BEMO-COFRA

Brazil-Europe MOnitoring and COntrol FRAmeworks

(Project No. 288133)

D2.1 State of play in production monitoring and control systems

Published by the BEMO-COFRA Consortium

Dissemination Level: Public

Project co-funded by the European Commission within the 7th Framework Programme
and
Conselho Nacional de Desenvolvimento Científico e Tecnológico
Objective ICT-2011-EU-Brazil

Document version: 1.0 Submission date: 2011-12-01

Document control page

Document file: D2.1 State of play in production monitoring and control systems_v1.0
Document version: 1.0
Document owner: COMAU

Work package: WP2 – Requirements Engineering and Validation
Task: T2.1 State of Play
Deliverable type: **R**

Document status: ☒ approved by the document owner for internal review
☒ approved for submission to the EC

Document history:

Version	Author(s)	Date	Summary of Changes made
0.1	Juliana Nogueira Vilela (COMAU)	2011-11-09	Content.
0.2	Juliana Nogueira Vilela (COMAU)	2011-11-17	Minor structural things and content.
0.3	Juliana Nogueira Vilela (COMAU)	2011-11-30	Translate corrections and content.
1.0	Juliana Nogueira Vilela	2011-12-01	Ready for submission.

Internal review history:

Reviewed by	Date	Summary of comments
Trine F. Sørensen and Helene Udsen (IN-JET)	2011-11-10	Structural things and content suggestions.
Pietro Cultrona (COMAU)	2011-11-28	Minor structural things and feedback.
Gonzalo Alcaraz (ISMB)	2011-12-01	Approved with comments.

Index:

List of Figures

1. Executive summary

This deliverable D2.1 "State of play in production monitoring and control systems" is the result of task T2.1 State of Play. It is a description of current manufacturing processes used in automotive manufacturing industries.

The complete car manufacturing process requires large investiments and a great deal of space and manpower, so automotive manufacturing industries only retain in house part of the production process. The usual manufacturing processes that are in the industries are: power train plant, body welding, painting shop and final assembly.

The focus of this deliverable is body welding and assembly line (BWA). BWA is characterized by advanced production systems for vehicle full body, body components manufacturing and complete turn key body shops with focus on cost-effective low, medium and high volume body welding and assembly systems. This process has as mission to assemble a multitude of panels and braces by welding, bolting or gluing processes all parts that compose a car body.

BWA solutions are designed to offer maximum flexibility of the production plant. So the controls architecture used in a BWA line is continuously changing and envolving, from a centralised controls architecture in direction of a fully distributed controls architecture. A modular architecture permits for example an easy change of line arrangement, specialy for BWA line that has a huge number of devices and robots.

For the correct behavior of BWA operations several electronic devices are used, as RFID to identify the part to be worked, electronic controllers to manage proper sequence of operations, drivers and position sensors perform accurate positioning and more.

This deliverable covers processes, precise definition of single roles and procedures, together with control logic (process model) of a BWA line. The identification is based on a COMAU's cases of body welding and assembly line of production plants from Brazil and Europe.

2. Introduction

2.1 Overview of the BEMO-COFRA project

The BEMO-COFRA project aims to develop an innovative distributed framework which allows networked monitoring and control of large-scale complex systems by integrating heterogeneous smart objects, legacy devices and sub-systems, cooperating to support holistic management and to achieve overall system efficiency with respect to energy and raw materials.

The BEMO-COFRA features a Service oriented Architecture (SoA) and a middleware able to expose smart objects, legacy devices and sub-systems' capabilities by means of web services thus supporting syntactic and semantic interoperability among different technologies coexisting in the overall monitoring and control framework. Wireless Sensor and Actuator Network (WSAN) devices, legacy sub-systems and devices will thus be able to interact and cooperate, orchestrated by a manager in charge of enforcing a distributed logic with the overall monitoring and control network.

BEMO-COFRA reuses the results of the well-reputed Hydra IP and Pobicos STREP and the recently started ebbits IP featuring a Service Oriented Architecture (SOA) and a middleware able to expose smart objects, legacy devices and sub-systems' capabilities by means of web services. Syntactic and semantic interoperability among coexisting technologies in the overall monitoring and control framework is made available.

The integration of heterogeneous smart objects, legacy devices and sub-systems will achieve overall systems' efficiency with respect to energy and raw materials and support holistic management. The BEMO-COFRA project will address both technological aspects and user needs to promote a wider adoption of large-scale networked monitoring and control solutions.

2.2 Purpose and context of this deliverable

This document D2.1 State of Play in Production Monitoring and Control Systems describes the current situation of automotive manufacturing industries. The most important automotive production processes and systems and their strengths and weaknesses are described. Automated car production is generally divided into areas dedicated to specific activities, and current solutions in industrial automation can be characterised as having a centralised controls architecture. The process of body welding and assembly (BWA) is explained in detail.

A typical BWA line consist of an intricate collection of loaders, rollers, framers, elevators, conveyors and clamping fixtures, lending itself to the widespread use of robots for picking, loading and welding, but also requiring the involvement of human operators, who typically provide the proper fit for mosto f the bolt-on functional parts of the vehicle with pneumatically assisted tools.

2.3 Scope

This document makes an overview of the state of play in production monitoring and control systems, by providing:

- Accurate identification of current manufacturing processes used in automotive manufacturing industries;
- Description of a Brazilian case;
- Efficiency managerial point of view;
- Precise definition of single roles and procedures, together with control logic (process model);
- Description of specific tasks according to the type, size and focus of selected plant manufacturing cells.

This deliverable completes the first task in WP2 Requirements Engineering and Validation and it plays an essential role for the future work in WP2. It forms the base for the scenario and requirements specification that will be documented in the forthcoming deliverable D2.2 Initial requirements report.

3. The Automotive Manufacturing Industries

3.1 Automotive production processes and systems

Automated car production is generally divided in areas dedicated to specific activities. On the whole car makers retain in-house only part of the production process, as the complete car manufacturing process requires large investments and a great deal of space and manpower. The majority of car manufacturers concentrate their efforts on the following parts of the manufacturing process:

- Power train plant: where engines are machined and assembled
- Body welding (also called ‘body in white shop’): where the body of the car is assembled and welded
- Painting shop: where the body in white is prepared for painting and finally painted and cocked
- Final Assembly: where the painted body is fitted with engine, suspension, trim and all the other parts.

Modern day Industrial Automation Systems control highly complex networks of high performance machine systems executing multi-parameter control of variables like precision motion, force, temperature, flow rate, pressure, etc. Not only is the control and monitoring of all these parameters important, transfer of control signals to and from these Distributed Control Systems to central controllers must be seamless, which makes networking a major component in successful implementation of these open systems. The reason why networking capabilities are needed in industrial Automation systems is threefold:

- To provide connectivity to different machines
- To enable data sharing and gathering
- To define a flexible solution facilitating integration of future advances in technology.

Industrial Automation is commonplace in most conventional manufacturing units. There is increasing pressure that these complex controls with extremely high throughputs and miniaturisation are implemented with cost-effective electronics and robust software. Though high-end machines for advanced industries are built in relatively smaller volumes compared to consumer goods, the need to curtail capital expense on them is borne out of the need for cheaper end products, and hence the need for each successive generation to perform at higher levels and lower cost. Combinations of high-speed data bus and fast embedded processors enable new cost-effective, high-performance architectures for advanced machine design and other real-time automation tasks. The industrial adoption of components originally designed for higher volume consumer applications are a certainty for the next generation of industrial controls.

The main weaknesses of present manufacturing systems, which highly affect overall efficiency and reduce competitiveness, basically refer to the following aspects:

- Process integration: limited integration among the processes involved in the engineering and management of the plants
- Flexibility: inadequate flexibility of the production plant, with limited capability for handling variations in product mix and volumes

- Scalability and reconfigurability: production systems are not designed to be easily reconfigurable
- Manufacturing efficiency: the monitoring of productivity is affected by low diagnostics capacity; there are usually no efficient instruments to detect engineering errors and to prevent installation problems, as well as efficient data logging to enable predictive maintenance
- Ramp-up time: the time to reach full production capacity is often too long and therefore too costly.

Current solutions in Industrial Automation Controls can be characterised as Centralised Controls Architecture. Backplane Based controllers were considered to be natural choices for the designers of yesterday as it was assumed that they could provide the high communication speeds needed for Industrial processes like synchronising motion, synchronising images and data acquisition. The rackmounted backplane which is the standard implementation for most Industrial and Laboratory Automation controllers uses bus solutions like VME, VXI, and PXI in addition to proprietary buses like Modbus. In recent times PCI buses have gained popularity in this market segment owing to the penetration of Windows based PCs.

In the conventional architecture, all sensors, motors, digital inputs and outputs and analogue signals are cabled from the point of use to converge at the centralised controllers with individual backplane cards designed to handle each specialised function. All signals are brought to the physical location of the system controller using multi-wire cable bundles. Machine Systems typically use several specialised backplanes to implement different control functions. Bus to bus communication between various subsystems is often through traditional RS-232/422/485 serial communication channels or through bus converters. This centralised approach limits reliability and configurability as hundreds of conductors are required to route signals to the central control chassis.

Overall, this traditional approach is cumbersome, relatively large and more expensive. Another big problem is the software used for controllers. Due to the lack of standard interfaces, different vendors have different software approaches for the development of various subsystems, and to integrate them has proved to be expensive and time-consuming.

To avoid the use of a centralised backplane based system, it is important to localise control of devices performing similar functions. This Distributed Control System (DCS) architecture uses some form of serial or parallel cable to link already digitised information from point of use. In DCS analogue signals are quickly digitised, and functions that do not need to be centrally supervised are localised. The advantages of using DCS are as follows:

- Greater Signal integrity (S/N) by reducing the distance that analogue signals must travel before they are digitised, important in applications where signal-to-noise ratio maximisation is demanded
- Cabling can be simplified and functional sub-systems can be modularised. These subsystems can be then plugged into bigger and more complex networks hence simplifying system configuration
- Remote monitoring of signals or control functions over a local area or public network is simpler with DCS architecture as it is inherently packet driven.

Many distributed control schemes have been developed and implemented for industrial applications over the past three decades. The oldest ones were based on Fieldbus and its derivatives with newer technologies like DeviceNet, Can or Profibus taking over. These buses had data transfer rates in the range of only a few MB/s which was far lower than backplane buses like VME or PCI. This hampered the adoption of DCS-based architecture by a majority of system designers even though distributed control systems were far more efficient compared to backplane based industrial automation systems.

Another point that turns the automation solutions less flexible reducing competitiveness is the way that the data is transfered among the manufacturing cells. Nowadays, a big part of these data is transfered by network cables that difficult a modification on the cell structure or a simply chage of place on the manufacturing sequence of the line. The use of wireless technology is a great improvement to guarantee more flexibility and reconfigurability at manufacturing scenario. The only concern is the fact that this technology is very affected by the environment.

The Body Welding and Assembly is the hardest environment in an automotive manufacturing industry and because of this the use of wireless devices is not yet widely accepted, as they could not work in a predictable way. So to guarantee that the framework proposed at this project will be run at all manufacturing scenario it will be based on and tested at a BWA line.

3.2 Body welding and assembly

The floor panel is the largest body component to which a multitude of panels and braces will subsequently be either welded or bolted. As it moves down the assembly line, held in place by clamping fixtures, the shell of the vehicle is built. First, the left and right quarter panels are robotically disengaged from pre-staged shipping containers and placed onto the floor panel, where they are stabilised with geometric fixtures and welded.

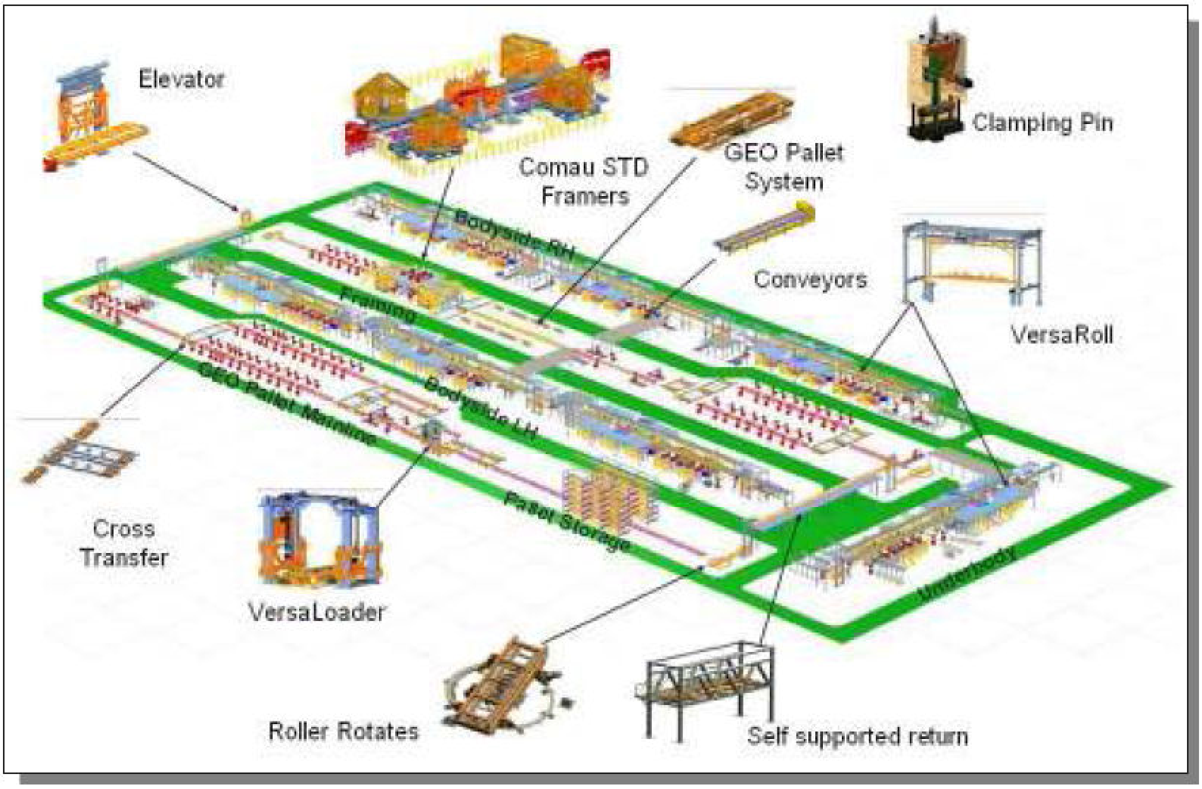

Figure 1 Body welding and assembly line

The front and rear door pillars, roof, and body side panels are assembled in the same fashion. The shell of the automobile assembled in this section of the process lends itself to the use of robots because articulating arms can easily introduce various component braces and panels to the floor panel and perform a high number of welding operations in a timeframe and with a degree of accuracy no human workers could ever approach. Robots can pick and load roof panels and place them precisely in the proper position for welding, assisted by vision devices.

The body is built up on a separate assembly line from the chassis. Robots once again perform most of the welding on the various panels, but human operators are necessary to bolt the parts together. During welding, component pieces are held securely in a jig while welding operations are performed.

As the body moves from the isolated welding area of the assembly line, subsequent body components including fully assembled doors, deck lids, hood panel, fenders, trunk lid, and bumper reinforcements are installed. Although robots help workers place these components onto the body shell, the workers provide the proper fit for most of the bolt-on functional parts using pneumatically assisted tools.

The controls architecture used in Body Welding and Assembly is continuously changing and evolving, from a centralised controls architecture in the direction of a fully distributed controls architecture. In the near future the architecture can be expected to be as shown in the figure below.

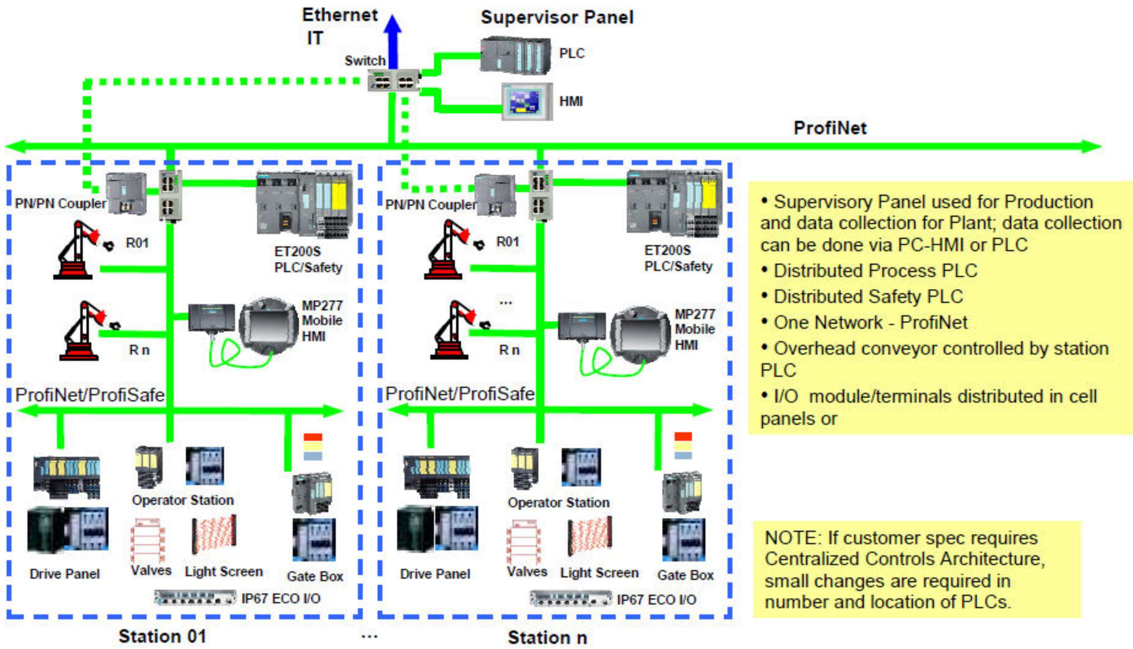

Figure 2 Fully distributed Controls architecture

Contemporary body welding and assembly is characterised by advanced production systems for vehicle full body, body components manufacturing and complete turnkey body shops with focus on cost-effective low, medium and high volume body welding and assembly systems.

BWA solutions are designed to offer maximum flexibility of the production plant. New product lines introduced on the market typically have the following distinctive characteristics:

- Self-contained large sub-assembly manufacturing machines
- High-speed part transfer systems
- Selectable and flexible station processes
- Capable of 4+1 model random or infinite model batch production.

These novel solutions offer excellent performance in the automated plant, featuring

- High flexibility, by way of modularity of all devices and structure
- Low time-to-market, accomplished by simple and rapid assembly operations
- Better process quality, through innovative positioning of robots, allowing all-points access
- Decreased cycle times via high-speed transportation systems
- Lower running costs, operators can access from under the structures for maintenance.

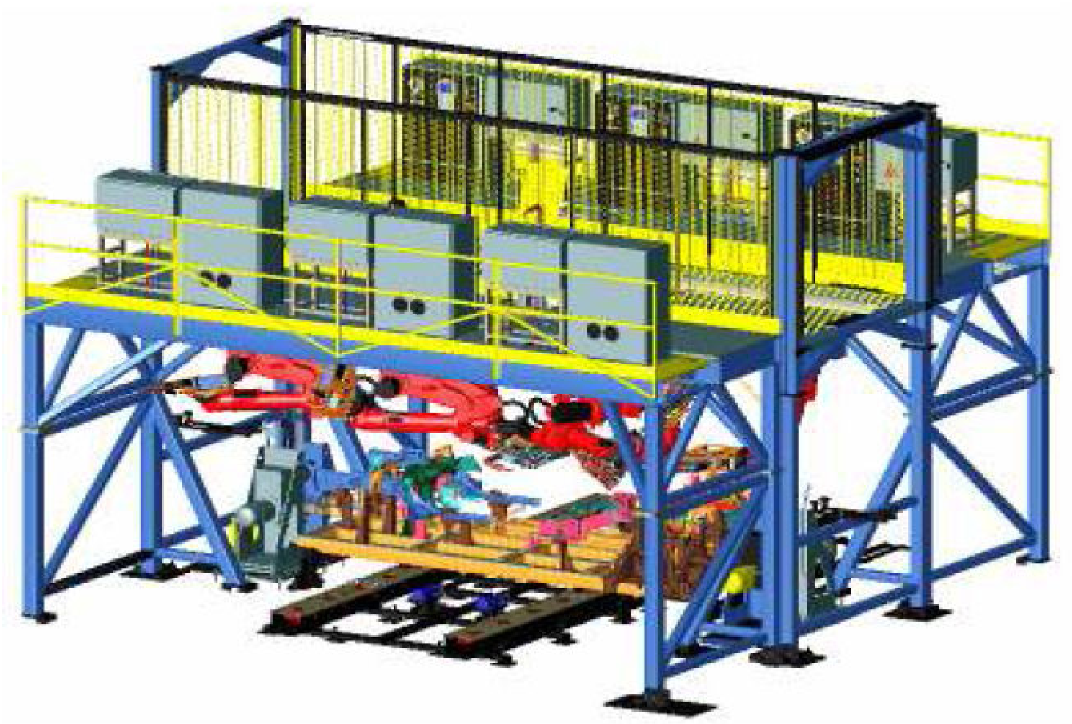

Figure 3 Access from below

The solutions are characterised by the modularity of the structure to be assembled in the production plant, requiring less space to perform the same operation. Moreover, the modular design of the production station allows rapid design of the production flow of the plant, without the need for any particular custom design.

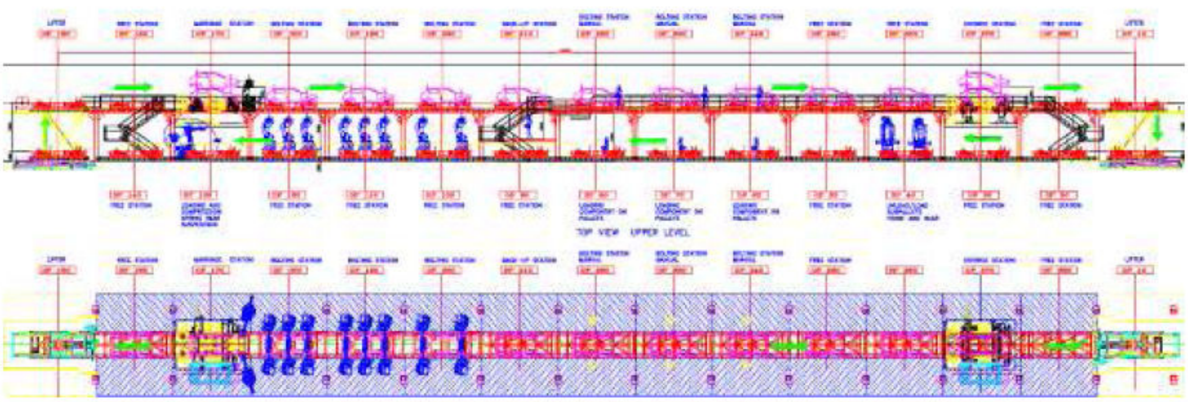

Figure 4 Body welding and assembly line

3.3 Brazilian Case – COMAU's Body Welding and Assembly Line

3.3.1 Overview – Brazilian case

COMAU's Body Welding and Assembly line case described is composed by a three model promiscuous line divided in:

- Underbody – Tabbing and Framing
  - Body welding and assembly line with 11 stations (manual and automatic)
  - System of accumulation/transfer of chassis to tabbing with capacity to 8 sets
  - Line of Tabbing and Framing with 09 stations (manual and automatic)
  - The lines must have a system to ensure the management and proper assembly of the 03 models with different versions of base and safety
- Motor Compartment
  - Line of assembly of Motor compartment with 08 stations (manual and automatic)
  - Line of assembly of Front rail with 04 manual stations
  - The lines must have a system to ensure the management and proper assembly of the 03 models with different versions of base and safety
  - Transfer system of Motor Compartment's lines by Shuttle
  - Transfer system of Front rail's lines by 'Pick & Place'
- Rear Floor
  - Line of assembly of Rear floor with 06 stations (manual and automatic)
  - The lines must have a system to ensure the management and proper assembly of the 03 models with different versions of base and safety
  - Transfer system of lines by Shuttle

3.3.2 System Specifications – Brazilian case

Table 1 System Specifications - Brazilian case

Description	Specification
Hours per Day	20,75hs
Journey/Day	3
Capacity	45,0jph
Efficiency considered	90%
Maximum cycle time per station	80s
Maximum complete cycle time of transfer per line by Shuttle	20s
Maximum complete cycle time of transfer per line with SKID*	20s

*SKID: a little car where the car body goes on top.

3.3.3 Energetic Specifications – Braszilian case

Table 2 Energetic Specifications - Brazilian case

Description	Specification - Brazil
Power Supply	440V
Frequency	60 Hz
Pneumatic pressure	6 bar

3.3.4 Description of Manufacturing Process – Brazilian case

3.3.4.1 Front Rail

STATION (S) 10 Geometry welding platform with dash panel

- Manual loading with platform's pneumatic hoist
- Manual loading of Dash Panel
- Activation of the push buttons and closing of the clamps
- Manual spot welding of geometry
- Activation of the push buttons and opening of the clamps
- Pick & Place's automatic transfer

S20 Geometry welding Front rail

- Automatic loading of the previous station's set
- Manual loading of the lower parts Left Hand (LH) and Right Hand (RH)
- Manual loading of the crash box lane
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps
- Pick & Place's automatic transfer

S30 Completion and geometry welding port lights

- Automatic loading of the previous station's set
- Manual loading of the port lights lane
- Activation of the push buttons and closing of the clamps
- Manual spot welding of geometry and completion
- Activation of the push buttons and opening of the clamps
- Pick & Place's automatic transfer

S40 Geometry welding lower parts and port lights

- Automatic loading of the previous station's set
- Manual loading of the lower parts LH and RH
- Manual loading of the crash box lane
- Activation of the push buttons and closing of the clamps
- Manual spot welding of geometry

- Activation of the push buttons and opening of the clamps
- Pick & Place's automatic transfer

3.3.4.2 Motor Compartment

S10 Completion welding

- Shuttle's automatic transfer
- Automatic loading by Pick & Place of previous station's set
- Activation of the push buttons and closing of the clamps
- Manual spot welding of completion
- Activation of the push buttons and opening of the clamps
- Shuttle's automatic transfer

S20 Geometry welding Sides

- Automatic loading of the previous station's set
- Manual loading of the sides LH and RH
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps
- Shuttle's automatic transfer

S30 Automatic completion welding

- Automatic loading of the previous station's set
- Automatic closing of the clamps
- Automatic spot welding by robots
- Automatic opening of the clamps
- Shuttle's automatic transfer

S40 Geometry welding tank

- Automatic loading of the previous station's set
- Manual loading of the tank
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps
- Shuttle's automatic transfer

S50 Geometry welding tank and side supports

- Automatic loading of the previous station's set
- Manual loading of the tank
- Manual loading of the side supports
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps

- Shuttle's automatic transfer

S60 Automatic completion welding

- Automatic loading of the previous station's set
- Automatic closing of the clamps
- Automatic spot welding by robots
- Automatic opening of the clamps
- Shuttle's automatic transfer

S70 Automatic completion welding

- Automatic loading of the previous station's set
- Automatic closing of the clamps
- Automatic spot welding by robots
- Automatic opening of the clamps
- Shuttle's automatic transfer

S80 Transfer

- Automatic loading of the previous station's set
- Confirmation of the type of Motor compartment present at the station
- Automatic removal of the Motor compartment by elevator, cargo bus and hook to Underbody's line

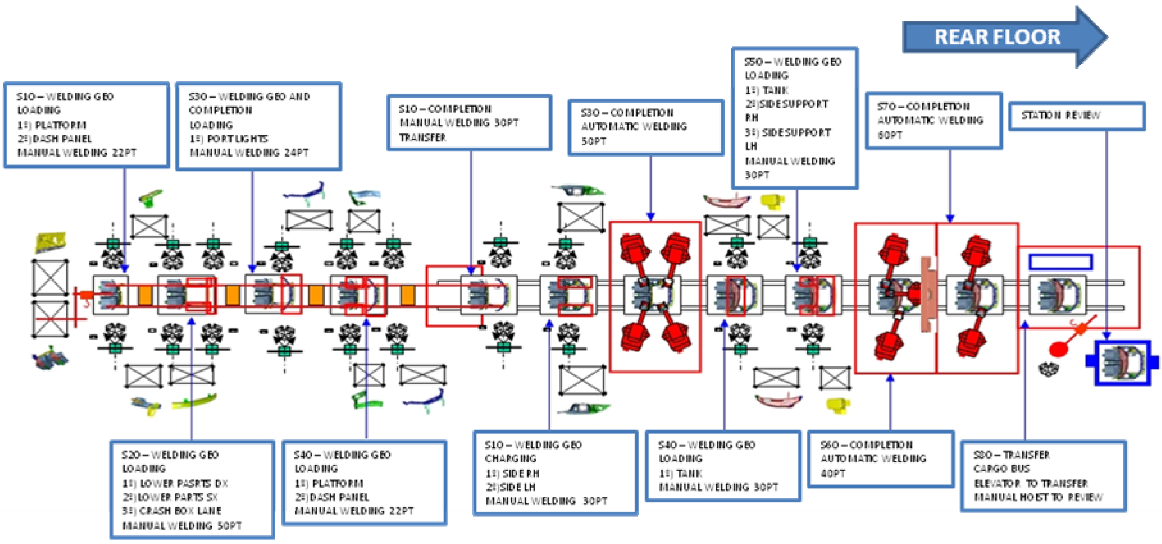

Figure 5 Front Rail and Motor Compartment line

3.3.4.3 Rear Floor

S10 Geometry welding Front Rail

- Manual loading of the side sill + cowl side LH and RH
- Manual loading of the cowl top
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps
- Shuttle's automatic transfer

S20 Geometry welding full floor

- Automatic loading of the previous station's set
- Manual loading of the rear floor
- Manual loading with carved of the centre floor
- Activation of the push buttons and closing of the clamps
- Manual spot welding geometry
- Activation of the push buttons and opening of the clamps
- Shuttle's automatic transfer

S30 Automatic completion welding

- Automatic loading of the previous station's set
- Closing of the clamps
- Automatic spot welding of completion by robots
- Opening of the clamps
- Shuttle's automatic transfer

S40 Automatic completion welding

- Automatic loading of the previous station's set
- Closing of the clamps
- Automatic spot welding of completion by robots
- Opening of the clamps
- Shuttle's automatic transfer

S50 Back – Up

- Automatic loading of the previous station's set
- Closing of the clamps
- Manual spot welding of completion
- Opening of the clamps
- Shuttle's automatic transfer

S60 Transfer

- Automatic loading of the previous station's set
- Advance of pick-up for automatic removal of complete floor
- Automatic transfer by Pick Up of the Rear Floor to Underbody's line

- Shuttle's automatic transfer

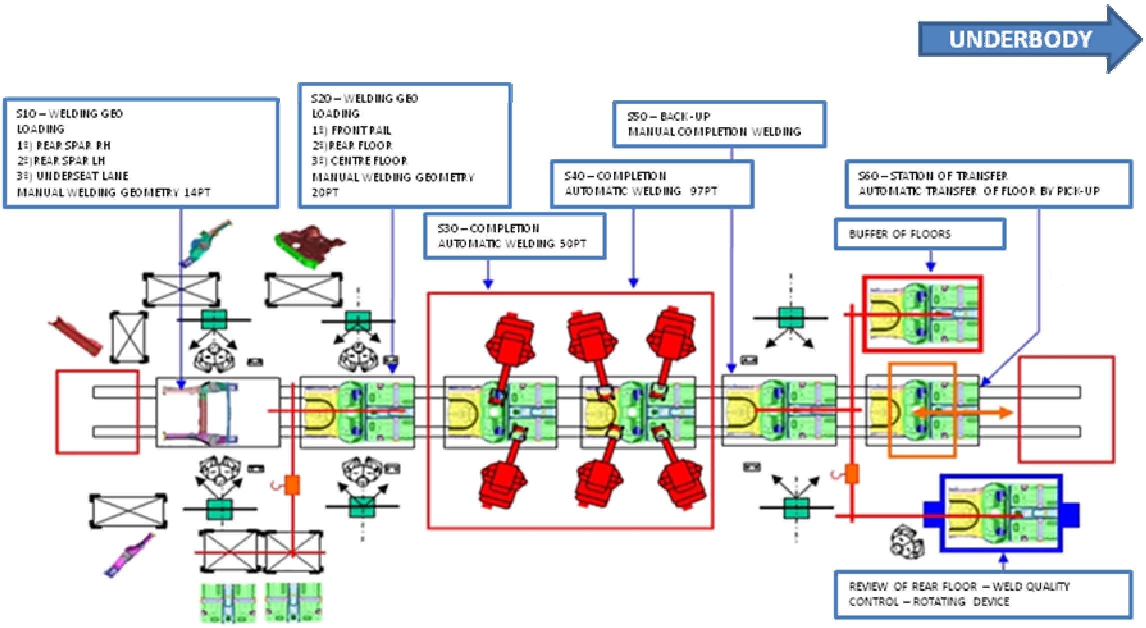

Figure 6 Rear Floor line

3.3.4.4 Underbody

S05 Arrival of empty SKID and elevator

- Arrival of empty SKID of the return line in the elevator
- Elevator lower with empty SKID
- Return the elevator to the height of the airline

S10 Loading of the Set and Floor

- Empty SKID comes bellow the line
- Recognition of model Floor to call the correct Motor compartment's model
- Automatic loading of the Motor Compartment by Post bus' elevator
- Confirmation of the Motor Compartment at the station
- Automatic loading of the Floor by Pick Up (which removes at the last station of Rear Floor's line and charges at station 10)
- Confirmation of the Floor's model
- If correct loading station releases the movement of the SKID
- If incorrect loading signal fault must be activated for removal with manual hoist of subgroup of the station
- Roller table rises automatically with SKID to remove the product of the groups of reference
- Automatic advance of SKID to S20

S20 Welding and loading of the arches

- Roller table with SKID downs automatically to support the product in groups of reference
- Manual loading of the arches
- Activation of the push buttons and closing of the clamps

- Manual spot welding
- Activation of the push buttons and opening of the clamps
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S30

S30 Empty Station

- Roller table rises automatically with SKID to remove the product of the groups of reference
- Predisposed to new model
- Automatic advance of SKID to S40

S40 Welding and loading of the spars

- Roller table with SKID downs automatically to support the product in groups of reference
- Manual loading of the spars
- Activation of the push buttons and closing of the clamps
- Manual spot welding
- Activation of the push buttons and opening of the clamps
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S50

S50 Welding and loading of the shock tower cap and back skin

- Roller table with SKID downs automatically to support the product in groups of reference
- Manual loading of the back skin
- Manual loading of the shock tower cap LH and RH
- Activation of the push buttons and closing of the clamps
- Manual spot welding
- Activation of the push buttons and opening of the clamps
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S60

S60 Welding and loading of the back skin

- Roller table with SKID downs automatically to support the product in groups of reference
- Automatic loading of the previous station’s subgroup
- Manual loading of the back skin
- Activation of the push buttons and closing of the clamps
- Manual spot welding
- Activation of the push buttons and opening of the clamps
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S70

S70 Manual welding of completion

- Roller table with SKID downs automatically to support the product in groups of reference
- Activation of the push buttons and closing of the clamps
- Manual spot welding

- Activation of the push buttons and opening of the clamps
- Automatic advance of SKID to S80

S80 Automatic completion welding

- Roller table with SKID downs automatically to support the product in groups of reference
- Automatic charging of the previous station's subgroup
- Closing of the clamps
- Automatic spot welding by robots
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S90

ST. 90 Pines automatic welding

- Roller table with SKID downs automatically to support the product in groups of reference
- Automatic loading of the previous station's subgroup
- Closing of the clamps
- Rotating device performs 90º rotated
- Automatic spot welding by robots
- Rotating device returns the position
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S100

S100 Manual MIG welding

- Roller table with SKID downs automatically to support the product in groups of reference
- Automatic loading of the previous station's subgroup
- Closing of the clamps
- Rotating device performs rotated 90º
- Manual MIG welding
- Rotating device returns the position
- Roller table rises automatically to remove the product of the groups of reference
- Automatic advance of SKID to S110

S110 Back up, deliberates the stretch and setting rivets

- Roller table with SKID downs automatically to support the product in groups of reference
- Automatic loading of the previous station's subgroup
- Recognition of the Underbody's model present at the station to call the correct corresponding side and automatic selection of grippers for robots
- Closing of the clamps
- Manual application of rivets to fasten the plate CIS (Chassis Identification Code) to identify the body
- Manual application of rivets to fasten the fender
- Inspection of visual quality of the subgroup (deliberates the stretch) and record in the form of process
- Roller table rises automatically to remove the product of the groups of reference

- If Tabbing station is empty, SKID feeds automatically the station, if it isn't SKID goes to buffer of Underbody (capacity of 8 SKIDS)

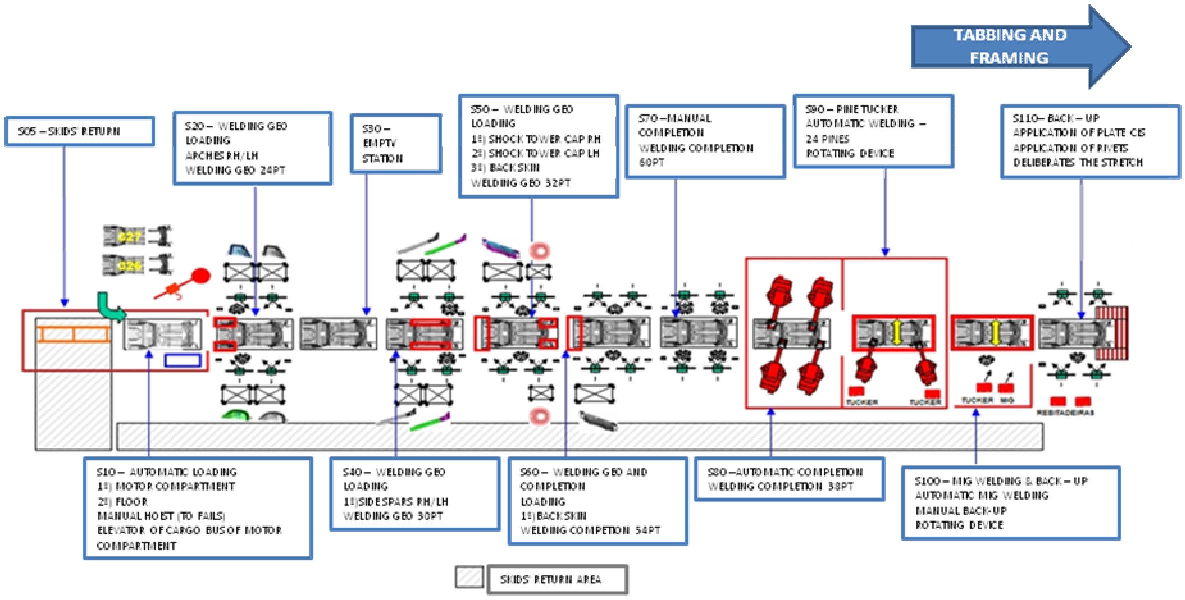

Figure 7 Underboby line

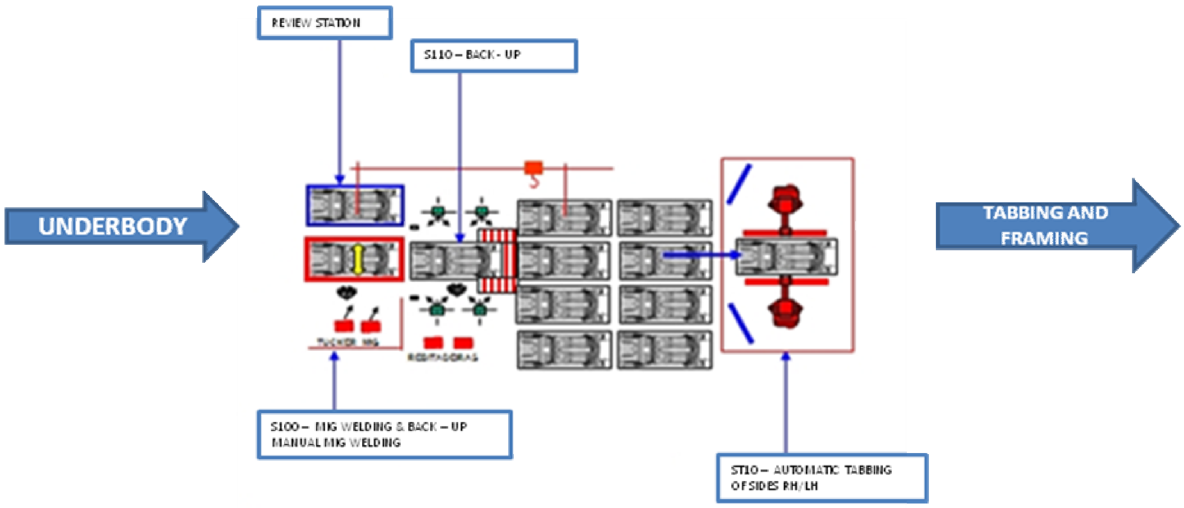

Figure 8 Buffer of Underbody (capacity of 8 SKIDS)

3.3.4.5 Tabbing and Framing

S10 Automatic Sides Tabbing

- Roller table with SKID downs automatically to support the underbody in groups of reference
- In accordance with the model at the station the robots with Tool Change System selects side's gripper previously identified
- Arrival of the Side by Cargo Bus
- Down of the Cargo Bus with the Sides by the Elevator
- The robots with the correct grippers remove the Sides of the Cargo Bus
- Cargo Bus returns
- Approach by the robots with the Sides to Tabbing position
- Automatic tabbing of all Sides' flaps
- Return of the robot
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S20

S20 Manual loading of Lanes

- Roller table with SKID downs automatically to support the body in groups of reference
- Manual loading of the cross members of roof and windshield in the body
- Tabbing with specific pneumatic hand tool of the cross members od roof and windshield
- Manual application of expandable term on the cross members
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S30

S30 Station of Exchange of Gates

- Roller table with SKID downs automatically to support the body in groups of reference
- Station without operations only with space to exchange the gates
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S40

S40 Framing

- Roller table with SKID downs automatically to support the body in groups of reference
- Recognition of the product model
- Exchange of gate if necessary
- Y linear advance of gates according to the model
- Closing of the clamps
- Automatic welding geometry with robots
- Openning of the clamps
- Gates return to the stand-by position
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S50

S50 Station of Exchange of Gates

- Roller table with SKID downs automatically to support the body in groups of reference
- Station without operations only with space to exchange the gates
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S60

S60 Empty Station

- Roller table with SKID downs automatically to support the body in groups of reference
- Parking lot side of the supports of reference geometric of roof for robots
- Automatic advance of SKID to S70

S70 Loading, Geometry definition and weld of roof

- Roller table with SKID downs automatically to support the body in groups of reference
- Recognition of the product model to automatic selection of correspondent roof
- Robot with gripper of geometry removes the roof directly of the tubular special and positions on a bench of geometry to confirm the positioning of the roof
- Robot positions the roof over the body and makes the coupling with station blocking
- Closing of the clamps
- Automatic welding of the roof
- Openning of the clamps
- Robot with gripper returns to the stand-by position
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S80

S80 Automatic completion welding

- Roller table with SKID downs automatically to support the body in groups of reference
- Recognition of the model
- Automatic completion welding with robots
- Roller table rises automatically to remove the body of the groups of reference
- Automatic advance of SKID to S90

S90 Transfer to the Cargo Bus of Body

- Blocking of the SKID in X and Y
- Elevator of SKID with body rises to height airline
- Arrived of the Cargo bus of body
- Elevator of SKID with body descends releasing the body over the cargo bus
- Advance of cargo bus withbody
- Automatic advance of SKID to return line

S95 Return empty SKID

- Arrived of empty SKID from return line
- Automatic transfer of SKID to return line

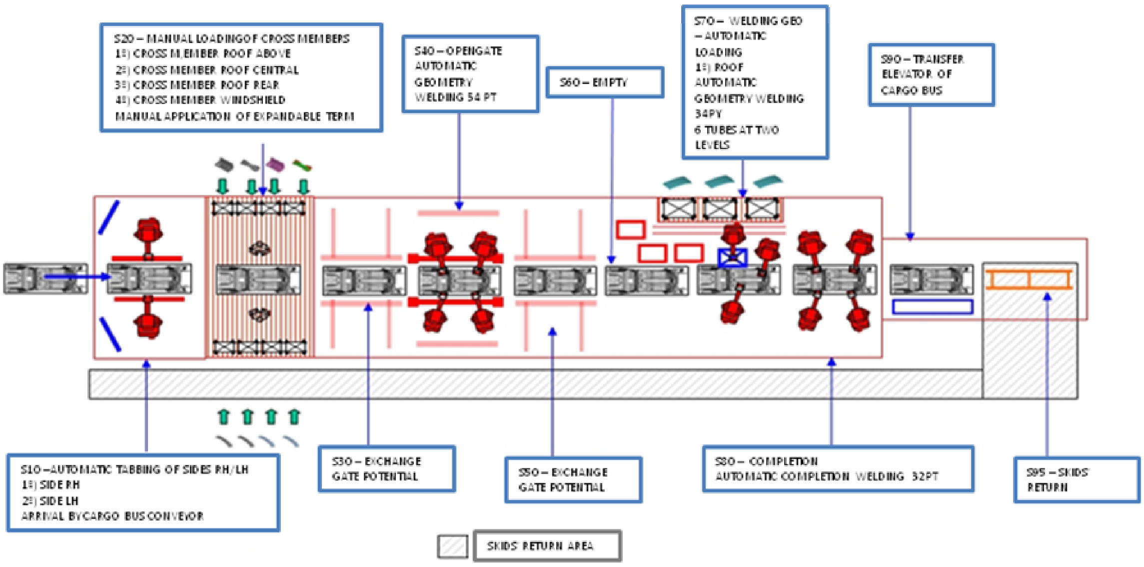

Figure 9 Tabbing and Framing line

3.3.5 Automation Network Architecture – Brazilian case

The automation network is divided in two main networks: plant automation network and process control network.

The plant automation network (PA) is a secured network designed for plant floor equipment connectivity. Communications is primarily local within the PA network. A firewall provides restricted access to and from the PA network. No production related communications shall pass through the firewall.

The process control network is an extension to plant floor equipment for lateral communication among devices as well as throughout the PA Ethernet network. Communications is primarily local within this network but includes communication back to applications servers typically located in the local data center on the PA network.

3.3.5.1 General Architecture

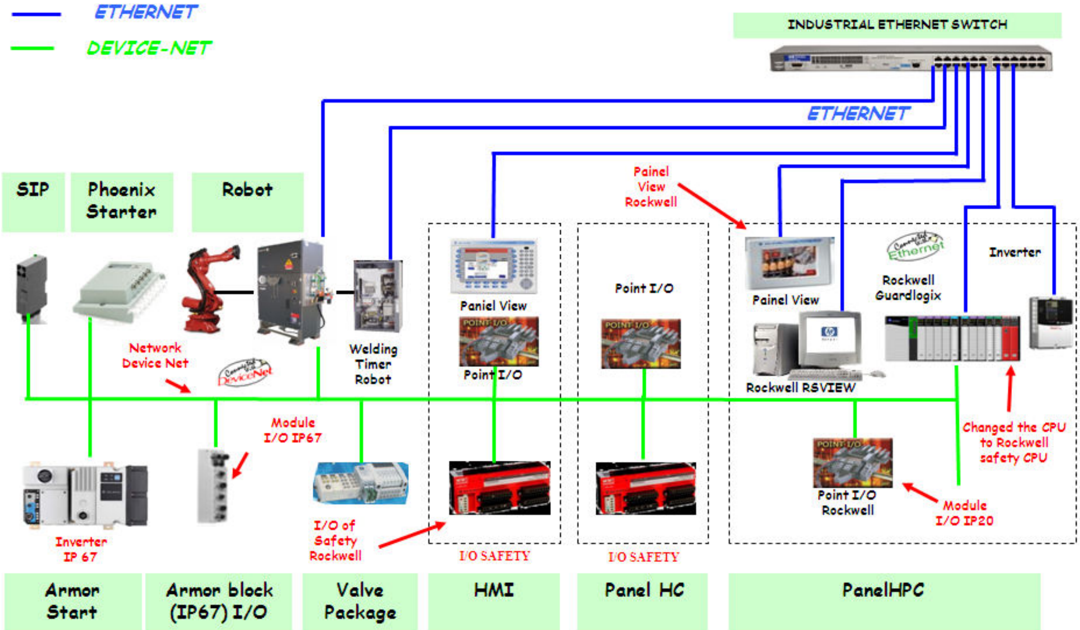

Figure 10 General Architecture Brazilian BWA line

3.3.5.2 DeviceNet Architecture

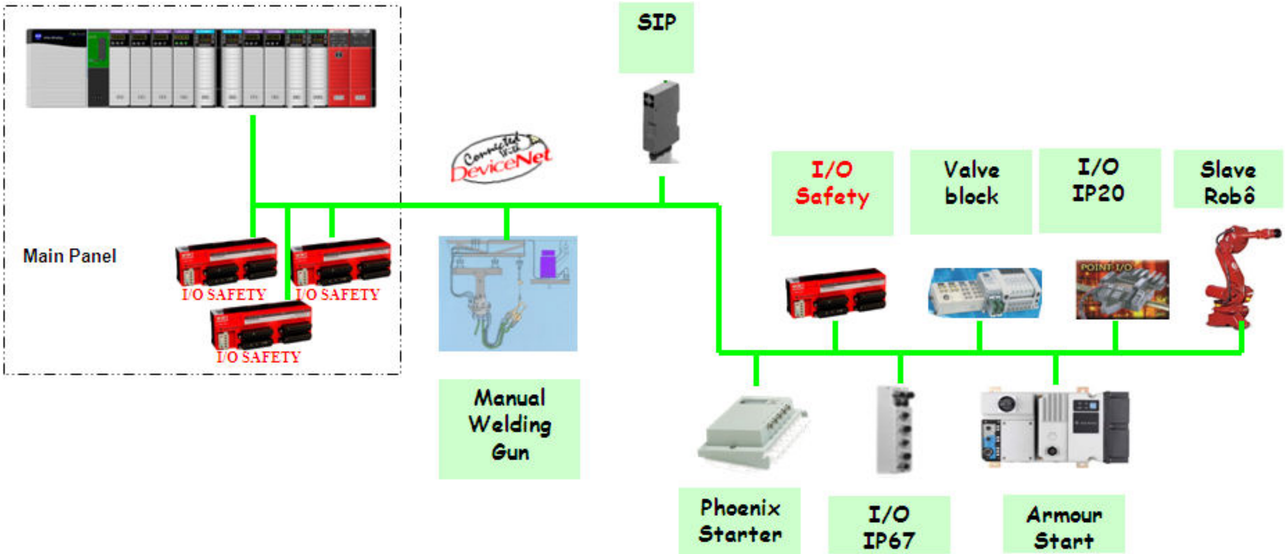

Figure 11 Process control network

3.3.5.3 Ethernet Architecture

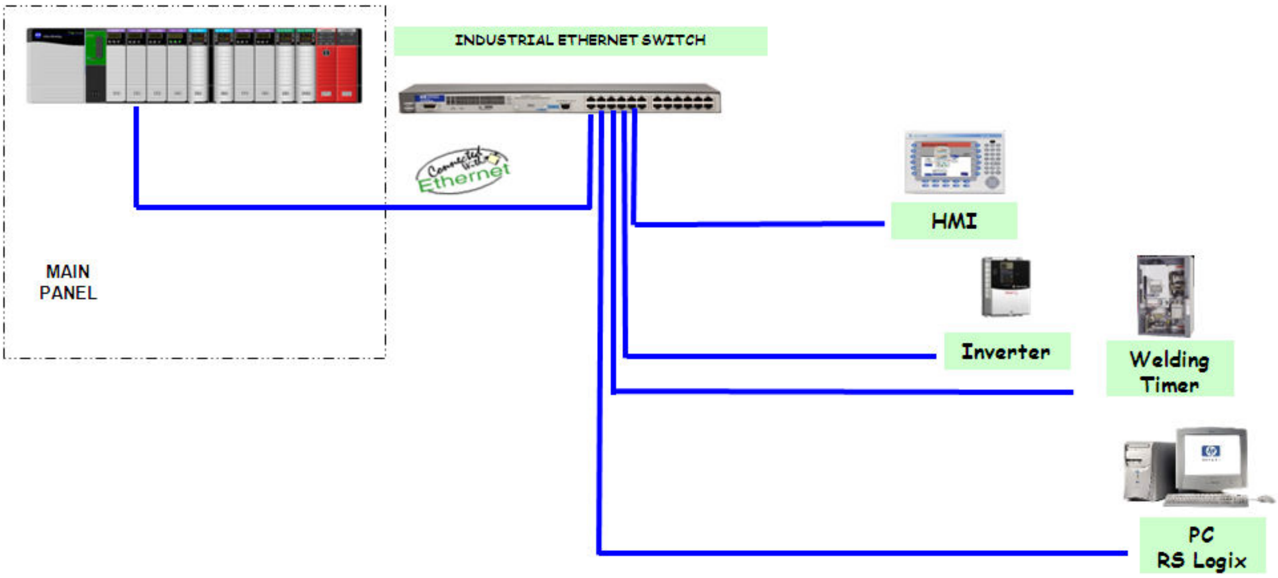

Figure 12 Plant automation network

3.3.5.4 Safety Architecture

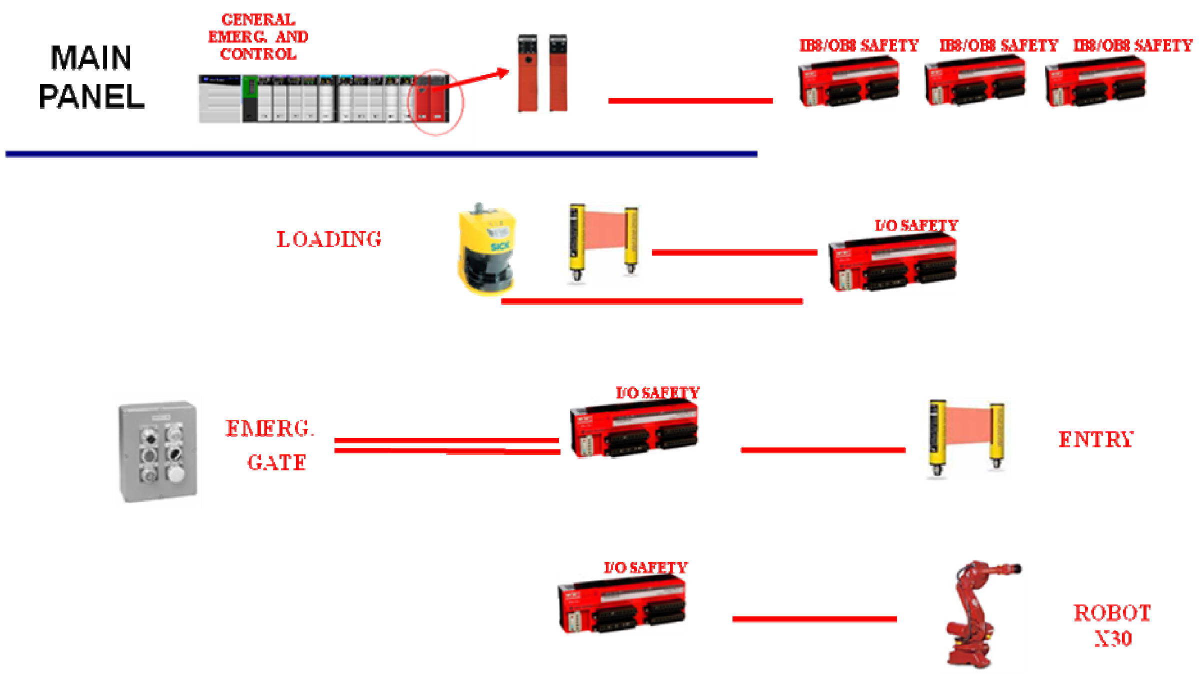

Figure 13 Safety network

3.3.5.5 Robot Architecture

Robot with Welding Gun

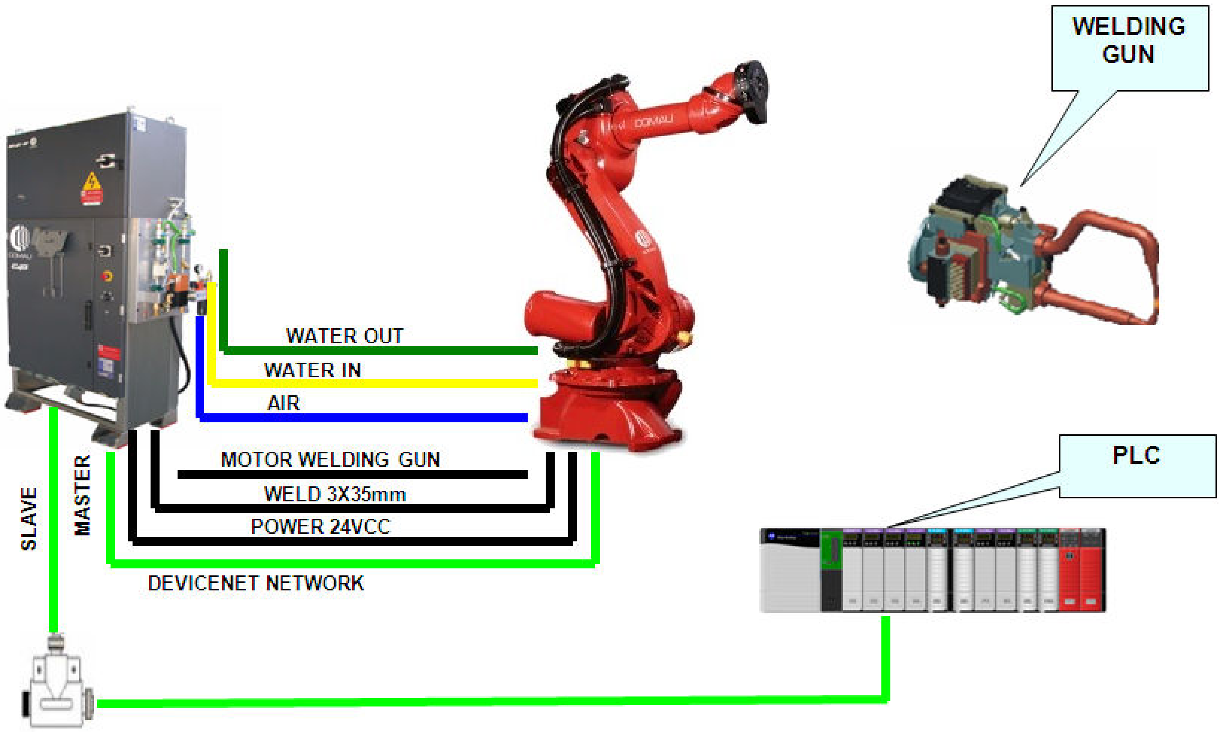

Figure 14 Robot control network - Welding Gun

Spot weld Panel with electric Welding gun

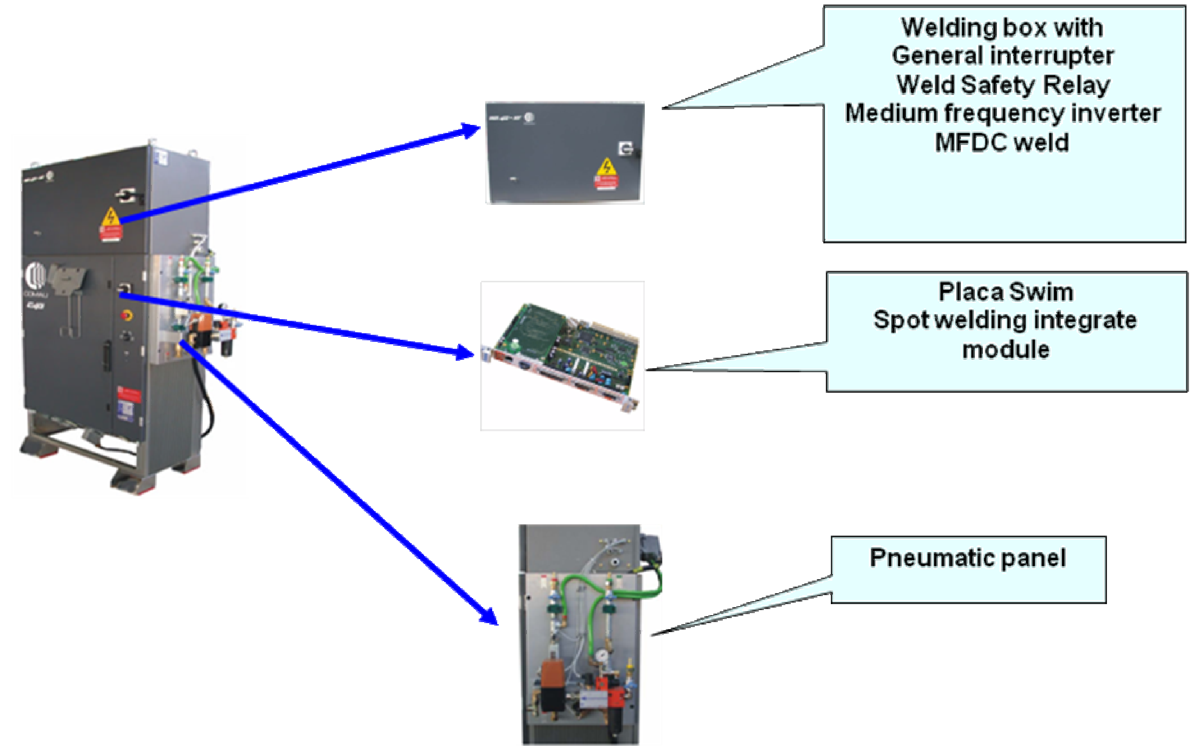

Figure 15 Spot welding panel

Robot NJ for manipulation

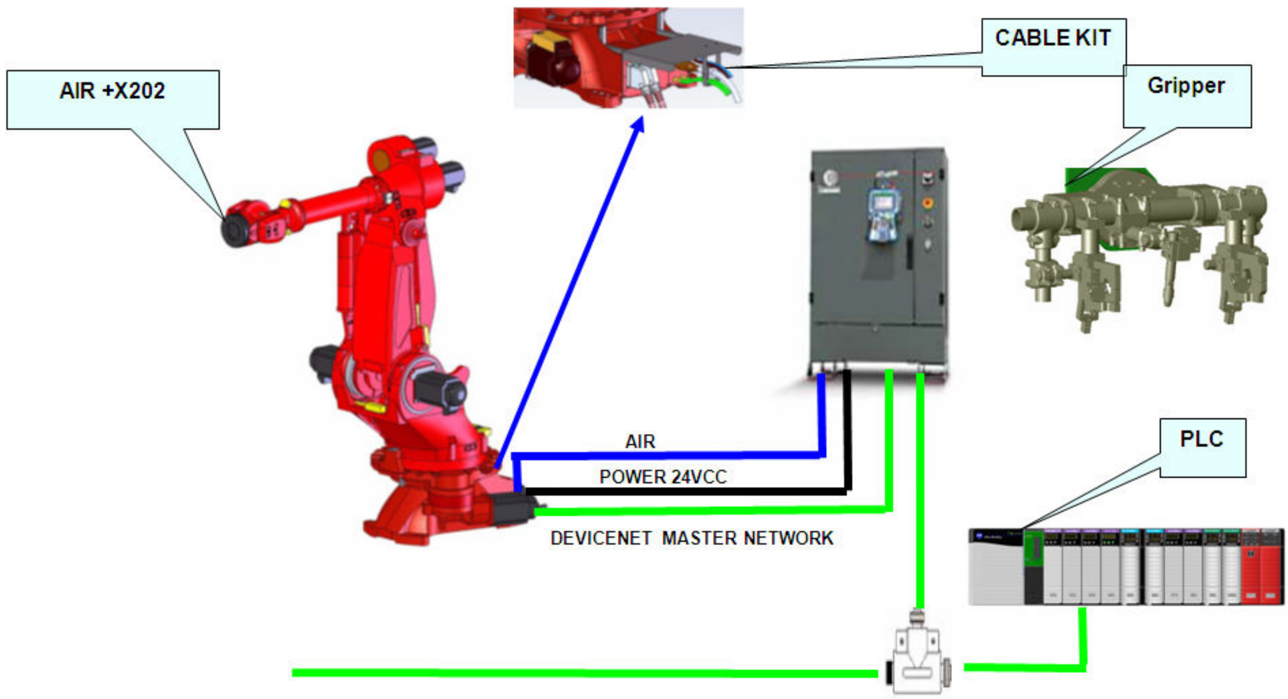

Figure 16 Robot NJ control network - Manipulation

Tool Change

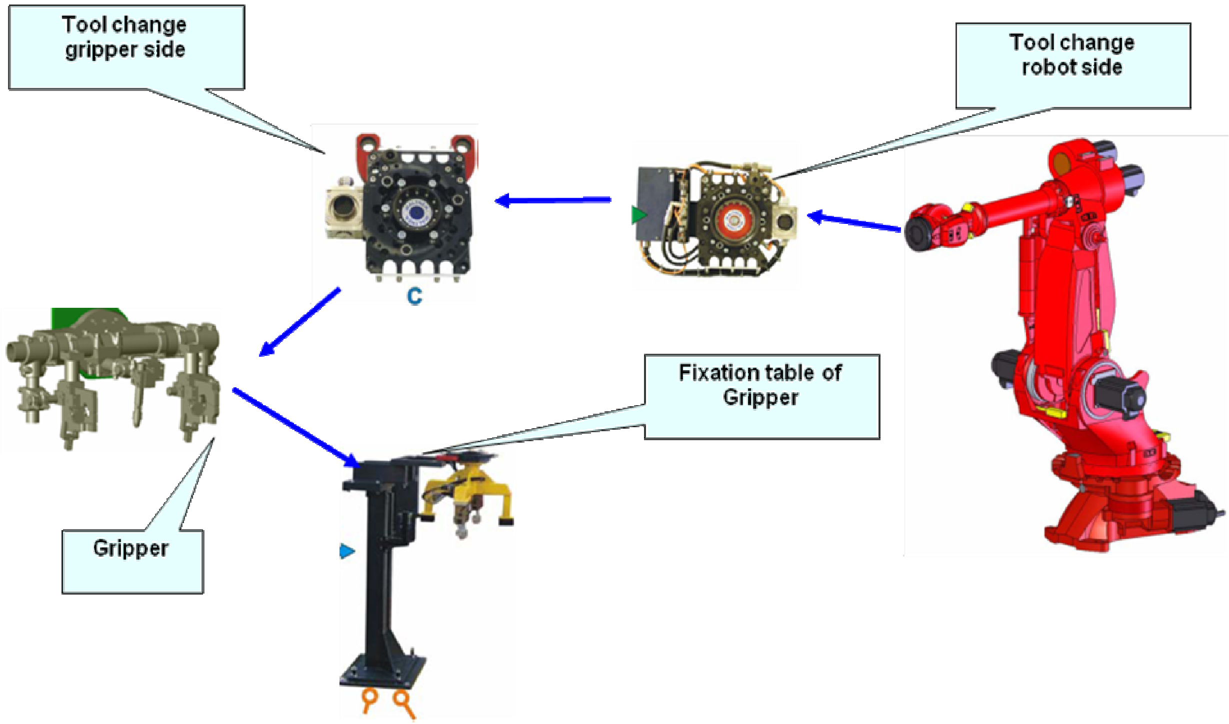

Figure 17 Tool change

Robot NH1 for Stud Welding

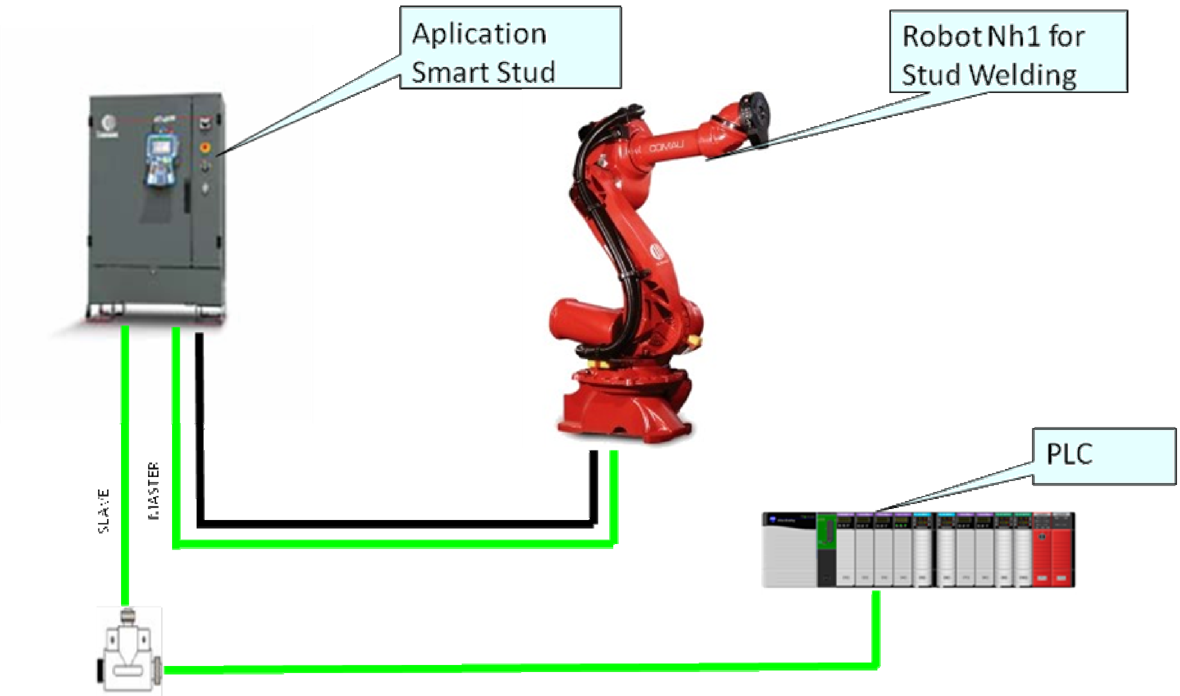

Figure 18 Robot control network - Stud Welding

Robot NX1 for manipulation

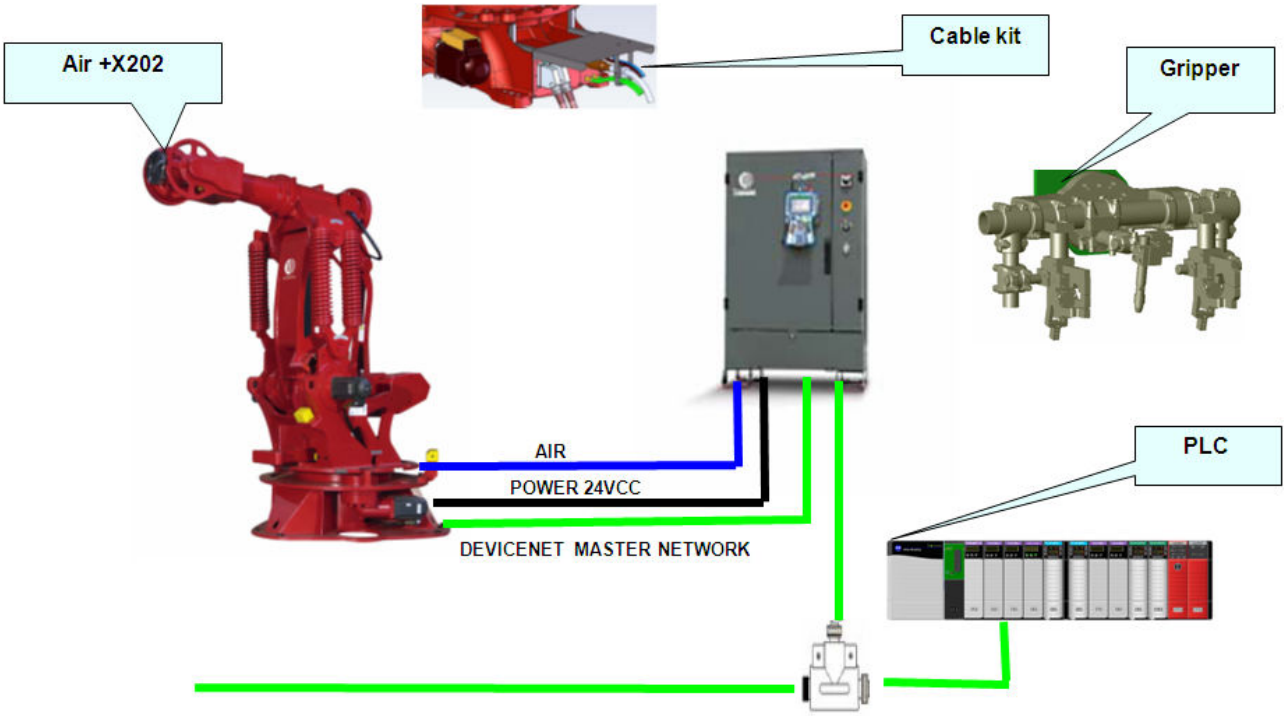

Figure 19 Robot NX1 control network - Manipulation

3.4 European Case – COMAU's Body Welding and Assembly Line

3.4.1 Overview – European case

The body welding and assembly line described bellow is composed by five main lines divided in four segments A-D. The lines are:

- Underbody versa roll
- Underbody versa pallet
- Bodyside versa roll (LH – left hand / RH – right hand)
- Body framing geo (geometry welding)
- Body framing respot (completion welding)

The lines have 15 station including elevators and repair stations. They are prosmicuous lines with 4 upperbody models and 3 underbody models in cycle. They have random mix capability and sequenced material delivery.

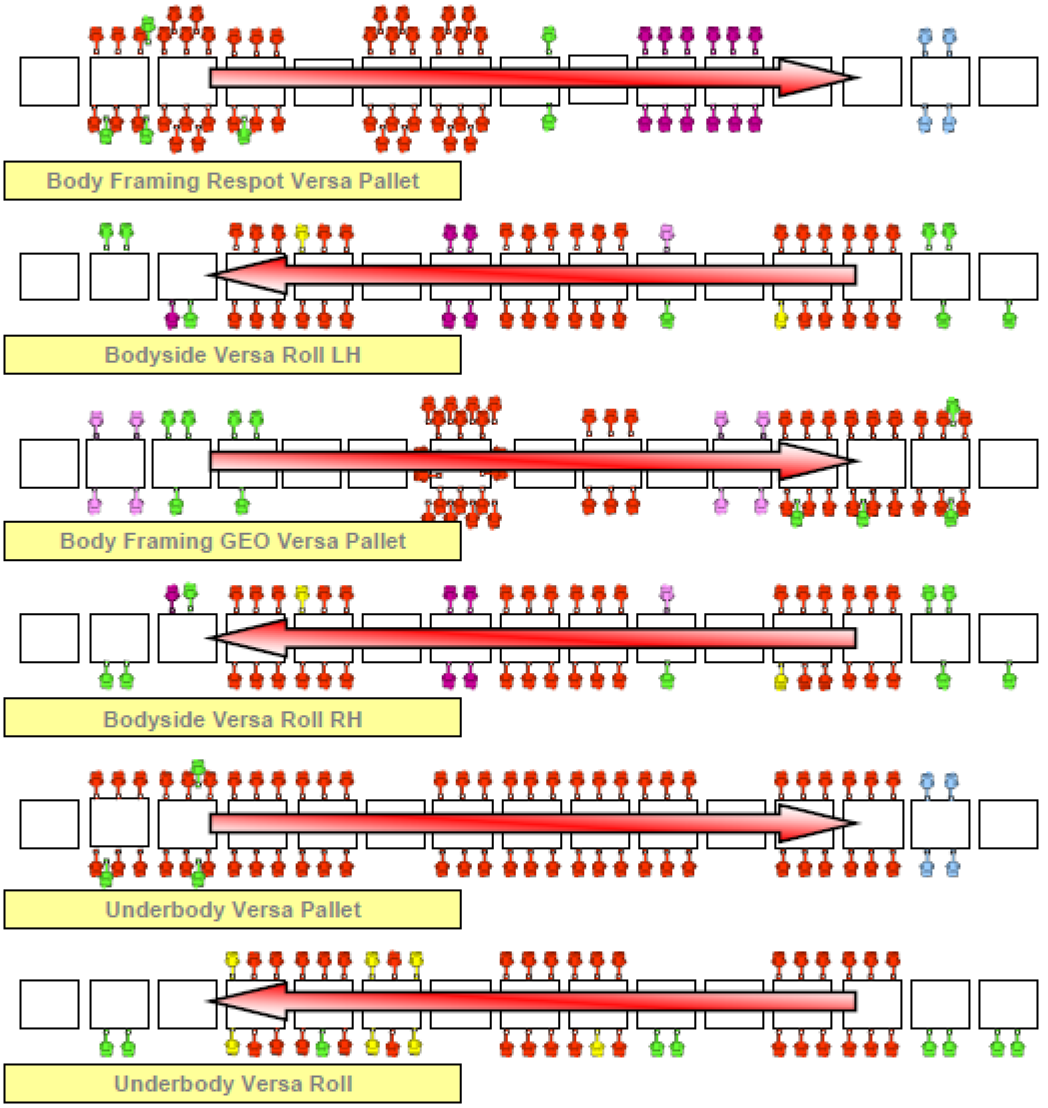

Figure 20 Standard Line Configuration

Table 3 System Specification - European case

Description	Specification
Hours per Day	21,5hs
Journey/Day	3
Capacity	30,0jph
Efficiency considered	85%
Maximum cycle time per station	102s

The European case is characterised by a high density of welding robots. For example, the Underbody Pallet Respot line has six welding robots per station, with opportunity to expand more four robots. Body Framing respot stations have ten welding robots and the Versa roll stations have six robots each.

All line services are integrated (electric, air, water) providing less power drops. The robots are installed with combo robot applications – they must have integrated weld gun and robot cable harness. With the high density of welding robots, the Open RoboGate framing station has a high number of spot welds, totalling a hundred.

The line permits product extraction and insertion for quality inspection and assurance.

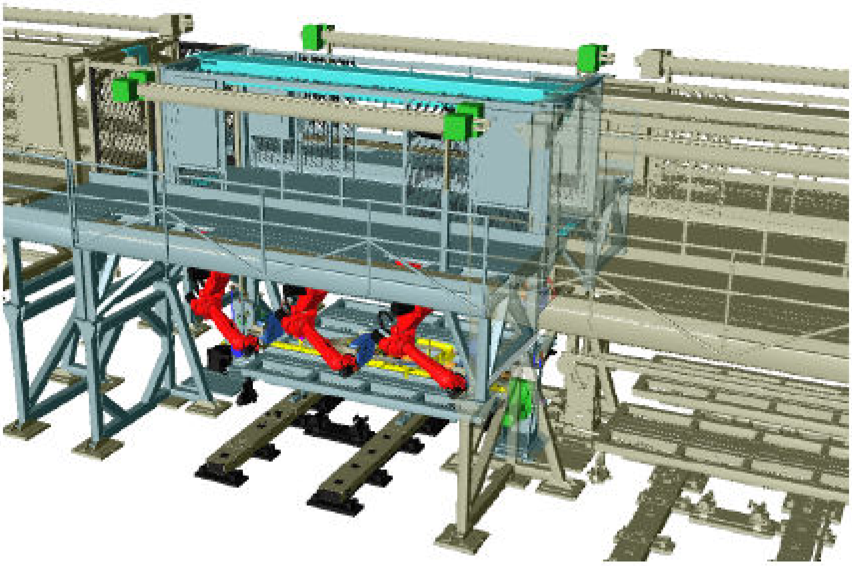

Figure 21 Underbody Versa Roll

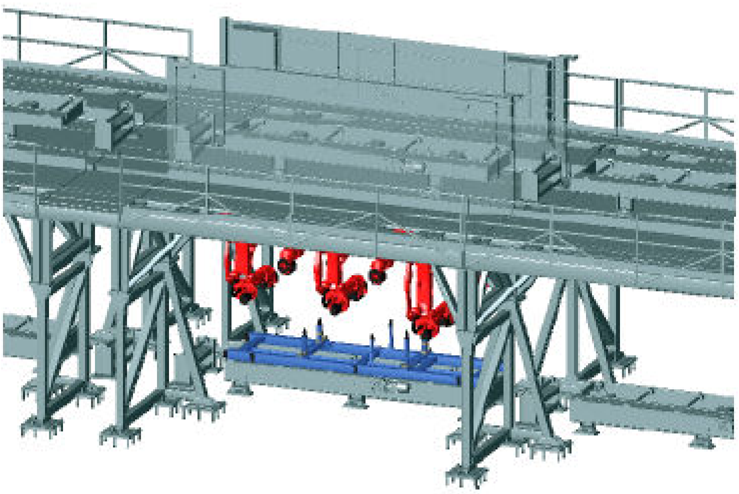

Figure 22 Underbody Versa Pallet

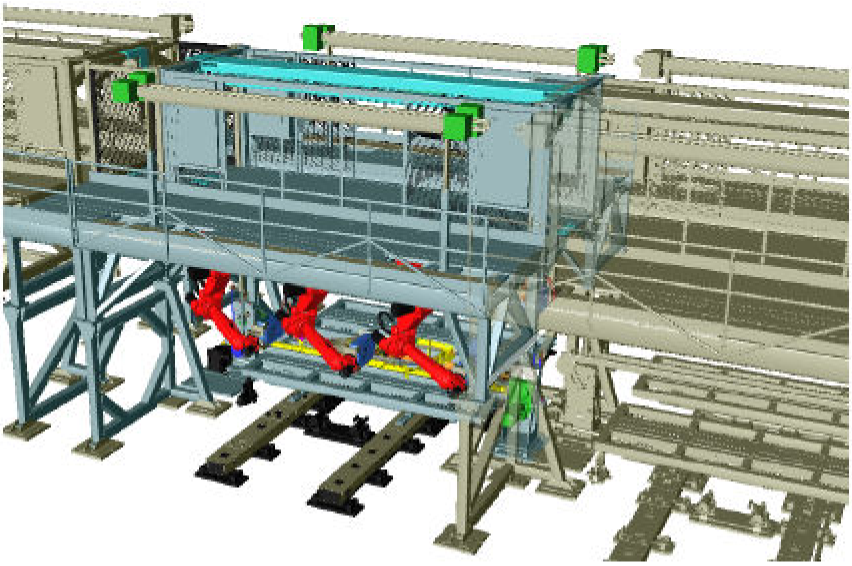

Figure 23 Bodyside Versa Roll

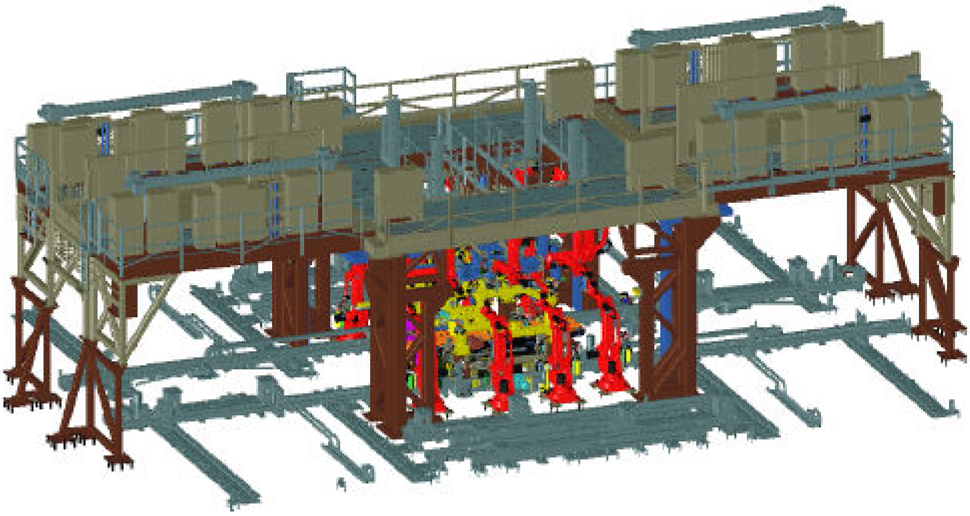

Figure 24 Body Framing Geo

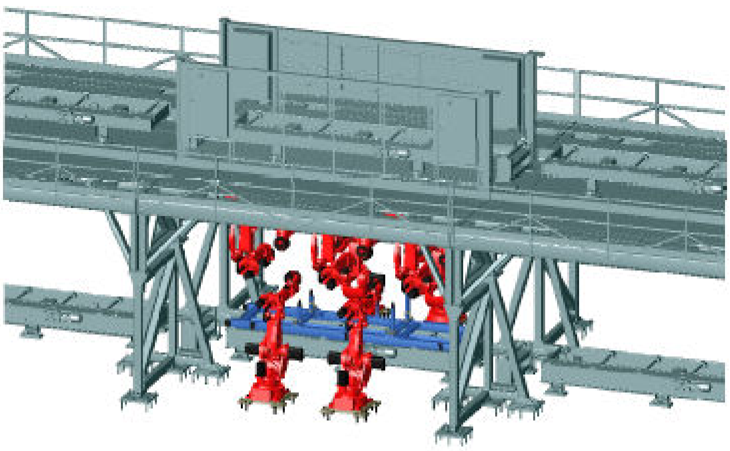

Figure 25 Body Framing Respot

3.4.2 Description of Manufacturing Process – European case

3.4.2.1 Unberbody Versa Roll

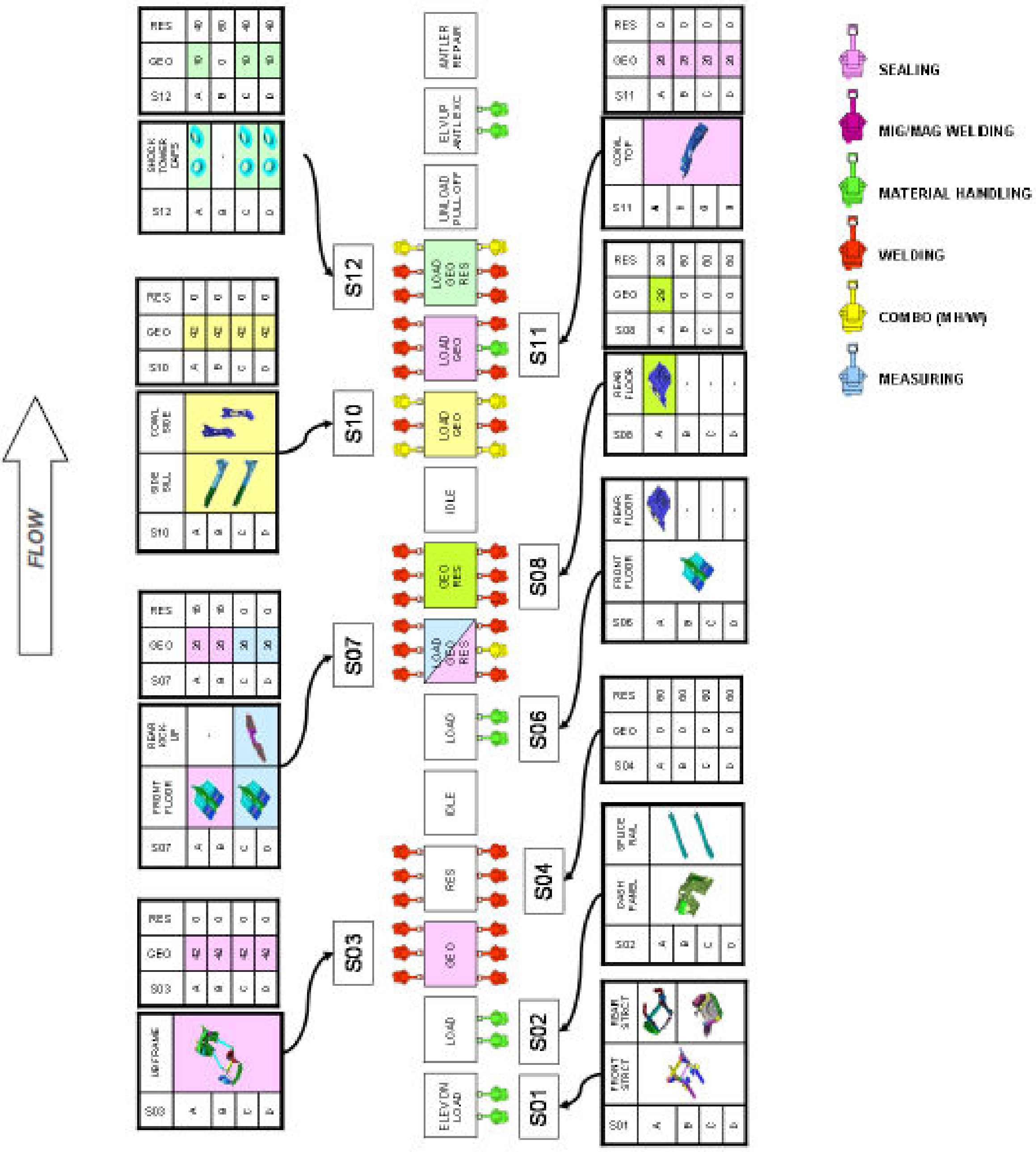

Figure 26 Underbody Versa Roll line

3.4.2.2 Underbody Versa Pallet

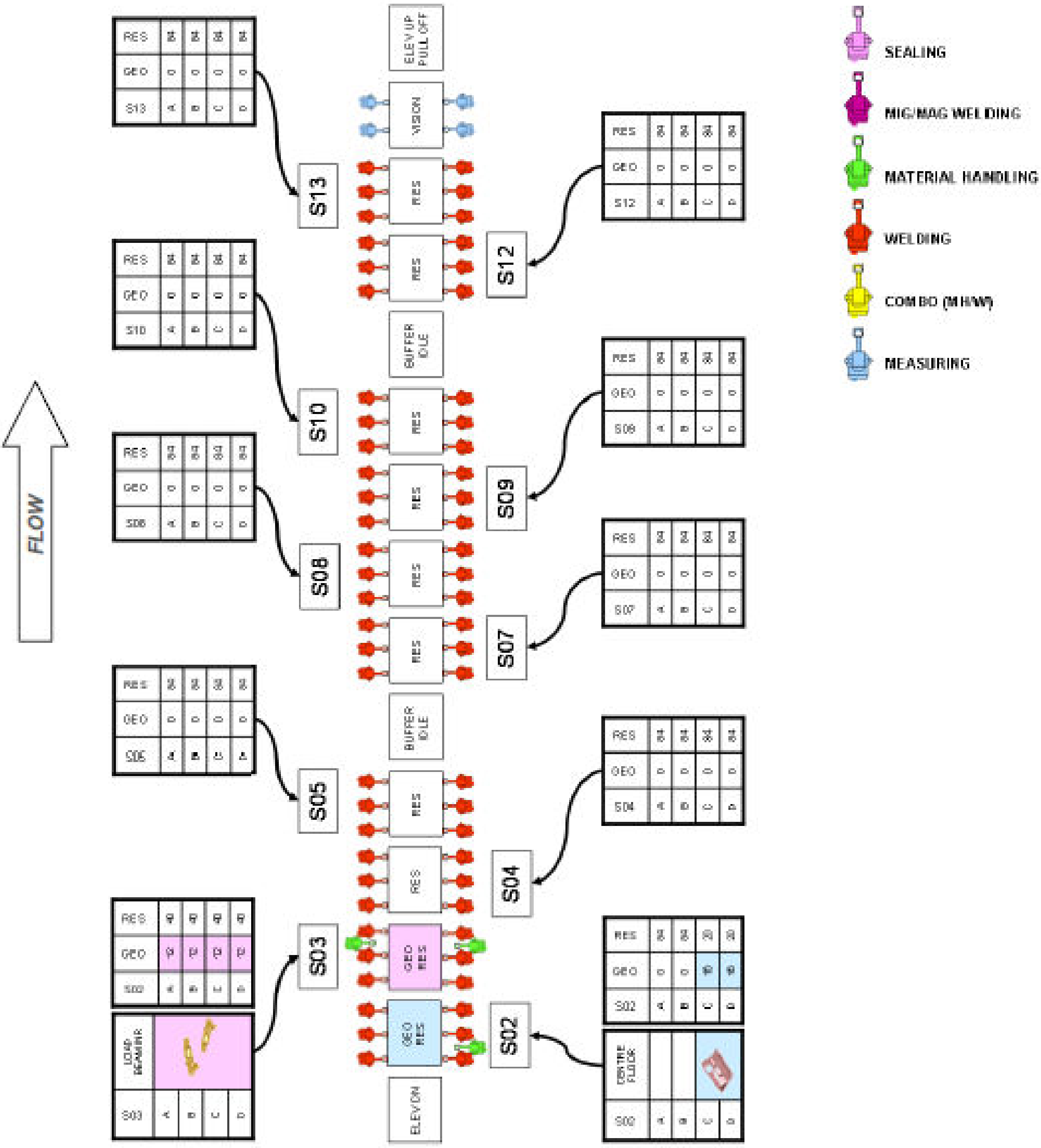

Figure 27 Underbody Versa Pallet line

3.4.2.3 Bodyside Versa Roll

Figure 28 Bodyside Versa Roll line

3.4.2.4 Body Framing Geo

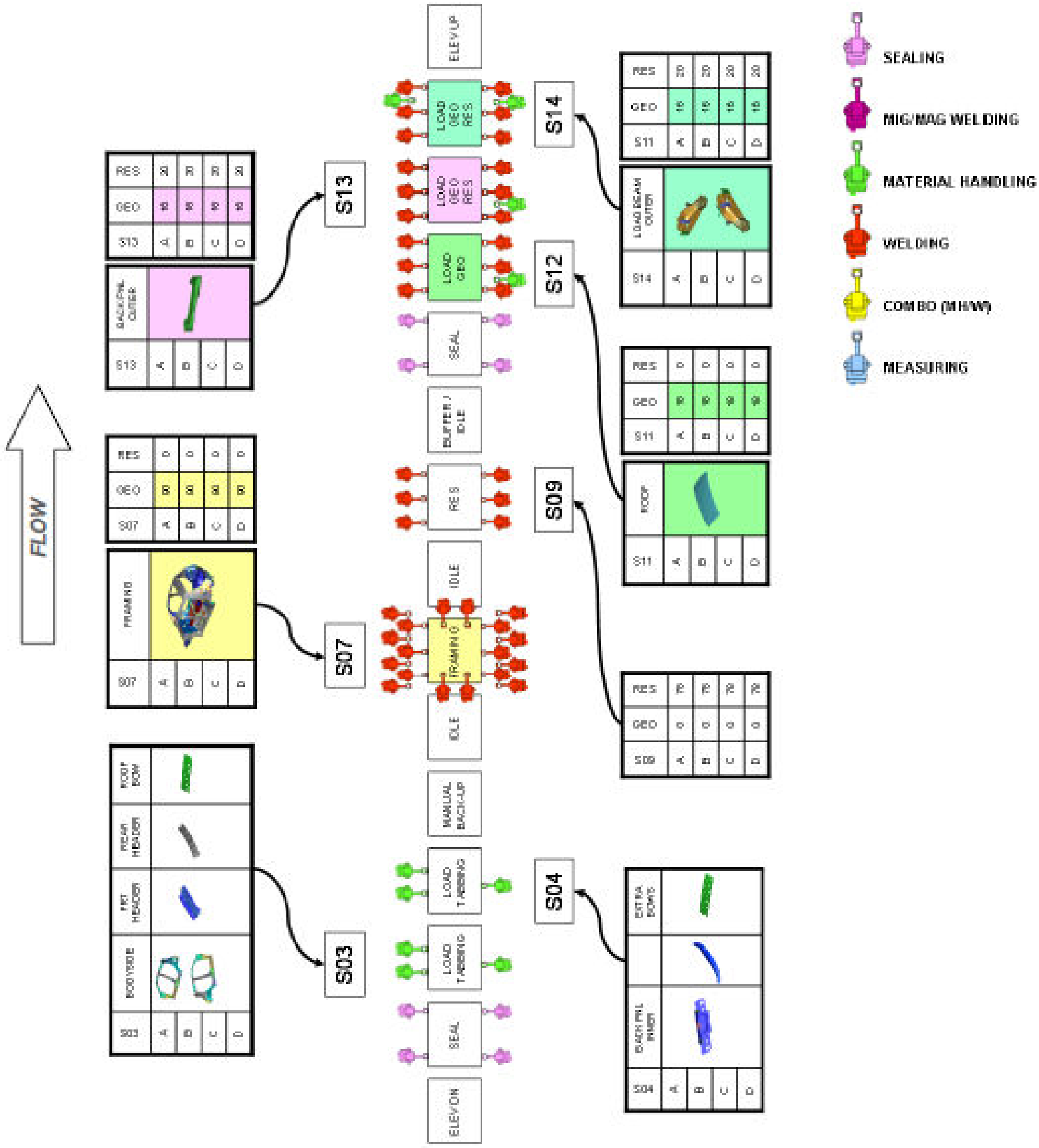

Figure 29 Body Framing Geo line

3.4.2.5 Body Framing Respot

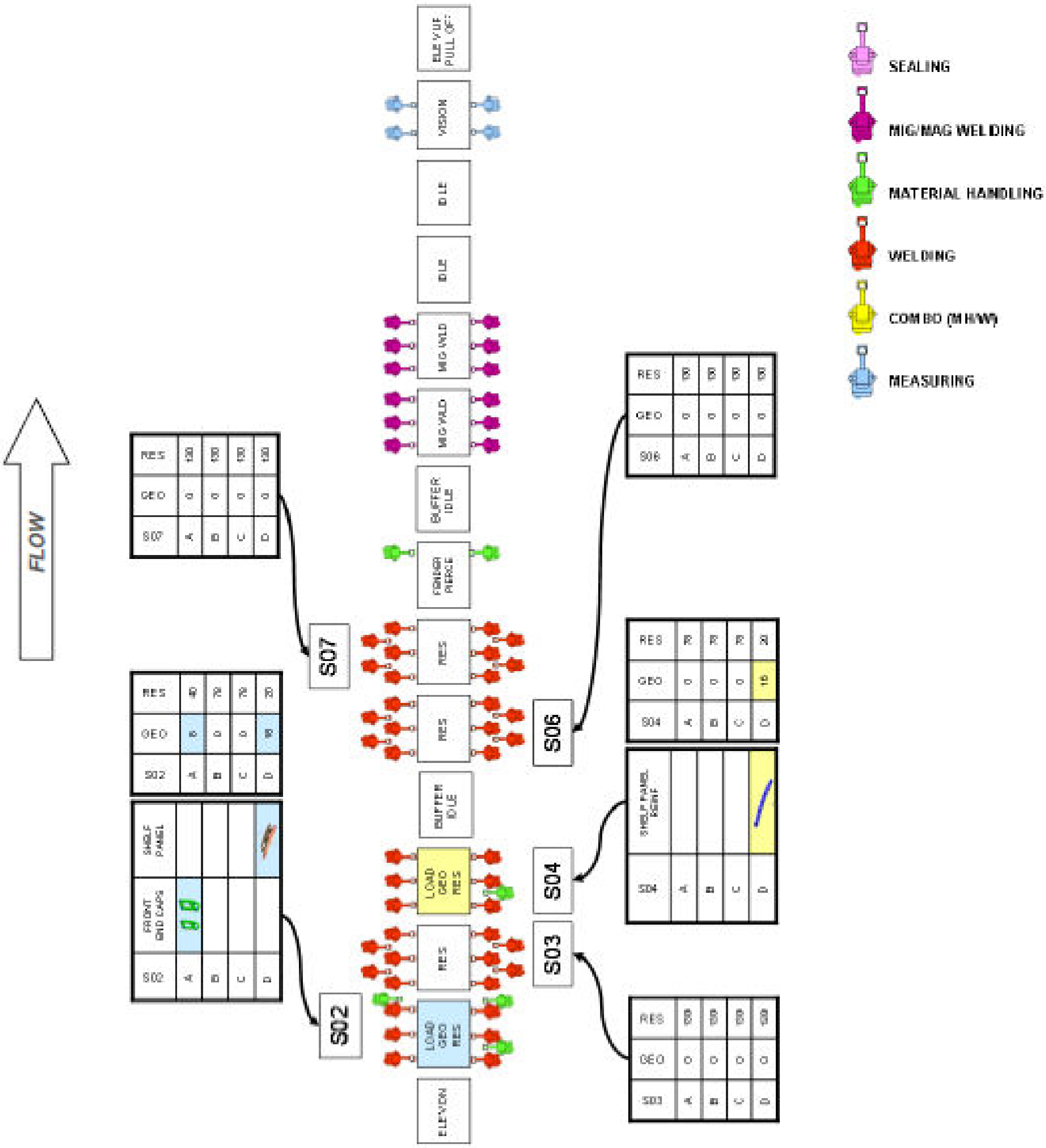

Figure 30 Body Framing Respot line

3.4.2.6 Overhead Pallet Transfer

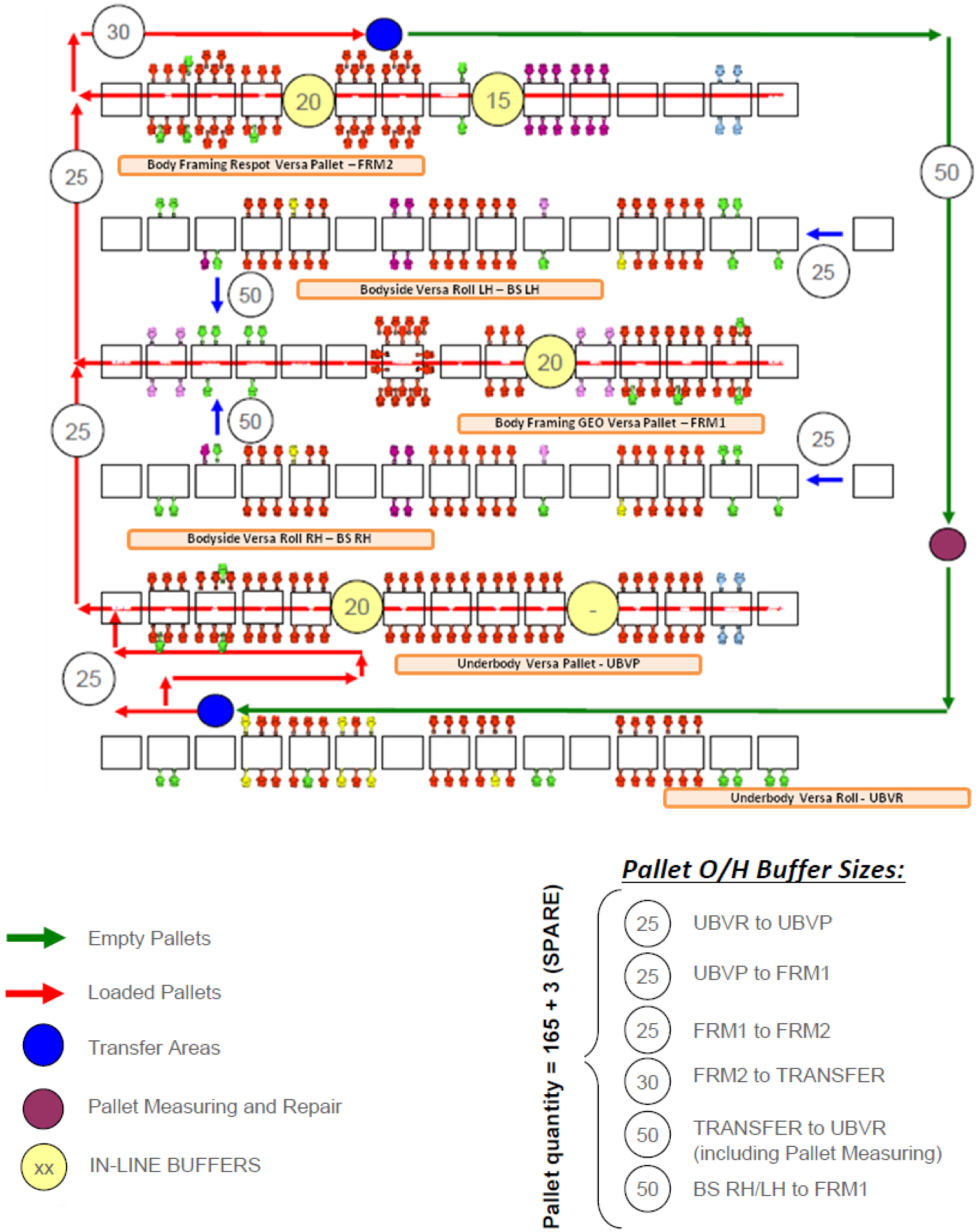

Figure 31 Over Pallet transfer line

3.4.3 Automation Network Architecture – European case

Normally Centralized Ethernet architecture is used only when systems, stations or cells can not be duplicated or modularized.

Cell PLCs and Line PCs Equipment shall have (2) RJ45 100 Mbps Ethernet ports:

- Industrial Ethernet (IETH).Automation LAN Ring
- Factory Production Ethernet LAN

IETH architecture is required to be applied in following applications:

- Use of IETH I/O for communication between PLCs and field equipment
- Use of IETH Peer-to-peer for communication between PLCs and HMI PC in their role as composes of distributed systems.

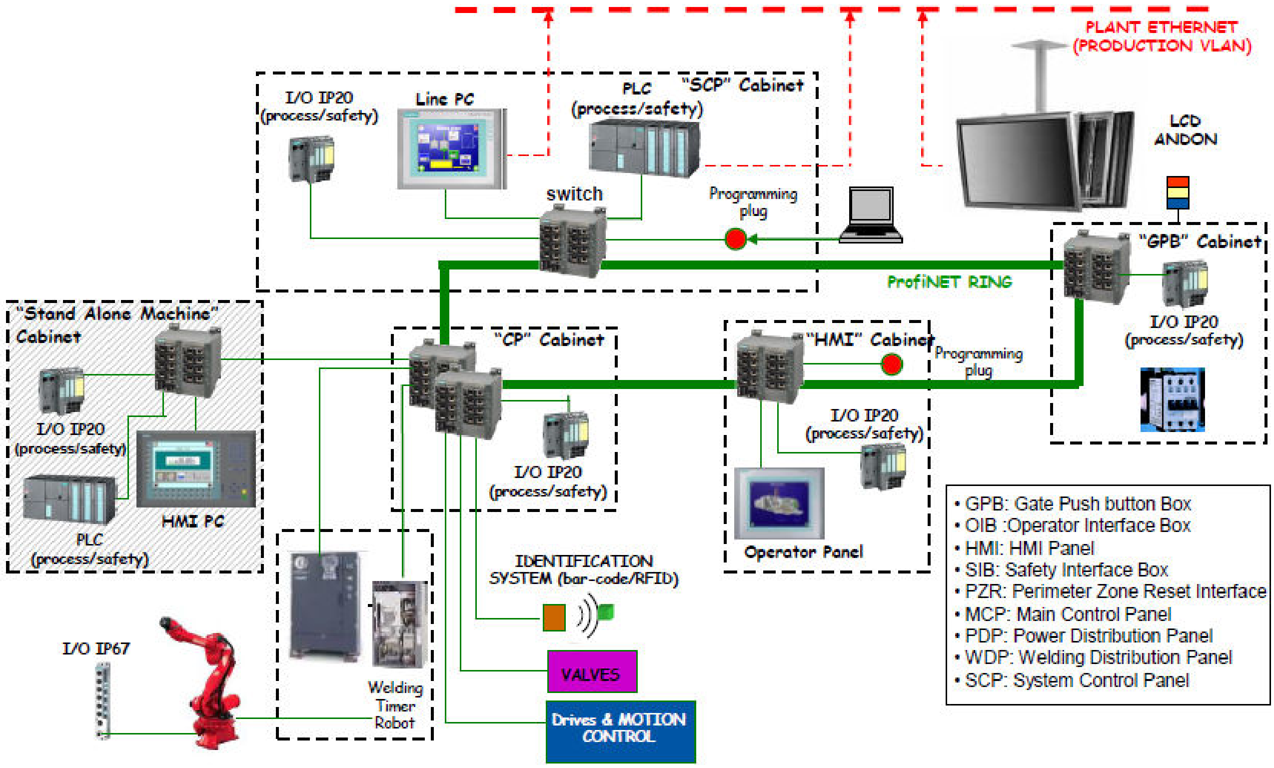

Figure 32 Centralised Network Architecture

Linear, Star and Tree arrangements are approved for the efficient construction of an Ethernet network. All daisy-chained devices shall apply Ring Topology to ensure the network availability even with any single device failure within a network.

- Every System/Line shall contain a Ring with managed switches.
- Every switch is functionally a central star with its devices.

To summarize there are 2 Ring levels:

- System/Line Ring: PLC, HMI, Identifications Systems ... etc.
- Device Ring: I/O devices when daisy chained.

The body welding and assembly line described before is a case of a line with systems, stations or cells that can be duplicated so each station is configured in a standard architecture "modular" with Modularized Ethernet.

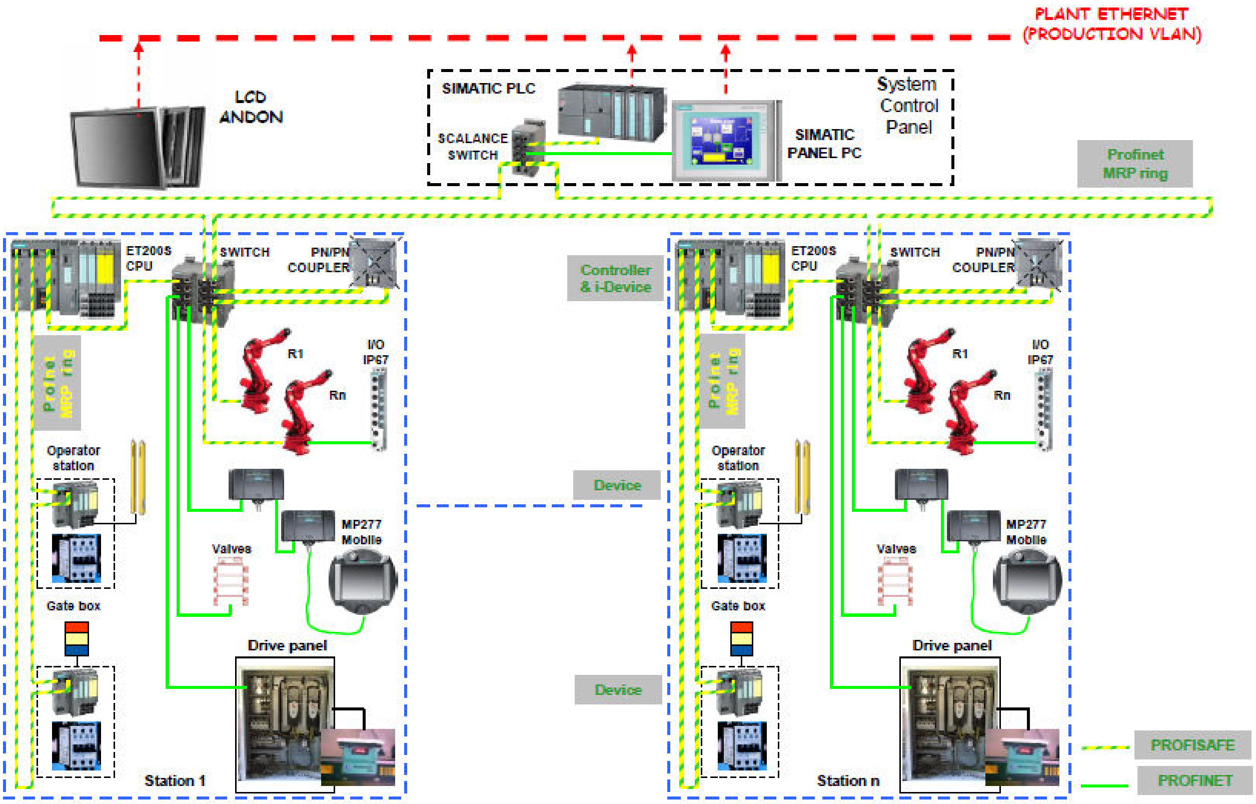

Figure 33 Modular Network Architecture

Modularized Ethernet architecture is required to utilize the most efficiently sized integrates Safety PLC. Controllers must provide highest flexibility and scalability with standard I/O and safety I/O on the controller-bus and the Safety HMI must provide safety commands to the Devices. The Motion-Drivers shal have direct real time Ethernet access with built-in diagnostics and integrated safety profile.

4. Conclusion

The Body Welding and Assembly process is a standard process wherever the automotive manufacturing industry is installed. This process is composed to various sub-processes and involves a huge number of pieces and operations to complete a car body.

An usual BWA line is composed by a Front Floor, a Motor Compartment, a Rear Floor, Underbody, Tabbing and Framing lines. The goal of these lines is join all parts of a car body at the correct geometry. It's usual the use of robots for these lines because robots with articulating arms can easily introduce various component braces and panels to the floor panel and perform a high number of welding operations in a timeframe and with a degree of accuracy no human workers could ever approach.

Robots perform most of welding on the various panels but human operators are necessary to bolt the parts together. During welding, component pieces are held securely in a jig welding operations are performed.

For these operations several electronic devices are used, as RFID to identify the part to be worked, electronic controllers to manage the proper sequence of operations, drivers and position sensors to perform accurate positioning and more. To manage all data of the process controllers are necessary and they recieve these data through a network dedicated to the lines. The network may have different topologies, the old ones are centralized networks, that are not much flexibles and spend a lot of cables, and the new ones are modular networks that permit an easy change of the arrangement of the line. The communication techonology use at the network depends on specialy of the devices that compose the network and the requirements for transmission of data.

Although when comparing the Brazilian case to the European case we may think that there are lot differences between the processes, this is a mistake because the goal of the BWA process is the same, what are different are the technologies involved, the number of robots, the devices' suppliers, the rules and the requirements production. The next table shows the major differences between Brazilian and European cases.

Table 4 Brazilan Case X European Case

Description	Brazil	Europe
Hours per day	20,75h	21,5h
Capacity	45,0 jph	30,0 jph
Efficiency considered	90%	85%
Maximum cycle time per station	80s	102s
Type of conveyor	Shuttle + SKID	Pallet
Quantity of robots	Less quantity of robots	Higher quantity of robots
Type of network	Centralised	Modular
Communication technology	Ethernet + DeviceNet	Ethernet+ProfiNet

The high number of devices on a BWA line makes a huge volume of data to be transfered to control the process. Nowadays, a big part of these data is transfered by network cables that turn the automation solutions less flexible reducing competitiveness. A modification on the cell structure or a simply chage on the manufacturing arrangement becomes more difficult because of the complex architecture of cables. The use of wireless technology is a great improvement to guarantee more flexibility and reconfigurability at manufacturing scenario. The only concern is the fact that this technology is very affected by the environment.

The Body Welding and Assembly (BWA) is the hardest environment in an automotive manufacturing industry and because of this the use of wireless devices is not yet widely accepted, as they could not work in a predictable way. The BEMO-COFRA project aims to develop an innovative distributed framework which allows networked monitoring and control of large-scale complex sub-systems and to validate this framework it will be tested at a BWA line. However, a complete BWA line has a large size and huge number of devices and volume of data transfer, so the next step is choose part of the BWA line to focus the tests.

5. References

[1] D2.1 Scenarios for Usage of the ebbits Platform, rev.1.0 – In-Jet Aps, Ebbits, 2010-11-30.

[2] D3.1 Enterprises Use Cases, rev. 2.0 – COMAU, Ebbits, 2011-02-28.

[3] COMAU's Standard Engineering Documents.