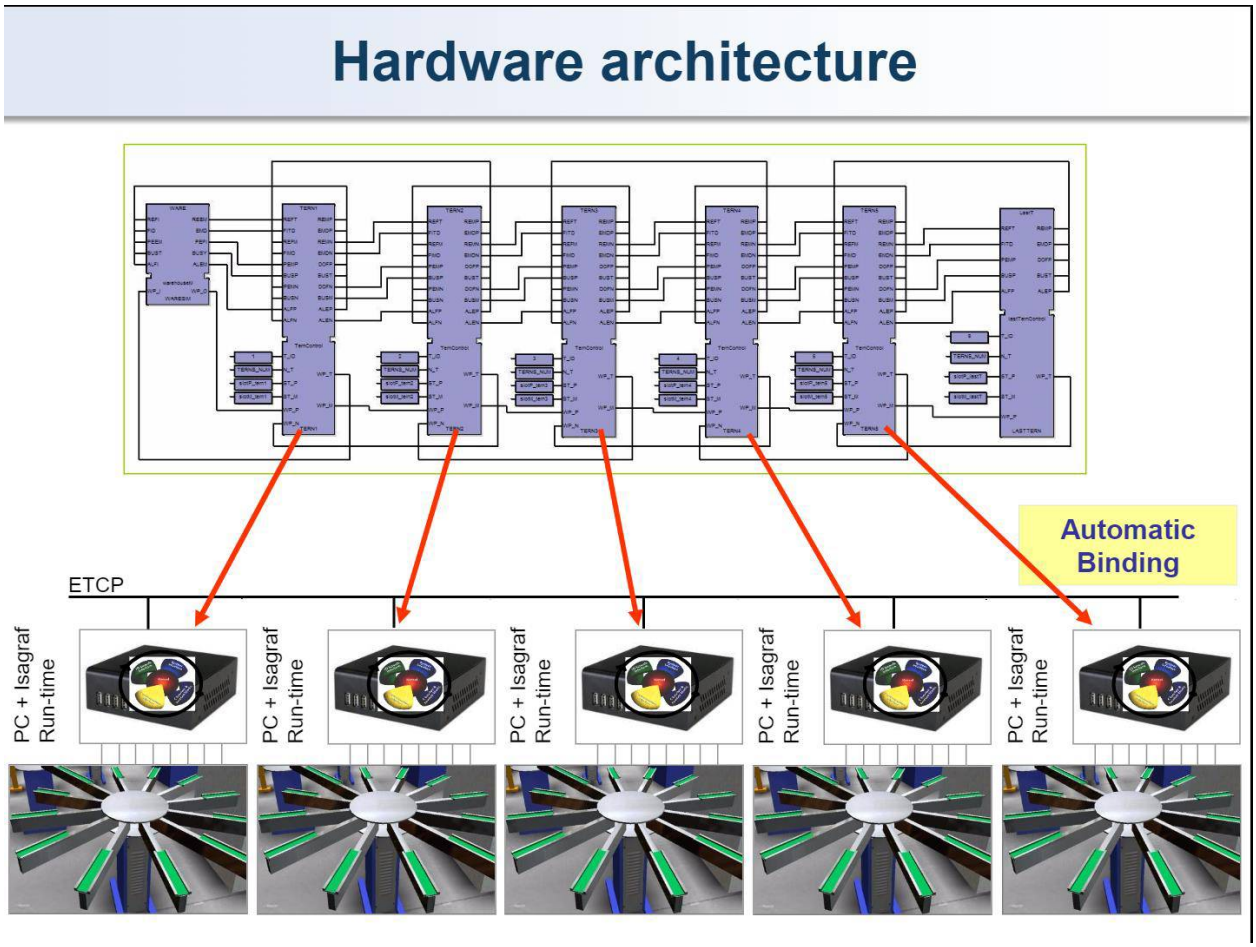


Molecular Line Control Tern Control Table Control



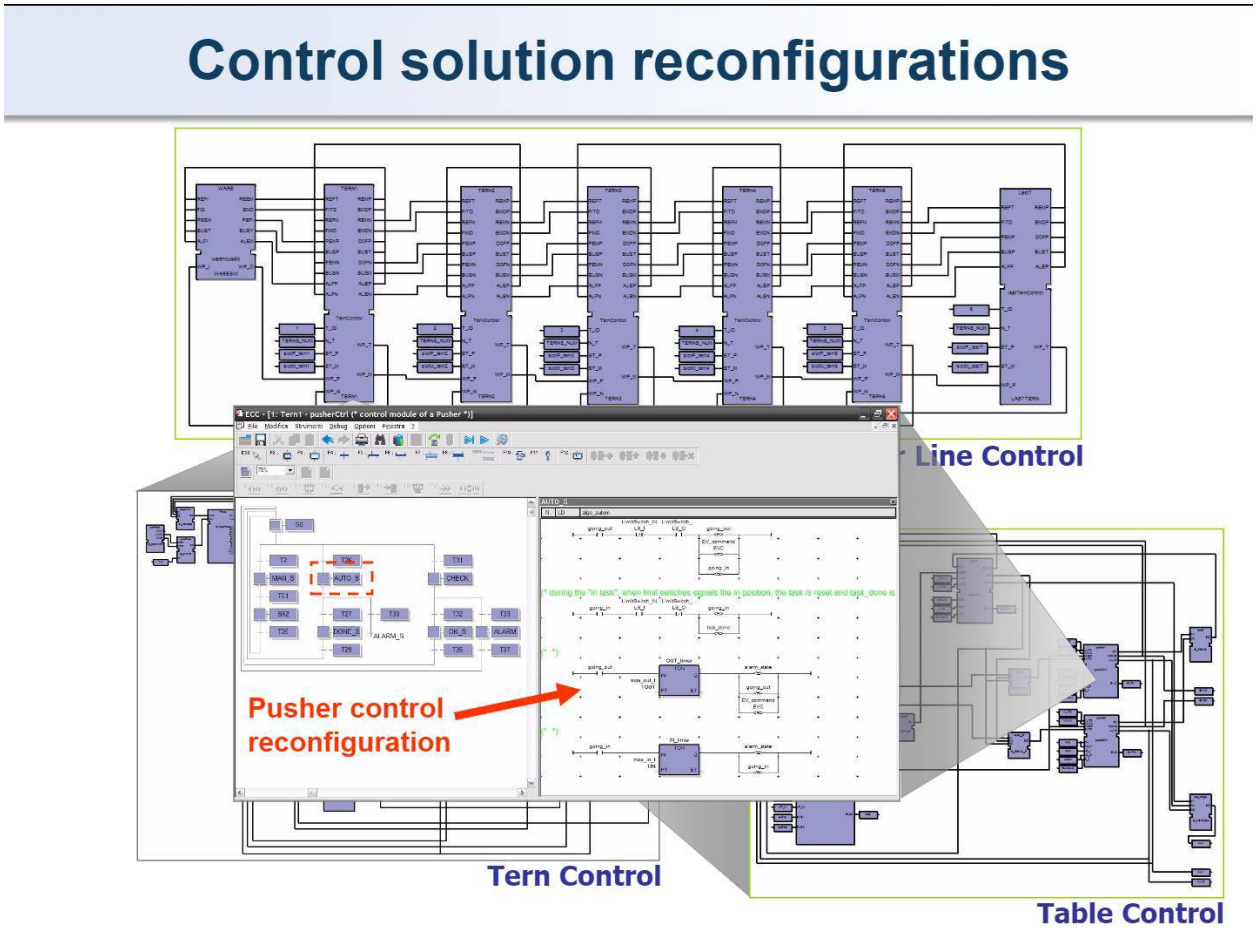
17 Hardware architecture

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



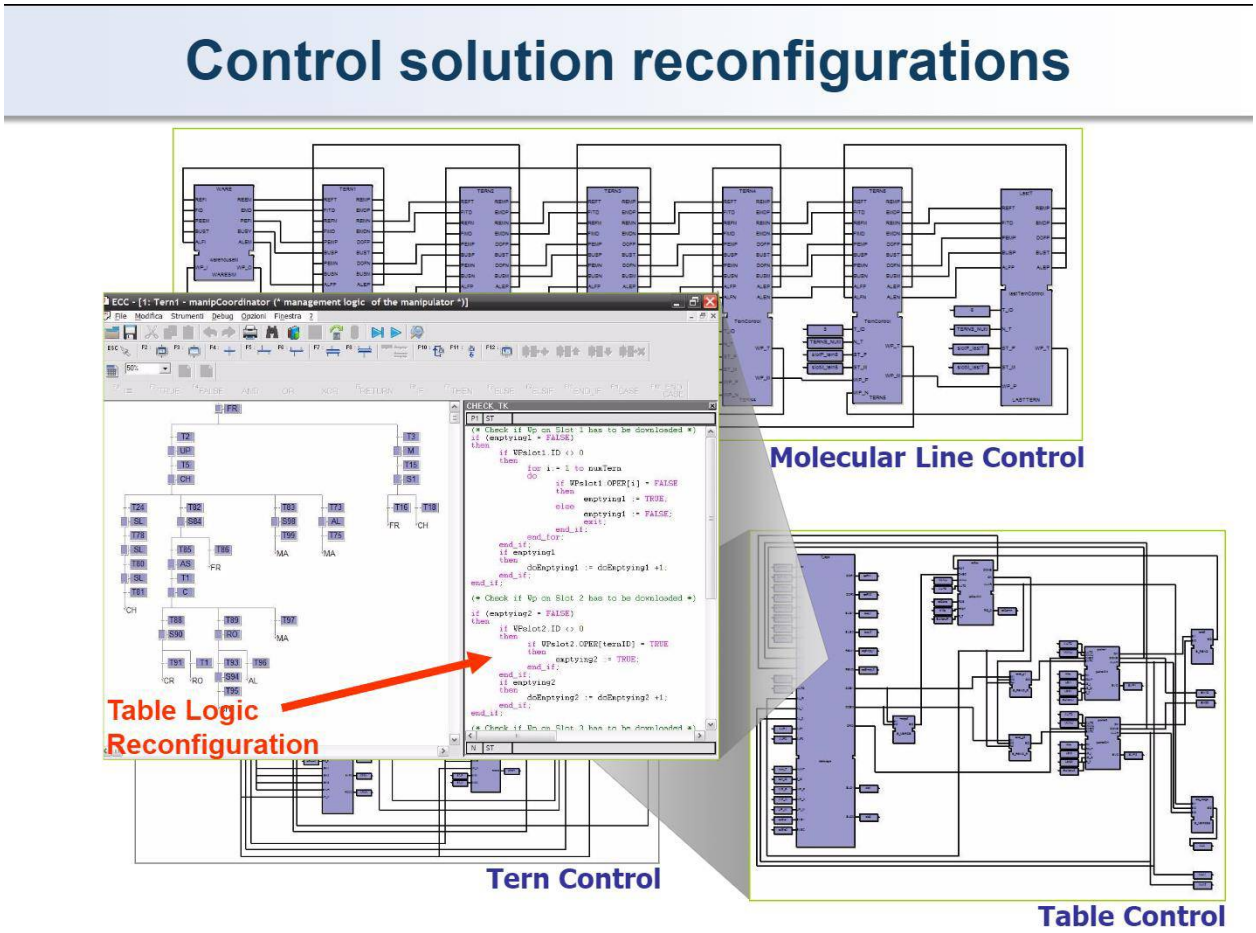
18 Control solution reconfigurations

Molecular Line Control Pusher control reconfiguration Tern Control Table Control

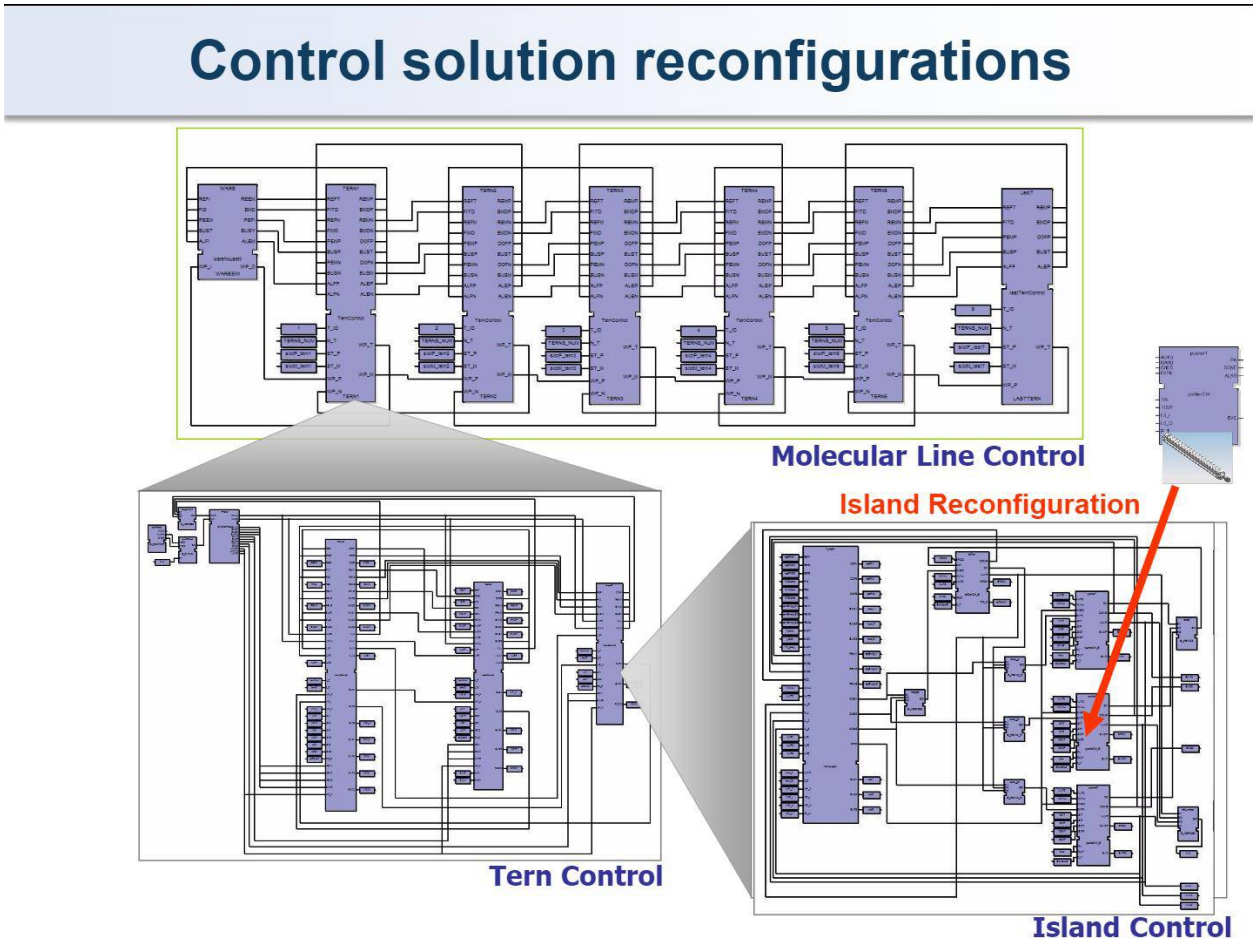


19 Control solution reconfigurations

Molecular Line Control Table Logic Reconfiguration Tern Control Table Control



Island Control Molecular Line Control Island Reconfiguration Tern Control



21 New cell integration

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

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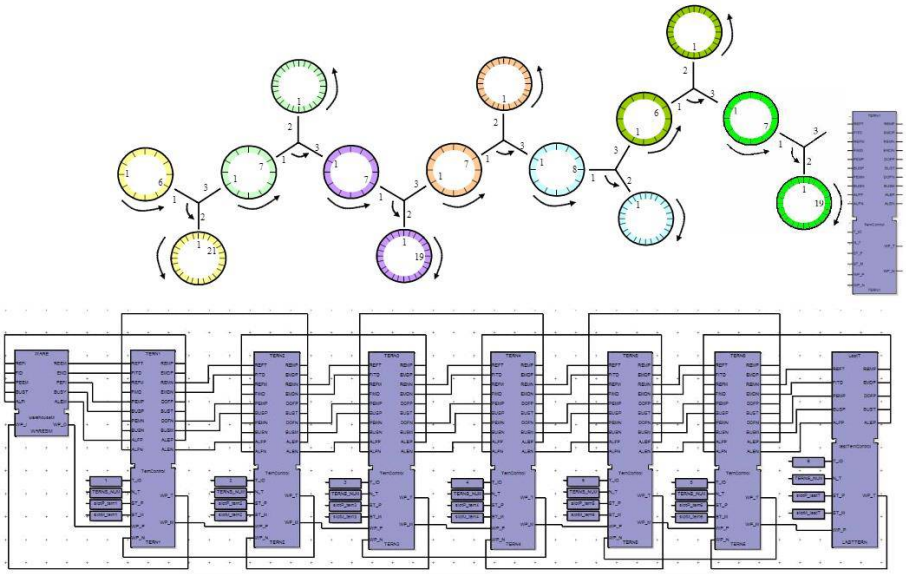
Control solution reconfigurations

- New cell integration -



→ Add FB Instance into the application, connect & play

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

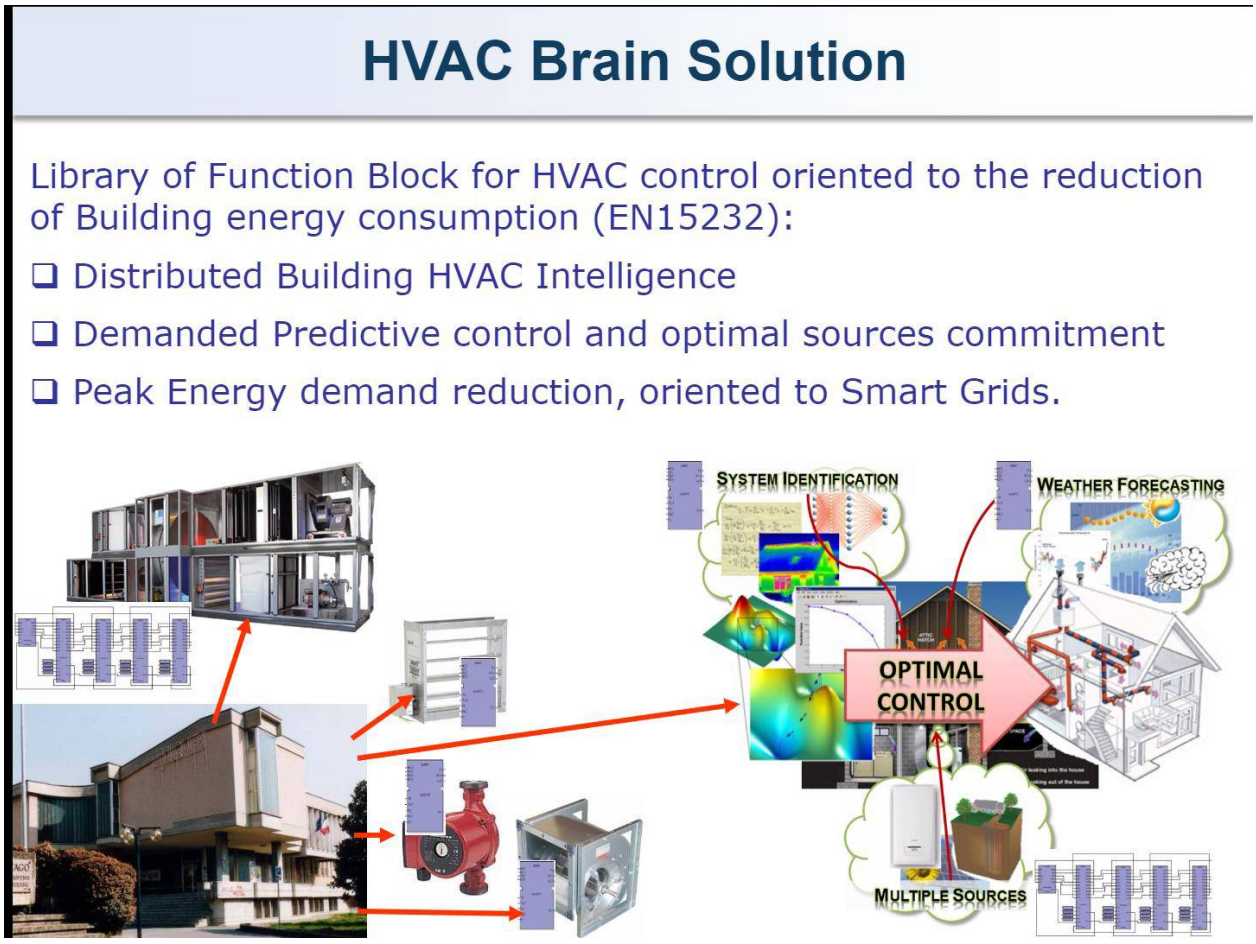
Main emerged benefits

- 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.



24 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. Already Installed on two Pilot Buildings in Italy. Validation ongoing! In collaboration with: